# CMS

# Status Report

**M. Della Negra**

**LHCC 8 March 2000**

General and Magnet
Tracker
ECAL
HCAL
Muon
Integration
Trigger&DAQ
Physics Reconstruction and Selection
Computing
Physics
*Animation*

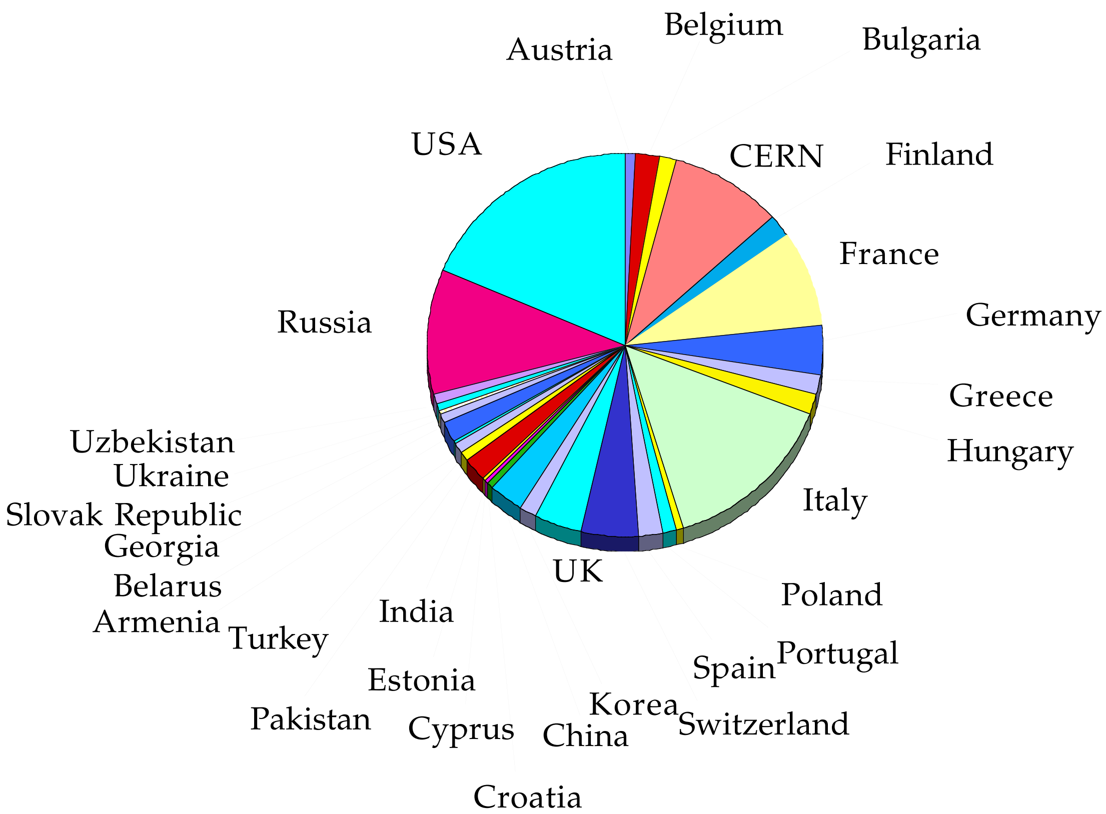
Compact Muon Solenoid

http://cmsdoc.cern.ch/cms/TRIDAS/distribution/3.Misc/LHCC-8.3.00.pdf

# The CMS Collaboration

| | Number of Laboratories |
|---|---|
| Member States | 58 |
| Non-Member States | 47 |
| USA | 36 |
| Total | 141 |

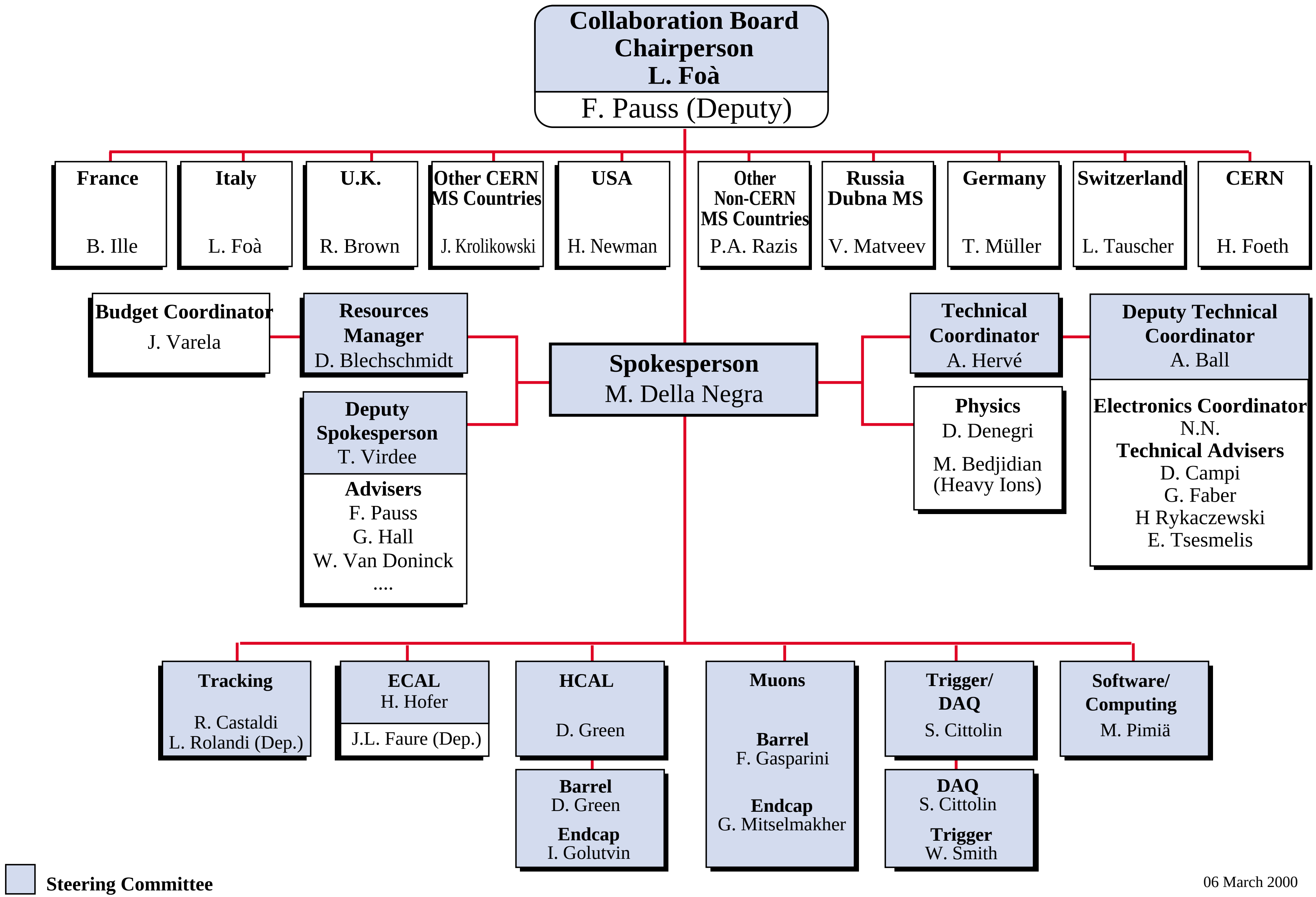
| | Number of scientists |
|---|---|
| Member States | 1036 |
| Non-Member States | 421 |
| USA | 335 |
| Total | 1792 |




February, 21st, 2000/av
http://cmsdoc.cern.ch/pictures/cmsorg/overview.html

**1792 Physicists & Engineers**
**31 Countries**
**141 Institutions**

# CMS Management Board and Steering Committee




06 March 2000

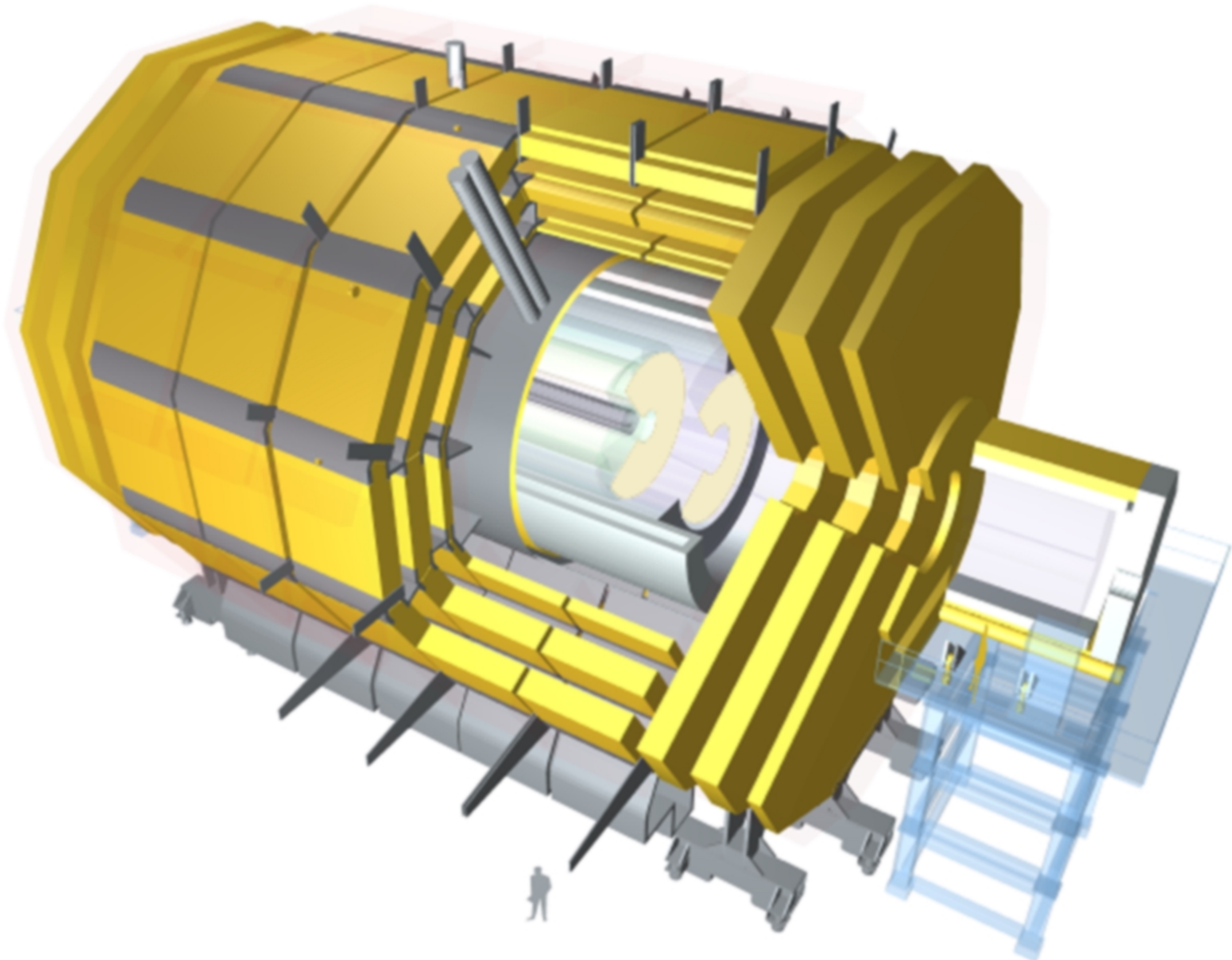
# MoU Signatures

| | |
|---|---|
| Austria | 3.90 |
| Belgium | 5.00 |
| Bulgaria | 0.60 |
| CERN | 85.20 |
| China | 4.70 |
| Croatia | 0.28 |
| Cyprus | 0.60 |
| Estonia | 0.09 |
| Finland | 5.00 |
| France-CEA | 5.60 |
| France-IN2P3 | 19.70 |
| Germany | 17.00 |
| Greece | 5.00 |
| Hungary | 1.00 |
| India | 4.40 |

| | | |
|---|---|---|
| Italy | 55.00 | |
| Korea | 2.60 | |
| Pakistan | 1.00 | |
| Poland | 3.00 | |
| Portugal | 2.00 | |
| RDMS-Russia | 20.50 | |
| RDMS-DMS | 6.40 | |
| Spain | 6.00 | |
| Switzerland-ETHZ/Univ. | 78.50 | |
| Switzerland-PSI | 8.50 | |
| *Taiwan* | | 2.30 |
| Turkey | 1.00 | |
| UK | 9.10 | |
| USA-DOE | 88.51 | |
| USA-NSF | 12.10 | |

| | |
|---|---|
| Sum of Contributions | 452.3 |
| CMS Cost (Full Silicon Tracker) | 455.9 |

# 1. Magnet and Installation



# Magnet. Surface hall

•The **construction** of the surface hall has progressed according to schedule in 1999

•The **first section** of the hall was **handed** to CERN on 17/1/00 and CMS will be **able to start assembly** of magnet yoke in July 2000, (as foreseen).

*In fact we plan to already store heavy parts of barrel yoke starting this month. (as soon as the cranes are operational).*

# Magnet. Underground area

- The **freezing** of the ground has been more difficult than foreseen for hydrological reasons.
- A **second set of holes** had to be drilled to inject liquid nitrogen and grout.
- Finally the 12-m shaft was tightened at the end of Nov. 99 and is now at –40m.
- The 20.4 m main access is also tight and digging has just started.
- At the present time the **underground works are 5 months late**.

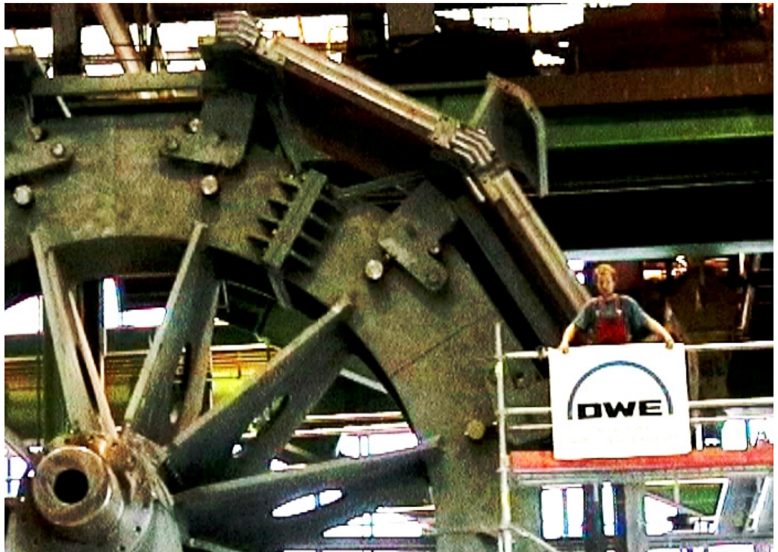
*These 5 months just match the actual schedule of the magnet, but the delay in civil engineering must not increase.*

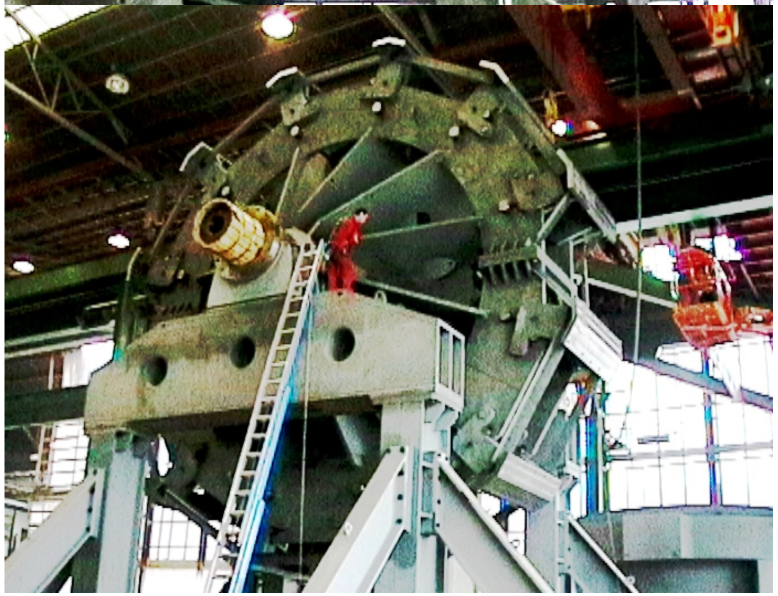
# Civil Engineering at Point 5


# Magnet. Yoke

- **All heavy plates**, 450 mm thick, satisfying the specifications, have been delivered by Izhora Zavod (St Petersburg).
- The **first Barrel Ring** was completed in September 1999 at DWE, and measured by photogrammetry.
- Two-Barrel Rings are already in storage at CERN Point 2.
- The third Barrel Ring will be delivered to CERN in mid March.
- The **outer vacuum tank** that is part of the assembly jig of the central Barrel Ring is under construction at DWE.
  The **inner vacuum tank** is being manufactured by FCI and will be delivered already in autumn 2000.
- **Production of Endcap** disks is 25% complete at Kawasaki H.I., Japan.
- Check first disk by photogrammetry at end-Mar '00.

# Trial Assembly of 1st Barrel Wheel (YB1)



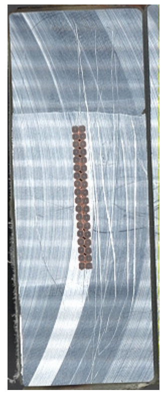
# YE2 half disk assembly in Kawasaki

# Magnet. Coil

- The **winding** pre-industrialization studies have been completed. The **winding model**, using dummy conductor, has been wound. INFN has organized the winding procurement through international tender and is financing it. The **contract** has been awarded to Ansaldo.

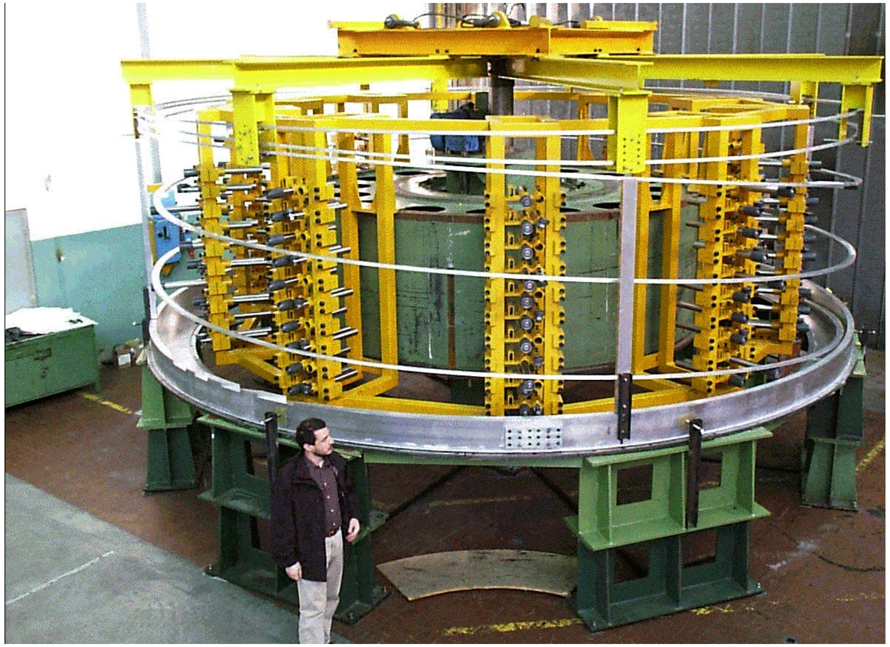
- For the **conductor** several large **procurements** have been organized by institutes as follows:

| Contractor | Contract Signature | |
|---|---|---|
| - Strands | Fermilab | yes |
| - Pure aluminium | Fermilab | yes |
| - Aluminium alloy | Fermilab | Feb 2000 |
| - Cabling | ETH Zürich | yes |
| - Coextrusion | ETH Zürich | yes |
| - EB Reinforcement | ETH Zürich | yes |



- **L2 Milestone: Delivery of 1km of conductor by Sept 2000**

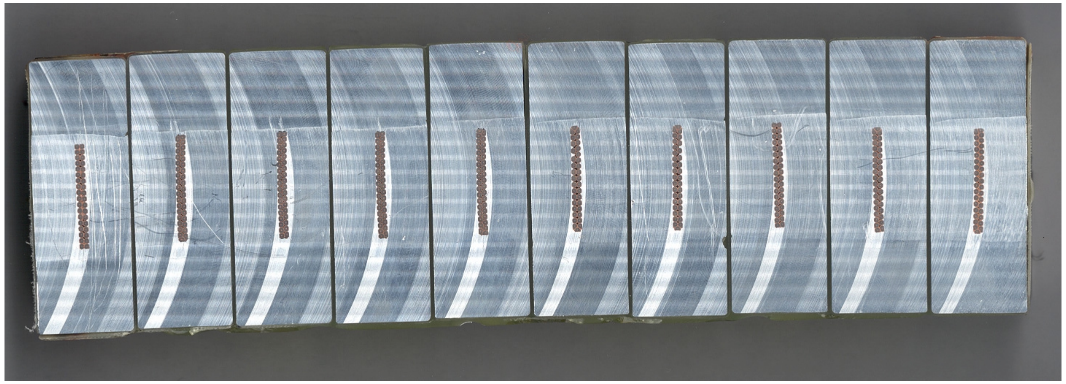
# Conductor and Winding Test



Model of winding machine (Pre-industrialisation)

Output of four layers

One layer stack of real conductor (2m in length)



# Magnet. Cost and Schedule

- Total Cost estimate **121.9 MCHF** is maintained.
- Components worth 84 MCHF under contract (70% of total cost)
- Sum of contracts awarded so far, are below the Cost Book estimate.
- But provision made for:
  - Conductor: increase test length for winding. Spare lengths to cover accidents.
  - Reserve for assembly operations and heavy lifting.

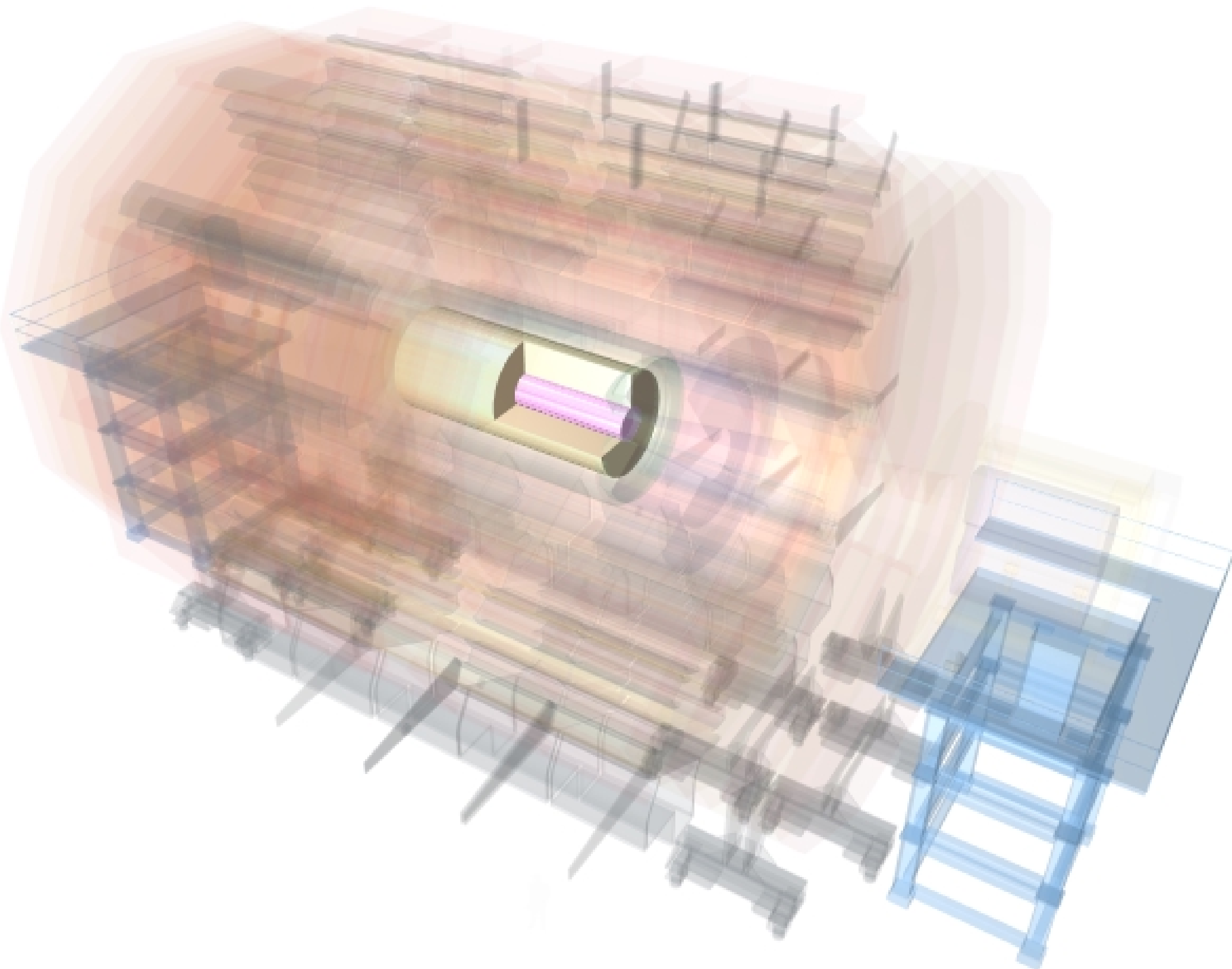
•The magnet **schedule**, based on **contractual dates** has a **5 months delay** w.r.t. to TDR. Delay is due to the considerable time required in negotiating high value contracts.

**•The CMS Master Schedule (V28) is being re-baselined, using contractual dates**

**•A new set of Milestones is being generated for LHCC.**

**•The time given to the sub-detectors for installation underground has been reduced by 4 months to keep to July 2005. This will require more shift work**.

