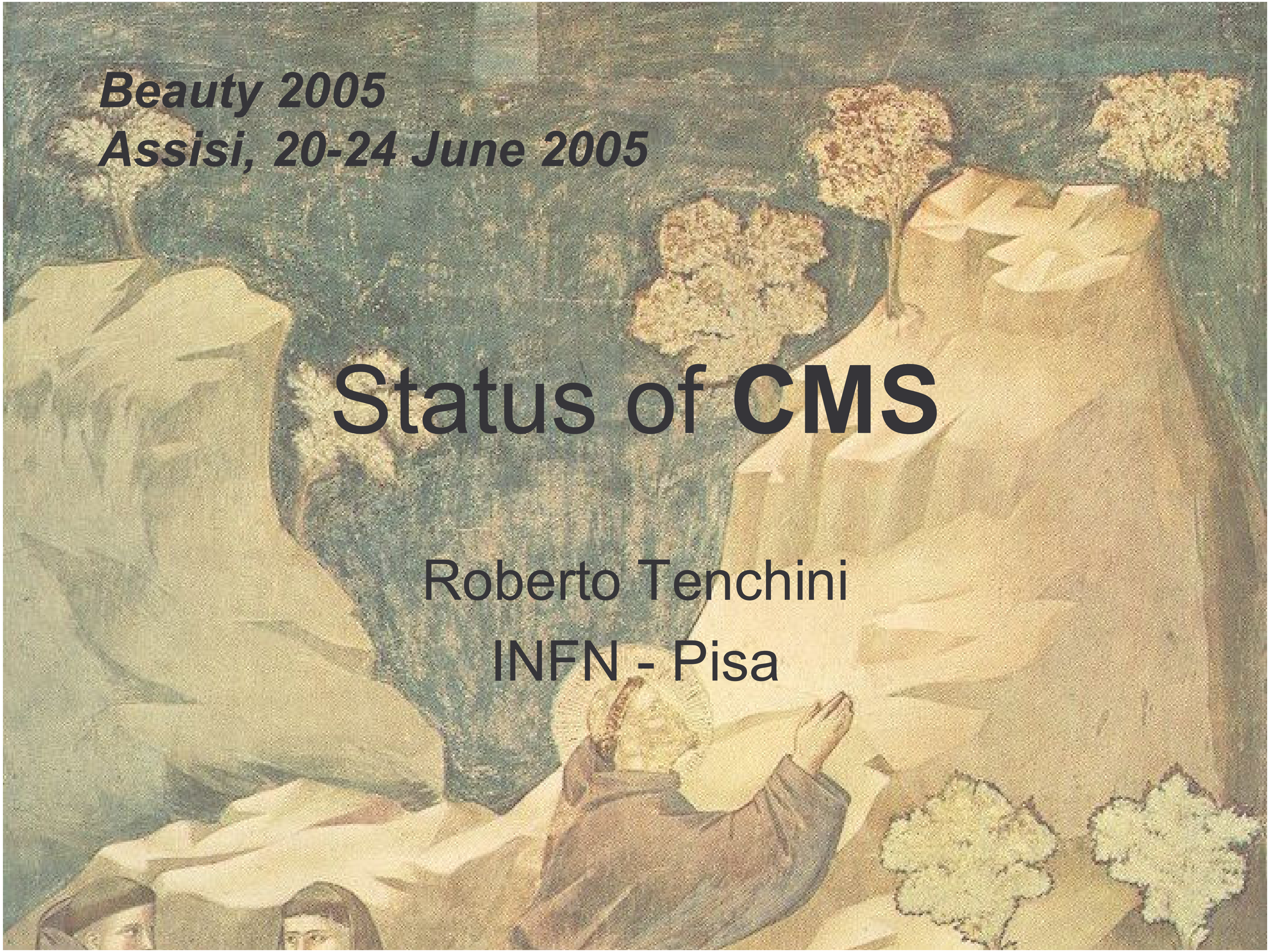


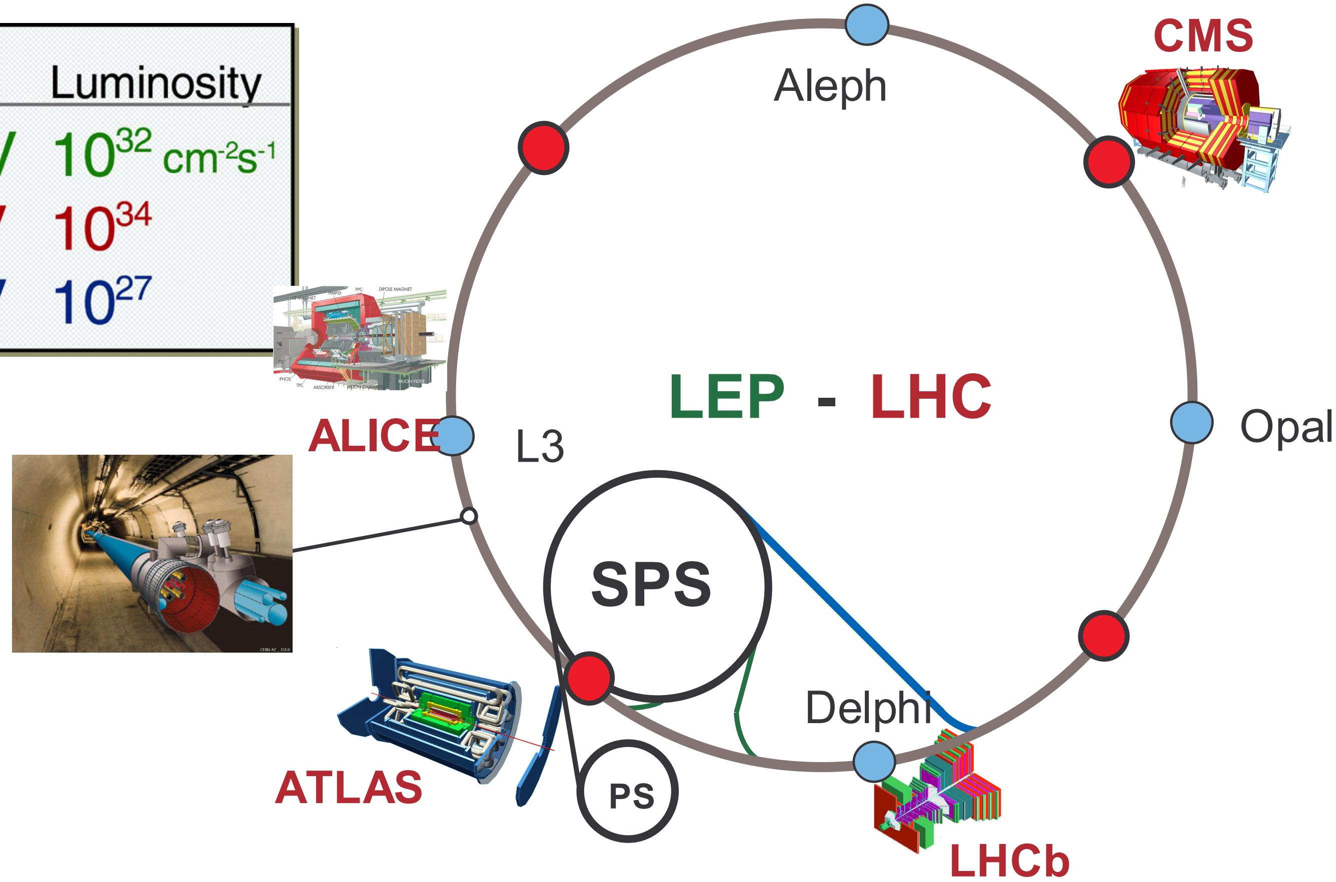
Beauty 2005
Assisi, 20-24 June 2005

Status of **CMS**

Roberto Tenchini
INFN - Pisa

Experiments at the LHC

	Beams	Energy	Luminosity
LEP	e^+e^-	200 GeV	$10^{32}\ cm^{-2}s^{-1}$
LHC	p p	14 TeV	10^{34}
	$P_b P_b$	1312TeV	10^{27}



- **2007 Pilot Run**
- **2008 10 fb^{-1}**
- **2010 100 fb^{-1}**

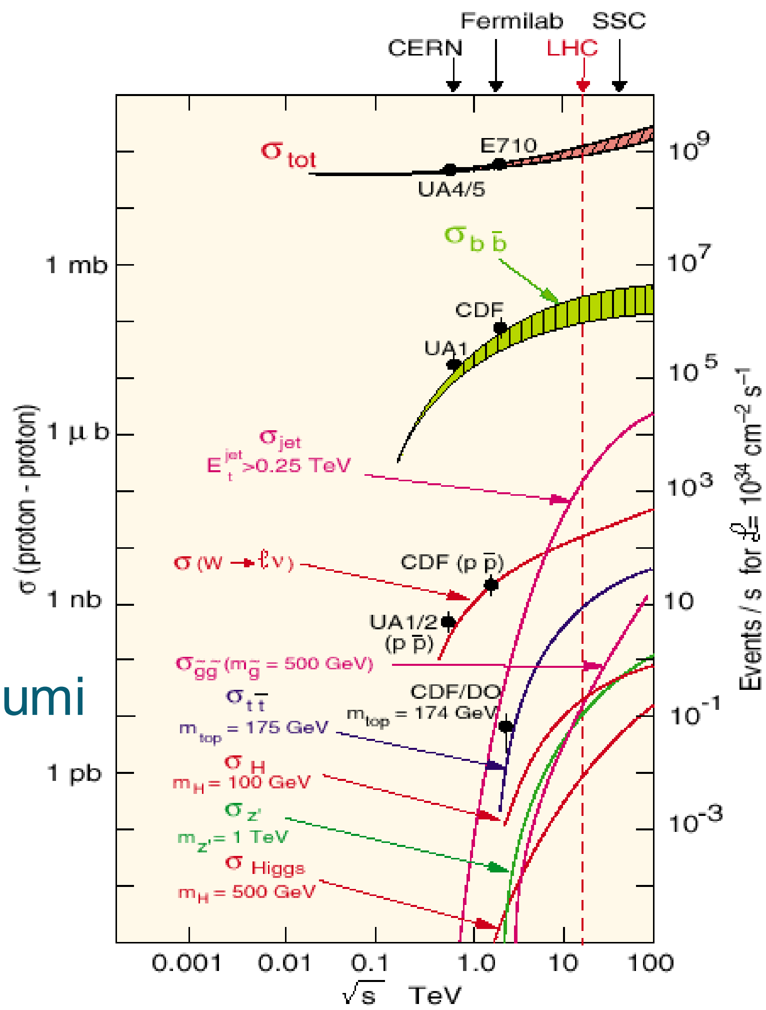
Experiments at LHC:
ATLAS A Toroidal LHC ApparatuS (proton-proton collisions)
CMS Compact Muon Solenoid (proton-proton collisions)
ALICE A Large Ion Collider Experiment (Ion-ion collisions)
LHCb (Study of CP violation in B-meson)

LHC cross sections and rates

At High Luminosity (10^{-34} cm^{-2} s^{-1})

SM Higgs (115 GeV/c^2): →0.1 Hz
t t production: →10 Hz
W→ ℓ ν: →10^2 Hz
bb production: → 10^6 Hz
Inelastic: →10^9 Hz