# 2. Tracker



# Tracker: technology decision

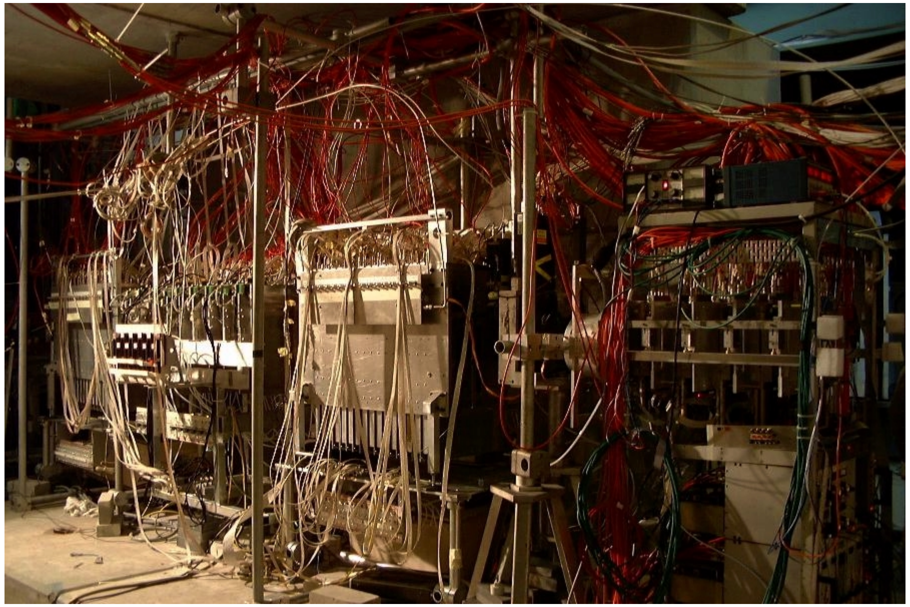
• Two stage Tracker in TDR (and MoU):
low luminosity (Phase I)and high luminosity (Phase II)

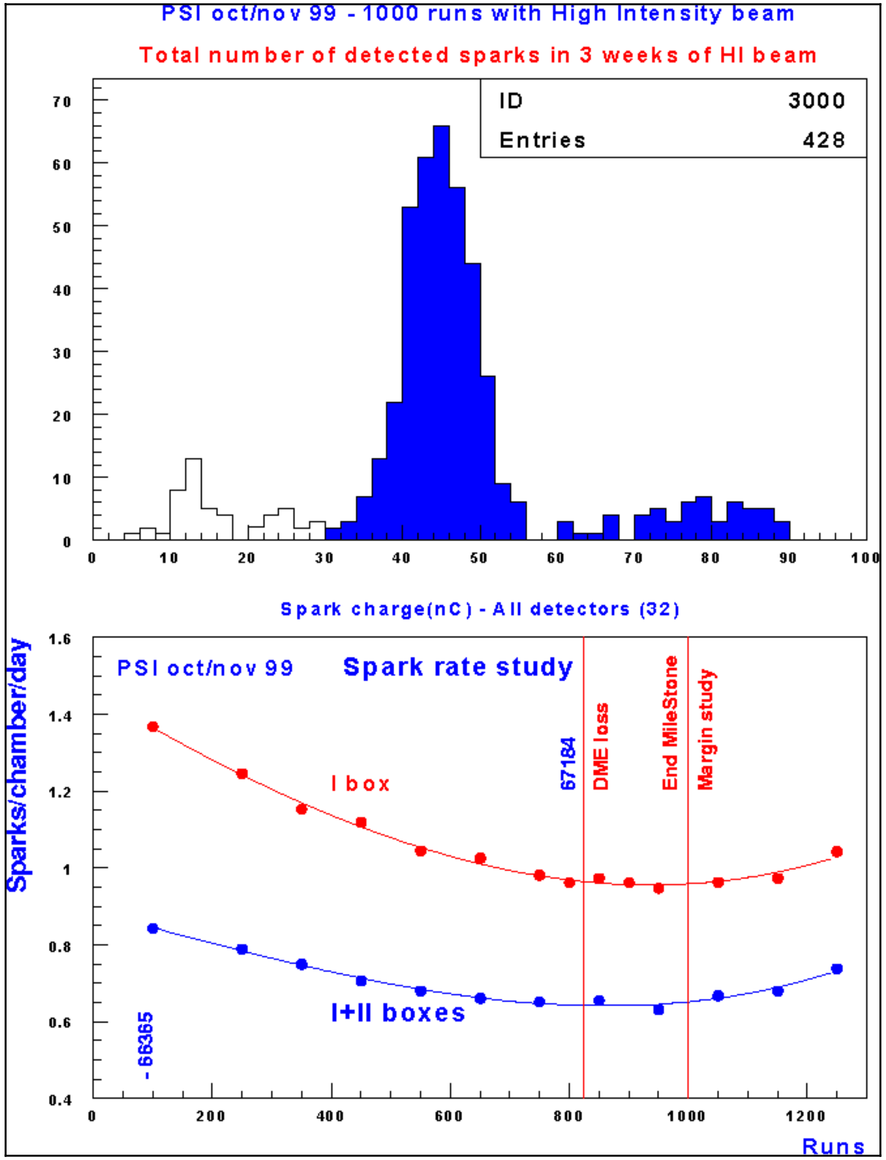
• TDR approved with an important Milestone on MSGC robustness

• All silicon layout studied as alternative solution
•low cost of Silicon sensors for large quantities in 6’’ technology
•possibility of streamlining module assembly through automation

• Internal review in December 1999 to compare the two solutions on an equal footing.

# Tracker. MSGC Milestone






The PSI test demonstrated the viability of MSGC with advanced passivation for tracking at large radii in CMS.

For chambers at the working point, the extrapolated strip loss in LHC lifetime is less than 1%.

# Tracker. Full Silicon

- The review showed that both solutions are technically feasible but highlighted the overall delay the project had incurred so far, raising concern about the collaboration to recover the lost time.

- Moving from two parallel technologies to a single one allows to concentrate all efforts onto a reduced set of problems

- Now propose a one stage full Silicon Tracker, with a performance similar to the one described in the TDR and within a cost ceiling of 77.5 MCHF.
  (next presentation by R. Castaldi : Addendum to CMS Tracker TDR)

| | **TDR Phase II Si + MSGC (MCHF)** | **TDR Phase I Si + MSGC (MCHF)** | **One Stage Full Silicon (MCHF)** |
|---|---|---|---|
| Pixels | 8.2 | 8.2 | 8.2 |
| Inner (Si) | 30.5 | 25.3 | 21.7 |
| Outer (MSGC or Si) | 42.6 | 34.4 | 38.2 |
| Mechanics+ Infrastr. | 6.1 | 6.1 | 9.4 |
| **TOTAL** | **87.4** | **74.0** | **77.5** |

# Tracker. Electronics status

- **Front end** *Working chips in three technologies*

  APV6 & APVM (Harris) *uncertainties about 10Mrad hardness*

  APVD (TEMIC DMILL) *instability problems solved*

  APV25 (0.25µm CMOS) *spectacular results from first iteration*

  ***=> 0.25µm technology selected because of large performance and cost gains***

- **Optical link steady progress** - *tendering now under way*

  *second most important cost driver for electronic system*

- **DAQ interface** PMC FED used in beam tests - final version being defined

- **Control system** 0.25µm chip set well advanced

Overall cost: 2.0CHF/channel *including contingency, spares...*

- **System.** First, small scale system to be evaluated in 25nsec beam

# Pixel. Status of detector

1) **Pixel sensor received** (submitted Q2 99, by CSEM)

- open atoll ring design for $p^+$-rings (as TDR ).
- Technique for bump bonding at 35µm established by PSI.
- Use of oxygenated silicon being explored

2) **Construction and tests of pixel minimodule (6 chips)**

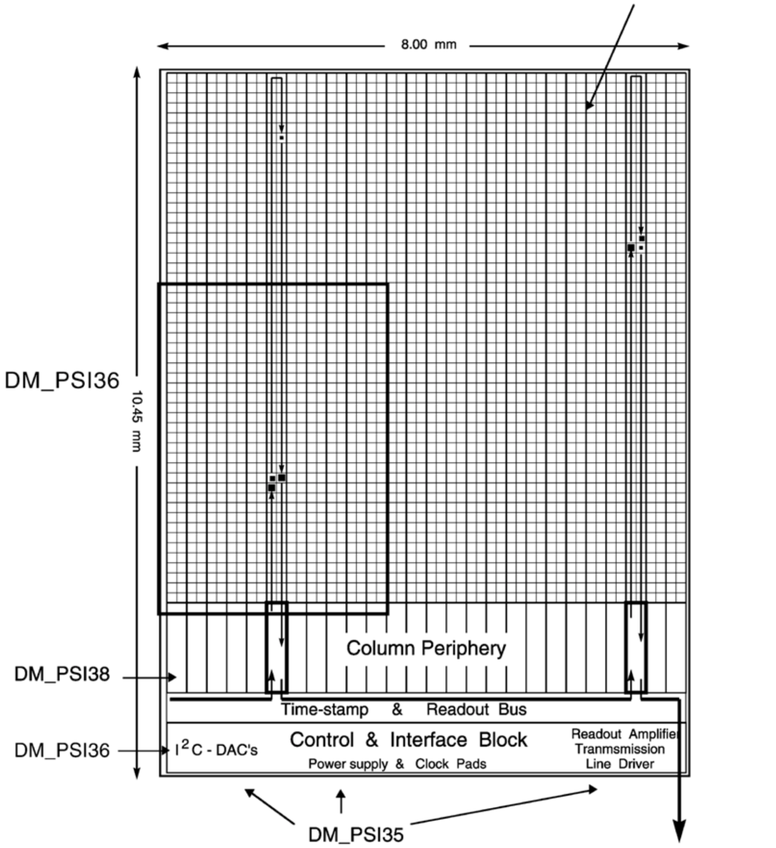
- 6 pixel chips (22x30 pixels, reduced architecture chips) on hybrid.

3) **Development of final Pixel ROC, 52x53 pixels** (ROC = Read Out Chip)

- Design of full architecture ROC on schedule. Target date for finished design of chip in DMILL technology Apr '00
- Translate design into Honeywell technology by Summer '00.

# Pixel. Readout chip and minimodule

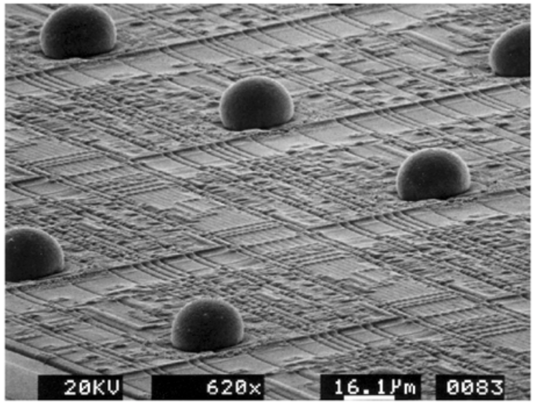
Syntesis of final Pixelchip finished in Spring 2000 !




- DM_PSI35 **Analog Block :** Faster peaking time (28ns), less timewalk ! **DAC, V-regulators, Amplifiers & Drivers**
- DM_PSI36 Test **CDA mechanism** and **data readout, I2C blocks**
- DM_PSI38 Test **Timestamp mechanism** (8) in Column Periphery

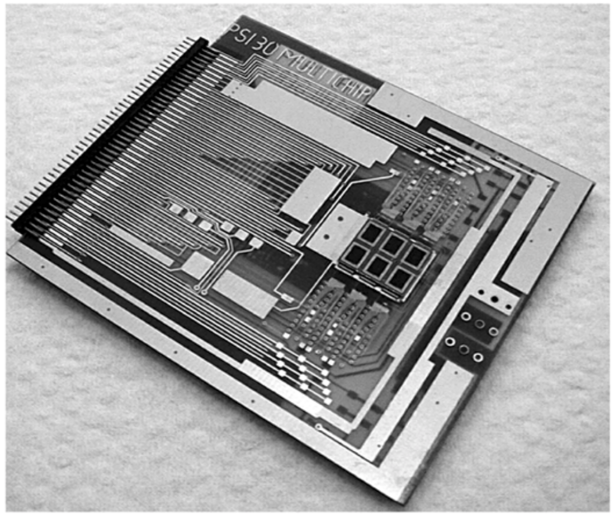
## Final chip 52x53 pixels

Test bumpbonding of several pixel chips to one sensor unit  Module bumping




- Prototype bumping at PSI
- final production planned in industry

Gain experience of operating 6 chips same hybrid  System aspects

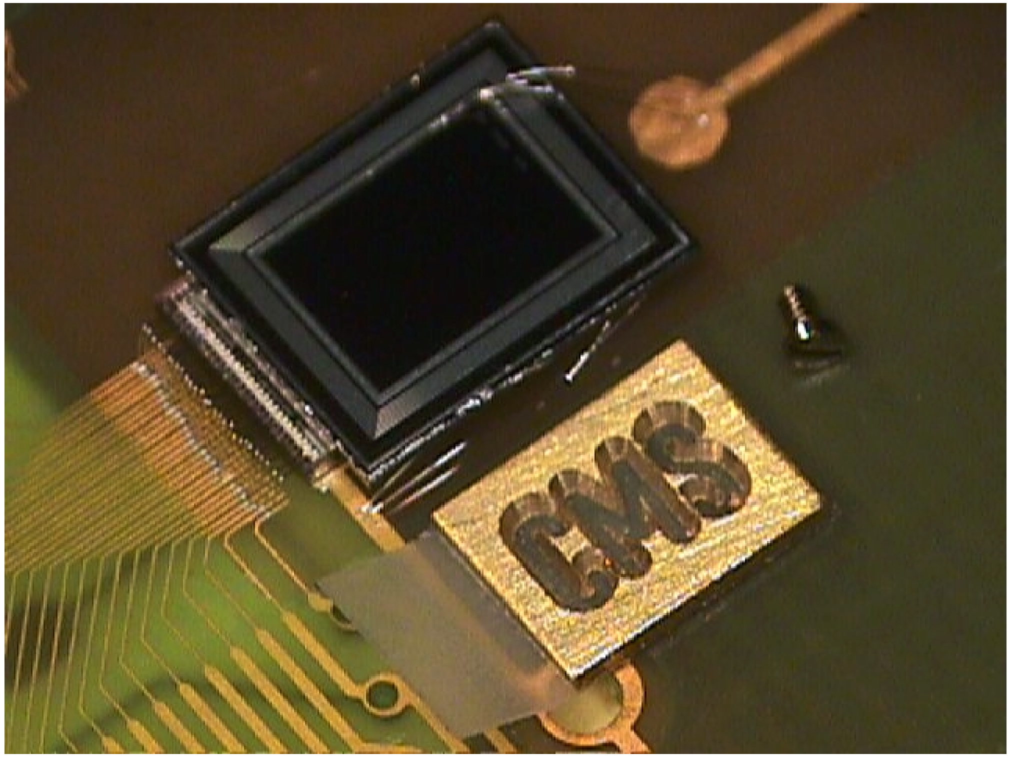


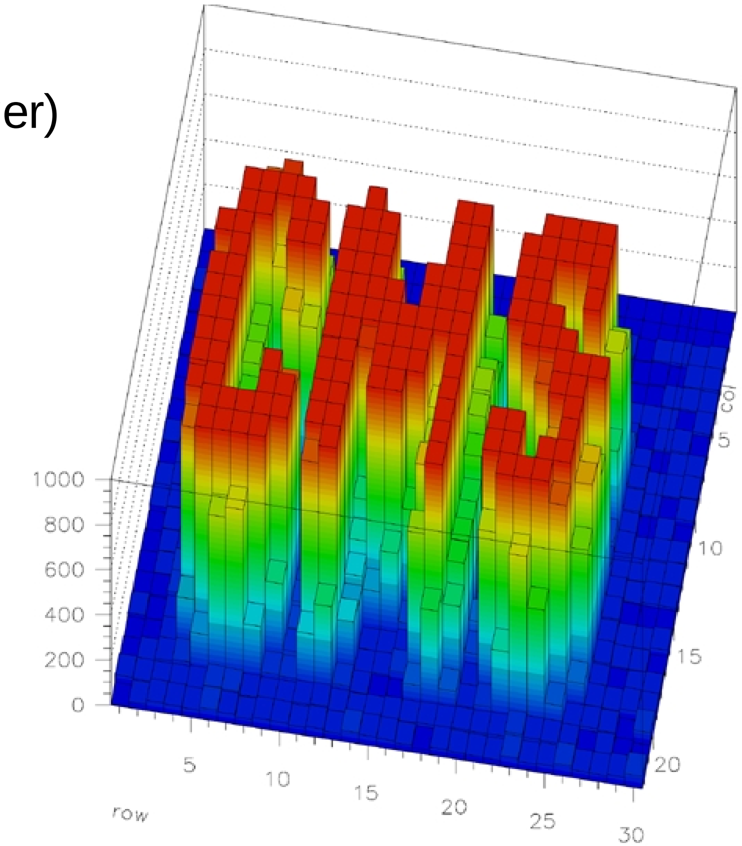

Successful operation of minimodule !

## Successful operation of minimodule (6 chips)

# Pixel. Test of assembly

- Illumination with 14KeV x-rays (Rb)
- x-ray mask (500µm brass)
- data taking with random coincidence (artif. trigger)



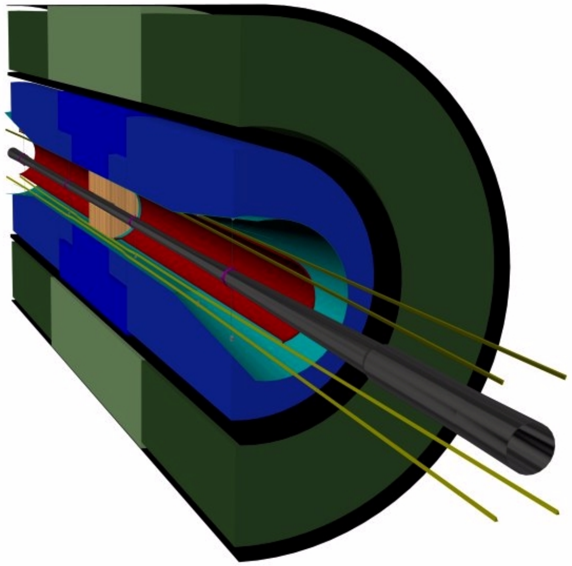




**Lego plot of pixel hit rate**

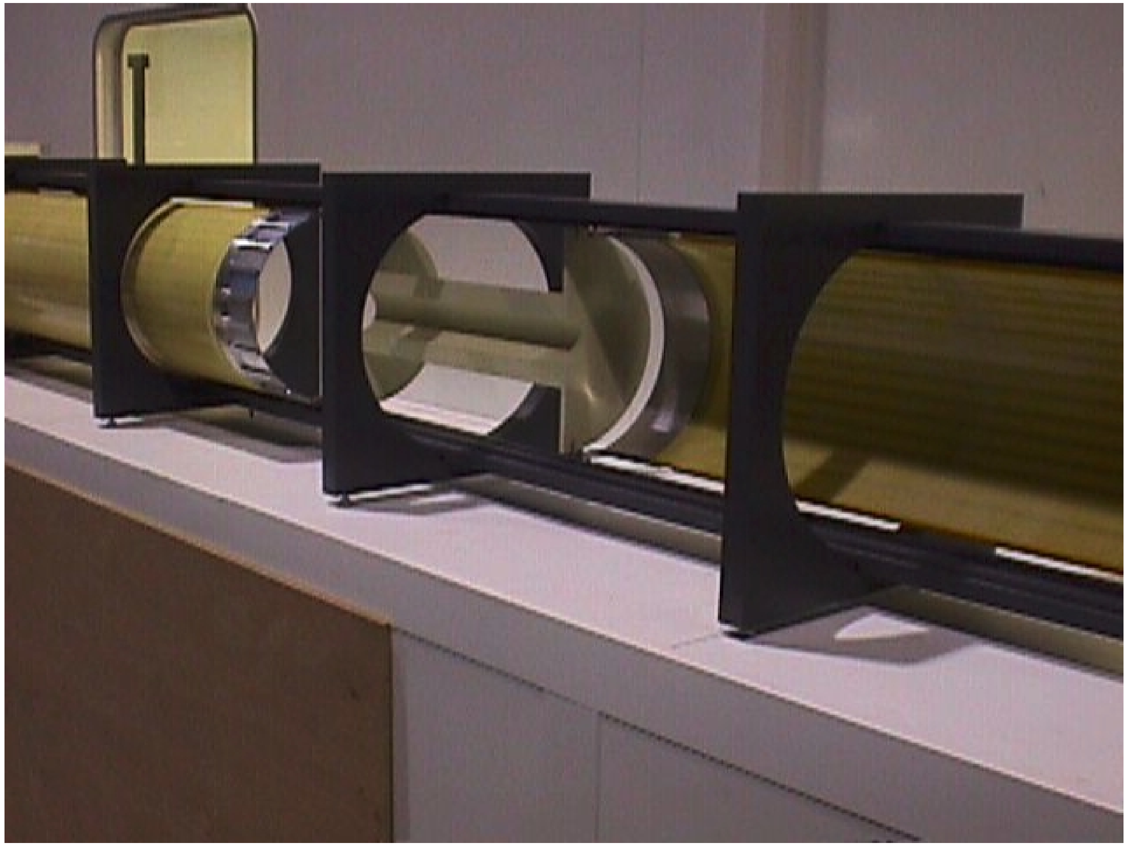
# Pixel. installation and supply tube

- Detector & Supply tube slide in on rails after beam pipe bake out !

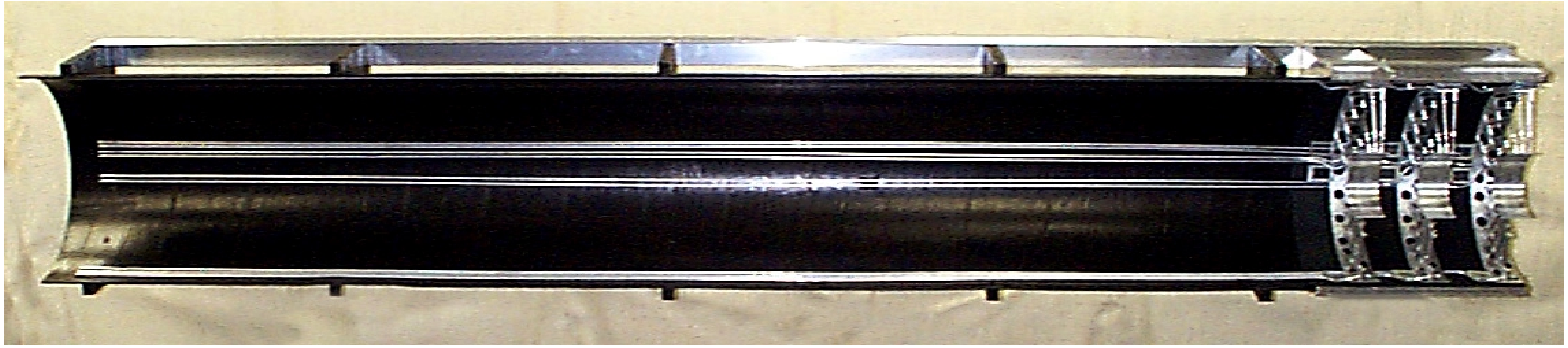
- Verify 3D - tolerances on CAD & mechanical model !

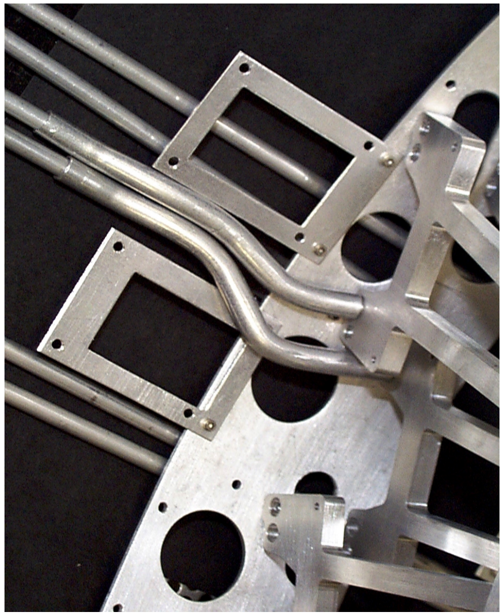


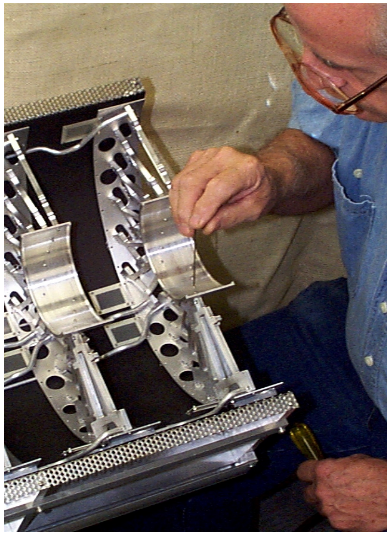
## Mechanical model for pixel insertion & cabling tests (Uni. Zürich / PSI)

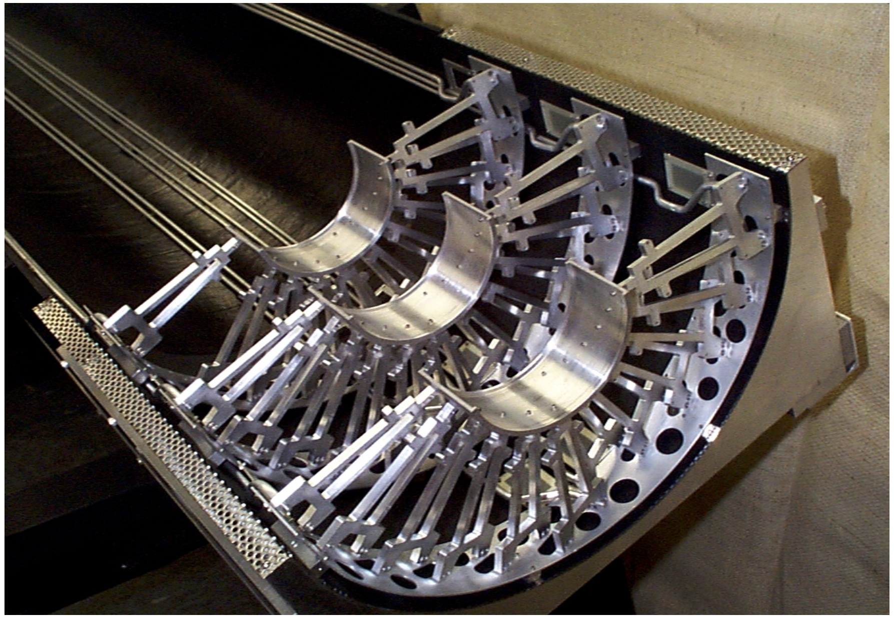


# Pixel. Model CMS forward

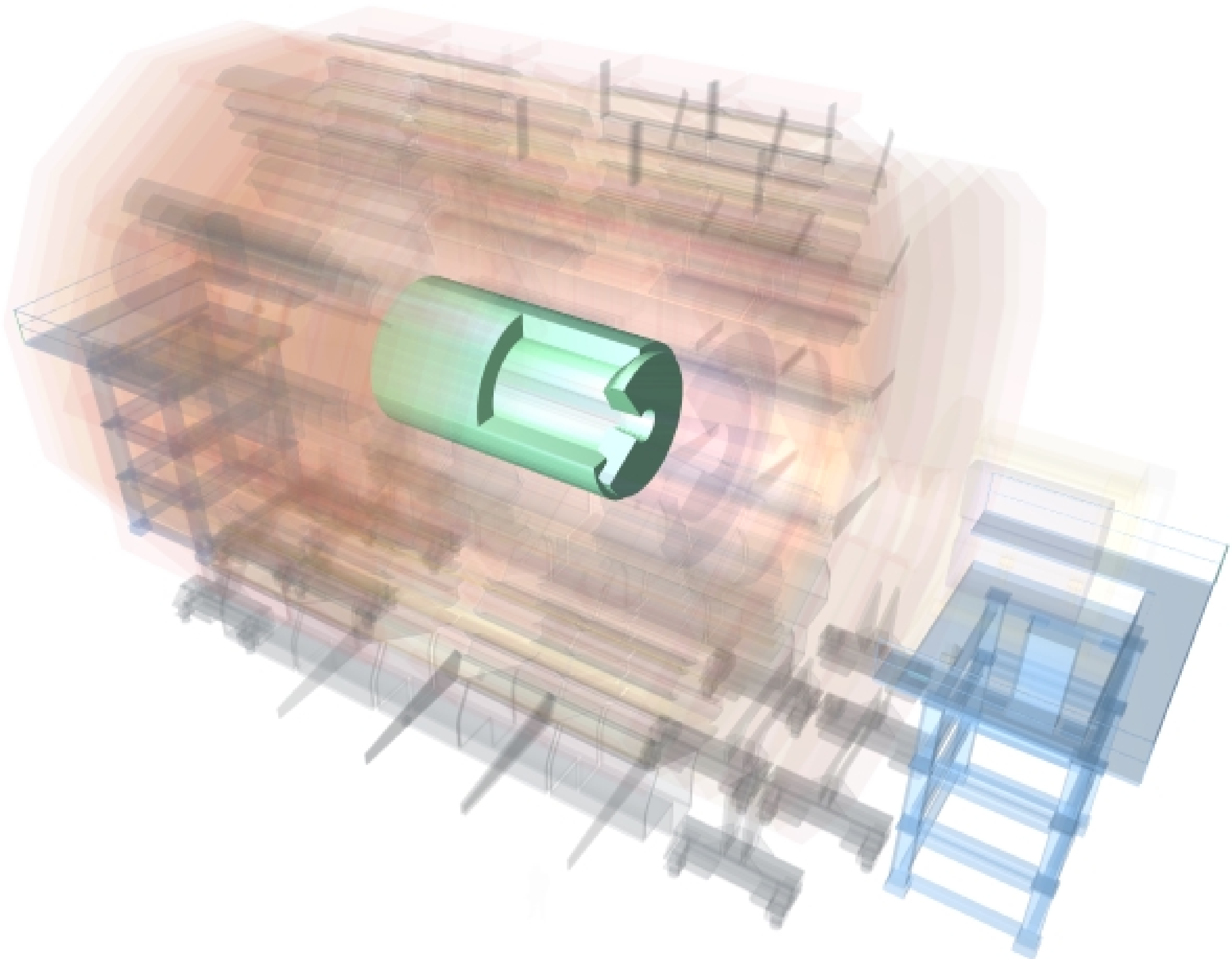






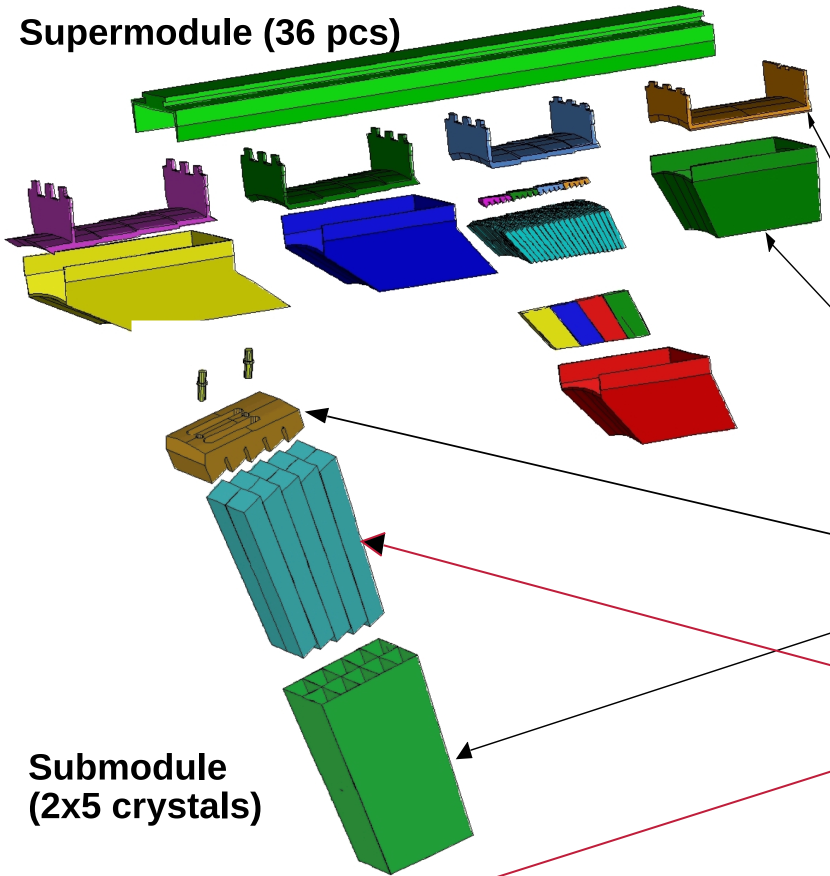


# 3. ECAL



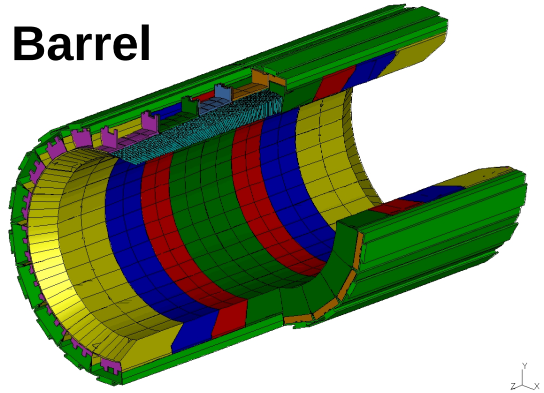
# ECAL. EB Exploded View

**Supermodule (36 pcs)**



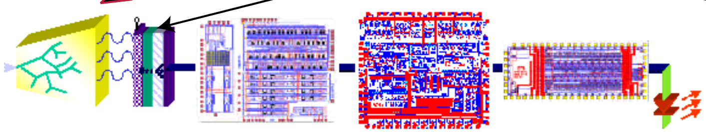
**Submodule (2x5 crystals)**

**Barrel**



**Mechanics**
Modules (144 pcs)
Tendering in 2000
Submodules (2448 pcs)
Contracts signed in 1999
Total value of 3MCHF

**PbWo4 Crystals**
Preproduction in Russia, R&D in China
Production agreement signed in Russia
Letter of Intent signed in China
both at 1.6 $/cc
Total Volume11 $m^3$ (77400 crystals)

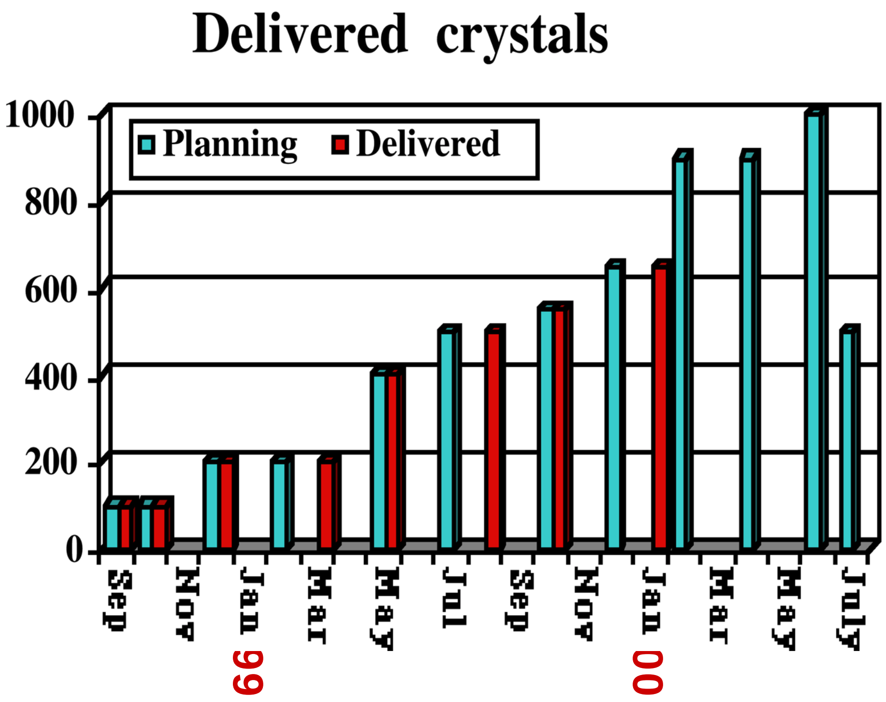


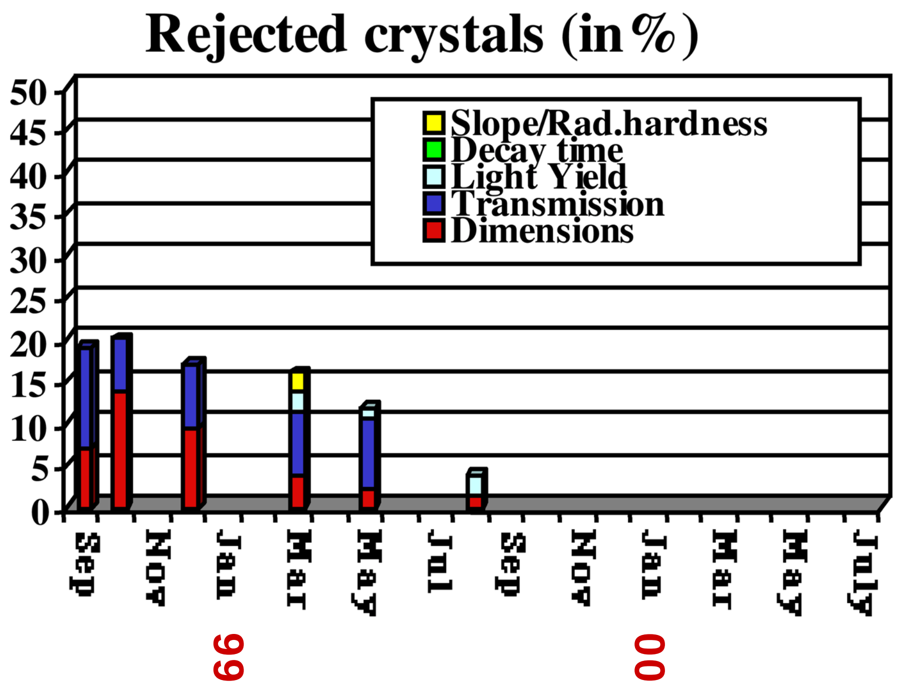
**Electronic Channel (80.000 pcs)**

**Avalanche PhotoDiode (120000 pcs)**
Hamamatsu
Contract Oct 1999. 7 MCHF

# ECAL. Status of crystal delivery (Russia)

2700 crystals have been delivered (end Jan 00)



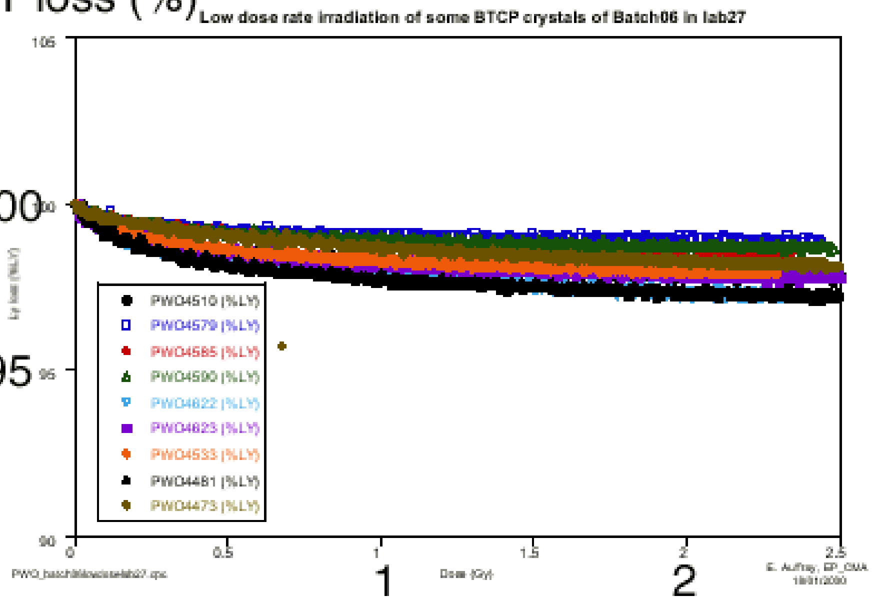




Schedule more or less followed, target yield achieved.
Agreement reached for production of half of the barrel crystals
End of development phase for endcap crystals

# ECAL. Russian Crystals-Radiation Tolerance

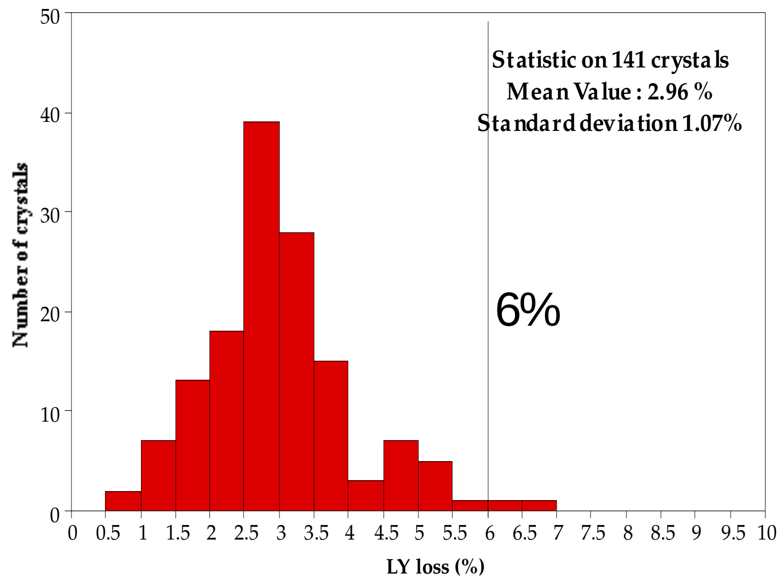
Low dose rate irradiation at TIS : Front Irradiation: 1.5 Gy, 0.15 Gy/hr

LY loss (%)




Dose (Gy)

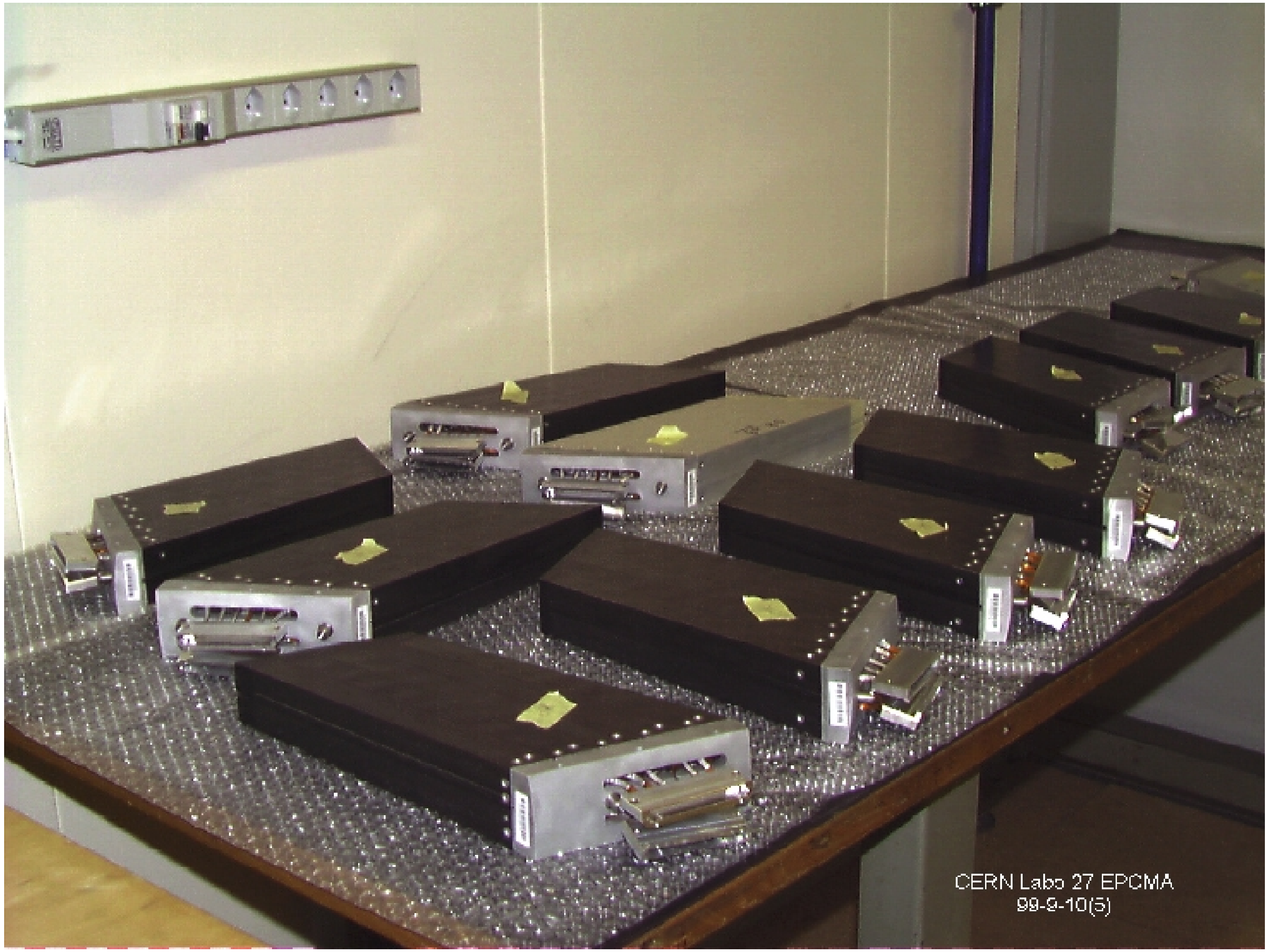
141 crystals



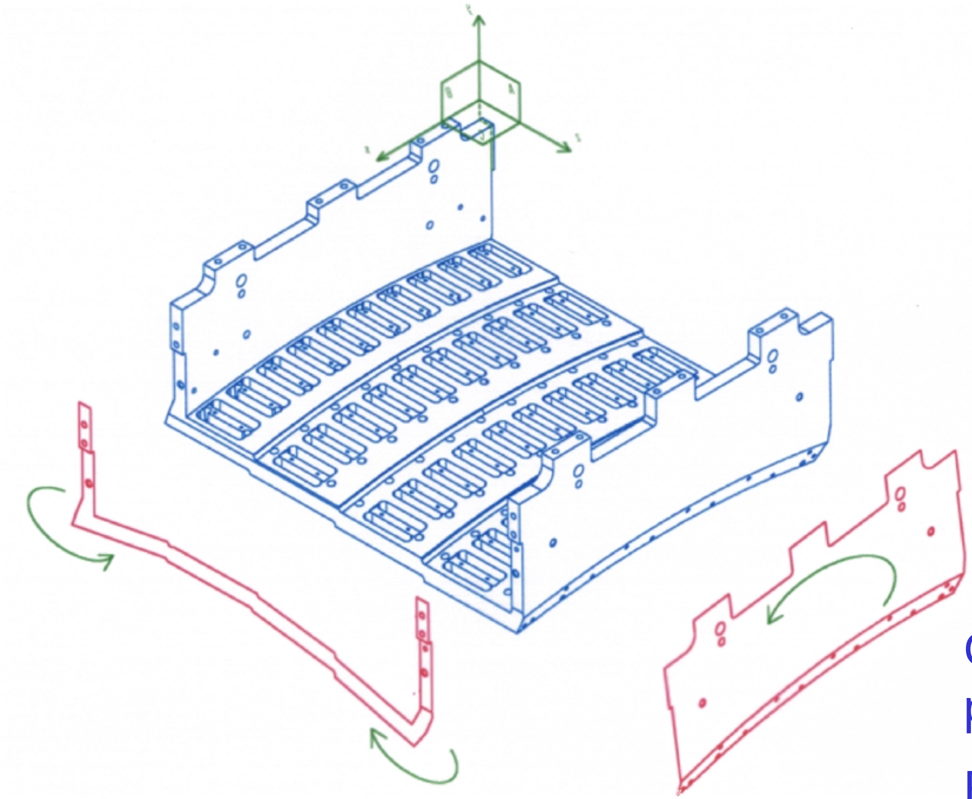

LY loss (%)

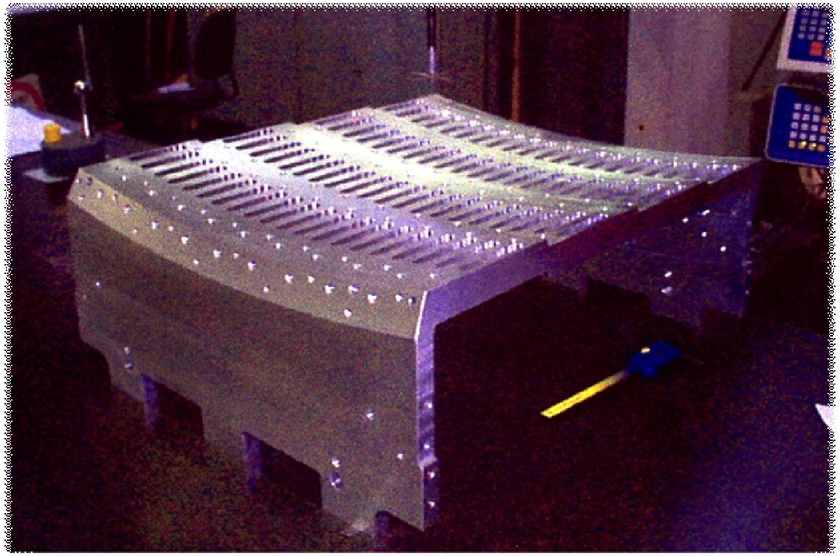
# ECAL: Submodules

Submodules for Module 0 (M0) have been assembled since Jun ‘99



# ECAL. Barrel grid





Grid for M0 was scheduled for Oct '99. But process used introduced distortion.

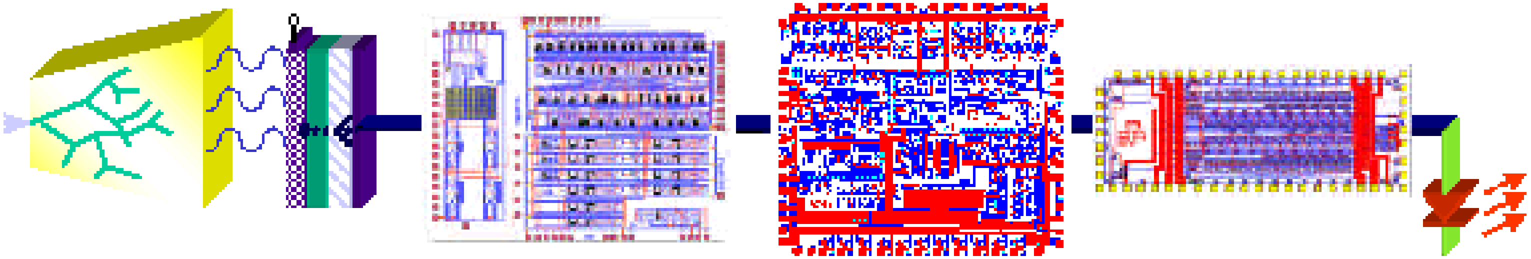
Re-machine first grid. 2nd grid is being built.

M0 should now be ready in September (9 months delay).

As backup investigate alternatives

# ECAL. Front-End chain

**LIGHT to LIGHT**



**APD** **FPPA** **ADC** **Serialiser** **VCSEL**

Hamamatsu
Contract placed
Start production
120k pieces

In Harris rad-hard technology - processing problems - low yield but perform well

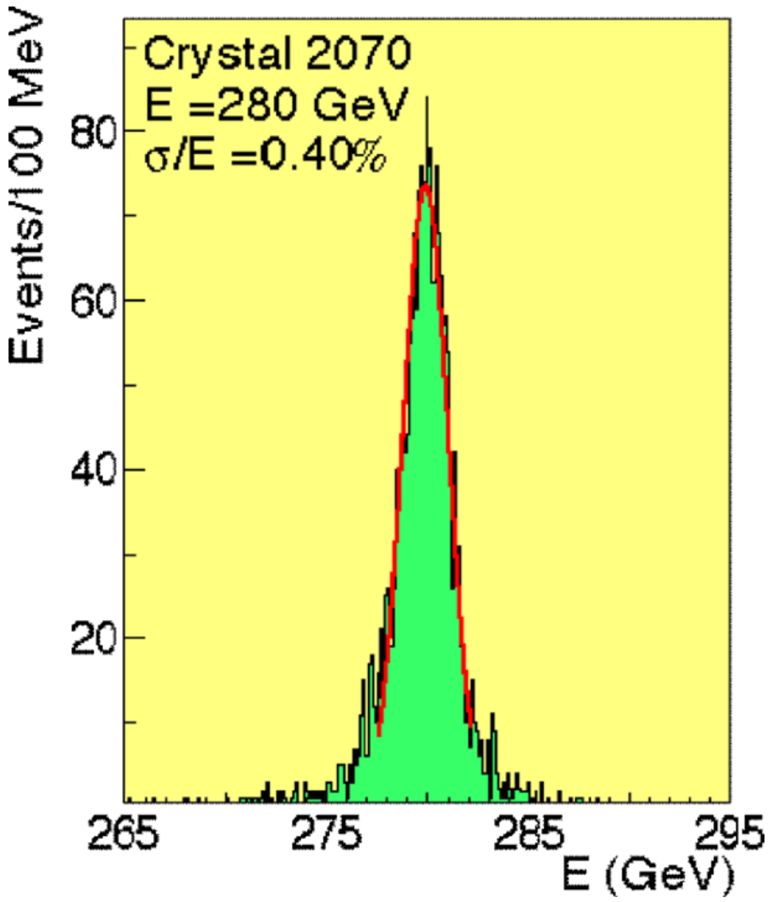
Analog Devices
OK

Problem of yield in pilot production
In-spec samples work
Delay in pre-production