Beam crossing every 25 ns
25 pileup event / beam crossing at High Lumi

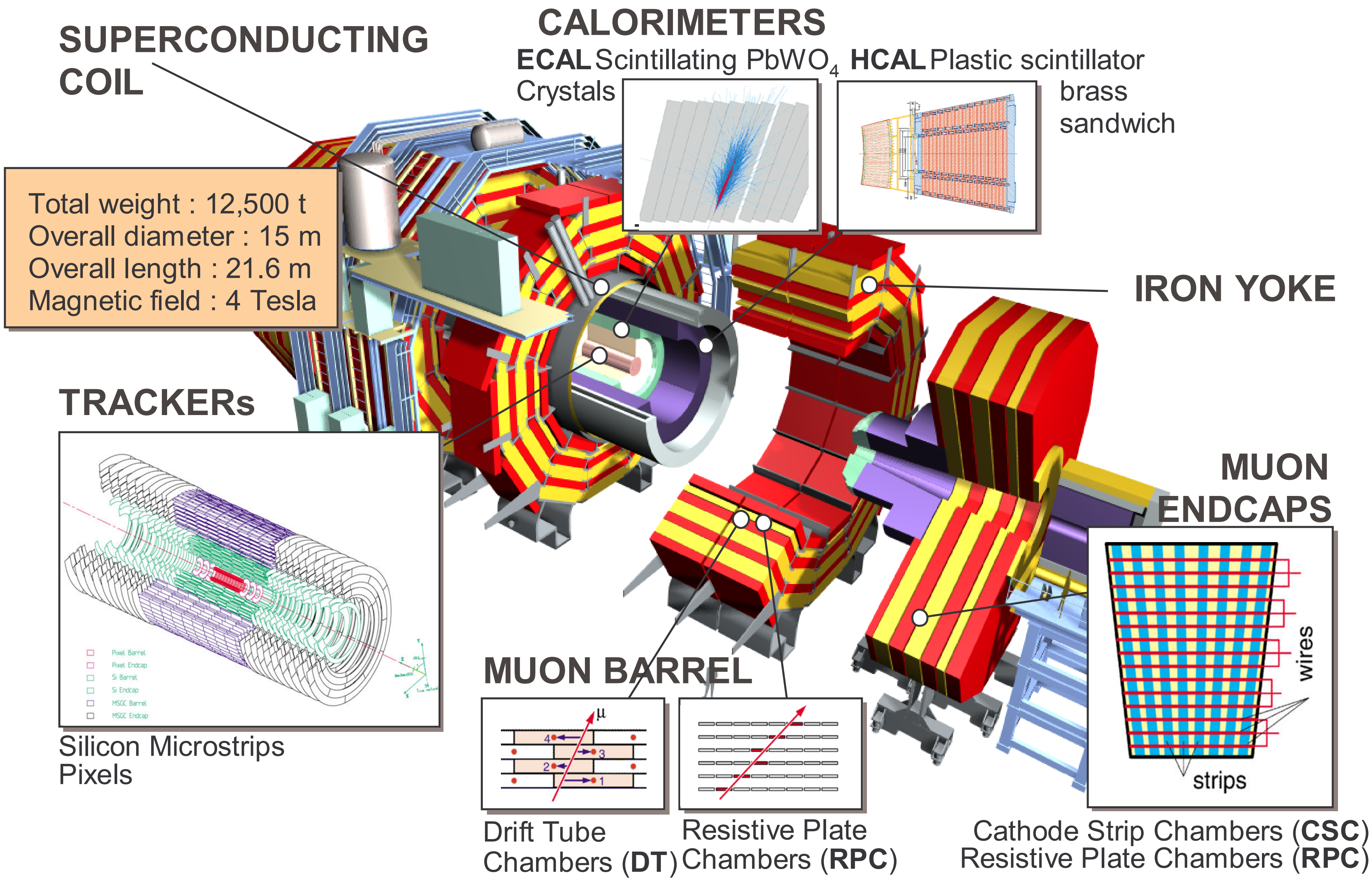


Constraints on LHC detectors

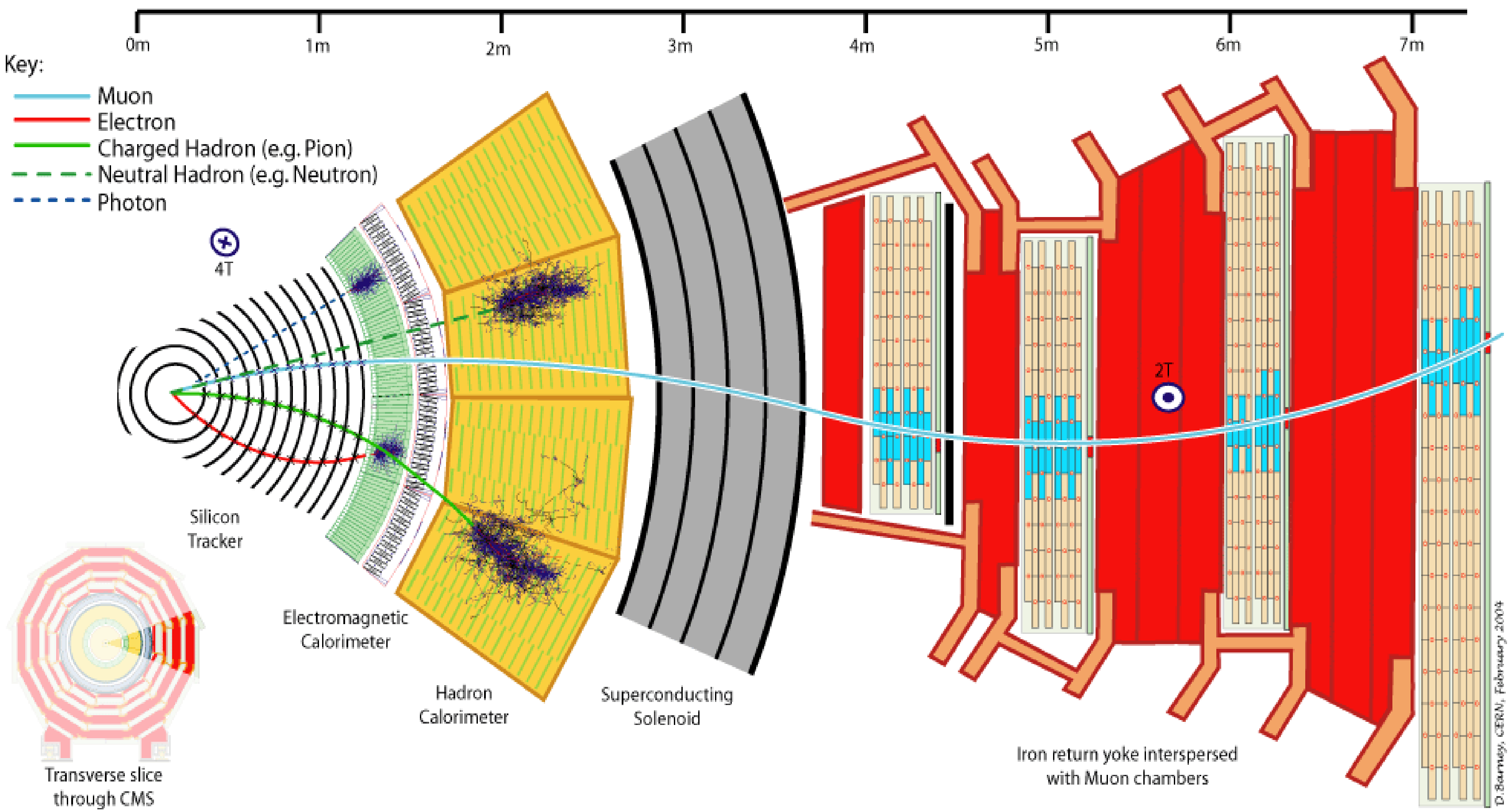
- Fast response
  - challenging readout electronics
- Granularity
  - large number of electronic channels
  - high cost
- High flux of particles from pp collisions $\rightarrow$ high radiation environment, e.g. in forward calorimeters:
  - -up to 10^{17} n/cm^2 in 10 years of operation
  - -up to 10^7 Gy
  - radiation hardness

$\Rightarrow$ <u>... An still maintain excellent physics performance</u>

The Compact Muon Solenoid (CMS)

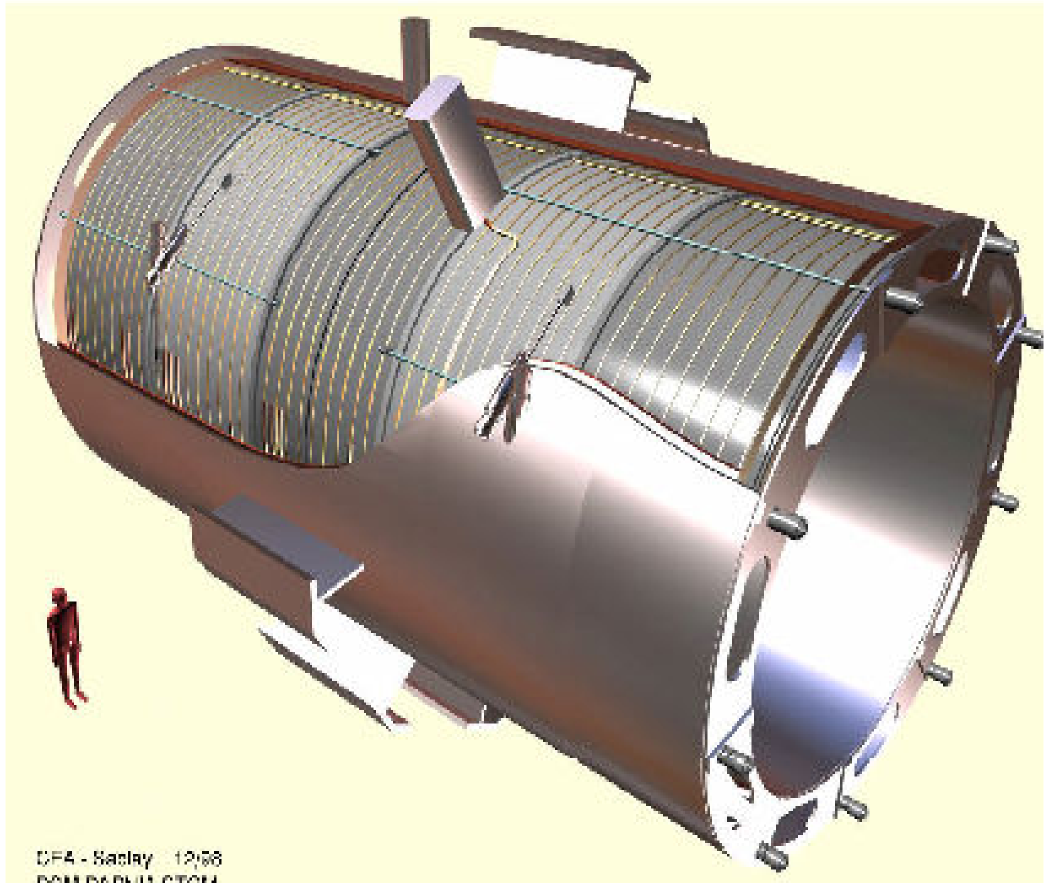


Particles through a CMS slice



The CMS solenoid

- Basic goal: measure 1 TeV muons with 10% resolution →B=4T
- $B=\mu_0 nI$; @2168 turns/m (4 layers) → I=20kA (SuperConducting Cable)
- Challenges: 4-layer winding to carry enough I, design of reinforced superC cable
- The superconductor chosen is Niobium Titanium (NbTi) wrapped with copper – needs to be cooled to ~4K
- Huge dimensions: 6m inner diameter x 12.5m lenght (built in 5 modules)

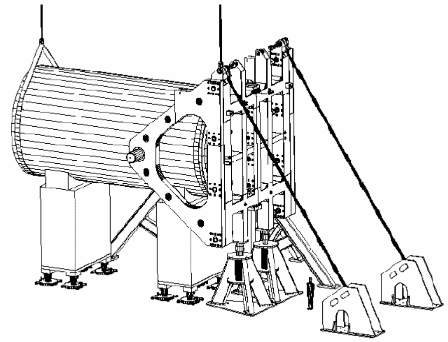


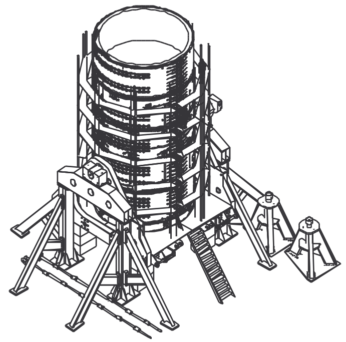
$$\frac{\Delta p}{p} \propto \frac{p}{qBL^2}$$

CMS Magnet: Cold Mass Completed

- **<u>1st Mar 05</u>**: Completion of Cold-Mass.
- All major industrial contracts for the Magnet now completed.
- All coil modules are electrically connected in series, hydraulic (welded) connections are completed and vacuum tight. Cold mass is ready to be covered by the outer radiation shield.

- Preparation of swiveling will start end of June, and be **executed beginning of August.**