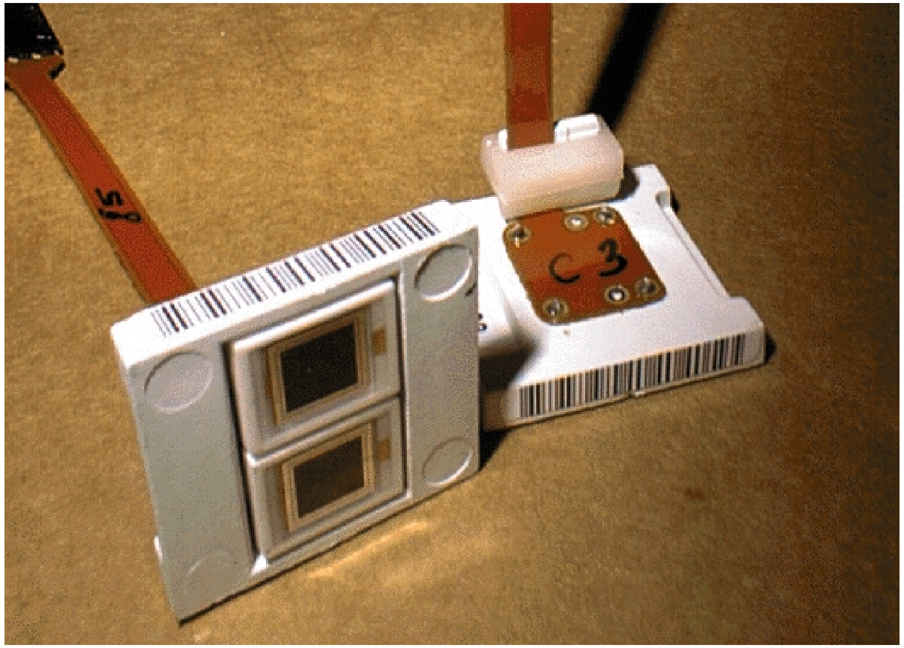
Discussing packaging

Foresee 2-400 channels test of whole chain in beam in Summer '00

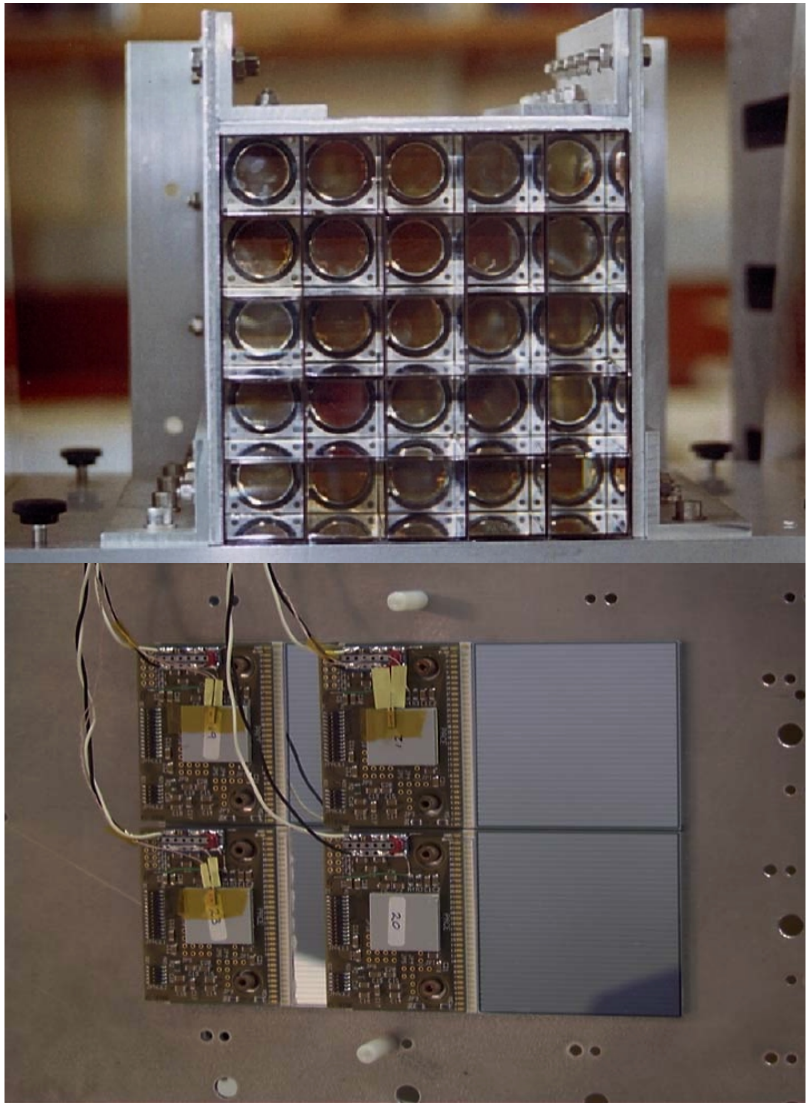
# ECAL. Barrel 99 test beam results



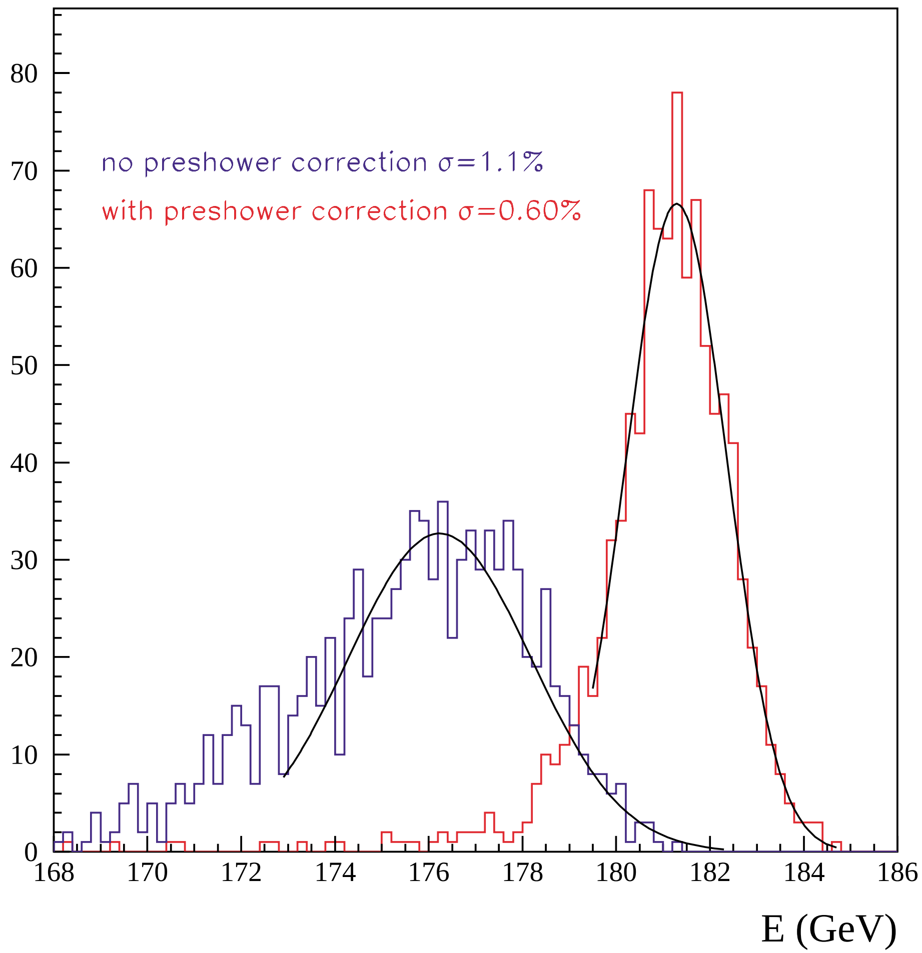

Two APDs 5x5 mm$^2$ surface area mounted in a supporting structure (capsule) glued at the rear of the crystal



# ECAL. Endcap 99 test beam results



180 GeV electrons at normal incidence



# ECAL. Milestones in 2000

**EDRs**

Nov 00: Endcap (Updated-5months delay)
Nov 00: Preshower (Updated-1month delay)

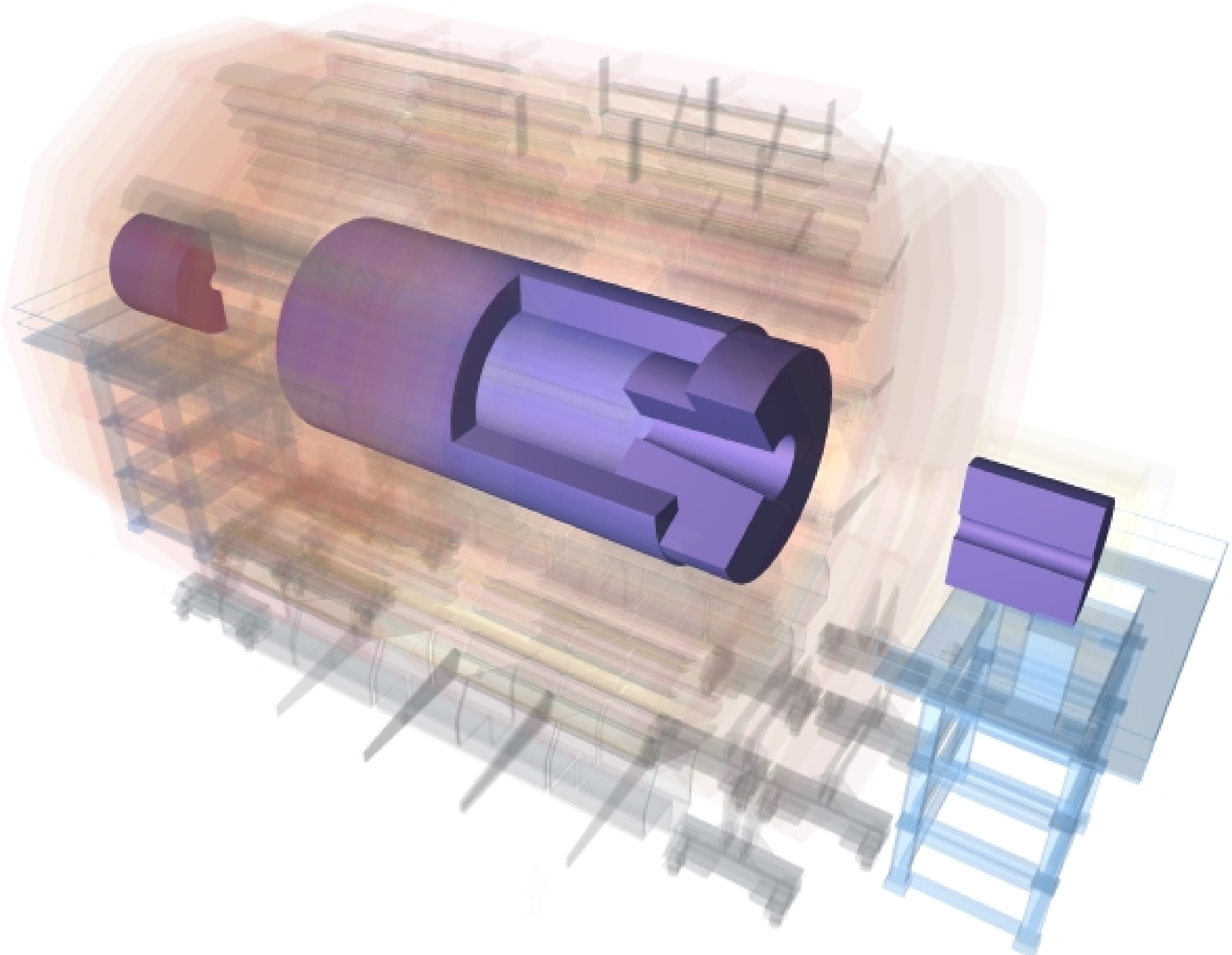
**Milestones**

Jul 00: Preshower pre-production of 50-100 Si sensors from different producers
Sep 00: nx100 electronics channels produced (Updated-9months delay)
(delay incurred due to problems in chip production)
Sep 00: 400 crystals Module-0 prototype (Updated-9months delay)
(delay incurred due to distortion of the grid)
Dec 00: 1000 crystals produced in China (Updated-9months delay)
(delay incurred due to instabilities in crystals - now overcome
Pilot production of several hundred crystals before Jun'00)
Jun 01: Supermodule 1 completed (Updated-12months delay)

**Projection**

Crystal production is on the critical path. For overall schedule to be kept investment is needed to increase crystals production. Decide this year amount to invest depending on LHC startup.

# 4. HCAL



# HCAL. Current Status

## Essentially on schedule

except front-end electronics which may fall on critical path

**HB - PPP1+ PPP2**

- HB absorber construction in progress
- Scintillator in full production
- EDR for tooling and lifting fixtures, Oct 99, Tooling contract awarded.
- Front-end electronics schedule is under discussion.

**HO - PPP**

- EDR in June 1999 - begin production Feb 00.

**HE - PPP**

- EDR in June 99. Begin absorber production.
- New PPP in May 2000 @ CERN.

**HF - PPP**

- In test beam in 1999
- EDIA workshop in Oct.99. EDR in Dec 99.
- PPP2 in May, 2000 @ CERN.

# HCAL. H2 test beam

**HB - PPP1**

**PPP2**

**HE - PPP**

**HO - PPP**

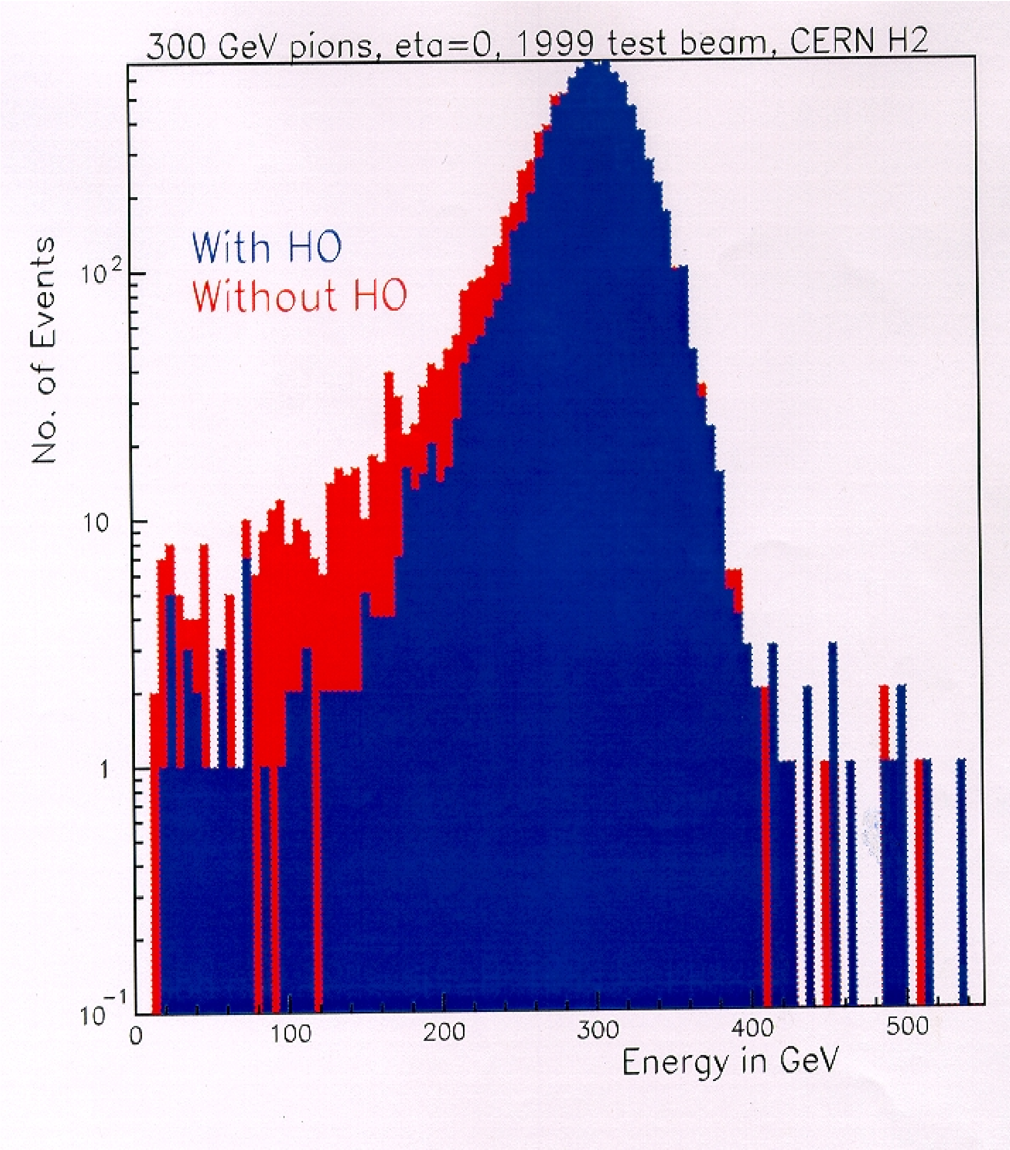
**HF - PPP**

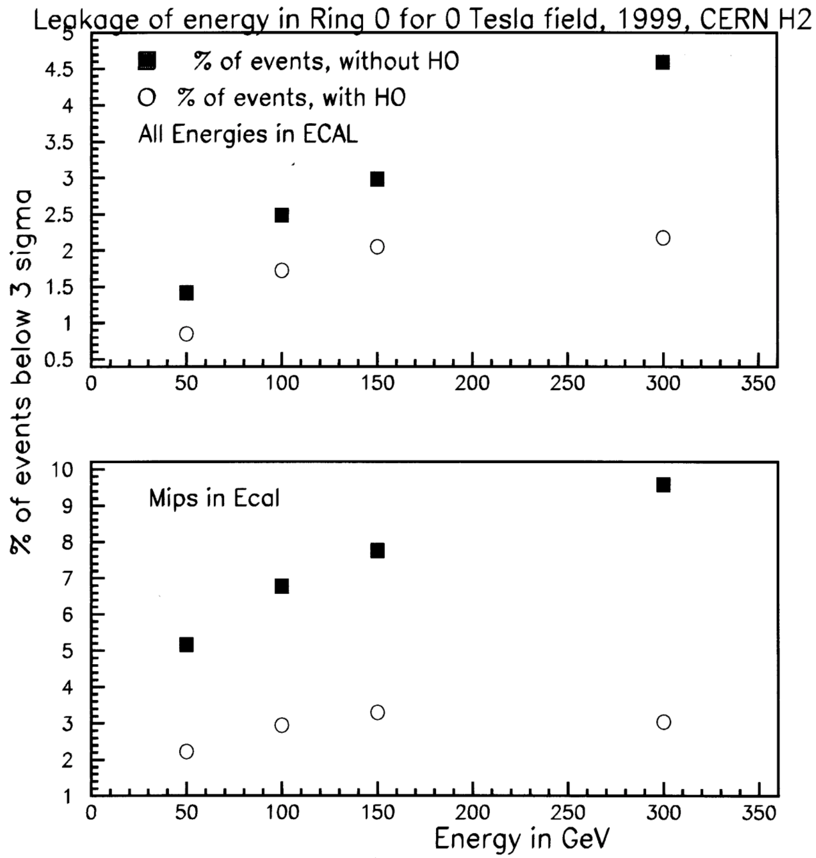
**“ECAL”**

**--------------**

**Comprehensive test of CMS calorimetry**

# HCAL: H2 Results

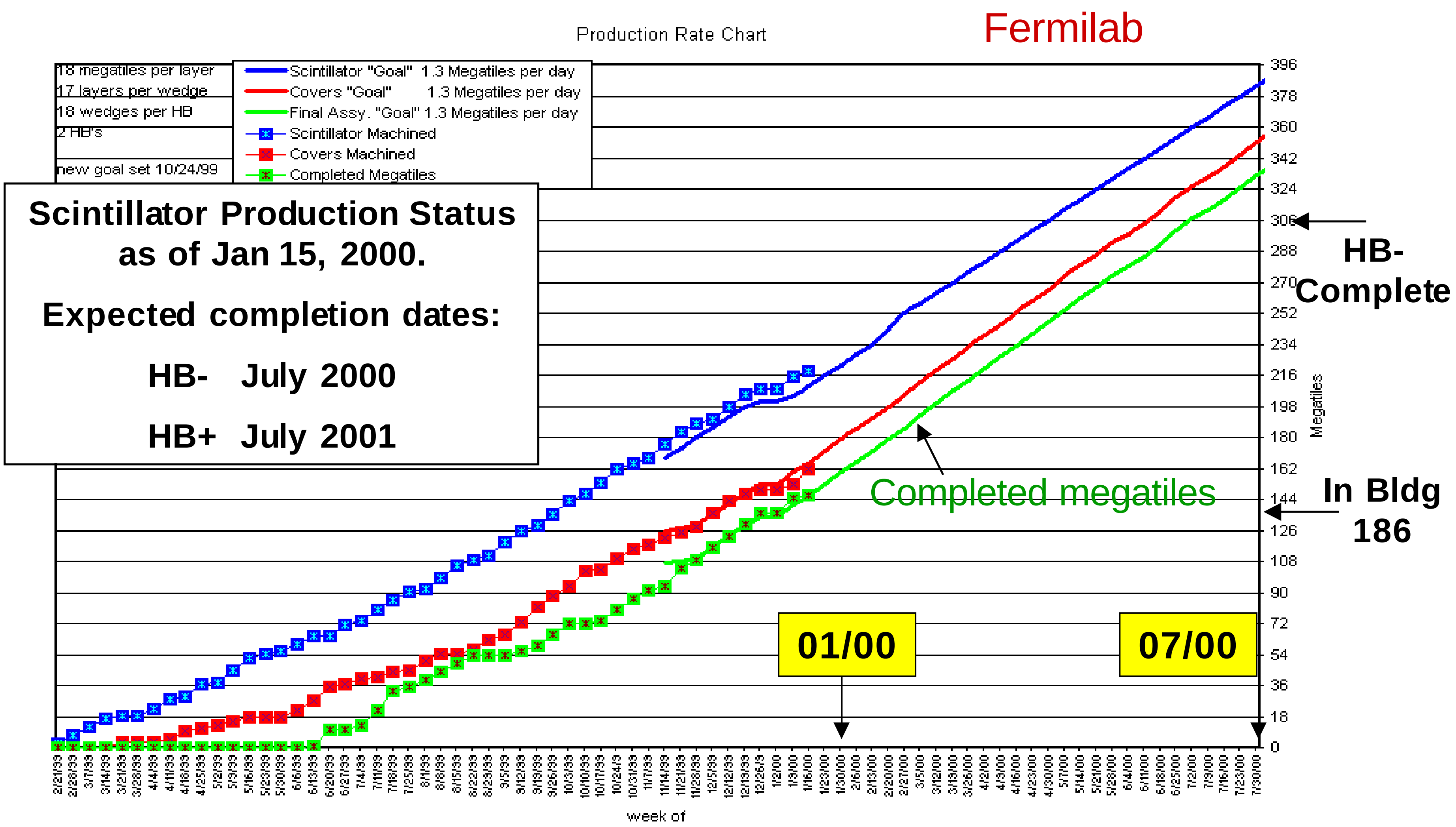


# HCAL. HB - Finished Wedges

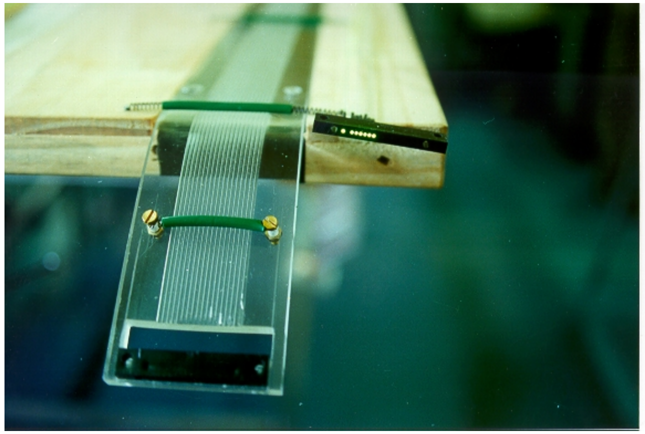
One half-barrel (18 wedges) will be delivered to CERN by end-00.

# HCAL. HB - Optics factory



# HCAL. HO

Pigtail construction in India



Take delivery of a new CNC machine in March

Scintillators, fibres and other optical materials ordered.

Production of HO will start end-March

# HCAL. HE - Plate machining

All the HE absorber is under contract

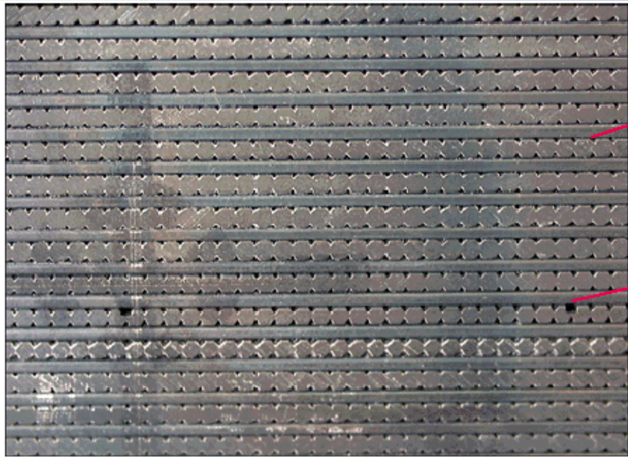
Brass plates procured in St Petersburg, machined in Minsk

# HCAL. HF Pre-Production Prototype

1st HF brick

First HF brick fabricated in RFNC-VNIITF, Cheliabinsk (Russia), using diffusion welding technique

Detail of the endface of a ‘brick’

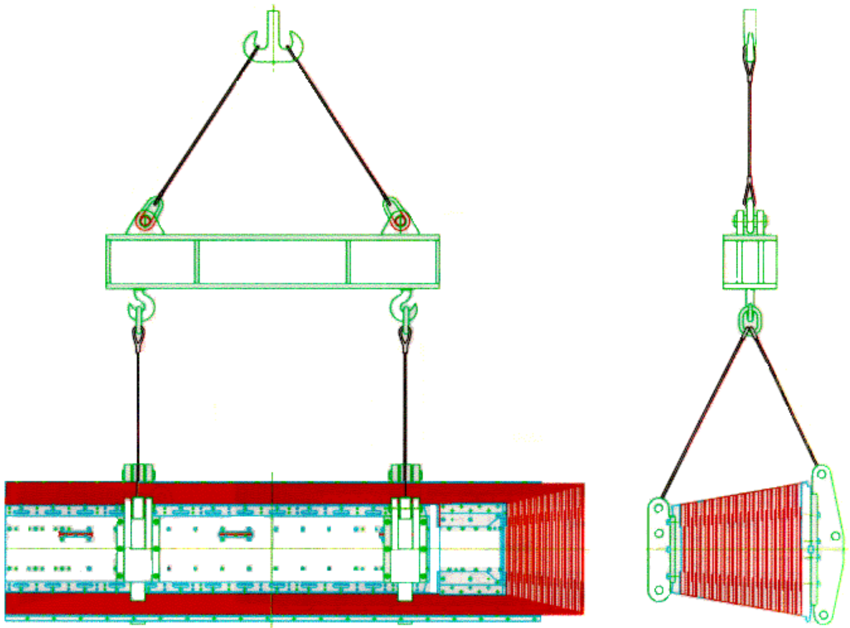



A close-up end view of the HF module shows intereleaved smooth and grooved plates.
The plates are diffusion welded together and each module ('brick') is made of around 100 plates

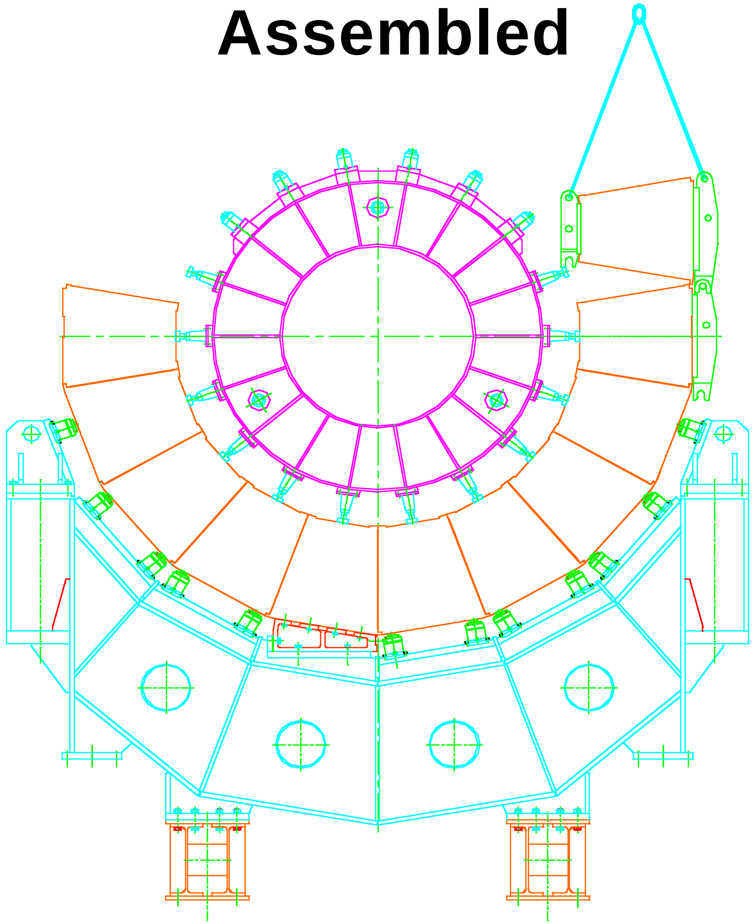
Engineering design transferred to FNAL
New PPP for May 00 - rectangular brick --> wedge

# HCAL. HB Assembly Scenario

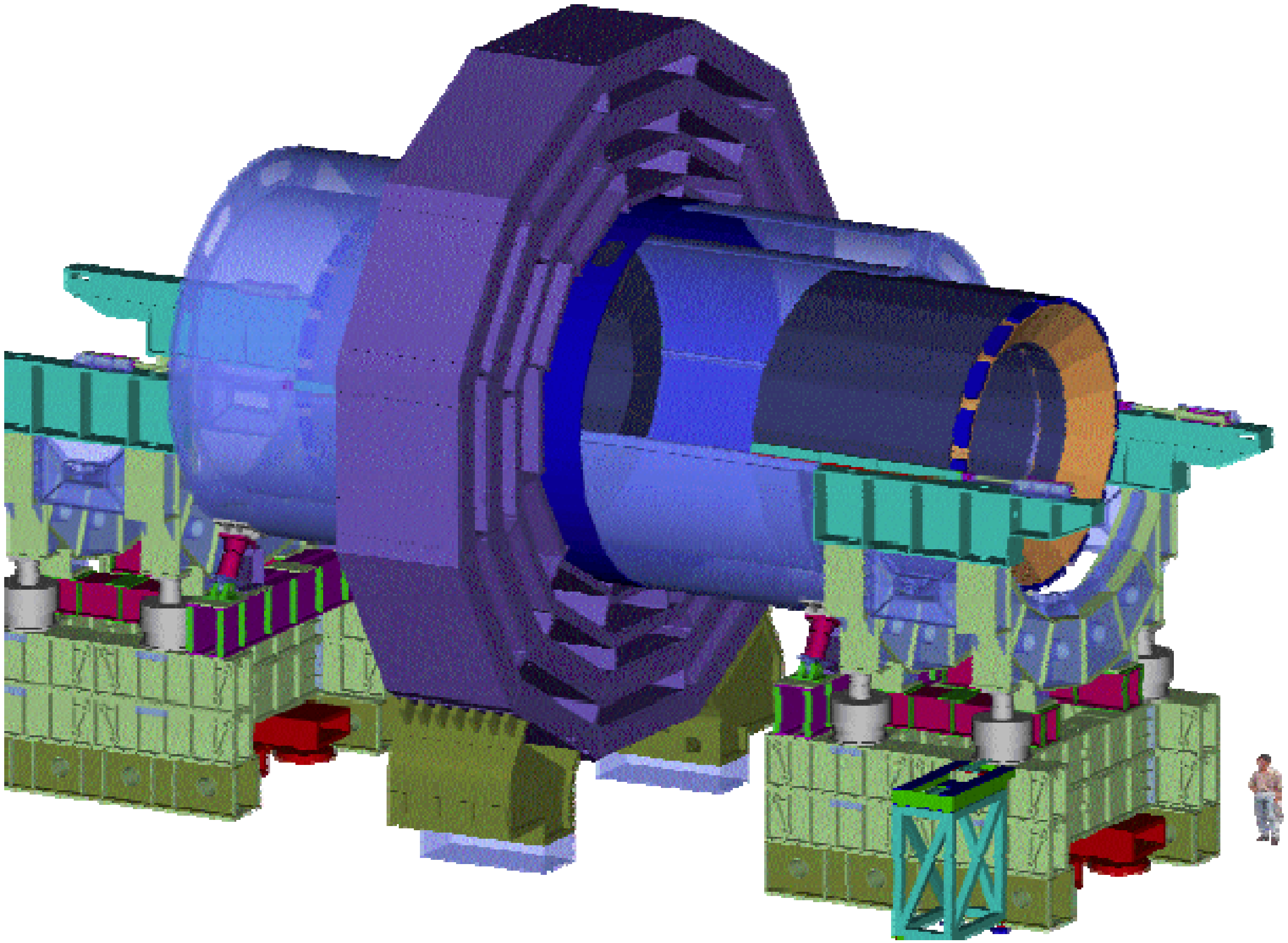
## HB Wedge Lifting Fixture



## HB Wedges being Assembled



# HCAL. HB Installation Scenario



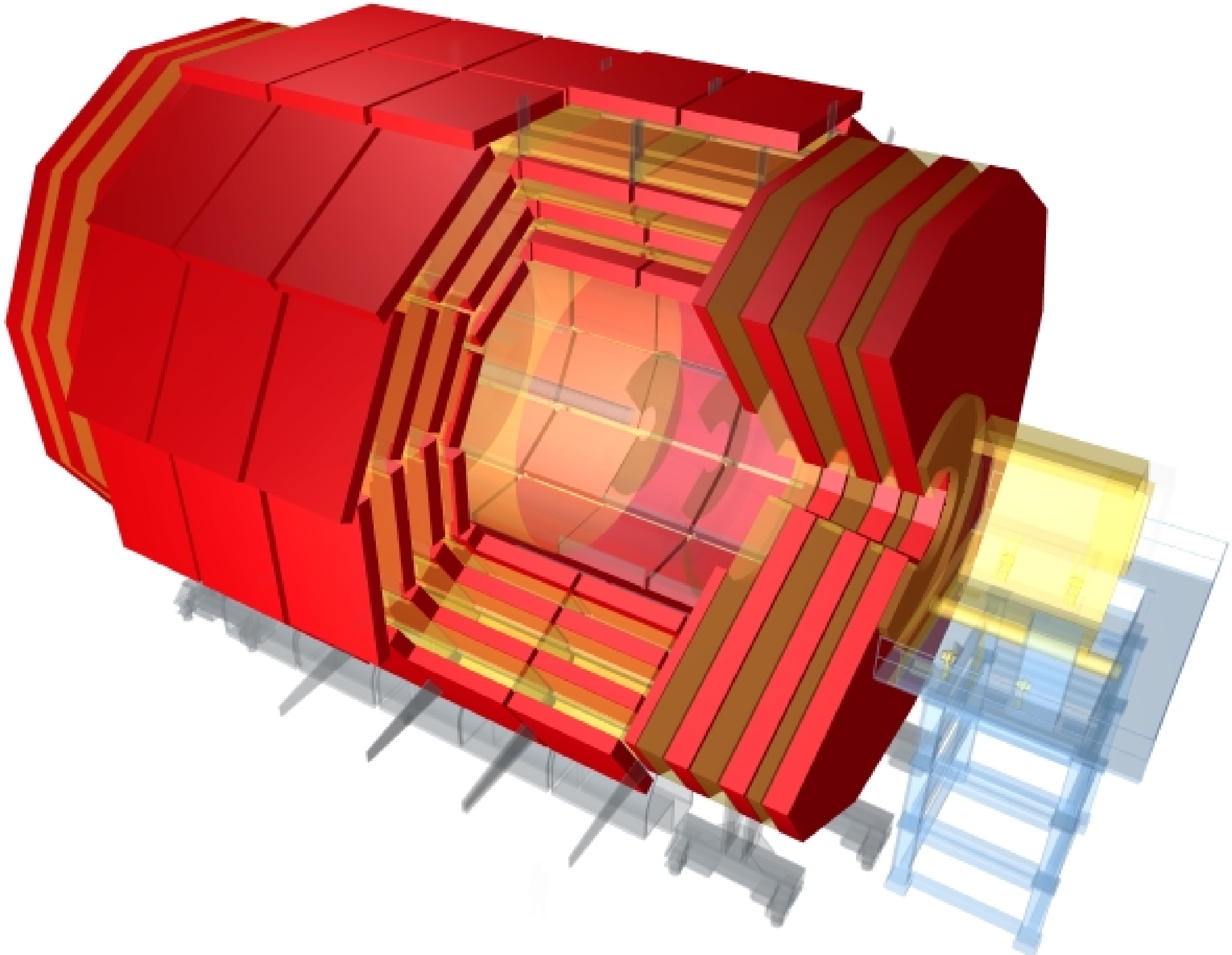
# HCAL. Summary

- Construction of HB  has begun as planned. HE has just begun at MZOR in Minsk. HO construction will begin soon.
- The EDRs necessary prior to construction have been held for HB, HO, HE, and HF. PPP of HB, HE, HO, and HF are in hand. PPP2 for HE and HF are under construction.
- The HCAL effort will now begin to shift to transducers and electronics. All HPDs and PMTs will be bought in 2000

Milestones in 2000:

- Nov ‘00: HB- (1/2 barrel) absorber modules delivered to CERN, and start installation of optics
- Oct ‘00: HF EDR complete.

# 5. Muon systems

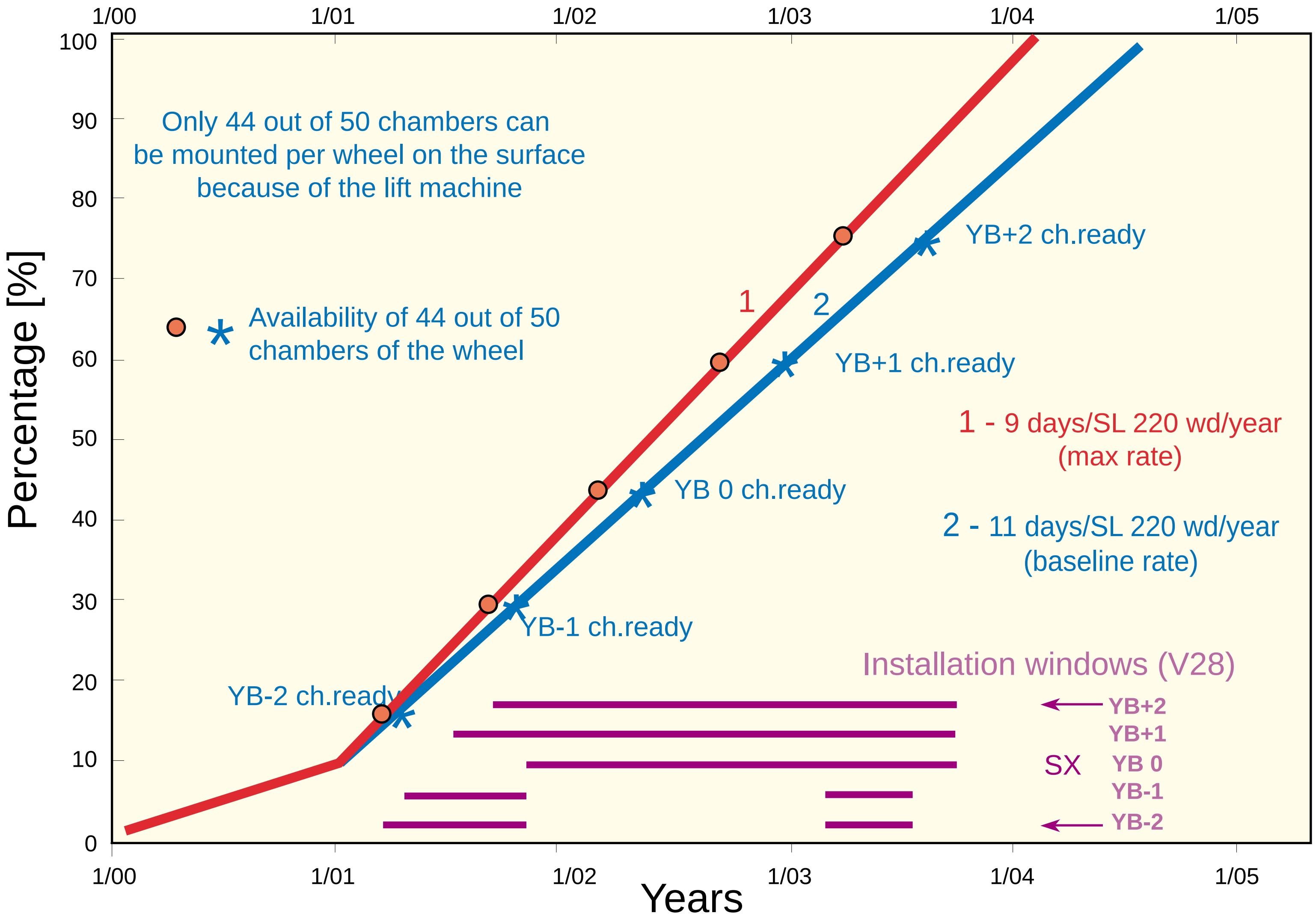


# MB. DT Construction Status

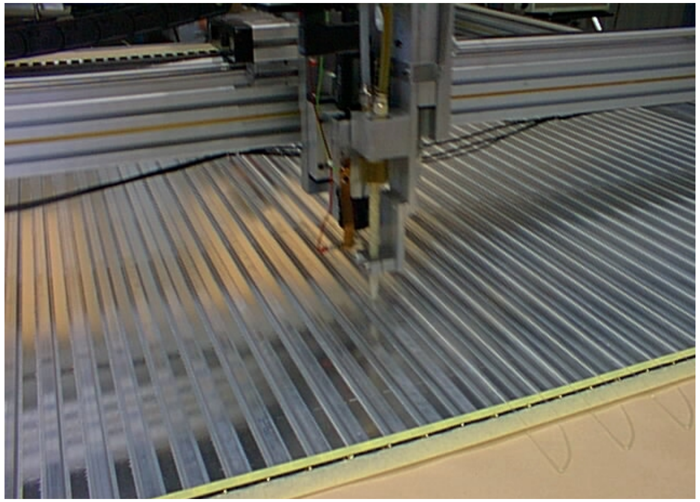
| assembly site | prod.lines | type of chamber (#) | ready | in production |
|---|---|---|---|---|
| Aachen | 3 | MB1 (70) | Jun 2000 | Sep 2000 |
| Legnaro | 3 | MB3 (70) MB4 (10) | Mar 2000 | May 2000 |
| Madrid | 3 | MB2 (70) | Jan 2000 | May 2000 |
| Torino | 1 | MB4 (30) | Oct 2000 | Jan 2001 |
| Volume production of plates | | (Torino $\rightarrow$ Dubna) | Sep 2000 | Oct 2000 |
| Volume production of I-Beams | | (Bologna $\rightarrow$ Protvino) | Jun 2000 | Oct 2000 |
| HV and Decoupling Boards | | (IHEP) | | Dec 1999 |
| Volume production of F-Ends | | | Jan 2000 | Mar 2000 |
| Volume production of F-End Boards | | | Jan 2000 | Mar 2000 |

Preproduction in 2000: 2 MB1 in Aachen, 7 MB2 in Madrid, 5 MB3 in Legnaro

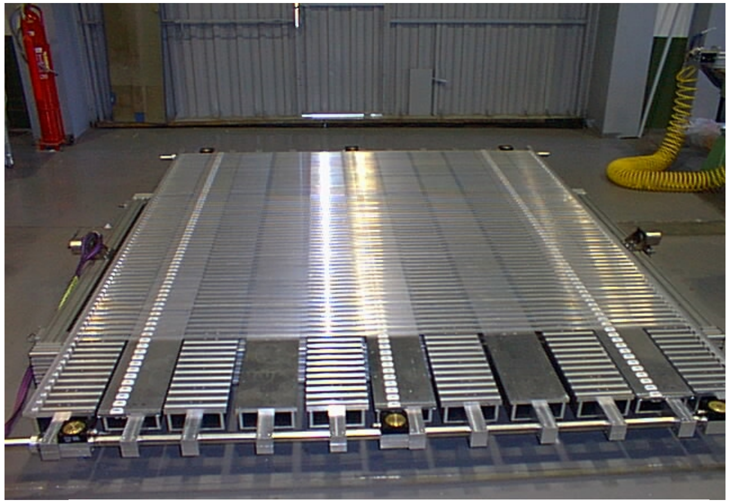
# MB. DT Chamber production



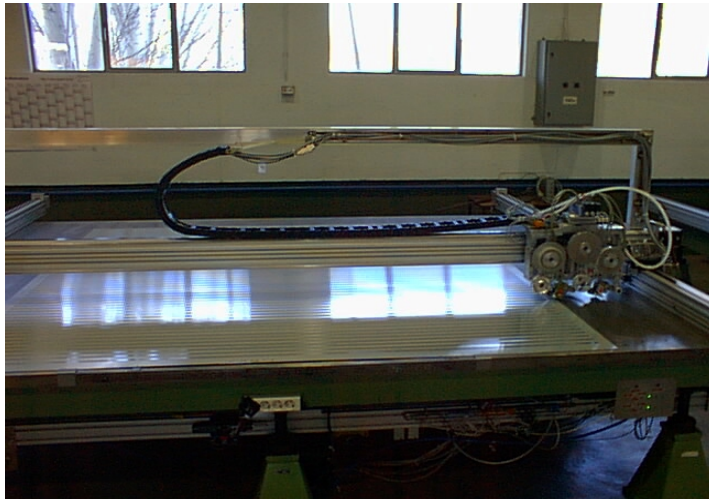
# MB.Assembly sites



Ciemat/MB2:Glue on top of 1st layer of I-beams



Ciemat/MB2:1st layer of I-beams



Ciemat/MB2 plate with glued strips

Legnaro/Theta SL assembly table

# MB. DT Electronics status

**Electronics inside the gas volume:**

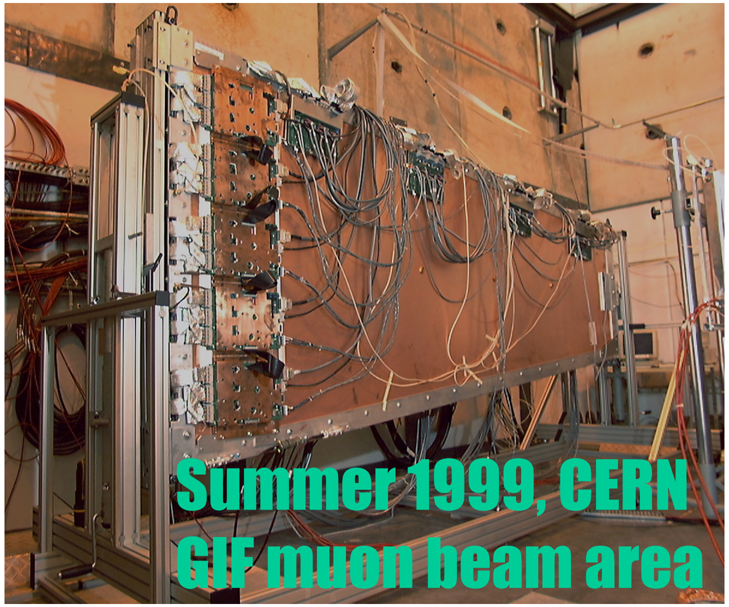
- The first final preproduction of F-ends is available and under test.
- F-end Board  preserie is available and under test.
- Preproduction of  HV Boards is done and mass production started in IHEP(Beijing, China).
- Electronics System Review (ESR) in fall 2000.

**Electronics on the Chamber:**

- The first ROB should  be ready in spring  2001.
- The first equipped minicrates should  be ready in September 2001.

| **item** (Electronics on Ch.) | **status** | **Start prod.** (6 months Contingency) |
|---|---|---|
| BTI | ready | 6/2000 - 1/2001 |
| BTI  modules | ready | 9/2000 - 3/2000 |
| TRACO | under test | 1/2001 - 6/2001 |
| TSS,TSM | design | 1/2001 - 6/2001 |
| TRB | design | 3/2001 - 9/2001 |
| TDC | 1st. Subm. | 12/2000 - 6/2001 |
| ROB | prototype | 3/2001 - 9/2001 |
| equipped  minicrates | | 9/2001 - 3/2002 |

# Muons. Endcap (ME)
# Cathode Strip Chambers (CSC)


432(*) 6-plane chambers

~ 6,000 $m^2$ sensitive area (all planes)

~ 2,000,000 wires in the system

~ 220,000 cathode channels

~ 160,000 anode channels

(*) 36 ME4/1 and 72 ME4/2 are staged and not included

# ME. CSC production status

- **Fermilab Site:**
  - Panel Production began in May ‘99
    (360 CSCs: ME1/2, 1/3, 2/1, 2/2, 3/1, 3/2)
  - Assembly: 4-6 chambers to be produced by Jun ‘00
    (144 large CSCs: ME2/2 and ME3/2)
- **Florida (UF) and California (UCLA) Sites:**
  - Final Assembly (with electronics) and System Tests - start Dec ‘00
    (72+72 CSCs: ME2/2, 3/2)
- **St.Petersburg, Russia (PNPI) and Beijing, China (IHEP) Sites:**
  - Final Assembly (with electronics) and System Tests - start Jan ‘01
    (144+72 CSCs: ME1/2, 1/3, 2/1, 3/1)
- **Dubna Site**
  - Final Assembly (with electronics) and System Tests - start Jul ‘01
    panel production began in Jan 2000
    (72 CSCs: ME1/1)

# ME. CSC electronics milestones

**YEAR 2000 Finalize on-chamber electronics**

6/30/00 Finish radiation tests of On-chamber electronics

8/01/00 Delivery of cathode and anode Pre-production ASICs

9/00 CSC Electronics System Review (ESR)

10/00 Start production of on-chamber electronics

**YEARS 2001-2002 Finalize off-chamber electronics**

3/01/01 Delivery of custom VME backplane;
Delivery of DMB, TMB-CLCT, CCB prototypes

8/01/01 Delivery of 672-ch ALCT and 288-ch ALCT pre-production boards

3/01/02 Delivery of Pre-production DMB, TMB-CLCT, CCB

10/1/02 Start production of Off-chamber Electronics

# Muon. RPC overview

**Barrel**

- Single gaps from industry
- RB1 assembled in China
- RB2 assembled in Italy
- RB3 assembled in Bulgaria
- RB4 assembled in Italy

**Problems**

Bulgarian funds not fully established

**Forward**

- Single gaps from Korea
- RE1 assembled in China
- RE n/1 assembled in Korea
- RB n/2 assembled in Pakistan
- RB n/3 assembled in Pakistan

**Problems**

Pakistan funds not fully established
Still missing money (0.7 -1.0 MCHF)

# Muon. RPC barrel

- Production of Bakelite already started (10% in February)
- Tender for single gap completed
- Front-end VLSI pre-production completed (1000 chips)
- Test towers under construction in Bari
- The first RB2 chamber ready by April
- Final front-end board ready by April
- Front-end irradiation test under way
- Tenders for VLSI and FE board in 2000


# Muon. RPC forward

The forward single gap will be built in Korea using Italian bakelite
The chambers will be assembled in China, Korea, Pakistan

| | |
|---|---|
| Definition of the single gaps design | March |
| Definition of the mechanics and the assembly procedure | April |
| Construction of single gaps in Korea | May |
| Assembly of a forward sector in Korea and Pakistan | July |

# Alignment

**Task** :Monitor the position of the μ-chambers and the CT detectors with respect to each other.

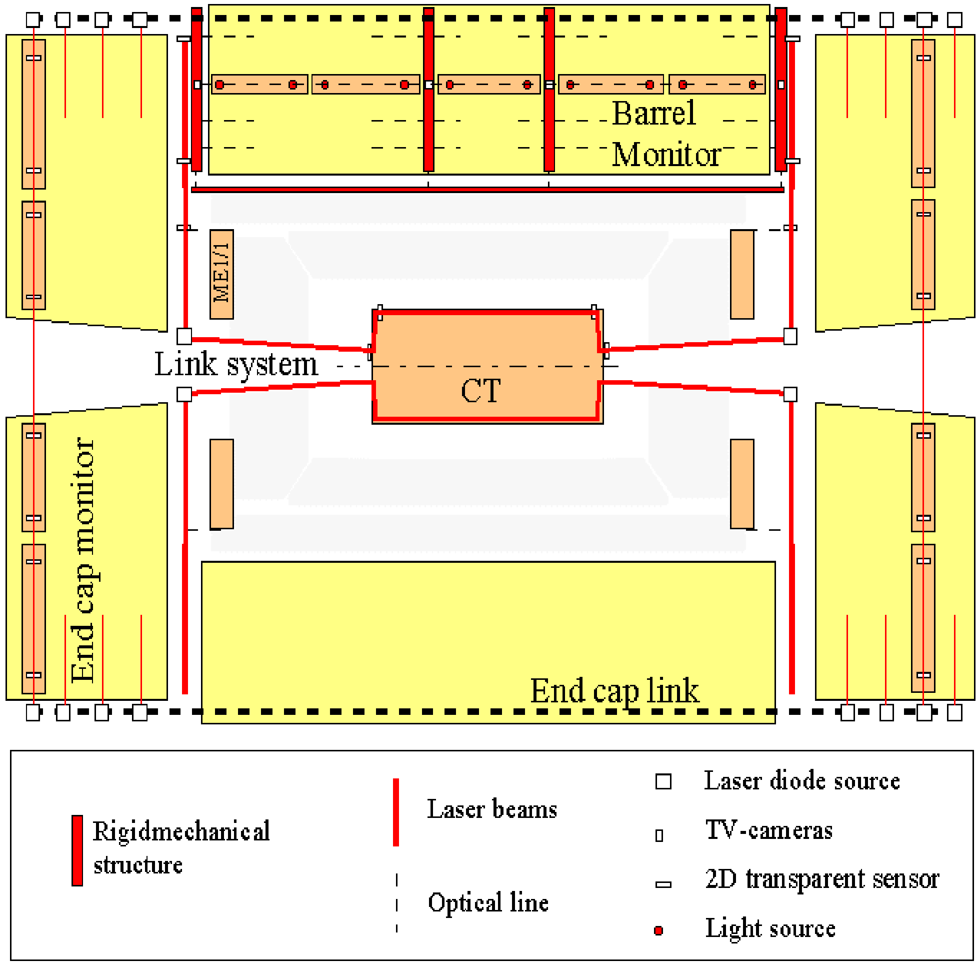
## Building blocks

- Internal tracker align.
- Internal muon : barrel and endcap
- The link tracker ∫ muons
 (3 alignment planes)

## System requirements

- track reconstruction: ~500 μm
- for $p_t$ measurement:
 ~150(350) μm at MB1(MB4)
 ~150 μm at ME1 layer

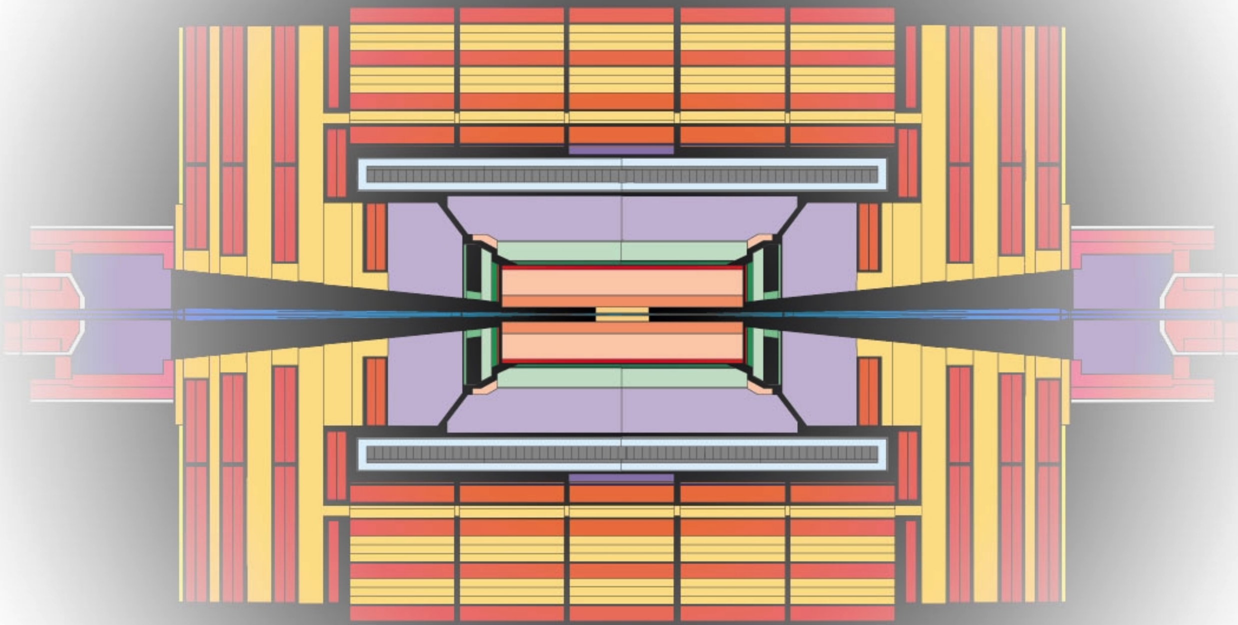
Alignment EDR in Fall '00



# Alignment. Barrel stand (CERN ISR I4-hall)

**Layout of the Minimal test of the barrel alignment: disposition of alignment components as for the central muon barrel wheels (ML2)**