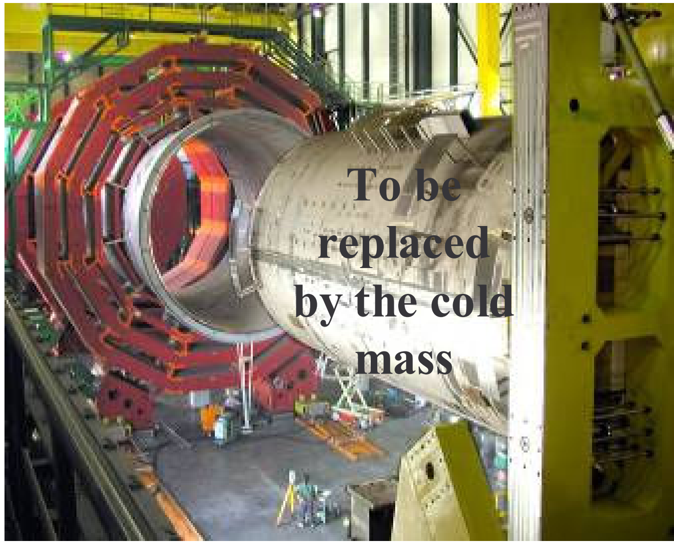




- **Q1-06: Finish Magnet Test on surface and 'Cosmics Challenge'**

Magnet Operations

- All modules in series with instrumentation
- Insulation >50Mohms
- Leak Tested



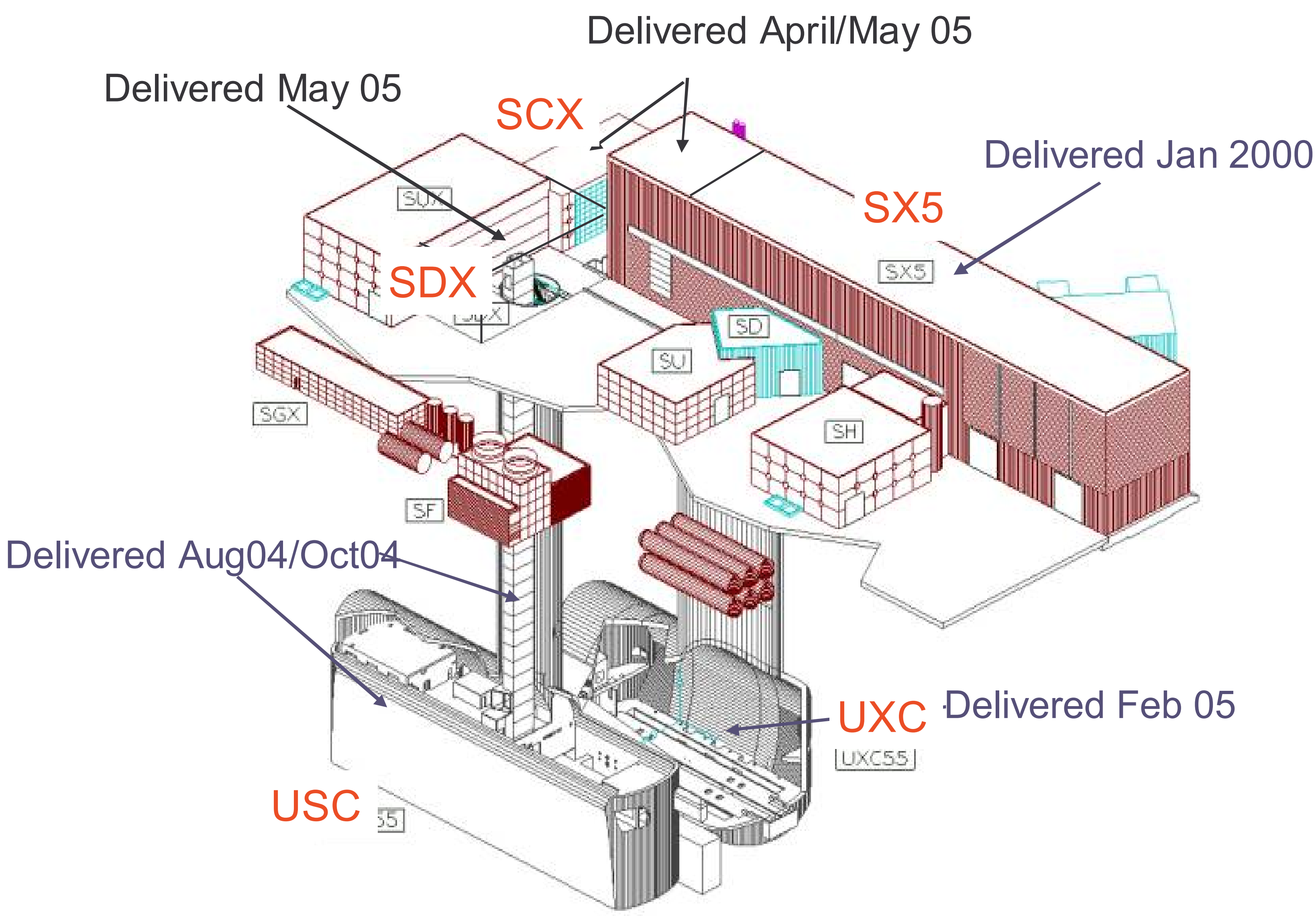
Swivelling in Aug 05

20 kA power converter tested

USC5 20 kA bus bars pushed through pillar wall

Dump resistors connected

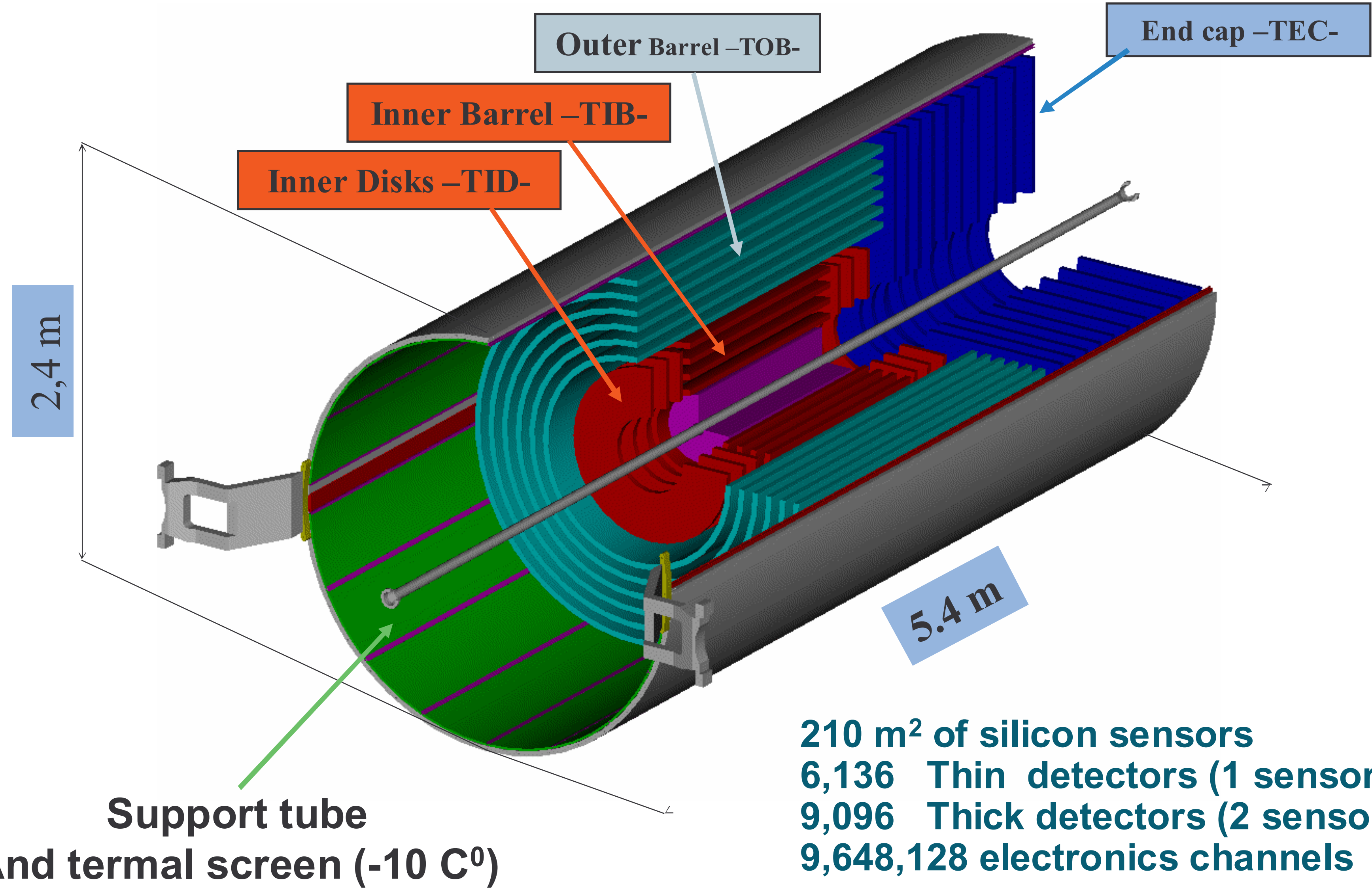
Civil Engineering Overview



UXC/USC5: CMS caverns

Delivered to the experiment
February 1st 2005.
Daily activity to install
all needed services

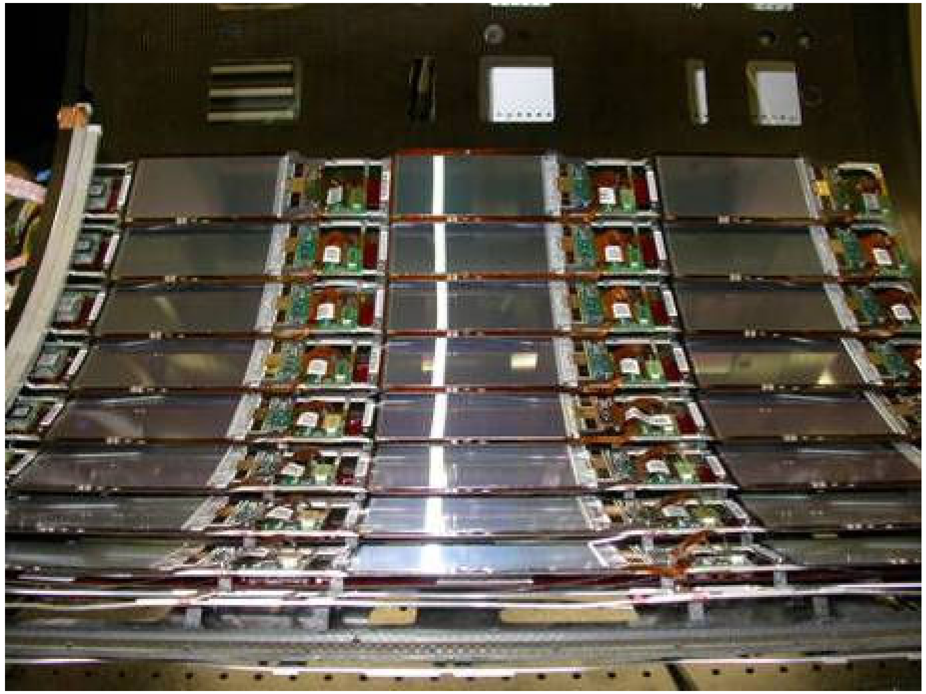
Silicon Strip Tracker



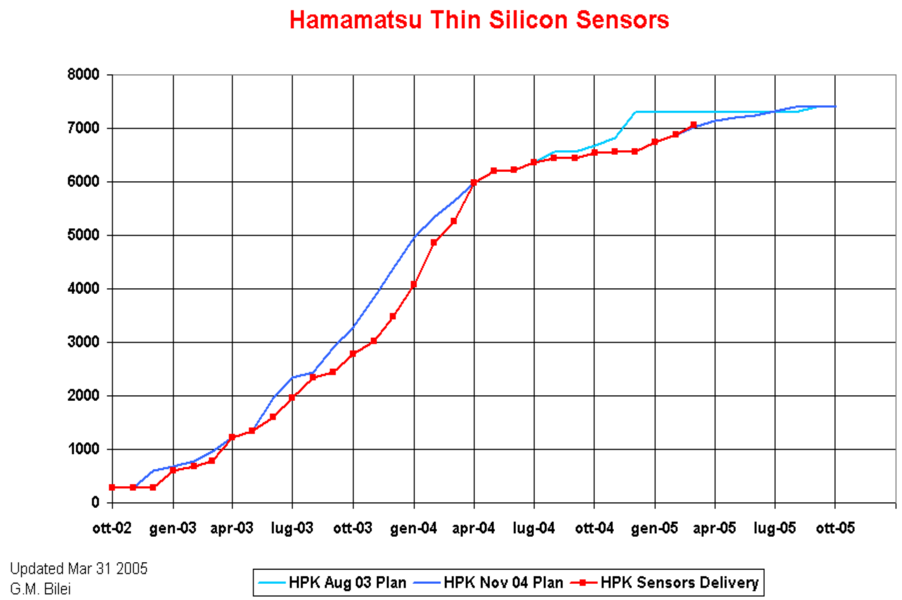
210 m² of silicon sensors
6,136 Thin detectors (1 sensor)
9,096 Thick detectors (2 sensors)
9,648,128 electronics channels

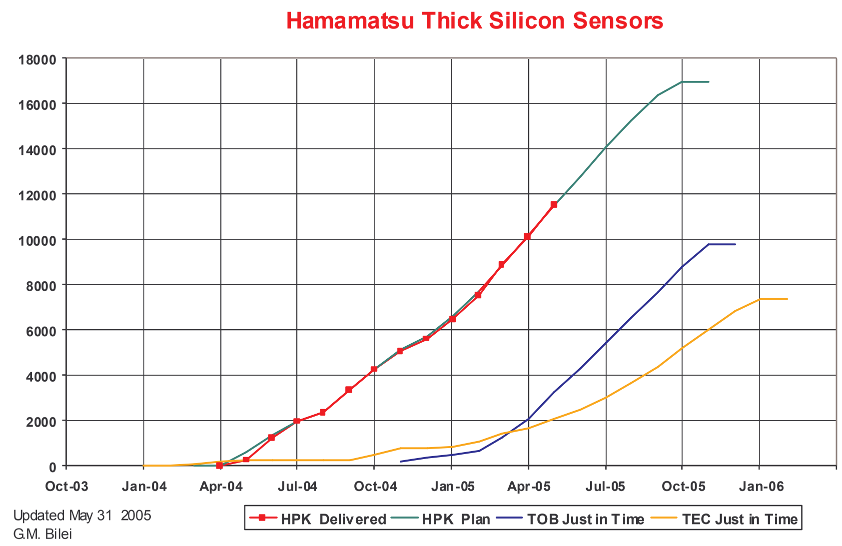
Tracker status

- All mechanical structures are ready.
- 20.000 sensors delivered/26.000 needed.
- 4.000 modules built /16.000 required
- Integration activities on rod, petals and shells started.
- Complete the production of modules by the end of 2005 and to install the tracker in November 2006.