# 6. Integration



# CMS integration center (CERN +ETHZ)



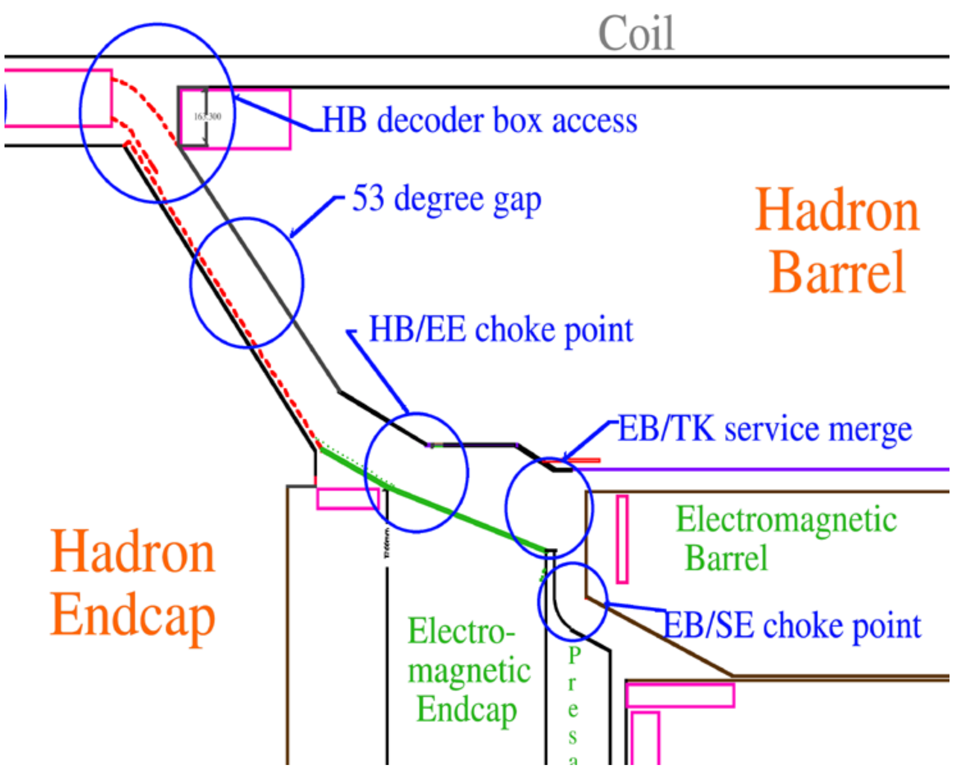



Integration Center at CERN II

1:1 Model study tracker insertion

# Integration. Barrel-endcap gap

## 1999 progress : inner part



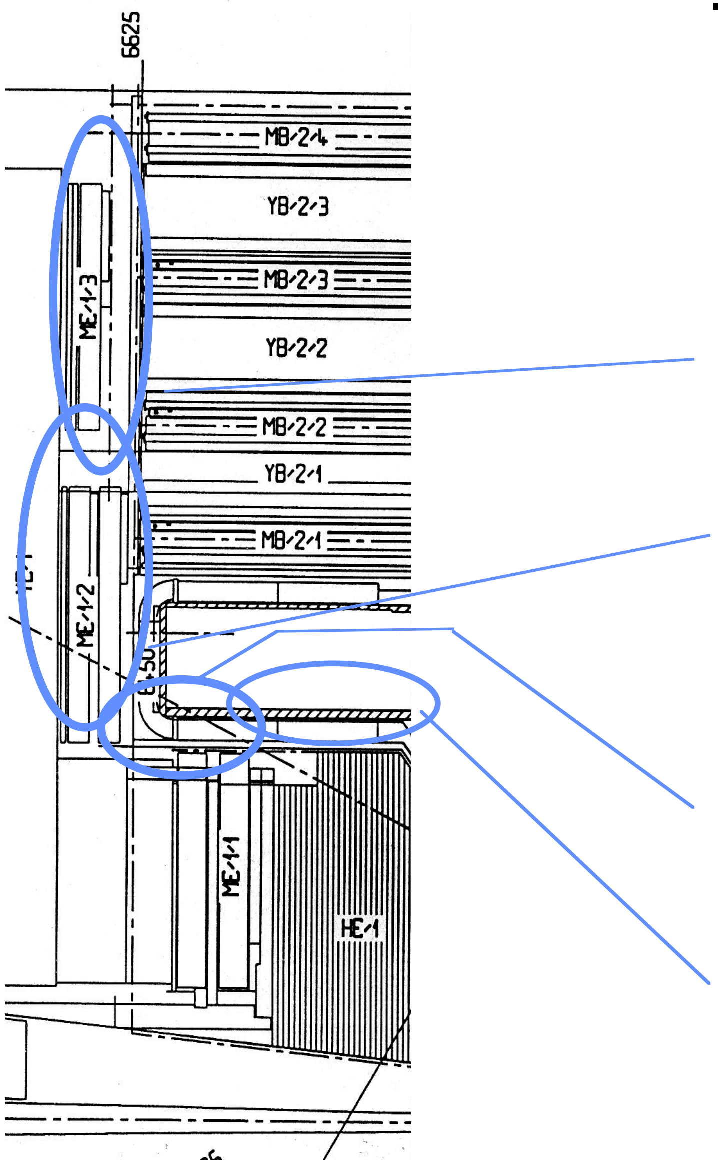

- **HB and HE geometries are fixed**
  - green light for manufacture
  - conical part optimized
    - scintillator recess
    - service channels

  → **in production**

- **EE+ SE envelope fixed - details for EDR**
- **Minimum cylindrical insertion**
- **53 deg gap nominal 140mm, with shims $\Delta z = \pm$ 20mm of EE+SE wrt HE.**
- **Models of both sides of 53 degree gap**

Cabling including EB/TK merge region

# Integration. Barrel-endcap gap




## Targets For 2000

**Barrel endcap gap- outer part:**

Many engineering complications:Task Force set up

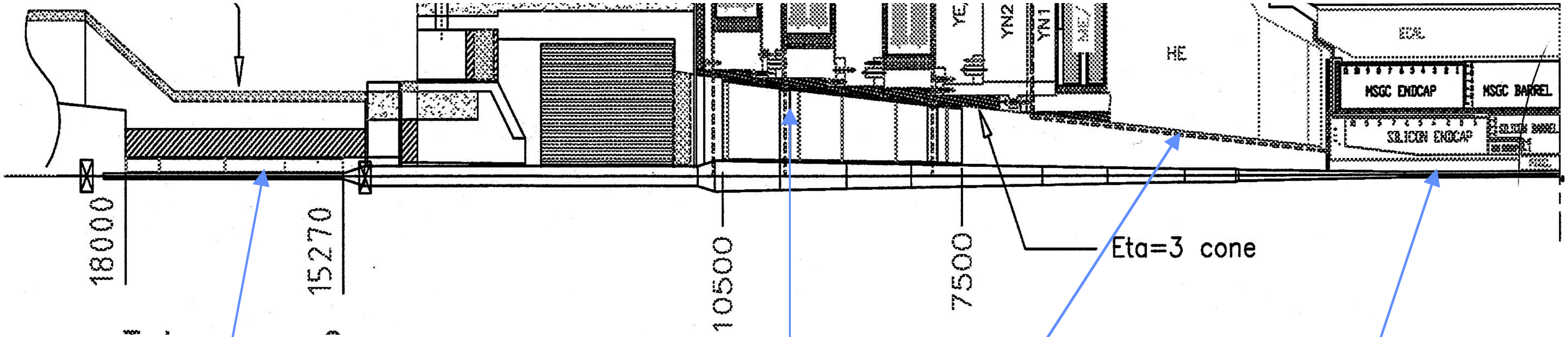
**ME 1/3 zone :** RE1/3 integration
MABs, EELV, z-stops

**ME1/2 zone :** RE1/2 integration
alignment channels
endcap services
barrel services round tank

**ME1/1 zone:** HE/SE/EE services over
support brackets ("Z")

**HE/Coil gap:** TK & EB patch panels
HE decoder & source boxes

# Integration. $\eta \geq 3$




forward shielding region
T2, lumi monitors
B.P. & Vacuum
HF/RS shielding

Totem T1,
lumi mon
shielding

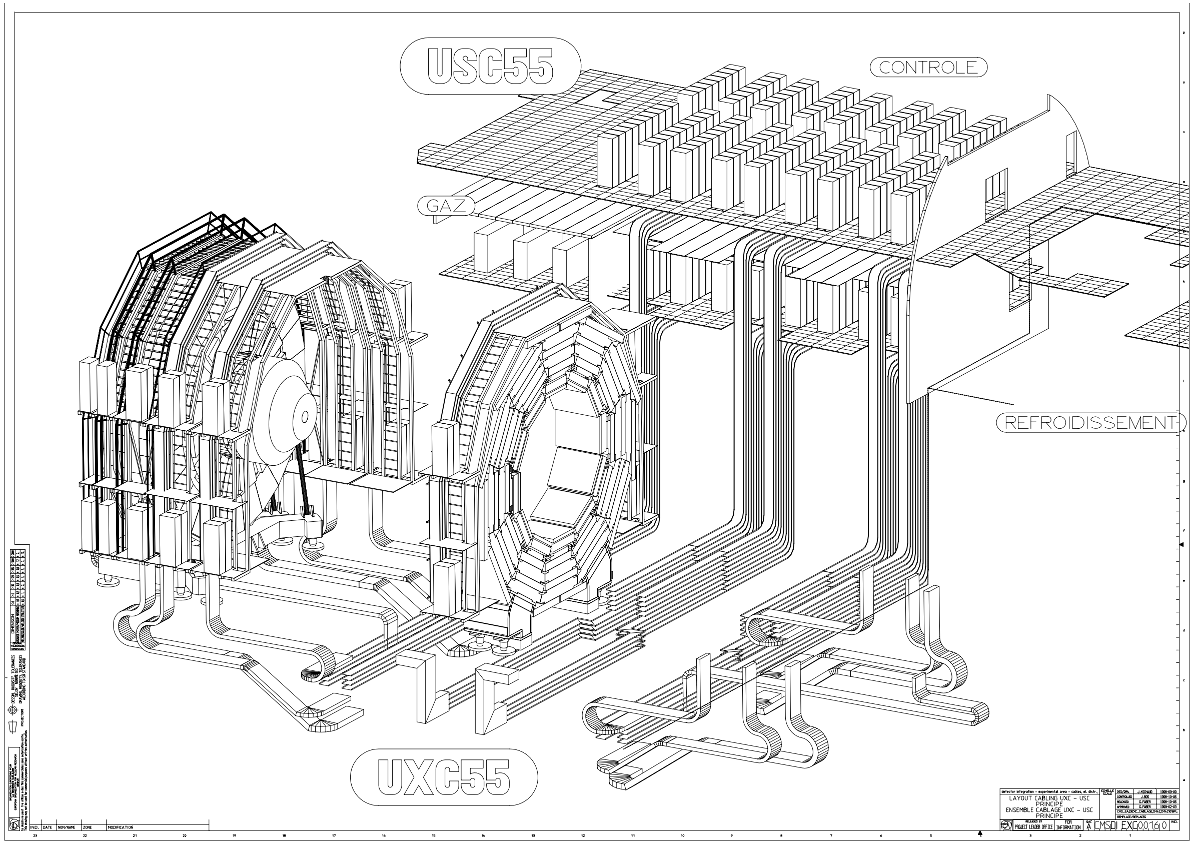
$\eta$ = 3 inner cone
EE inner edge
SE support,
Alignment

Beampipe
Pixel insertion

: progress in 99 : EDR of forward shielding , EDR of HF brick element
CMS/TOTEM agreement & lumi workshop

: targets for 2000 : Baseline beampipe design ( vacuum, pixel, background)
HF shielding
$\eta$ = 3 support cone
TOTEM & lumi monitor design

# Integration. Services & maintenance




**Targets for 2000:**
**Develop design of services supplying CMS**

**cooling**
**inertion**
**gas**
**local racks**
**cable chains**

**Develop maintenance scenarios**

**long/short shutdowns**
**equipment required**
**sub-system task inter-compatibility**

# 7. Trigger and data acquisition

**40 MHz**
**COLLISION RATE**

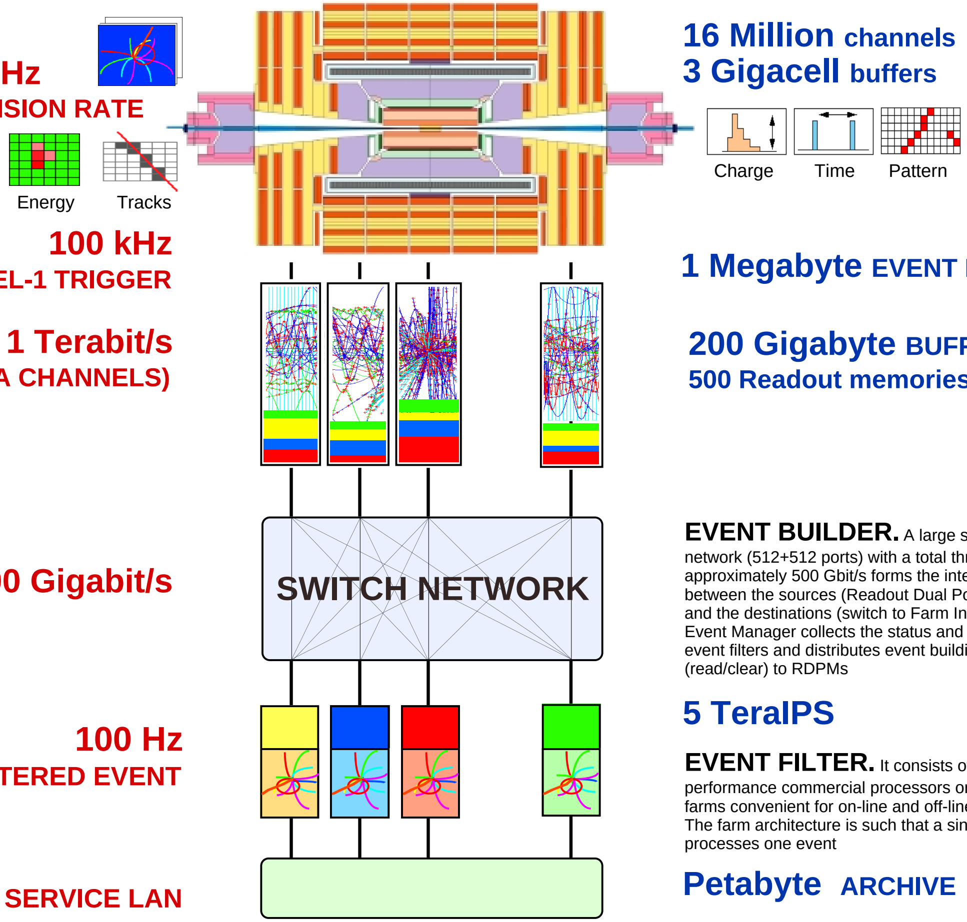
**100 kHz**
**LEVEL-1 TRIGGER**

**1 Terabit/s**
**(50000 DATA CHANNELS)**

**500 Gigabit/s**

**100 Hz**
**FILTERED EVENT**

**Gigabit/s SERVICE LAN**




**16 Million channels**
**3 Gigacell buffers**

**1 Megabyte EVENT DATA**

**200 Gigabyte BUFFERS**
**500 Readout memories**

**EVENT BUILDER.** A large switching network (512+512 ports) with a total throughput of approximately 500 Gbit/s forms the interconnection between the sources (Readout Dual Port Memory) and the destinations (switch to Farm Interface). The Event Manager collects the status and request of event filters and distributes event building commands (read/clear) to RDPMs

**5 TeraIPS**

**EVENT FILTER.** It consists of a set of high performance commercial processors organized into many farms convenient for on-line and off-line applications. The farm architecture is such that a single CPU processes one event

**Petabyte ARCHIVE**

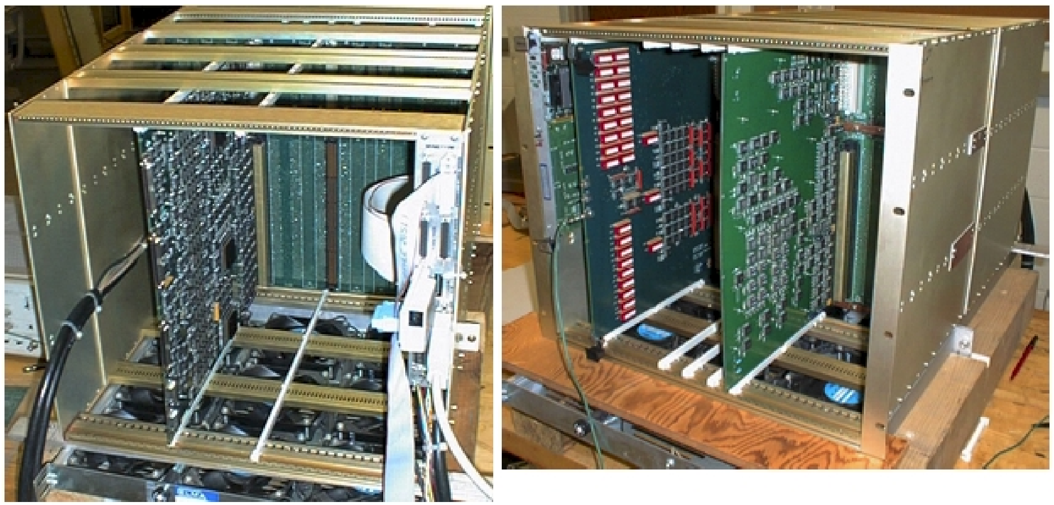
# Level 1 Trigger Update

## Level 1 Trigger TDR for November 2000

Recent improvements in Calorimeter trigger:

Jet algorithm & Tau-Trigger

New design of jet algorithm with sharper efficiency turn-on and tau-jet bit for narrow jets based on 4x4 regions sums into 12x12 region jets with sliding windows logic.



Prototype Crate with

- 160 MHz Backplane: timing & signals excellent
- Proto. Receiver Card (rear): VME, sharing, Adder ASICs checked
- Proto. Clock Card (front): Clocking checked
- Proto. Electron ID Card (front): VME, dataflow, timing checked

# Muon Trigger Progress

**Drift Tubes:** 2nd Prototype Bunch & Track Identifier and Control Board tested with cosmics, simulation, neutrons. Beam tests with track Correlator show clean triggers with 0.5 mm position and 2 degree angle resolution with 95% efficiency. Track-finder design is mature.

**RPC:** Front end, sorter, and Pattern Logic chips have been tested. Link technology verified (including radiation tolerance).Optical fiber multiplexing simulated.

**CSC:** Prototype Comparators, Anode & Cathode Local Charged Track & Motherboard beam test meet performance requirements. Design to send RPC data to CSC's to kill ghosts developed. Muon Port Card, Sector Receiver, Sector Processor and Sorter prototypes under design.

# Global Muon Trigger: 1$\mu$ efficiency

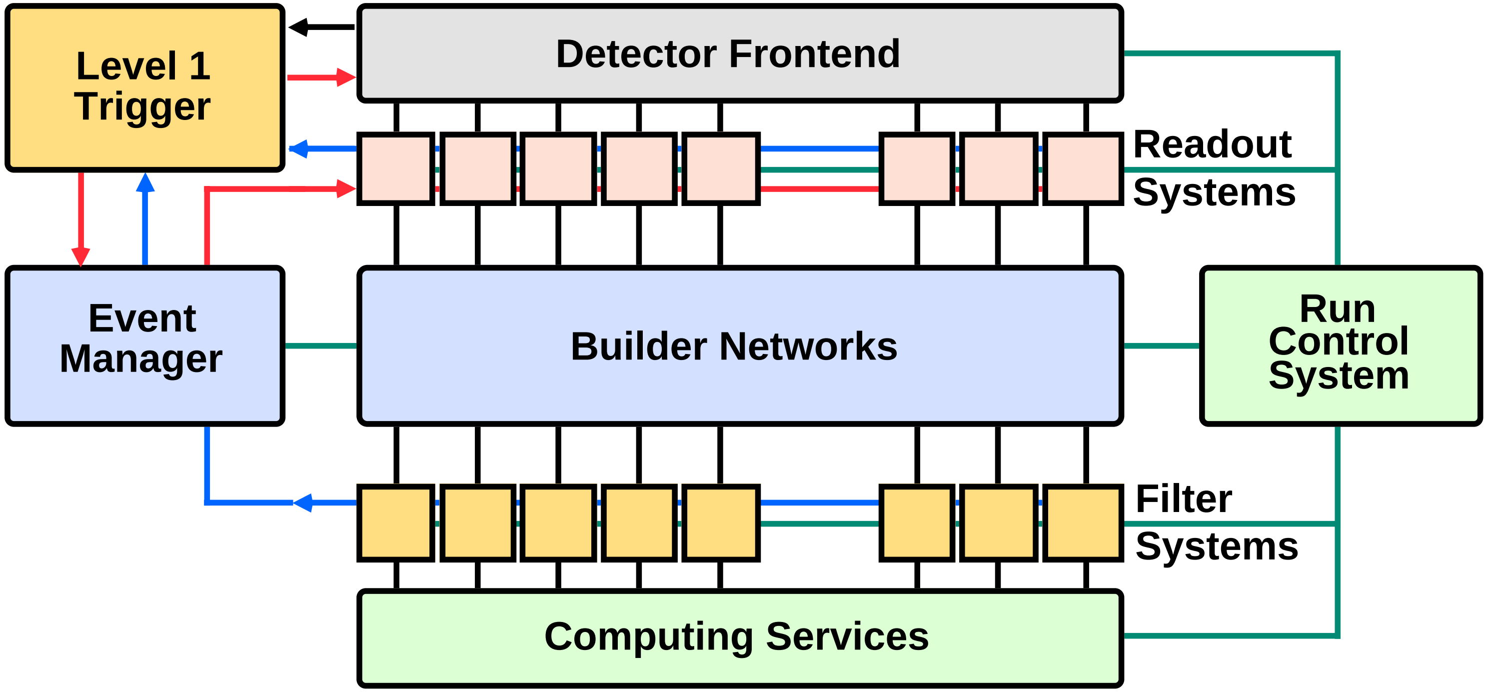
$-0.8 < \eta < 0.8$:

| | no muon found | one muon found | two muons found |
|---|---|---|---|
| RPC | 4.49 ± 0.10 % | 95.49 ± 0.61 % | 0.02 ± 0.01 % |
| DT | 6.08 ± 0.11 % | 93.70 ± 0.60 % | 0.22 ± 0.02 % |
| GMT | 1.04 ± 0.05 % | 98.78 ± 0.70 % | 0.18 ± 0.02 % |

$1.2 < \eta < 2.1$:

| | no muon found | one muon found | two muons found |
|---|---|---|---|
| RPC | 7.07 ± 0.12 % | 92.88 ± 0.56 % | 0.05 ± 0.01 % |
| CSC | 5.37 ± 0.10 % | 93.76 ± 0.57 % | 0.87 ± 0.04 % |
| GMT | 1.76 ± 0.06 % | 97.83 ± 0.58 % | 0.41 ± 0.03 % |

# DAQ main parameters



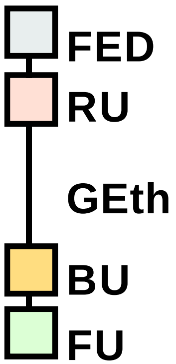

| | | | |
|---|---|---|---|
| Collision rate | 40 MHz | I-O units bandwidth (512+512) | 400 MByte/s |
| LV1 Maximum trigger rate | 100 kHz | Builder network (512x512 port) | ≥ 500 Gbit/s |
| Average event size | ≈ 1 Mbyte | Event filter computing power | ≈ 5 $10^6$ MIPS |
| Data production | ≈ Tbyte/day | High Level Trigger acceptance | 1 - 10 % |
| Event Flow Control | ≈ $10^6$ Mssg/s | Overall dead time | ≤ 2% |

# DAQ. Towards TDR: R&D and demonstrators

## DAQ TDR by November 2001

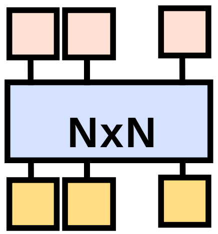
## Current R&D program: Design and prototype

### Two DAQ demonstrators:




### 1) DAQ Column

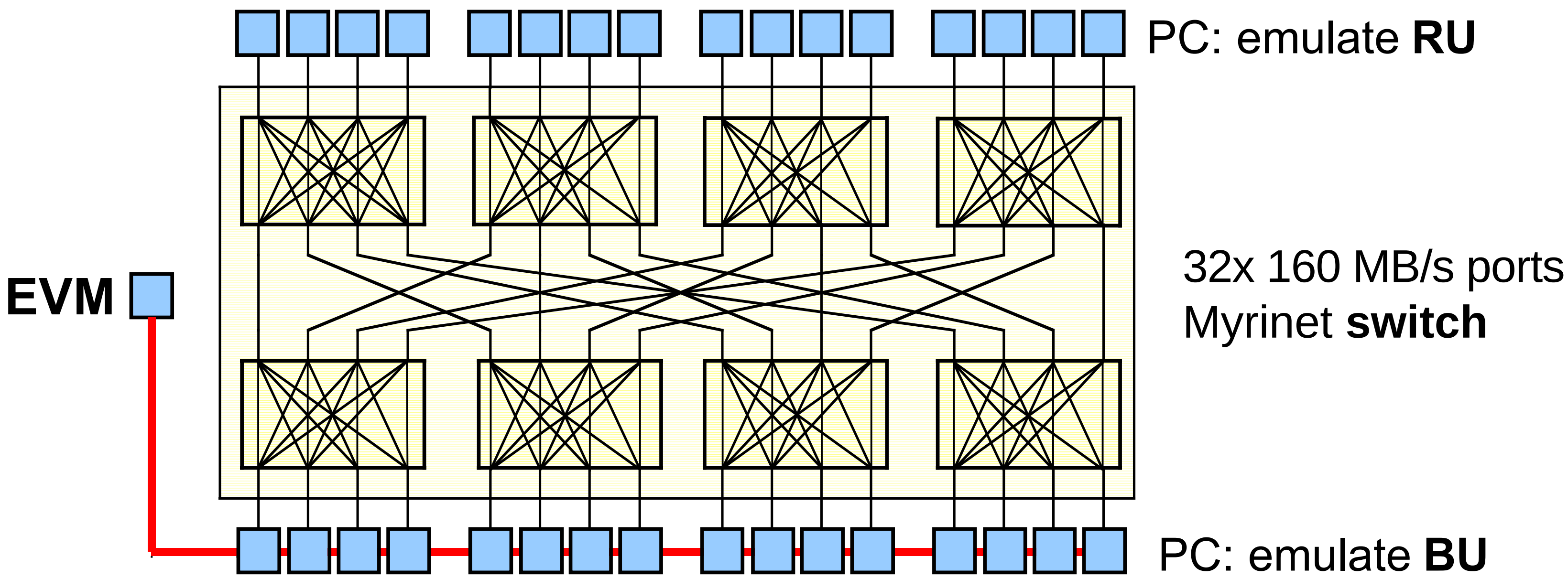
- Develop/integrate hardware software prototypes of column components (FED, RU, BU, FU)
- Evaluate OS (VxWorks, Linux)
- Evaluate commercial standards (e.g. PC, PCI 64-66)
- Study/Design subsystem functionality and interfaces (Detector F/E, RUN control, HLT, Mass Storage)
- Apply prototype in test beam data acquisition systems