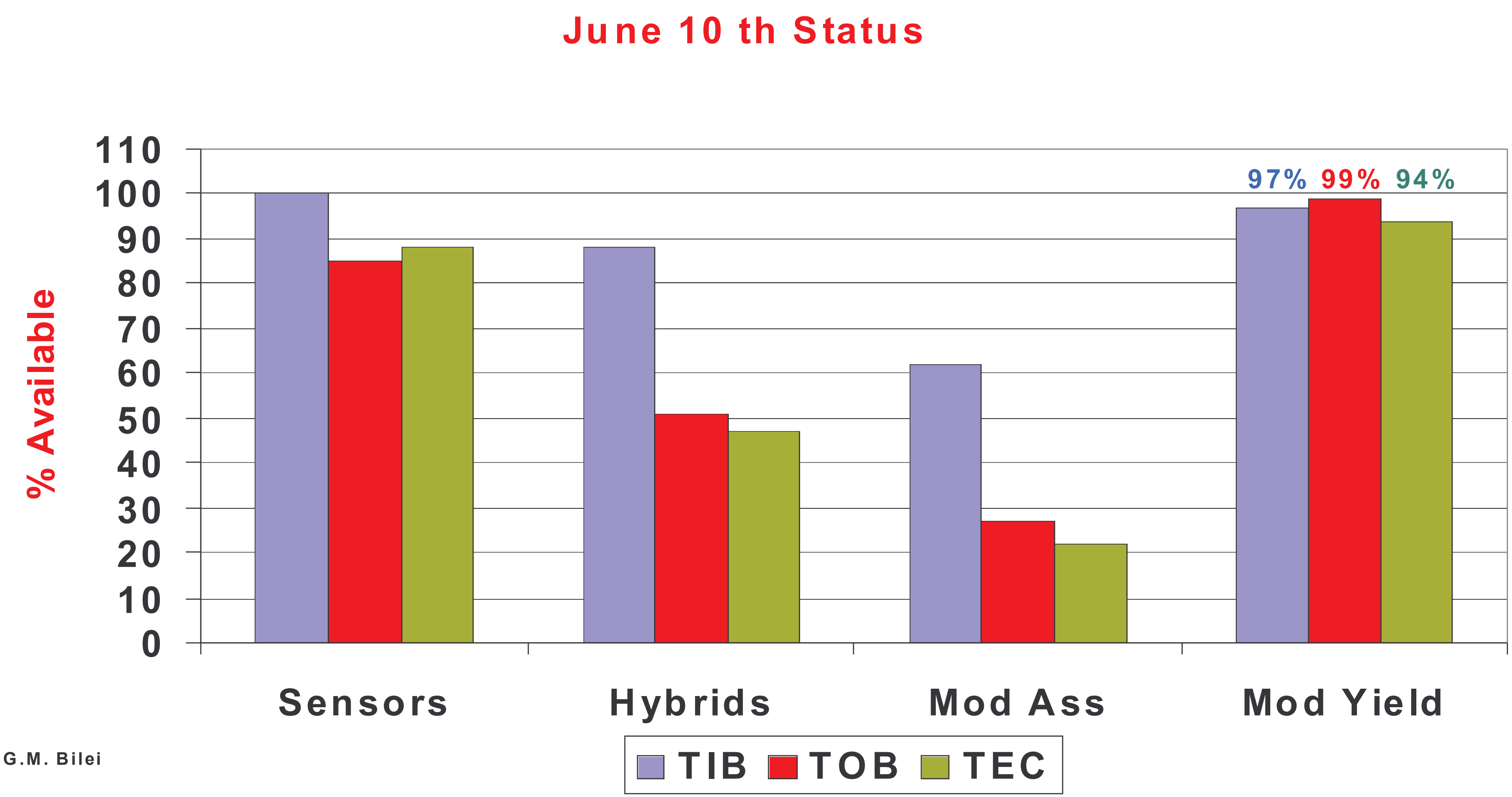
Sensor Production off Critical Path





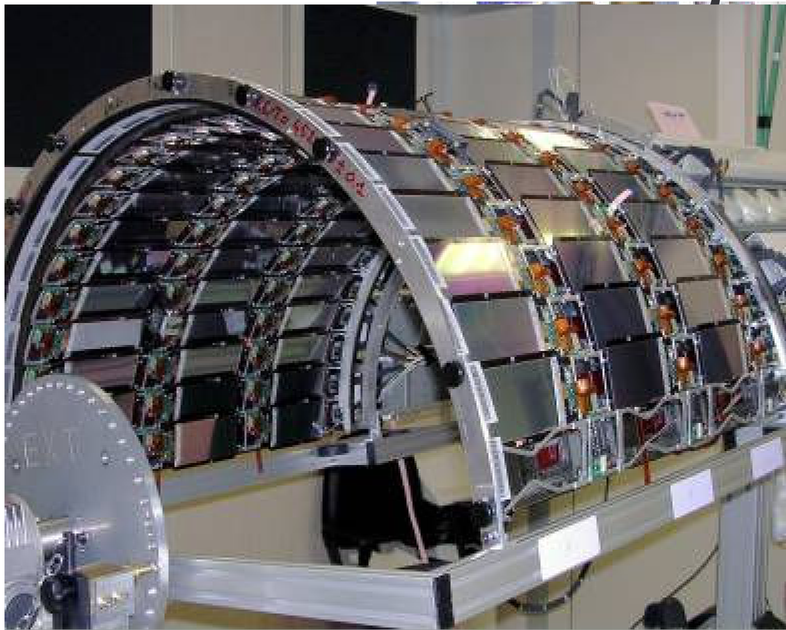
- HPK thin sensor production complete (7000)
- HPK thick sensors: 11500/17000 received (end Mar). Accelerate Rate from 1300/mo to 1500/mo. End production in Oct 05.

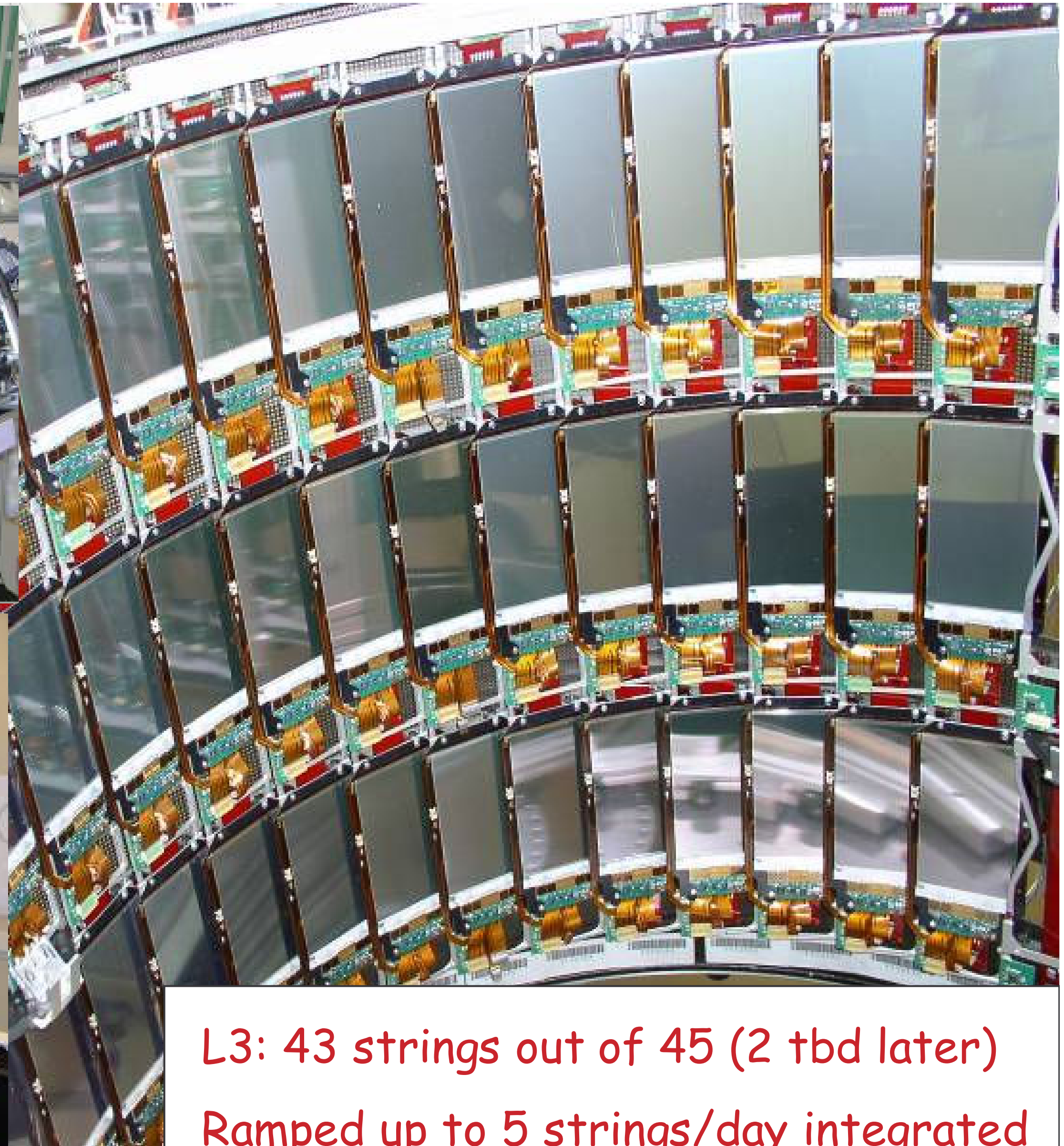
CMS Tracker Module Production



G.M. Bilei

Module Integration into TIB Shells





L3: 43 strings out of 45 (2 tbd later)

Ramped up to 5 strings/day integrated

Tracker Support Tube

Tracker support tube & thermal screen
<u>Cooled Successfully 15 June 2005</u>

Pixel detector

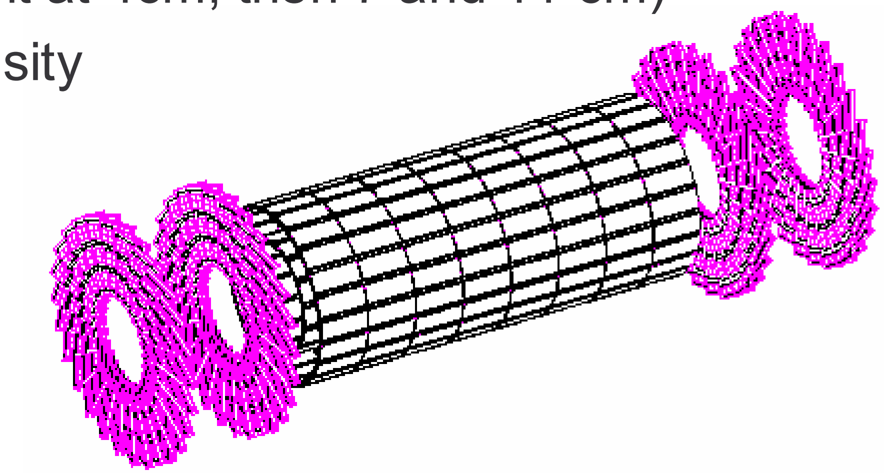
Very close to beam pipe (first point at 4cm, then 7 and 11 cm)

Different scenario for High luminosity

Small pixel size (150μm).

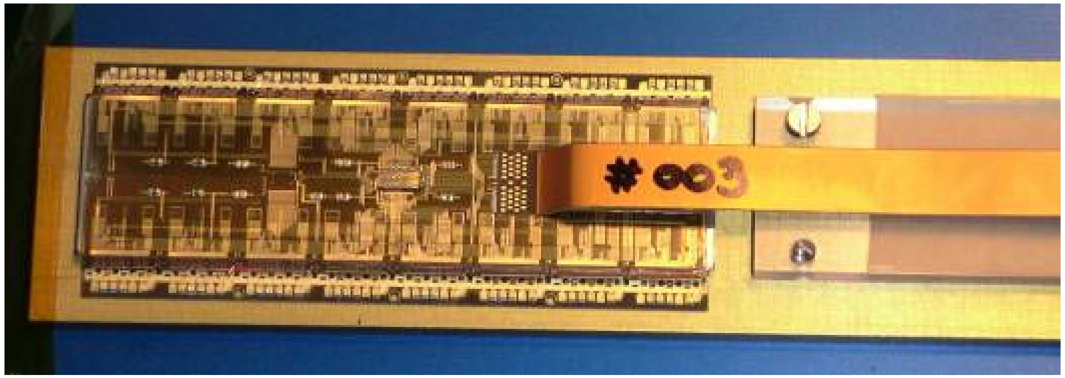
Occupancy: 10^{-4}.

Resolution: ~20μm.



Sensors
Barrel: 10% delivered in April. Last delivery May 06.
Forward: Delivery starts in Sept. ’05

Installation at start of physics data taking (2008)
(3 barrel +2 endcap disks)



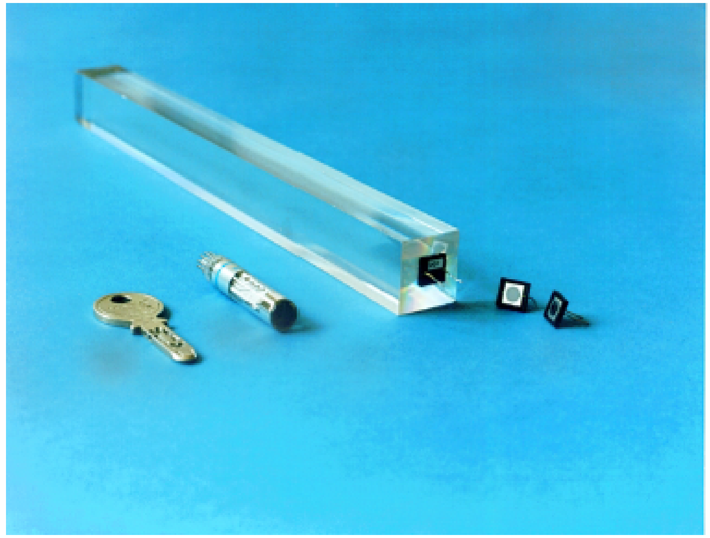
ECAL

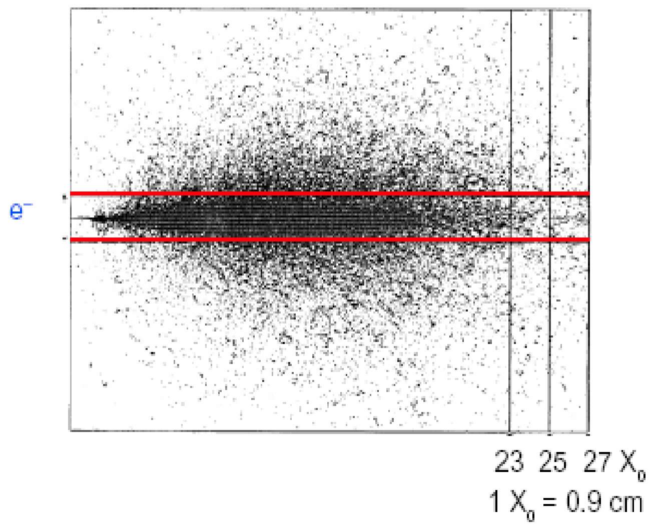
- 75.000 lead tungstate crystals
  - compact
  - fast (95% light emitted in 25ns)
  - highly granular (2.19cm Moliere rad)

Readout with
•Avalanche PhotoDiodes (barrel)
•Vacuum Phototriodes (endcap)

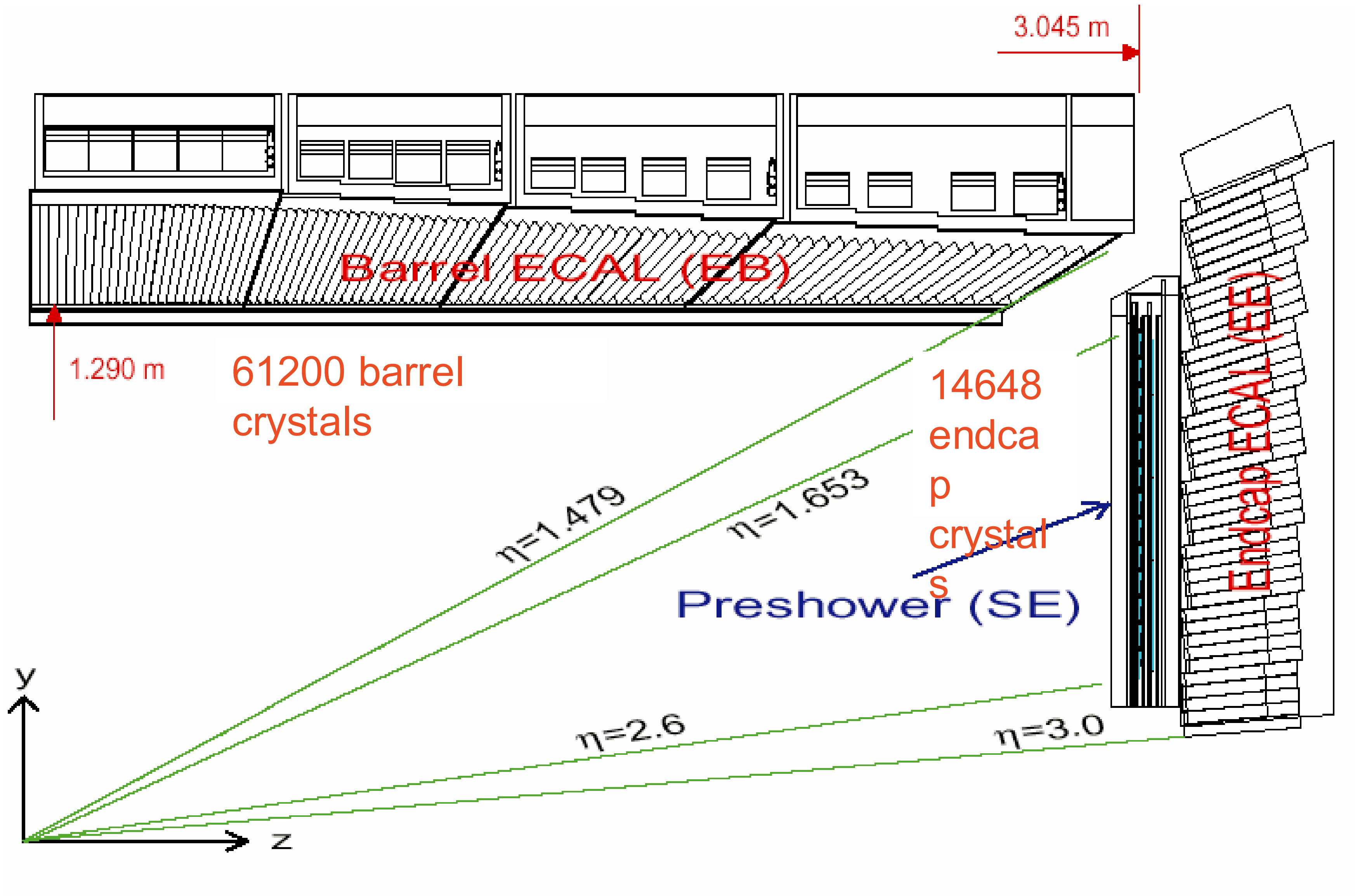
Excellent energy resolution

$$\frac{\sigma(E)}{E} = \frac{3\%}{\sqrt{E}} \oplus \frac{150 MeV}{E} \oplus 0.40\%$$





ECAL



3.045 m
Barrel ECAL (EB)
1.290 m
61200 barrel crystals
14648 endcap crystals
Endcap ECAL (EE)
Preshower (SE)
η=1.479
η=1.653
η=2.6
η=3.0
y
z

ECAL Status

- **Crystals** 37300 barrel crystals delivered
- **Bare Supermodules**

18 (out of 36) bare SMs assembled.

- **Photodetectors** : All 130k APDs and 11000 VPTs (~70%) delivered
- **'Dressed' Supermodules**

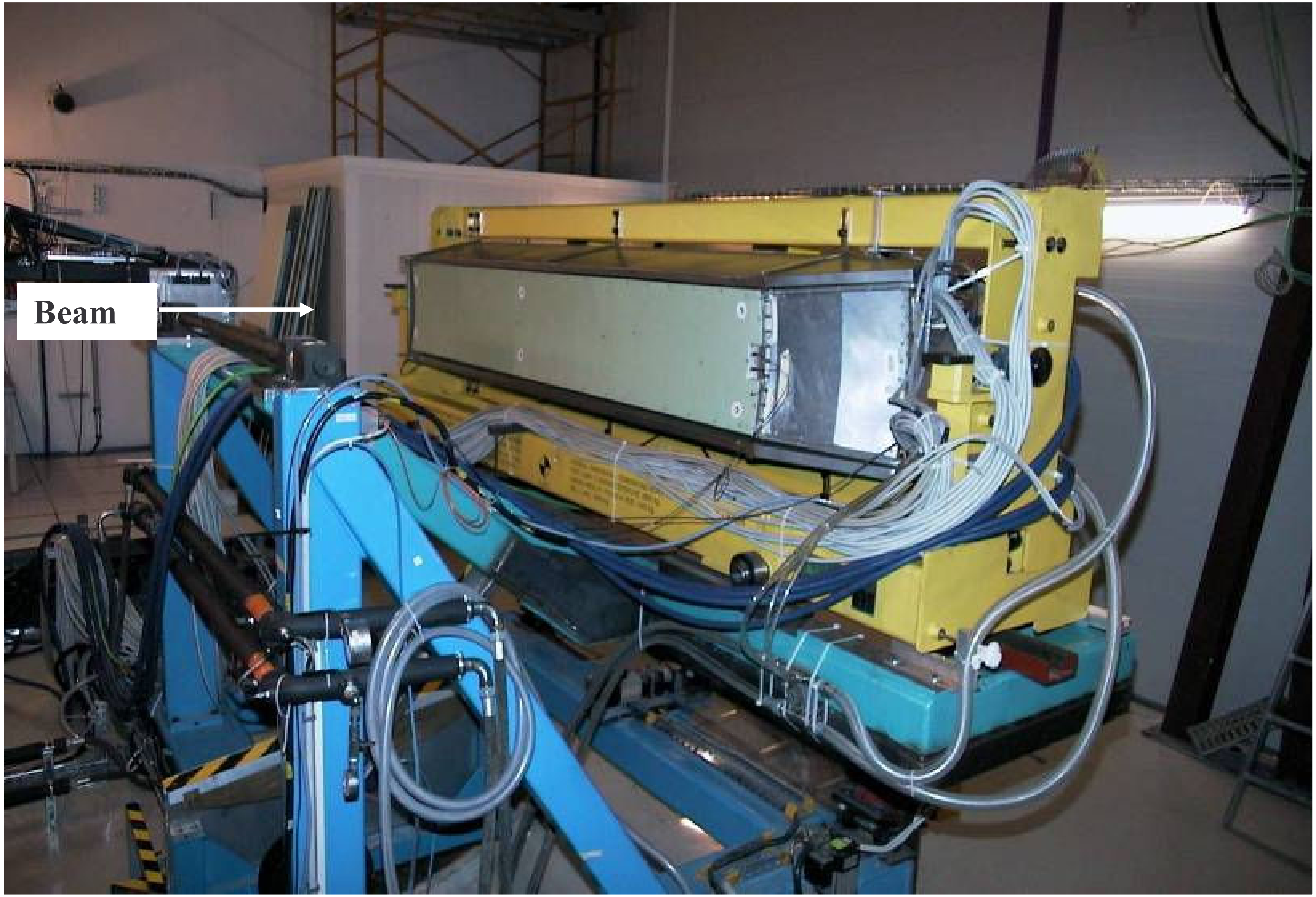
Good results from first fully 'dressed' SM for Sept/Oct Beam test. Ramping-up. 2 production SMs being dressed now. 3 dressing lines ready.

Concern

Crystals: delivery defines ECAL critical path.

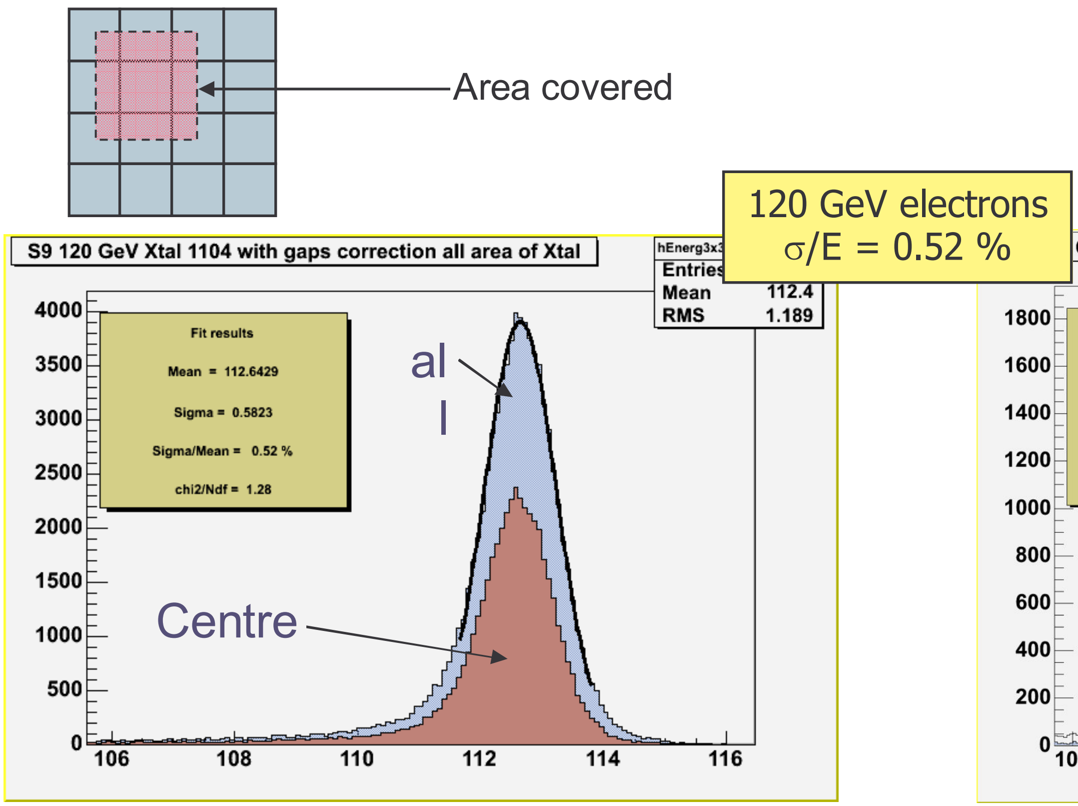
ECAL endcaps will be installed during in the shutdown before 2008 physics run

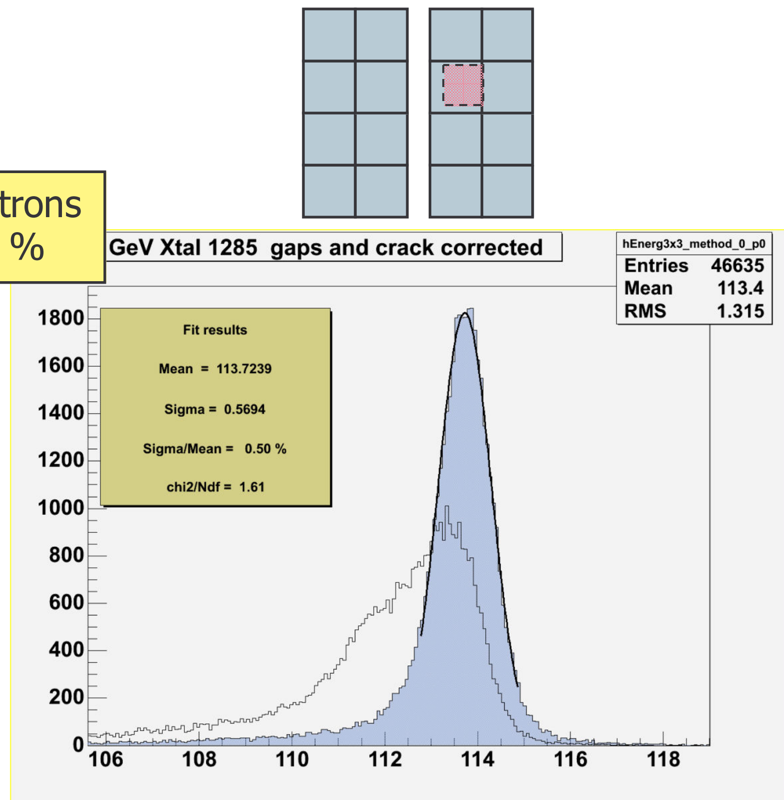
ECAL SM in Test Beam: Oct 04



Energy resolution over large areas

- Corrections for “local containment” – not hitting the crystals in the middle – work as well as previous results and Monte-Carlo studies suggest
- Also corrections for losses close to 6 mm inter-module voids



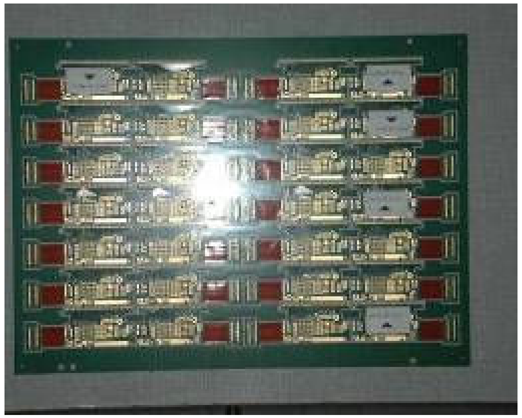


ES : Preshower

- Silicon Sensor production nearly completed (>90%)
- PACE3 chipset submitted for production
  - Successful engineering run : 560 packaged ASICS tested with 80% yield
- System tested in beam
  - S/N ratio at mip > 7 in high (calibration) gain
- Pre-production of hybrids started in Greece