### 2) EVENT BUILDER:

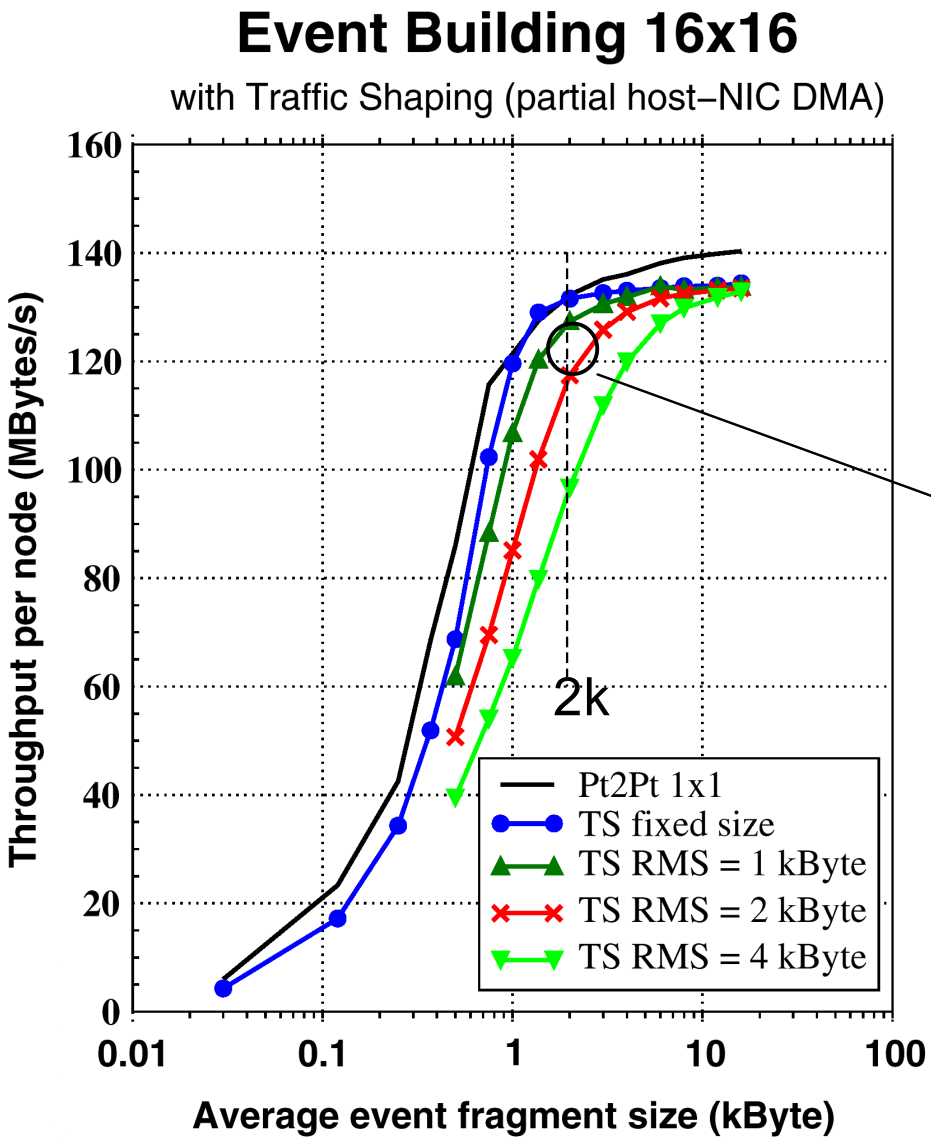
- Study event data acquisition protocols. Exploit maximum bandwidth
- Evaluate switch technologies for control&data (Myrinet, GEthernet)
- Design/Measure/Simulate protocols and behavior of large structures

# DAQ. EVB demonstrator set-up




- 32+1 Linux PCs (450 MHz PII BX PCI 33 MHz/32bit) **(50%ATLAS)**
- Myrinet switch (M2M-OCT-SW8, NIC: M2M-PCI64[A] )
- 16x16 two-stage Banyan network out of 4x4 crossbars
- **Myrinet** between **RU**s and **BU**s (full duplex). N-to-N traffic
- **Fast Ethernet** between **BU**s and **EVM**. N-to-1 traffic
- No emulation of Level-1 trigger

# Performance for variable size event fragments

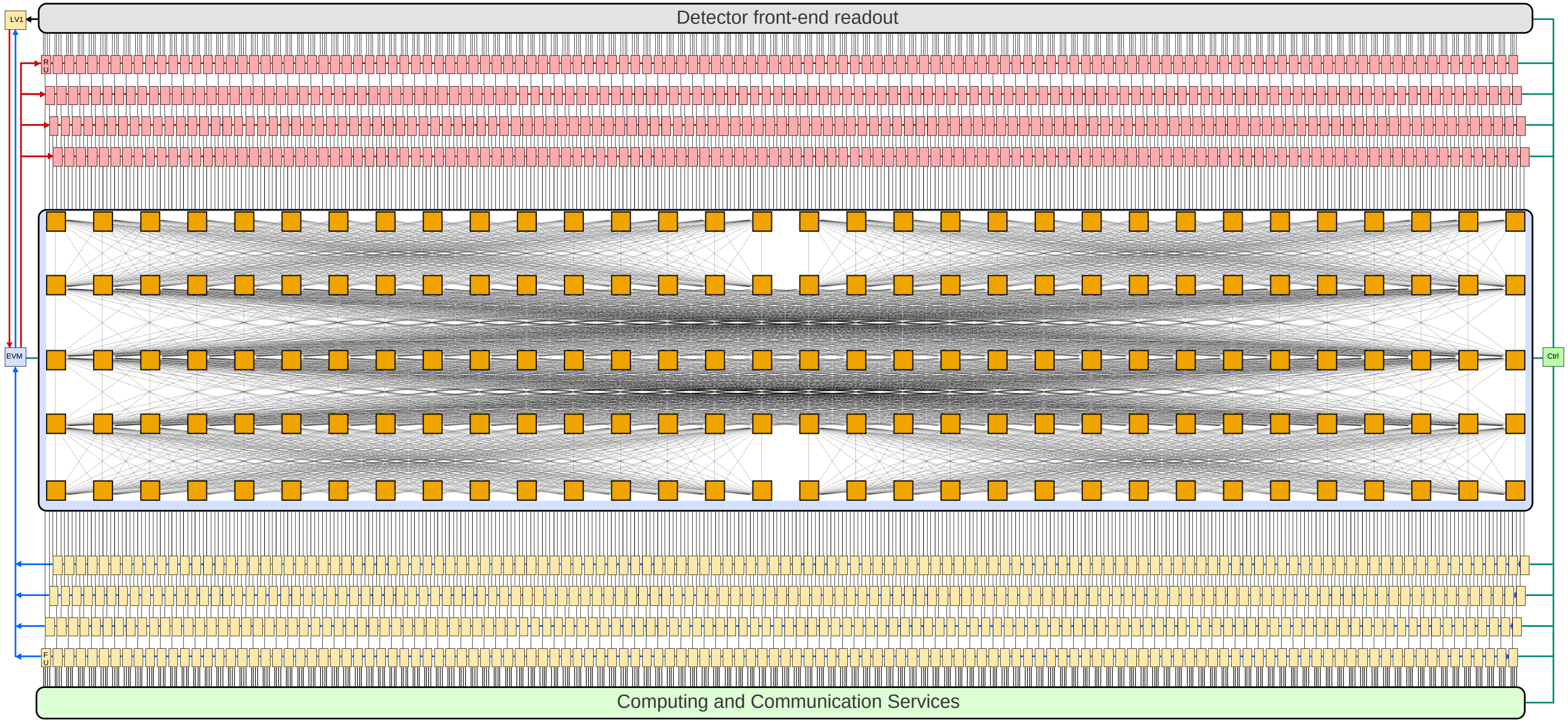



decrease of efficiency with larger RMS of fragment size distribution (in agreement with Monte Carlo)

Fragment rate per node for **nominal average of 2k and RMS 2k †: 60 kHz**

[†with full host-NIC DMA about 80 Mbyte/s or 40 kHz]

# DAQ. The final system



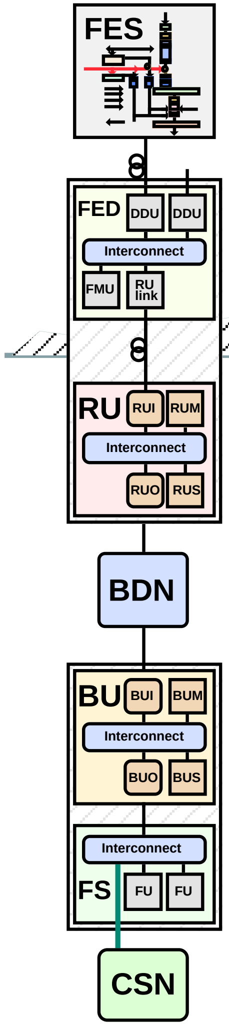

| | | | | | |
|---|---|---|---|---|---|
| Collision rate | | 40 MHz | No. of In-Out units (RU&FU : 200-5000 byte/event) | | 1000 |
| Level-1 Maximum trigger rate | | 100 kHz(*) | Readout network (e.g. 512x512 switch) bandwidth | ≈ | 500 Gbit/s |
| Average event size | ≈ | 1 Mbyte | Event filter computing power | ≈ | 5 $10^6$ MIPS |
| Event Flow Control | ≈ | $10^6$ Mssg/s | Data production | ≈ | Tbyte/day |
| | | | No. of readout crates | ≈ | 250 |
| | | | No. of electronics boards | ≈ | 10000 |

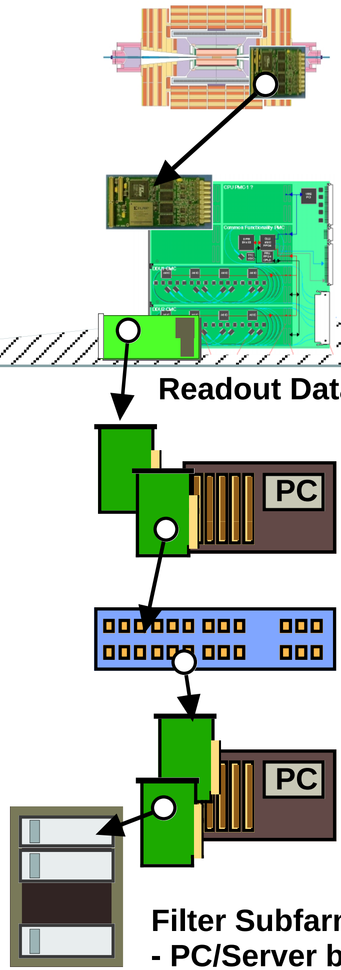
(*) The TriDAS system is designed to read 1 Mbyte data events up to 100 kHz level-1 trigger rate. In the first stage of implementation (Cost Book 9), the DAQ is scaled down (reduced number of RUs and FUs) to handle up to 75 kHz level 1 trigger rate

# DAQ. Myrinet evaluation 1999

- **Event builder demonstrator 16x16** based on **Myrinet** multistage switch and Linux **PC**s established.
- Measured **event building performance**: For **nominal event fragment sizes** with average and RMS of 2 kbyte achieved about **60 kHz trigger rate** or 120 Mbyte/s per node (almost **2 Gbyte/s aggregate**)
- That is, **today**, **only a factor two off** from CMS needs.
- **Measurements** provide parameters for **simulation** of large scale (512x512) systems

# DAQ. Readout design and R&D summary




**FrontEnd System**
- Analog/Digital Links

**FrontEnd Driver**
- VME 9U mother board
- PMC DDUs
- PMC Readout link

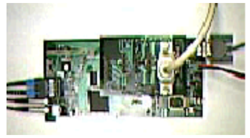
**Readout Data Link**

**Readout Unit**
- PC based
- PCI-IOP IN-Out-Memory

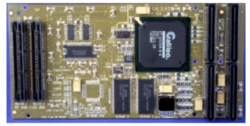
**Builder Data Network:**
- Switch (Myrinet/GEthernet)

**Builder Unit**
- PC based
- PCI-IOP IN-Out

**Filter Subfarm**
**- PC/Server based**
**- GE IN-OUT network**



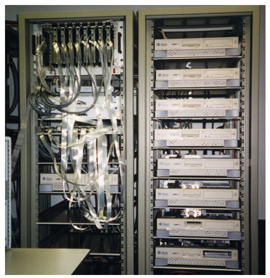
- Trigger links
- Link tests



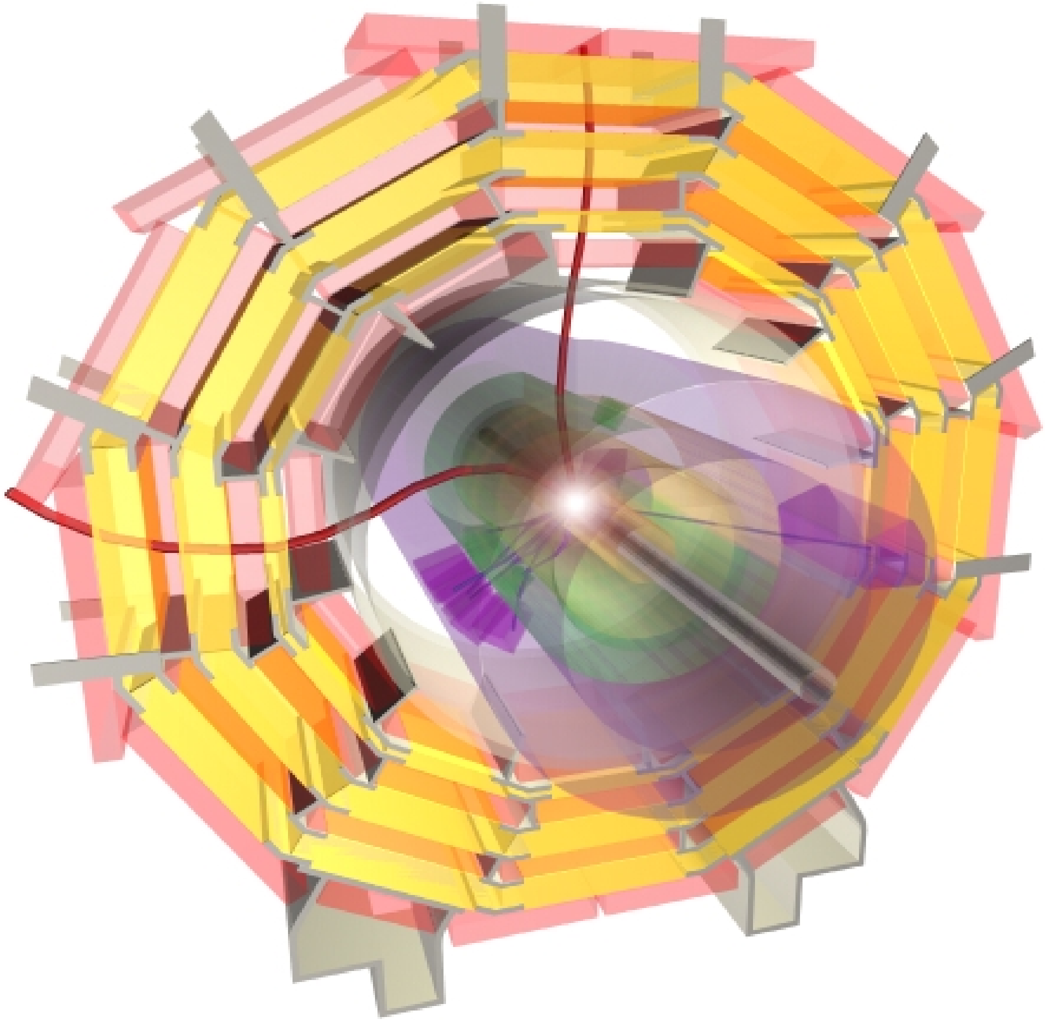
- Generic DDU
- FED link

- PCI RUM-IO
- Software:
  - DAQ toolkit
  - Test beam


- Myrinet 16x16
- GEthernet 7X7
- PC
- Linux, Vxworks



# 8. Physics Reconstruction and Selection (PRS)



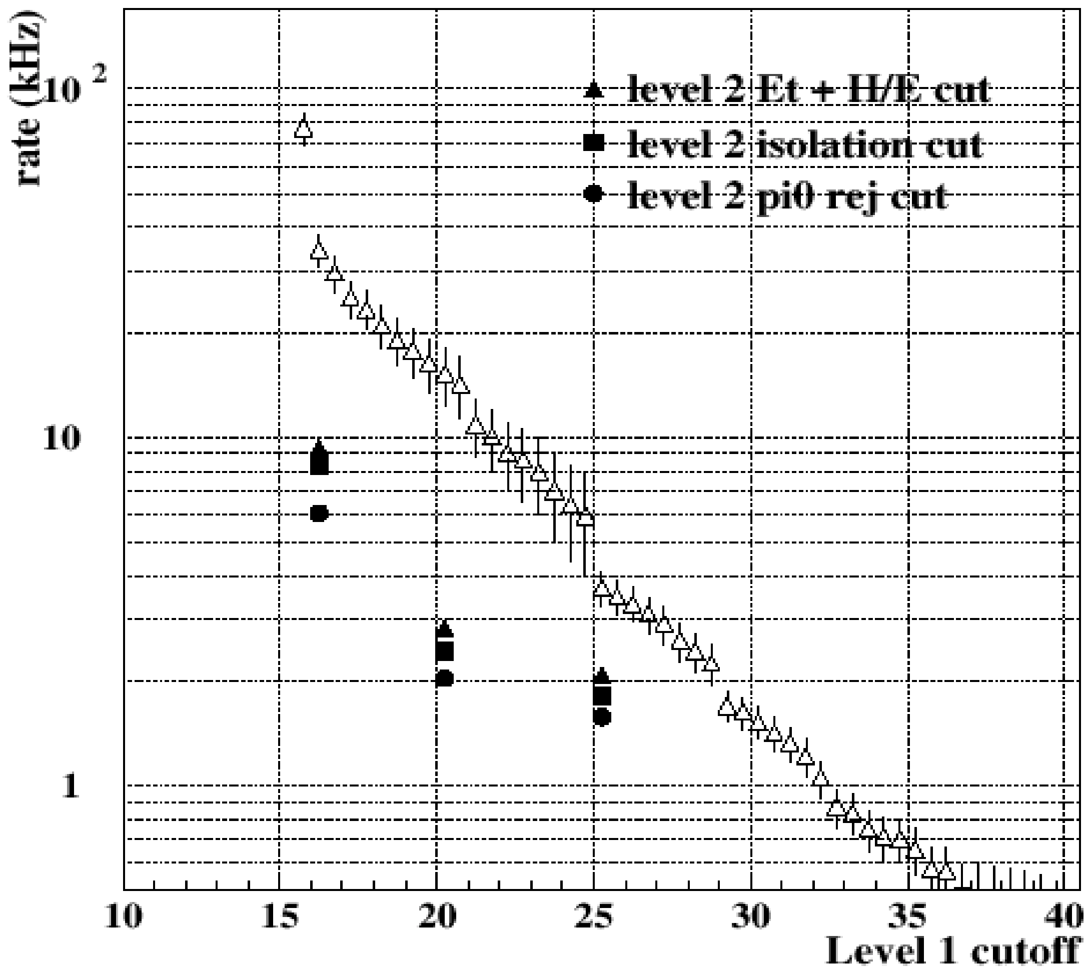
# High Level Trigger

- Basic Job: 100 kHz to 100 Hz (keeping physics)
- After hardware Level-1 assume two steps:
  - Level-2 only uses calorimeter & muon data
    - Read only 25% of the data and get rejection factor A2.
  - Level-3 uses tracker data as well
    - Provides final rejection factor A3*A2 = 1/1000
- New CMS Project: Physics Reconstruction & Selection (PRS):
  - Four groups established in April 99:
    - b/$\tau$ (vertex), Electron/Photon, Jet/Missing $E_T$, Muons
  - Charge: evaluate full chain (from Level-1 to offline) of physics selection. First priority (till end 2000): HLT.
- CMS decided not to submit Physics TDR, but to push with the deployment of OO software
  - First (DAQ) milestone: HLT prototype 1 - Nov ‘99
  - Partially met because of C++ hill/mountain
  - **HLT milestone delayed to July ‘00**

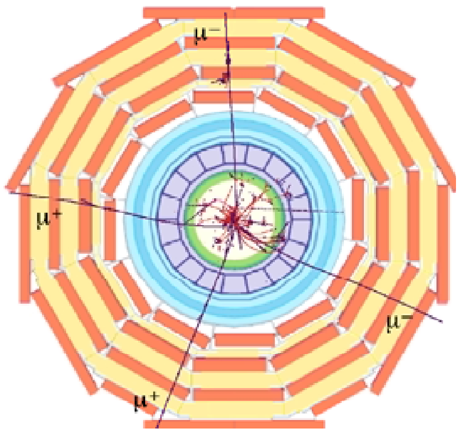
# e Level-2 rate (preliminary)

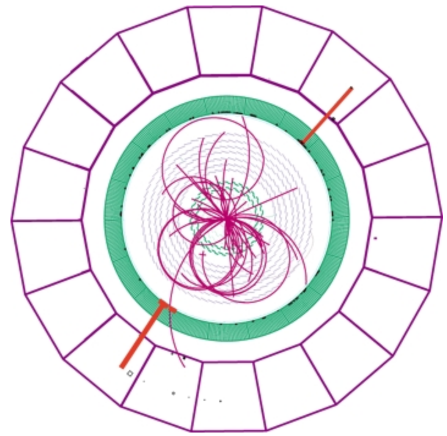
**Single electrons (barrel only)**

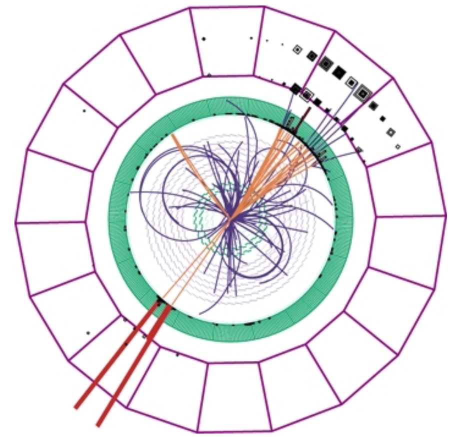
Full Geant simulation of QCD jets.
Implemented in ORCA3:
Level-1 trigger simulation.
Full calorimeter response including high luminosity pile-up.
Level-2 rejection factor: in 3-10 range
Good efficiency: 94%

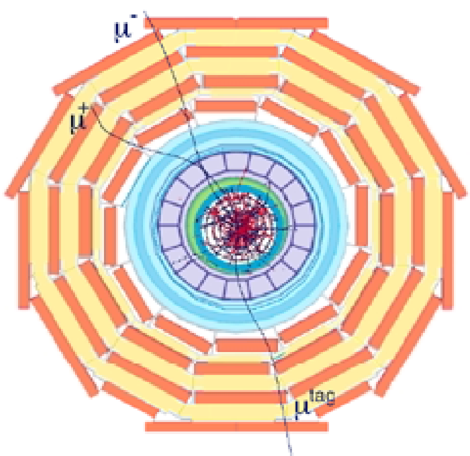


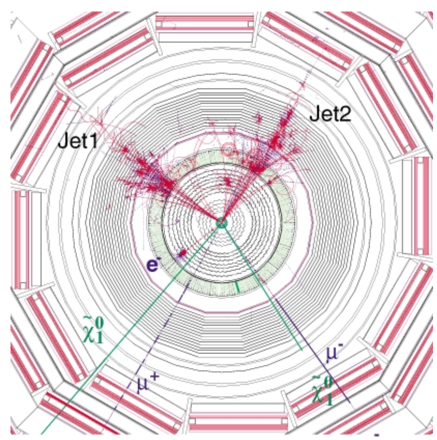
# 9. Software/Computing

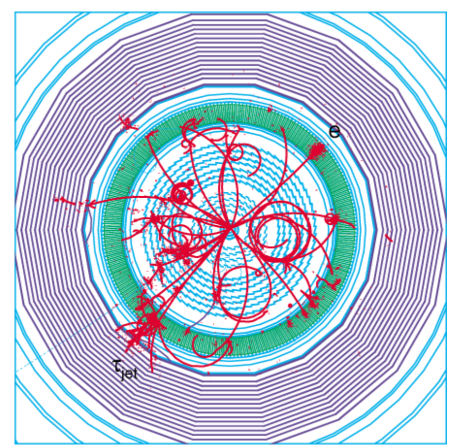




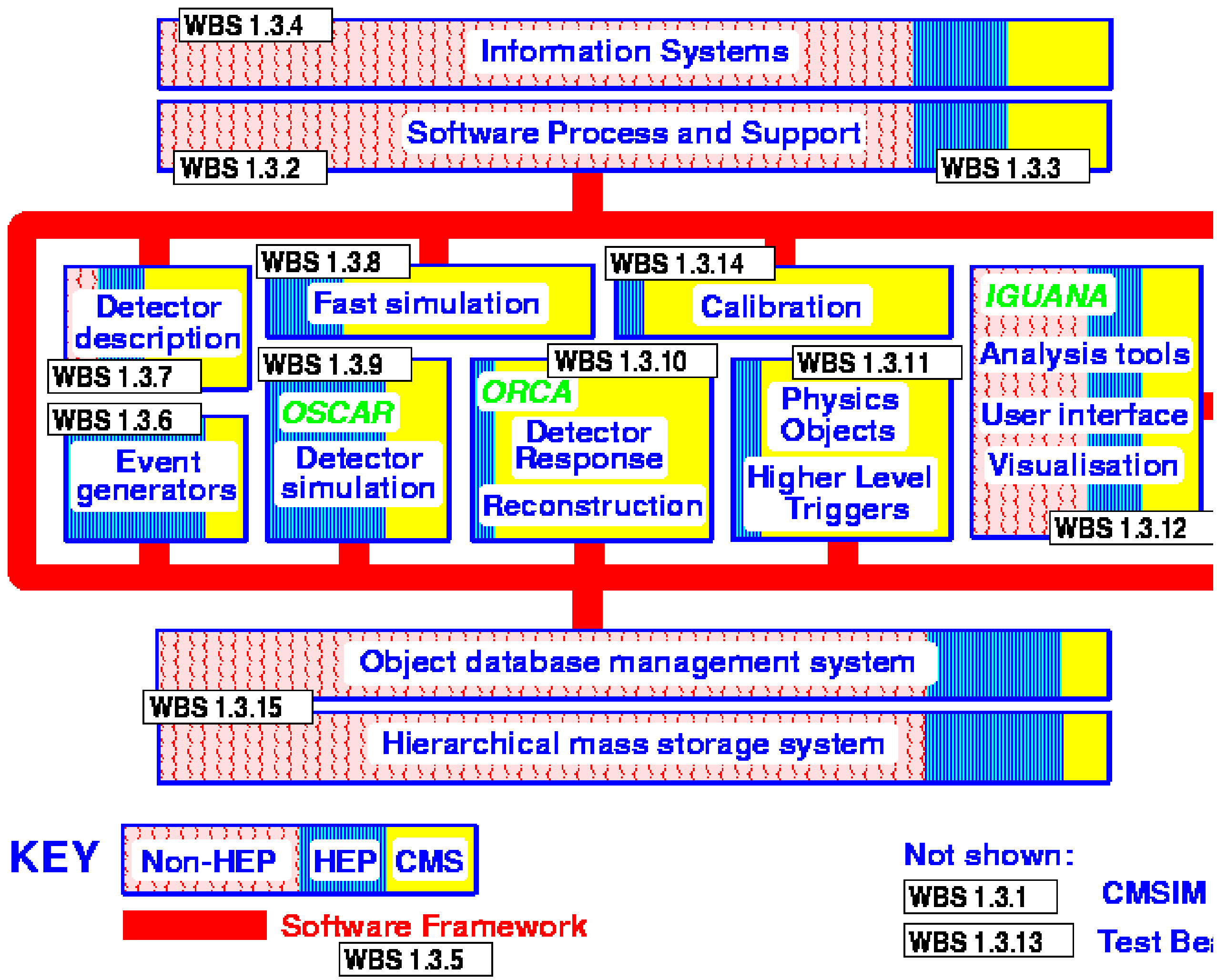


# Software tasks

- 1.1 Project Management
- 1.2 Computing
- 1.3 Software
- 1.3.1 CMSIM
- 1.3.2 Software Process
- 1.3.3 Software Support
- 1.3.4 Info. Systems
- 1.3.5 CARF
- 1.3.6 Event Generators
- 1.3.7 Det. Description
- 1.3.8 Fast Simulation
- 1.3.9 OSCAR
- 1.3.10 ORCA
- 1.3.11 *OBSOLETE (was POR / HLT)*
- 1.3.12 User Analysis Environment
- 1.3.13 Test Beam
- 1.3.14 Calibration
- 1.3.15 ODBMS



# Software

## Test Beams

Complete OO software chain since beg- ‘99 for tracker and muon test beams

DAQ and storage of data in ODBMS, reconstruction and analysis

## ODBMS

Extensive use in test-beam environment ( > 1 Tbyte)

Extensive tests of performance and use in a distributed environment (RD45, GIOD, MONARC,...)