Preshower module

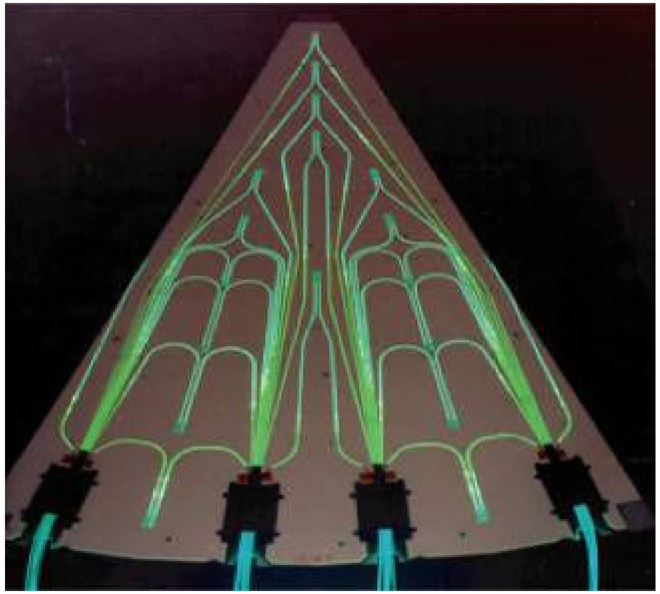
System Mother Board



The hadron calorimeter HCAL

CMS HCAL is constructed in 3 parts:

- Barrel HCAL (HB)
  - Brass plates interleaved wit plastic scintillator embedded with wavelength-shifting optical fibres (photo top right)
- Endcap HCAL (HE)
  - Brass plates interleaved with plastic scintillator
- Forward HCAL (HF)
  - Steel wedges stuffed with quartz fibres ~10000 channels total

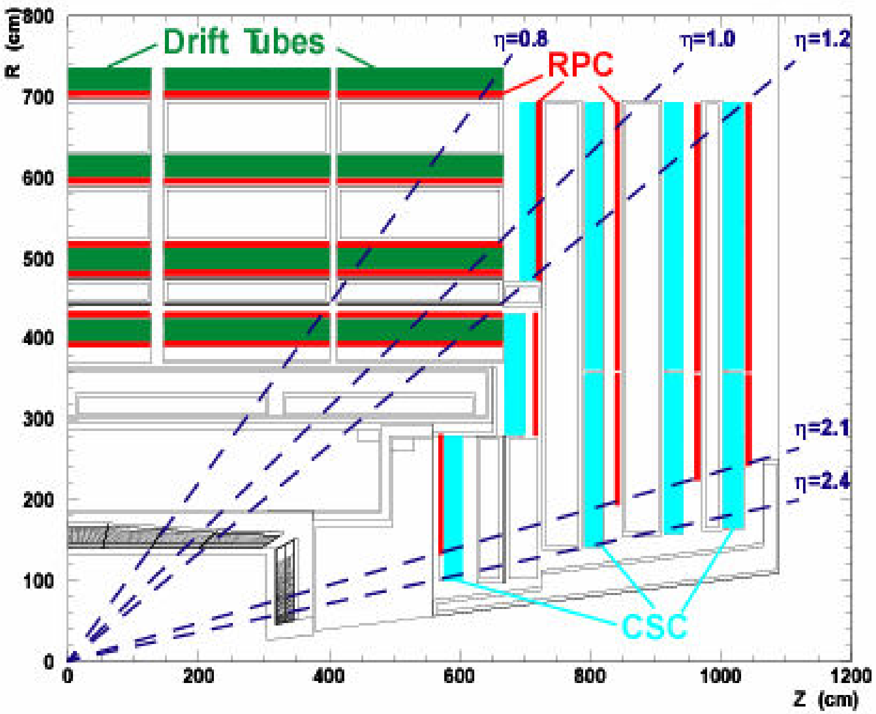


Inside SX5 - the Hadron Calorimeter

Most of HCAL is in SX5 – two half-barrels and two endcaps

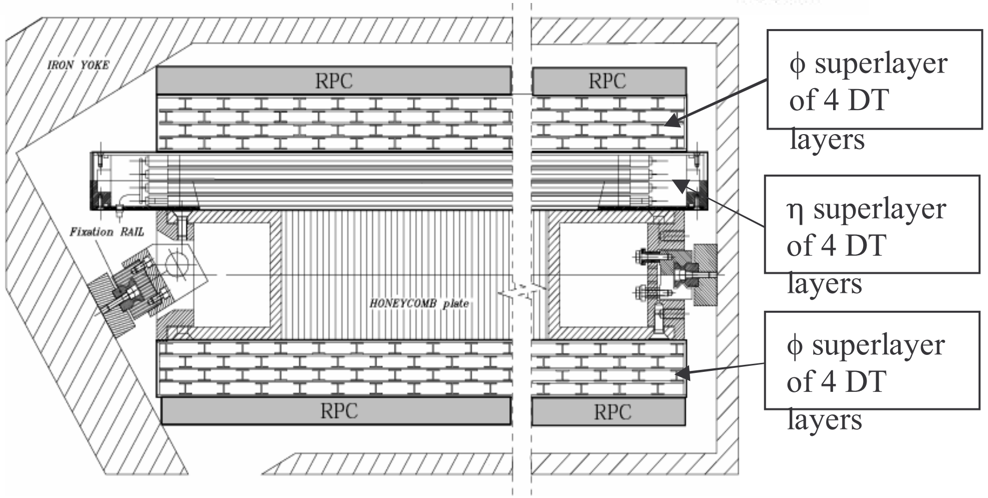
(HF almost completed at CERN)

The Muon Chambers



Position measurement:
Drift Tubes (DT) in barrel
Cathode Strip Chambers (CSC) in endcaps

Trigger:
Resistive Plate Chambers (RPCs) in barrel and endcaps



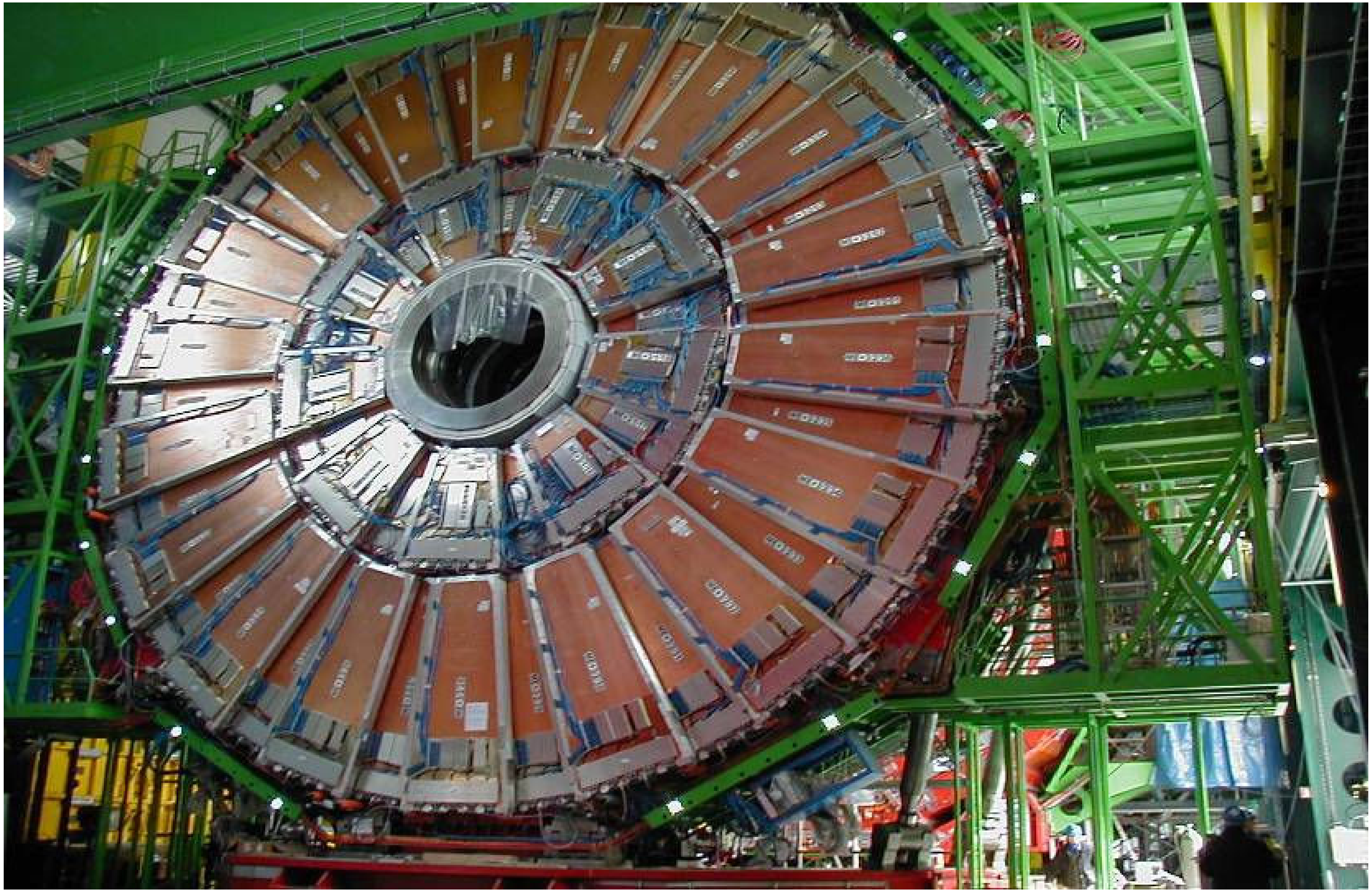
195000 DT channels
210816 CSC channels
162282 RPC channels