Milestone for filling ODBMS at 100MB/s (170MB/s) met in June 1999

## OSCAR Project

Detailed simulation of CMS using the GEANT4 toolkit

Complete CMS detector by end of 1999, modify to include all-Si tracker

# ORCA Production for HLT

**Oct 99: ORCA3 production reading CMSIM signal and min.bias,**

Used by Physicists studying HLT

30k events/day processed. Calorimeter pileup required 200 min. bias events (=70 MB) for every signal event !

**Spring 2000, ORCA4 production:**

2 M events ORCA reconstructed with high-luminosity pile-up

2-4 Terabytes in Objectivity/DB

100 CPUs: large farm as part of IT project

**Meeting the HLT production requirements for Spring 2000 is already a "1% Mock-Data challenge"**

# Software/Computing Plans

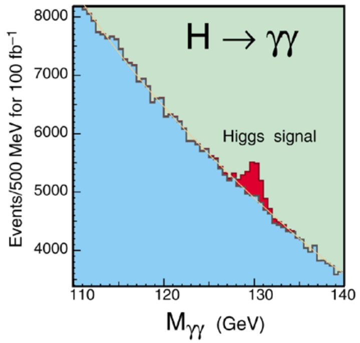
Tie ORCA project to concrete experimental requirement, **the HLT verification**, provides a powerful focus;

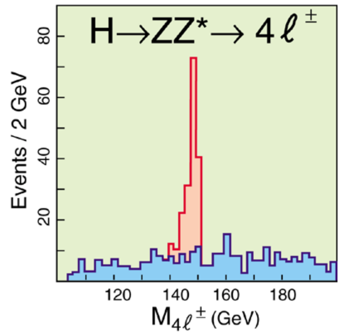
CMS Computing and Software model is designed to meet LHC requirements; use **ORCA and HLT** to study this model in depth

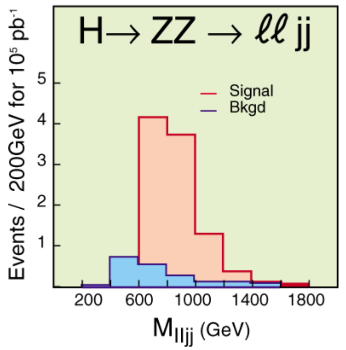
This HLT study is the first in a series of increasingly complex **"mock-data challenges"**

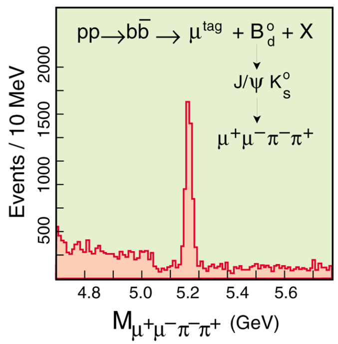
| | | |
|---|---|---|
| HLT L2 (calo+muon) reduction | July | 2000 |
| HLT L3 (tracker) reduction | Fall | 2000 |
| Trigger TDR | End | 2000 |
| DAQ TDR | End | 2001 |
| Computing TDR | | 2002 |
| Physics TDR | | 2003 |
| 20% Mock-Data Challenge | | 2004 |

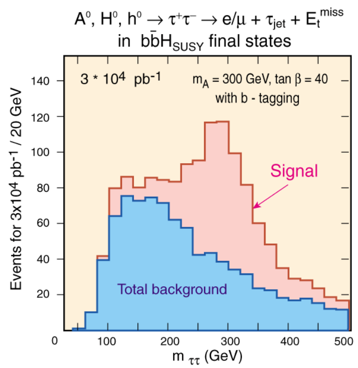
# 10. Physics

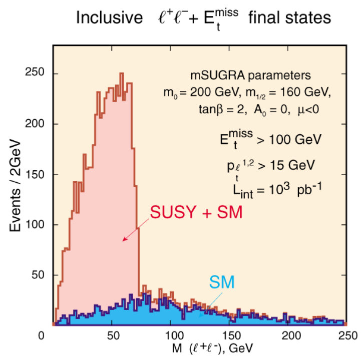

H → γγ
Higgs signal
Events/500 MeV for 100 fb−1
M γγ (GeV)


H→ZZ*→ 4 ℓ ±
Events / 2 GeV
M 4ℓ ± (GeV)


H→ ZZ → ℓℓ jj
Signal
Bkgd
Events / 200GeV for 10⁵ pb⁻¹
M lljj (GeV)


pp→bb̄ → μ tag + B°d + X
J/ψ K°s
μ+μ−π−π+
Events / 10 MeV
M μ+μ−π−π+ (GeV)


A°, H°, h° → τ+τ− → e/μ + τjet + Et miss
in bb̄H SUSY final states
3 * 10⁴ pb-1
mA = 300 GeV, tan β = 40
with b - tagging
Signal
Total background
Events for 3x10⁴ pb⁻¹ / 20 GeV
m ττ (GeV)


Inclusive ℓ+ℓ−+ Et miss final states
mSUGRA parameters
Et miss > 100 GeV
SUSY + SM
SM
Events / 2GeV
M (ℓ+ℓ−), GeV

# $H^+$ search in $gb \rightarrow \bar{t}H^+$, $H^+ \rightarrow \tau^+\nu$, $\tau^+ \rightarrow \pi^+ + n\,\pi^0 + \nu$, $\bar{t} \rightarrow \bar{b}q\bar{q}$

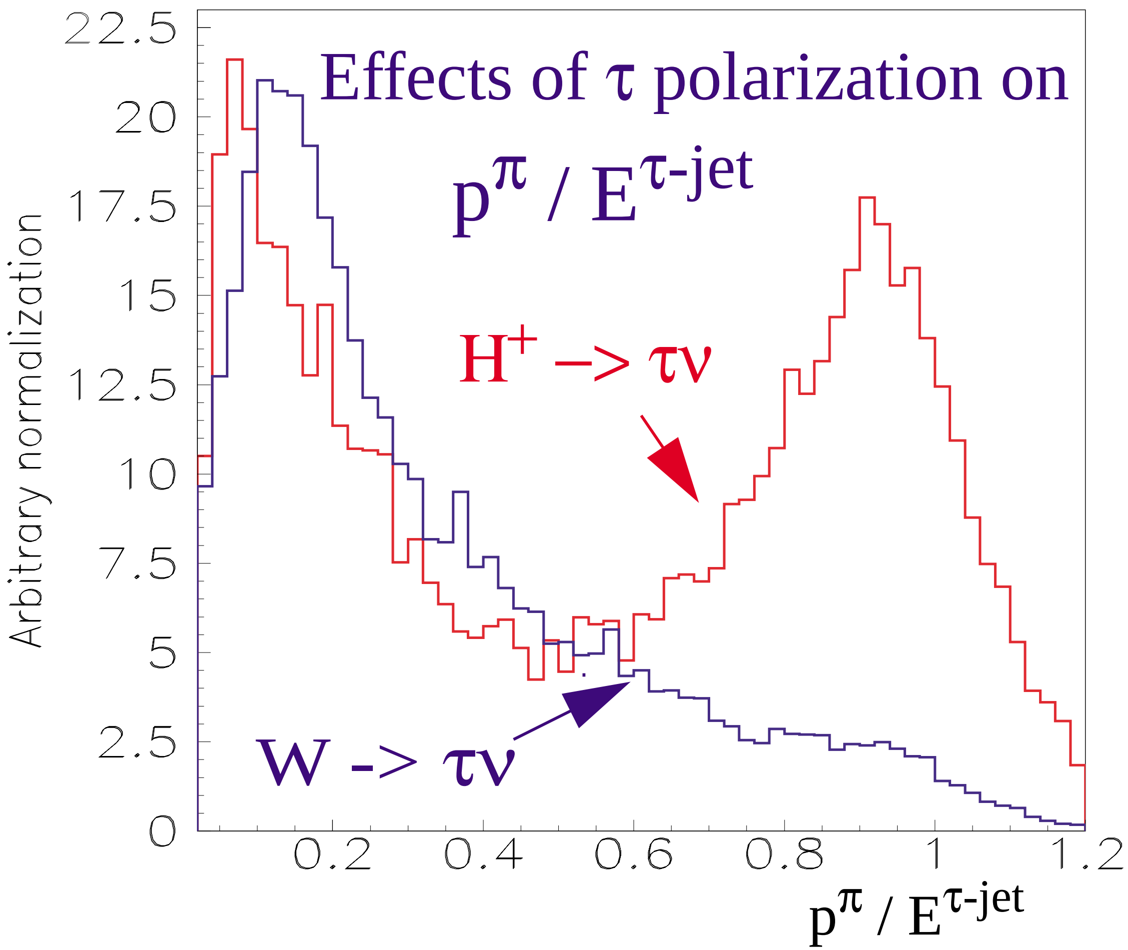
$\tau$ polarization leads to harder pions from

$H^+ \to \tau^+\nu$, $\tau^+ \to \pi^+ + \nu$

than from

$W \to \tau\nu$, $\tau^+ \to \pi^+ + \nu$

in $t\bar{t}$ and W+jet bkgd's



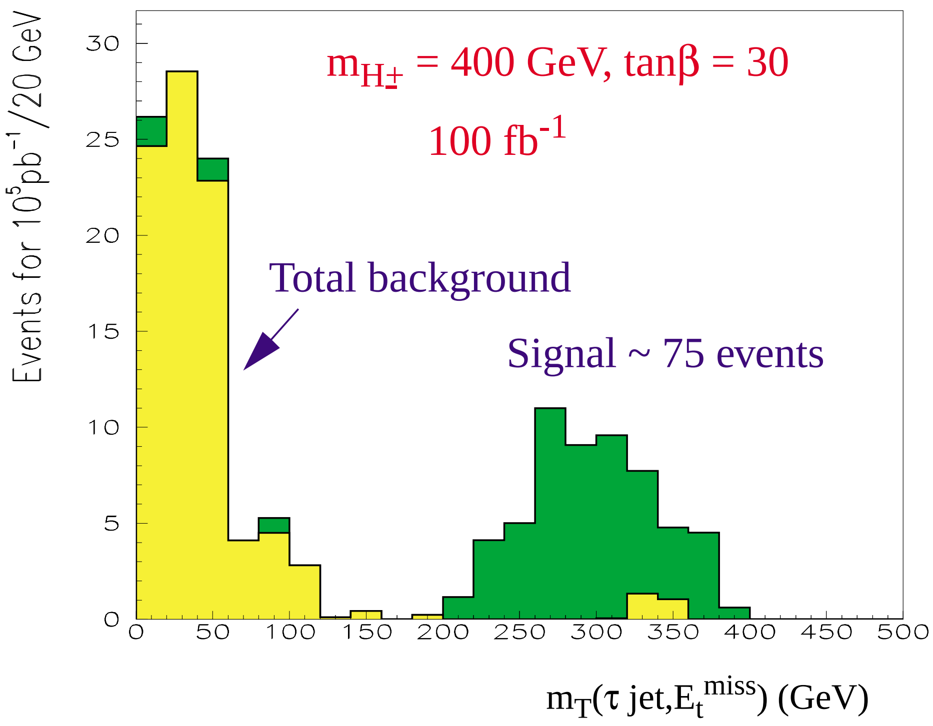

Main selection cuts:

- $E_t^{\tau\text{-jet}} > 100$ GeV
- $p^{\pi}/E^{\tau\text{-jet}} > 0.8$
- $E_t^{miss} > 100$ GeV
- W and top mass reconstruction from jets
- b-tagging for t -> bqq to reduce W+jet bkgd
- veto on a second top to reduce $t\bar{t}$ bkgd

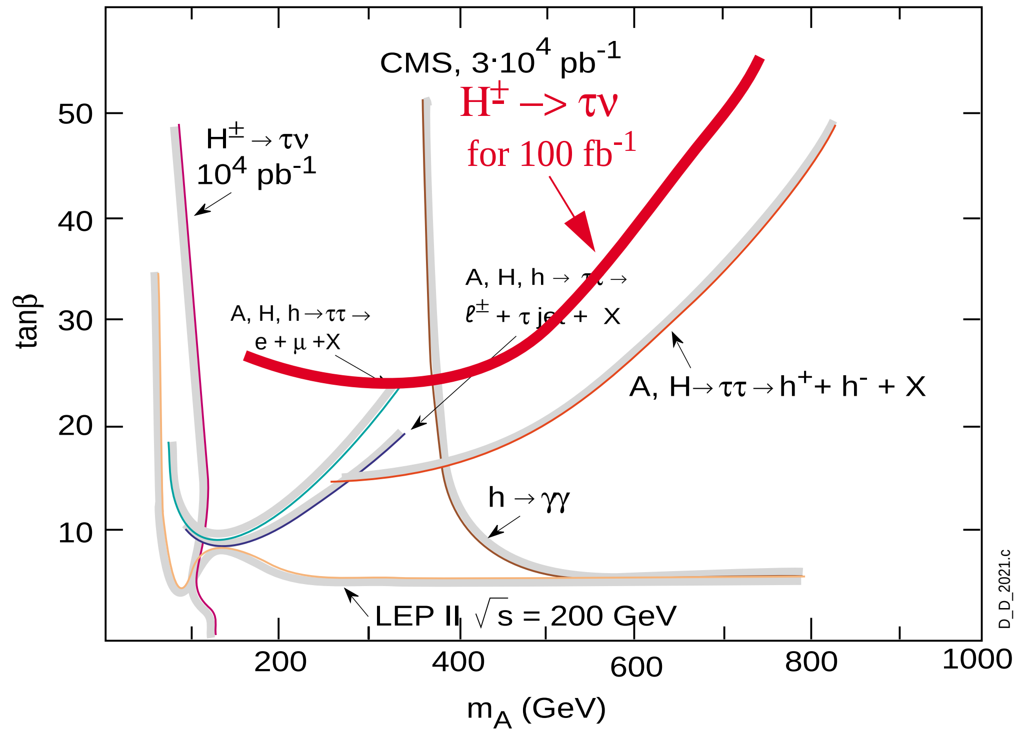
# $H^+$ search in $gb \rightarrow t\bar{H}^+$, $H^+ \rightarrow \tau^+\nu$, $\tau^+ \rightarrow \pi^+ + n\,\pi^0 + \nu$, $\bar{t} \rightarrow b\bar{q}\bar{q}$

example: $m_{H+}$ = 400 GeV, $\tan\beta$ = 40: $\sigma$ ~ 1 pb, BR($H^+$-> $\tau\nu$) ~ 14%

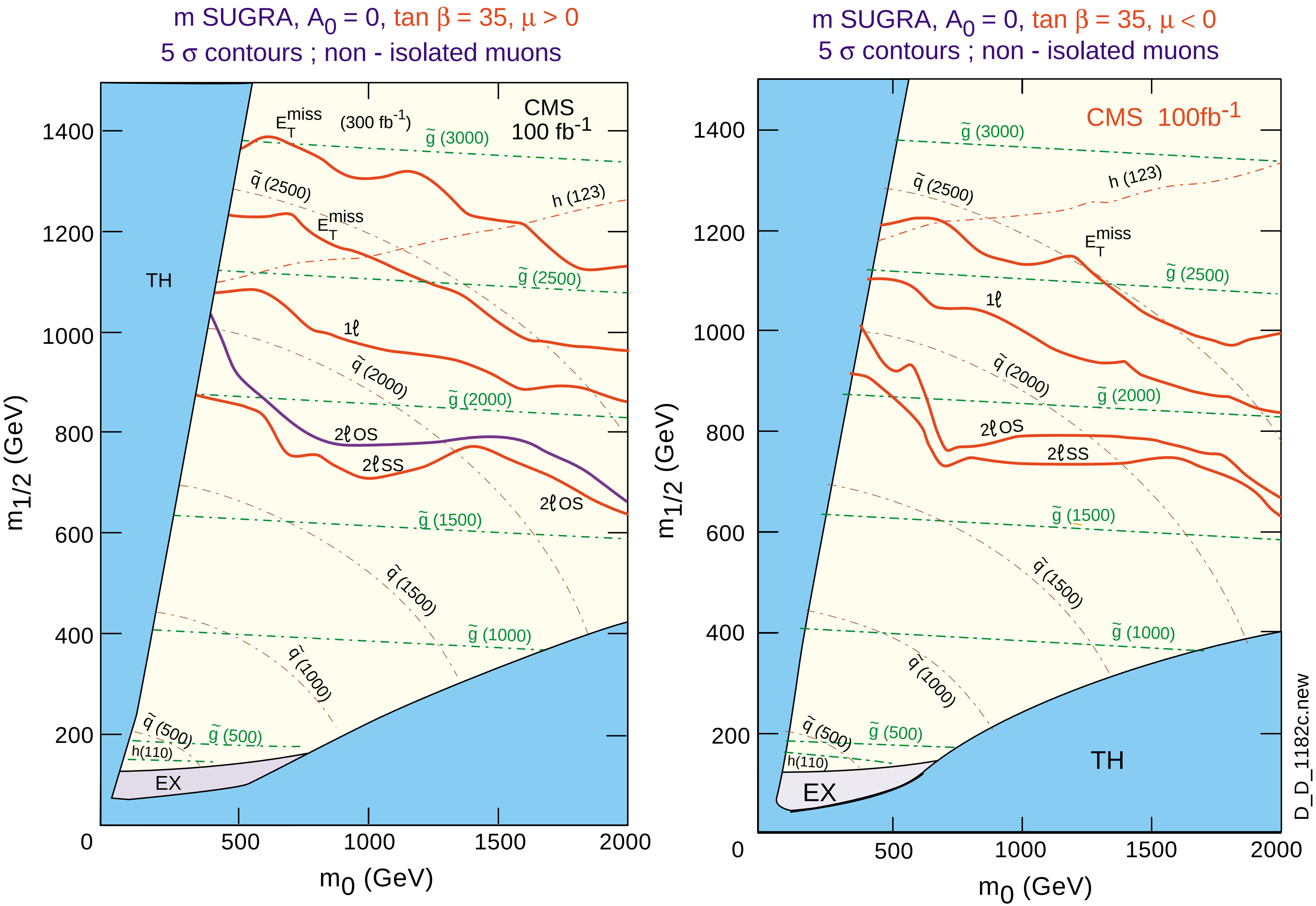
Reconstructed transverse mass $m_T(\tau\ \text{jet}, E_t^{miss})$




MSSM parameter space coverage for $H^\pm$

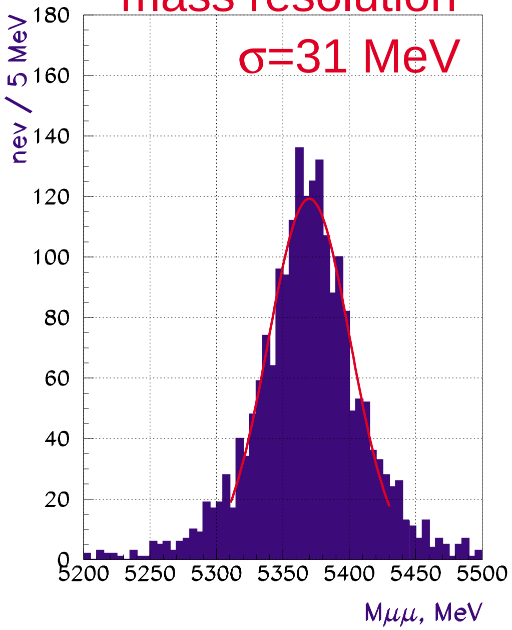


# Explorable domain in $\tilde{q}$, $\tilde{g}$ searches in n leptons + $E_t^{miss}$ + > 2 jets final states (high tanβ)

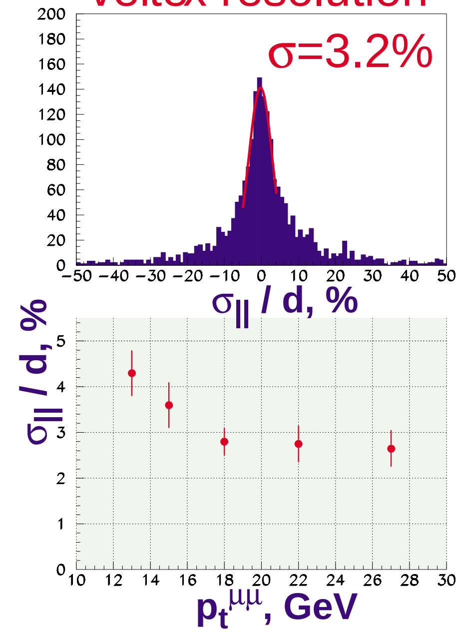


# SM Workshop: $B_s^0 \to \mu^+\mu^-$

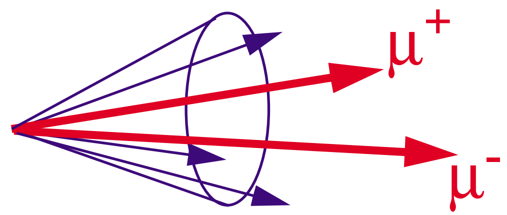
mass resolution




vertex resolution




tracker + calorimeter isolation




Background suppression

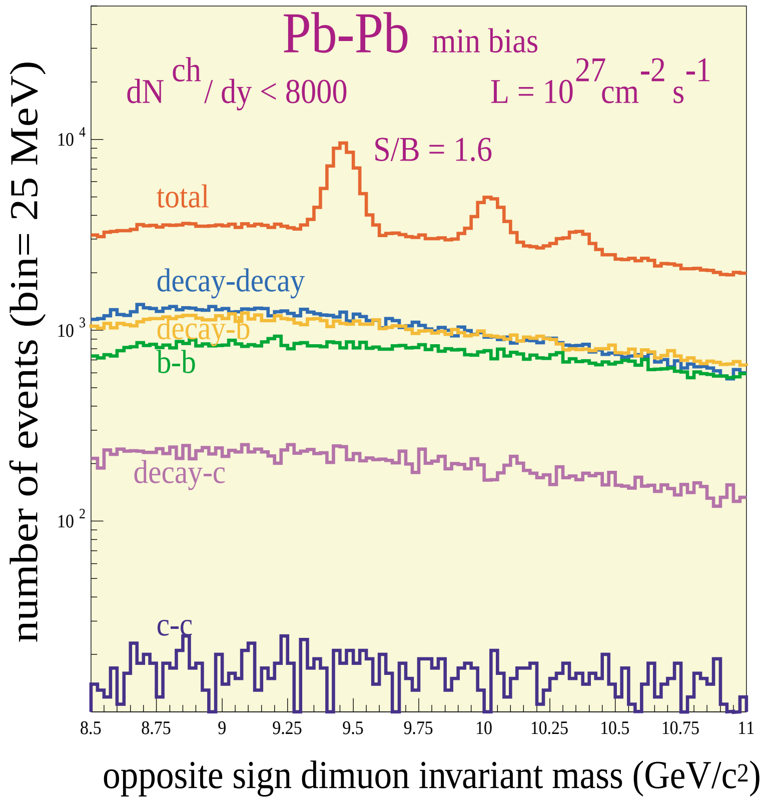
1. Mass window $1.1 \times 10^{-2}$
2. vertex selections $<2.3 \times 10^{-4}$
3. isolation track+calo $1.3 \times 10^{-2}$

Expected samples of reconstructed events assuming SM Br = $3.5 \times 10^{-9}$

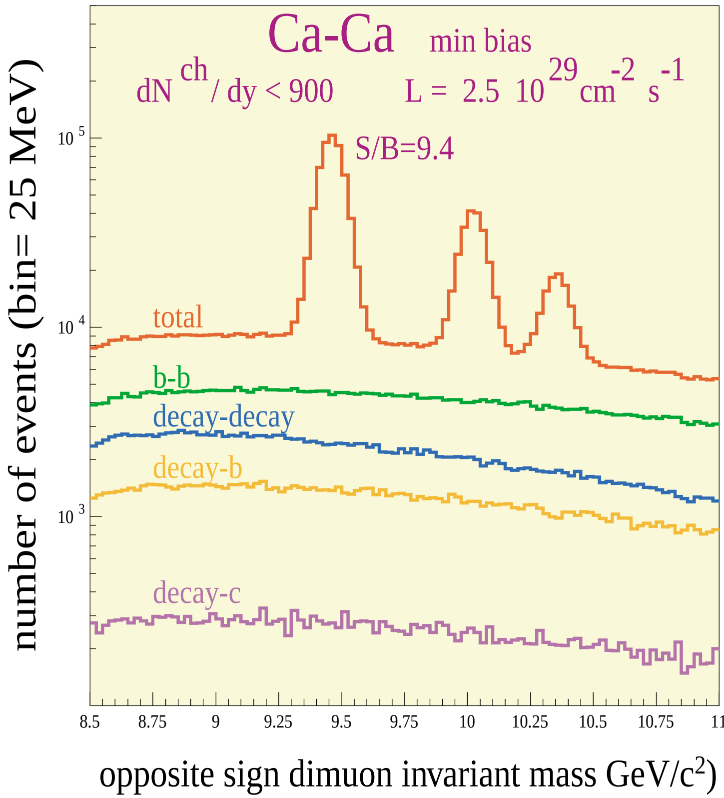
| | $30\ fb^{-1}$, low luminosity | $100\ fb^{-1}$, high luminosity |
|---|---|---|
| SIGNAL | 21 events | 26 events |
| Background | < 3.0 events at 90 % C .L. | < 6.4 events at 90 % C .L. |

# $\Upsilon$ detection in CMS with heavy ion beams

Barrel region only




Barrel region only




## Efficiency for $\Upsilon \rightarrow \mu\mu$

MSGCs 64%

All Silicon 76%

**Expected number of events for one month run at luminosity indicated on figures**

| **Resonance** | $\Upsilon$ | $\Upsilon'$ |
|---|---|---|
| Ca-Ca | 340000 | 115000 |
| Pb-Pb | 22000 | 7500 |

CMS

Compact Muon Solenoid