Status of DT and RPC

Produced >80% of DT and >60%RPC. 20% installed

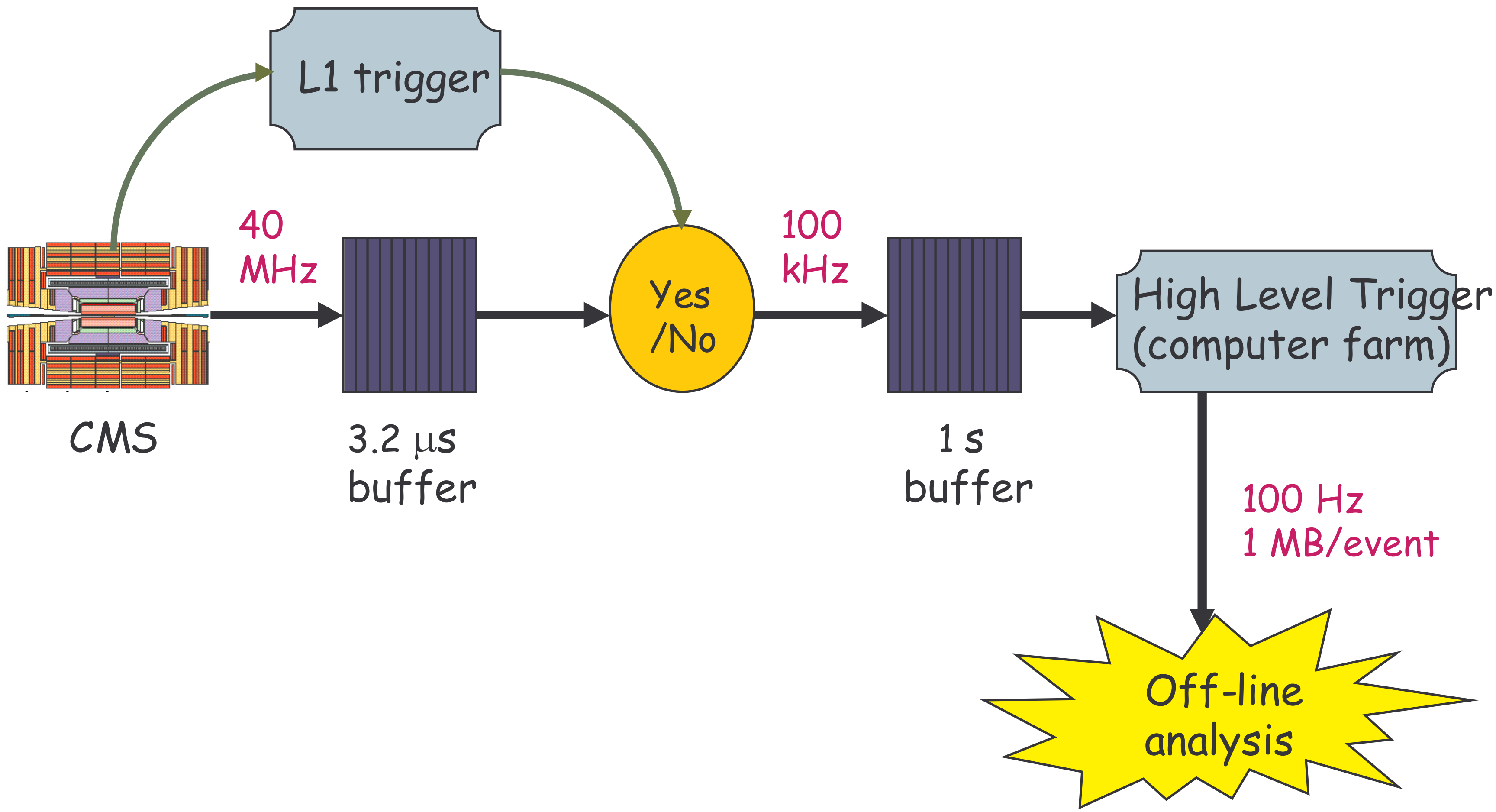
Endcap Muons: CSCs at SX5

CSCs installed: 60% (out of 396)
CSCs commissioned (cosmics): 40%

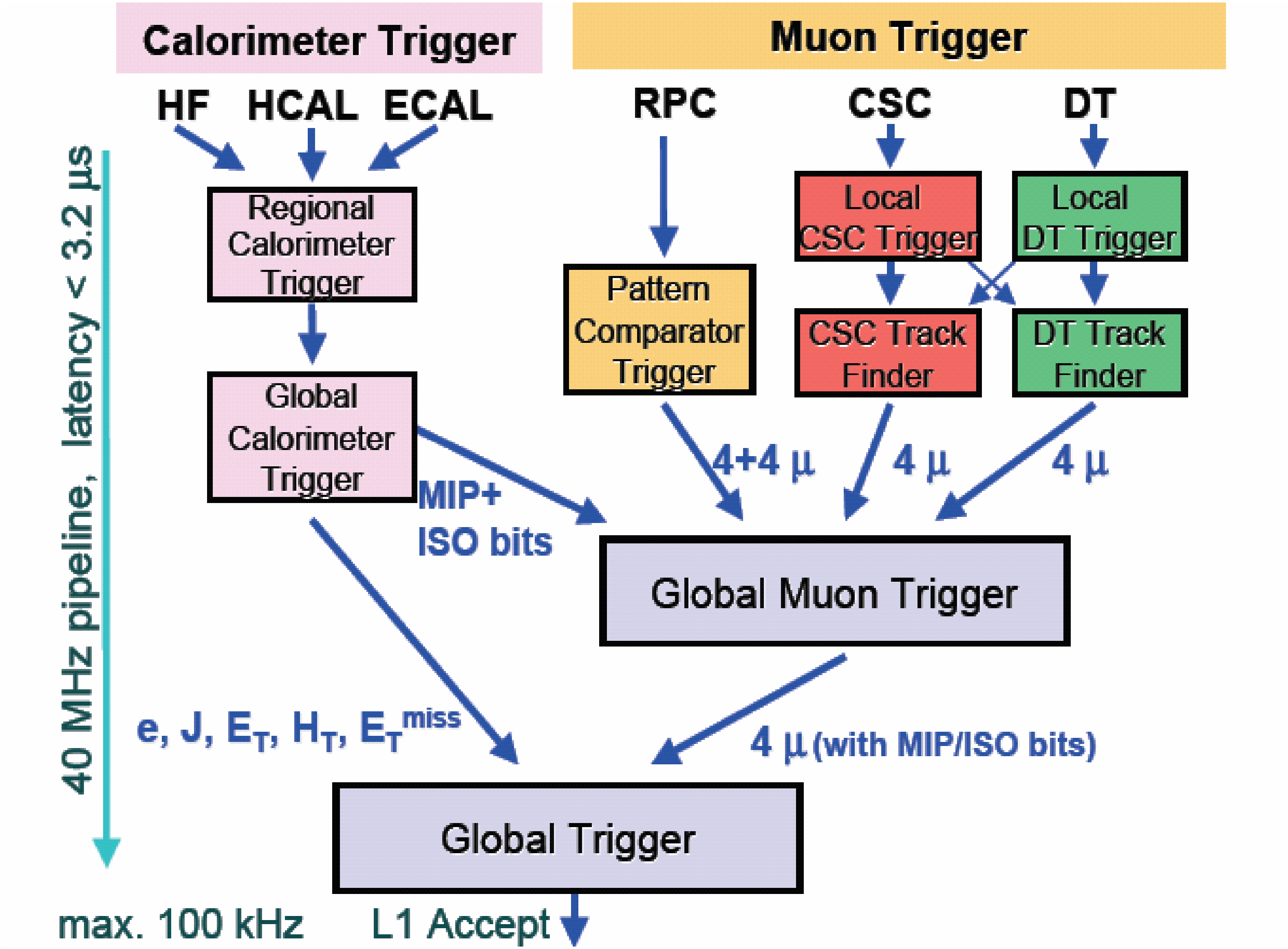


Trigger and DAQ

- Level 1 trigger based on muon & calorimeters ,
- then High Level trigger using reconstruction algorithms



Level-1 Trigger



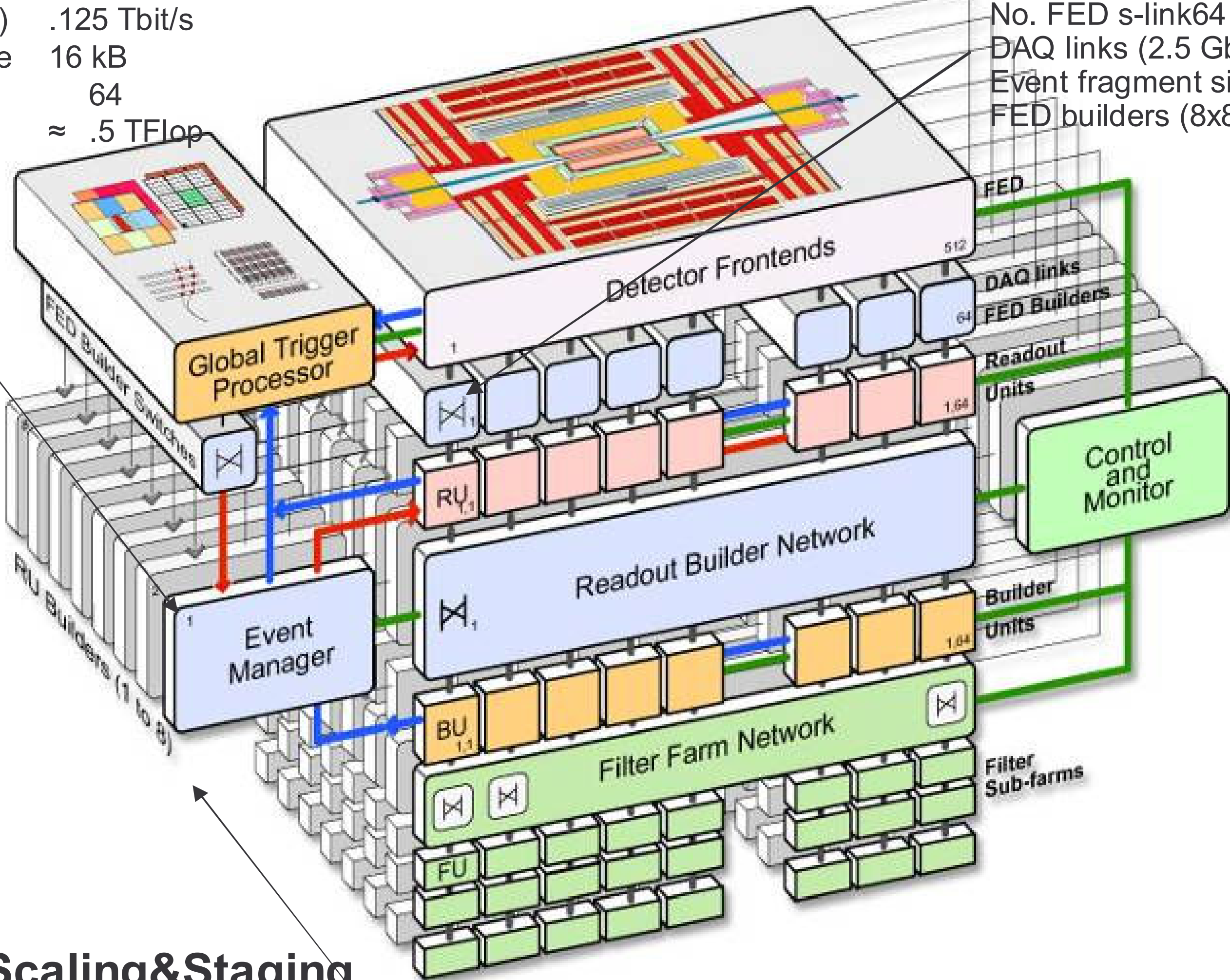
3D-EVB: scalable DAQ

DAQ unit (1/8th full system):

Lv-1 max. trigger rate	12.5 kHz
RU Builder (64x64)	.125 Tbit/s
Event fragment size	16 kB
RU/BU systems	64
Event filter power	≈ .5 TFlop

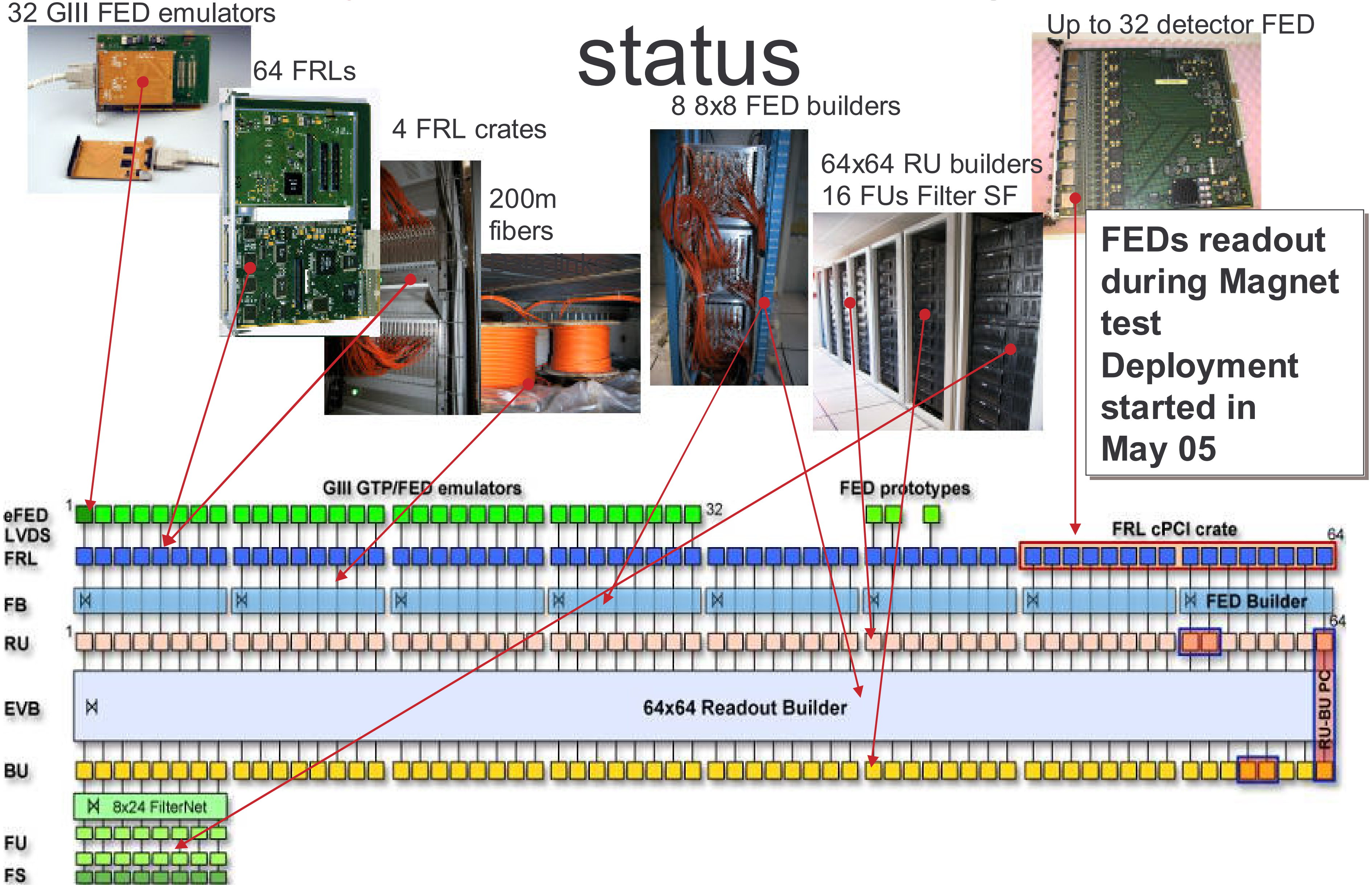
Data to surface:

Average event size	1 Mbyte
No. FED s-link64 ports	> 512
DAQ links (2.5 Gb/s)	512+512
Event fragment size	2 kB
FED builders (8x8)	≈ 64+64



DAQ Scaling&Staging

Cessy Preseries: integration status



CMS Trigger and B-physics

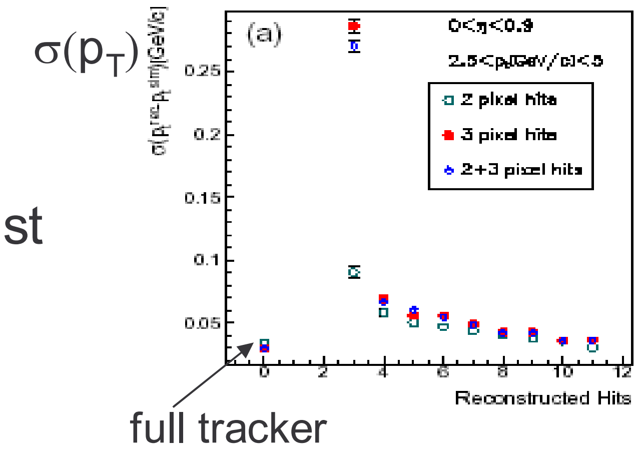
Level-1 Trigger designed to cover widest possible range of discovery Physics (Higgs, SUSY ...)

B Physics selection triggered by single μ or 2μ triggers.
Only a small fraction of HLT output accounted for inclusive b,c (~5Hz 1μ)

Exclusive B events selected exploiting online tracking

Studies on some benchmark channels:
$B_s \to \mu\mu$, $B_s \to J/\psi\ \phi$, $B_s \to D_s \pi$

- Restrict B_s reconstruction to Region of Interest around the μ
- Use reduced # hits/track



HLT triggers for B's

$B_s \to \mu+\mu-$

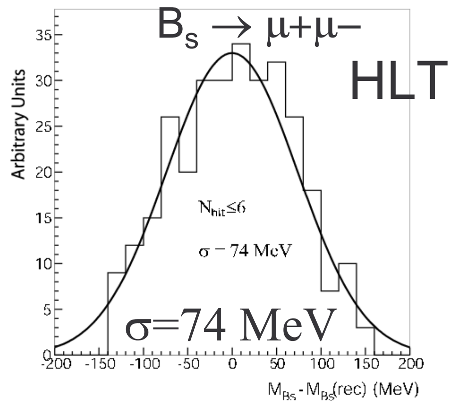
Lvl-1 ε	HLT ε	events ($10\ fb^{-1}$)	Trigger rate	offline evts ($10\ fb^{-1}$)	offline backgr.
15.2%	33.5%	47	<1.7 Hz	7	<1

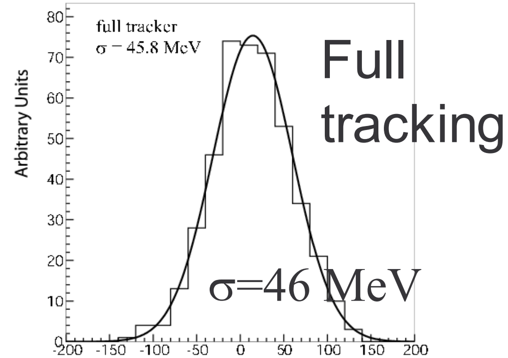
5σ signal in $15\ fb^{-1}$

$B_s \to J/\psi\phi$

Lvl-1 ε	HLT ε	events ($10\ fb^{-1}$)	Trigger Rate	Offline evts ($10\ fb^{-1}$)
16.5%	11.9%	84 k	<1.7 Hz	~60 k

With ~200k evts expect $\sigma(\sin\phi_s)$~0.025 and $\sigma(\Delta\Gamma_{s}/\Gamma_s)$~0.015





B_s mass resolution

$B_s \to D_s\pi$

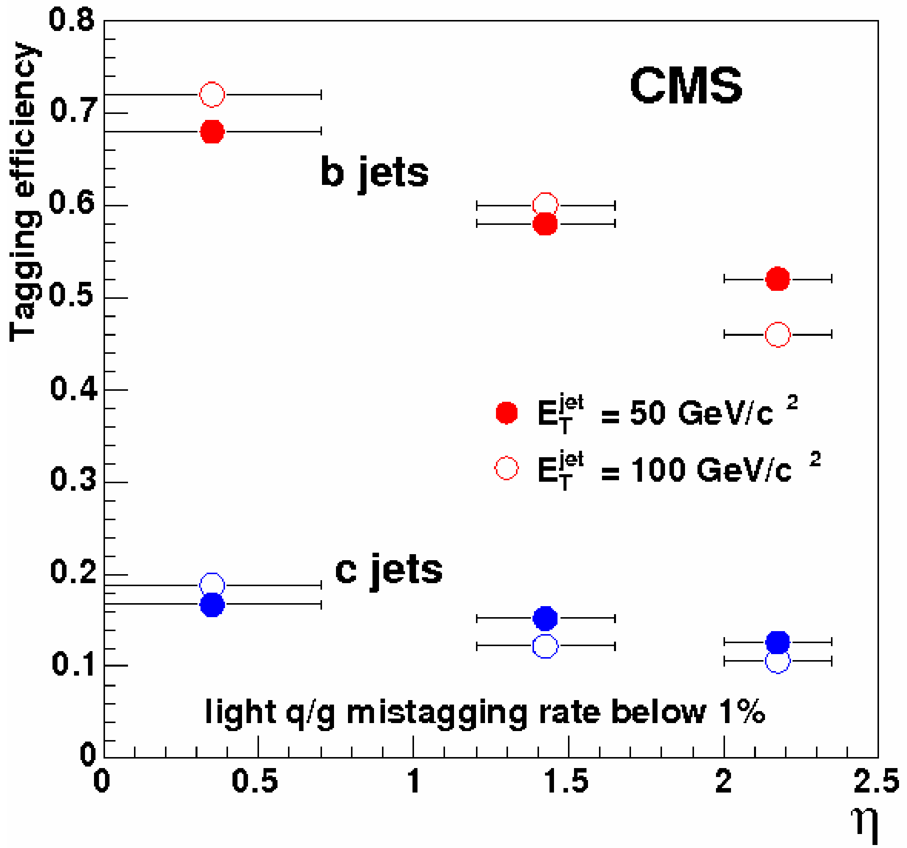
Triggered by μ from opposite b decay. Number of selected signal events depends on the bandwidth allocated to this channel.

For 5Hz expect ~300 events in $20\ fb^{-1}$ → up to $\Delta m_s < 20\ ps^{-1}$

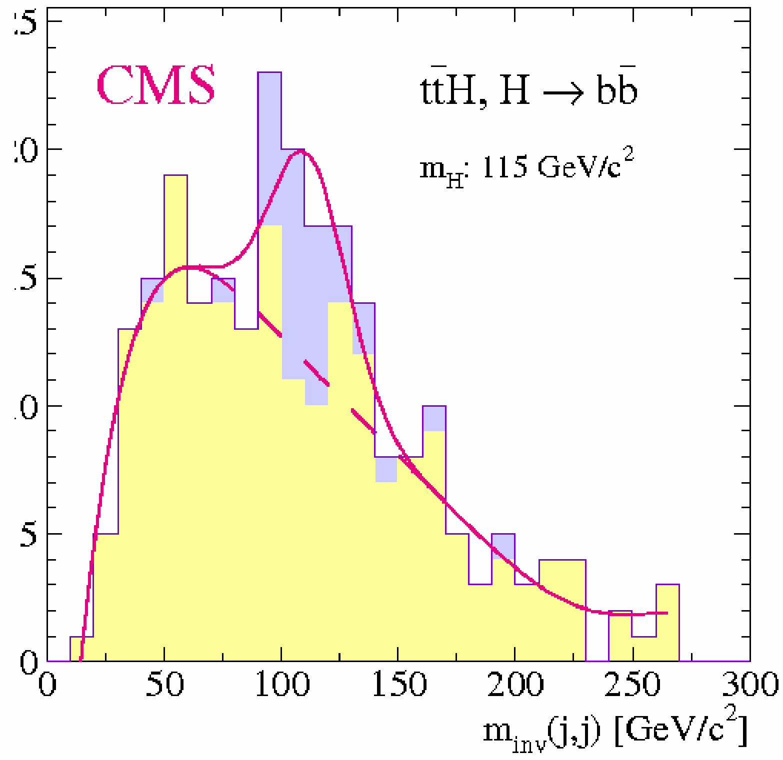
B's as a tool for Higgs Physics

EXAMPLE : $t\bar{t}H \rightarrow \ell^{\pm}\upsilon_l q\bar{q}b\bar{b}b\bar{b}$

Track counting method
with impact parameter



Jet-jet invariant mass for 30 fb^{-1}

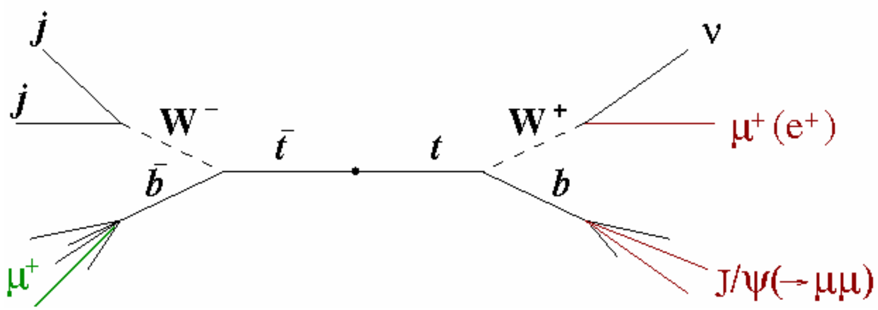


B's as a tool for Top Physics

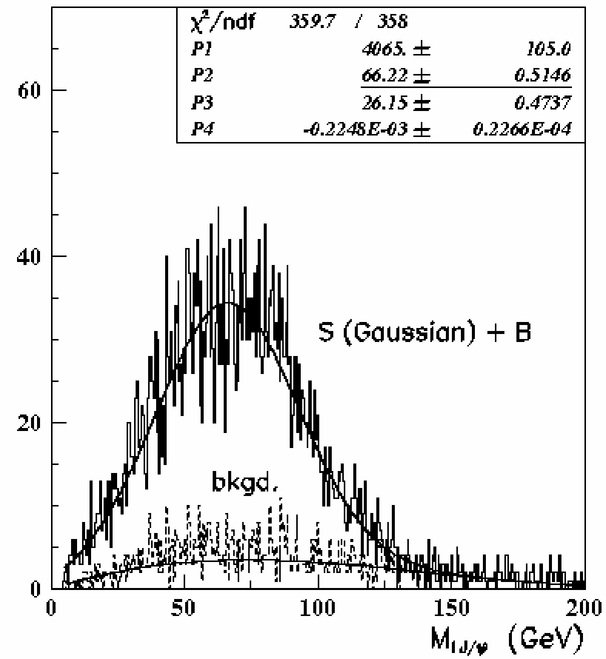
With 800 pb for ttbar production and 320 pb for single top LHC is a **top factory**

EXAMPLE :

Top mass from decays
to final state with J/psi



Lepton-J/Psi invariant mass for 100 fb^{-1}
Expect correlation to m_top



Conclusions

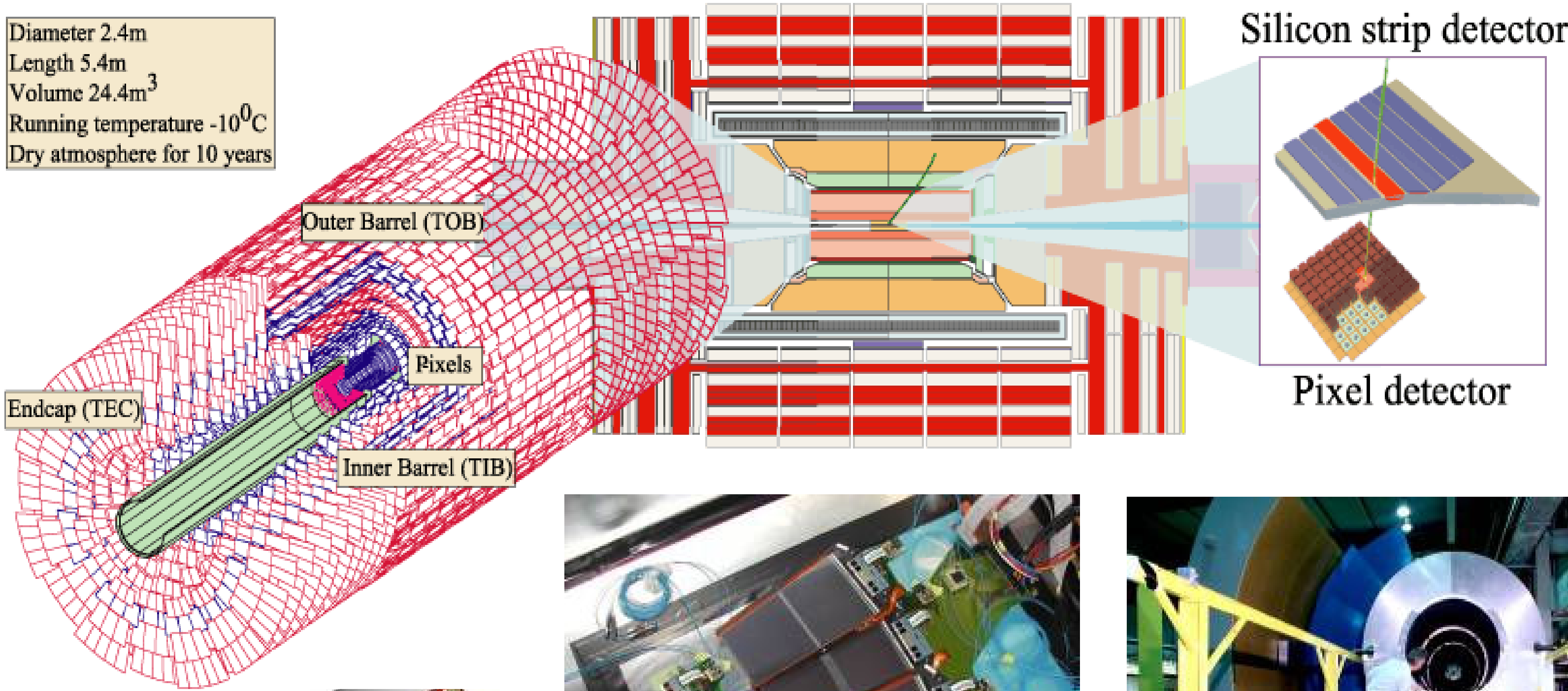
- **Initial CMS* detector will be ready and closed for beam on 30 June 2007.**

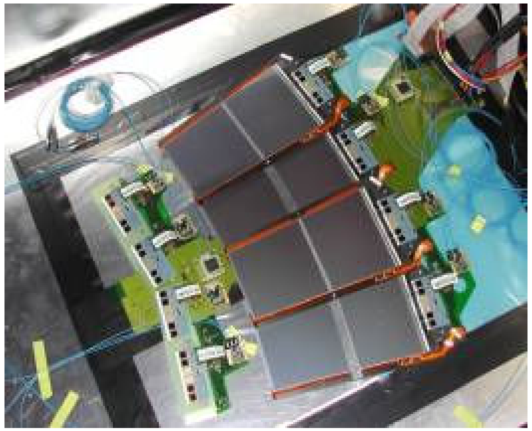
(*ECAL endcaps and pixels (even though ready) will be installed during winter 2007 shutdown in time for **physics run in 2008**.)

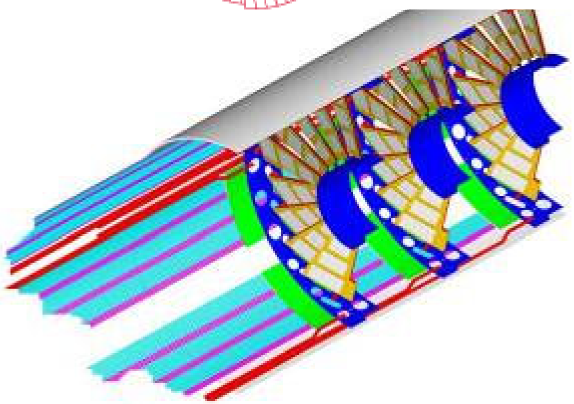
- **An exciting period is in front of us …. aiming for BEAUTYful physics**

Backup Slides

The Tracker



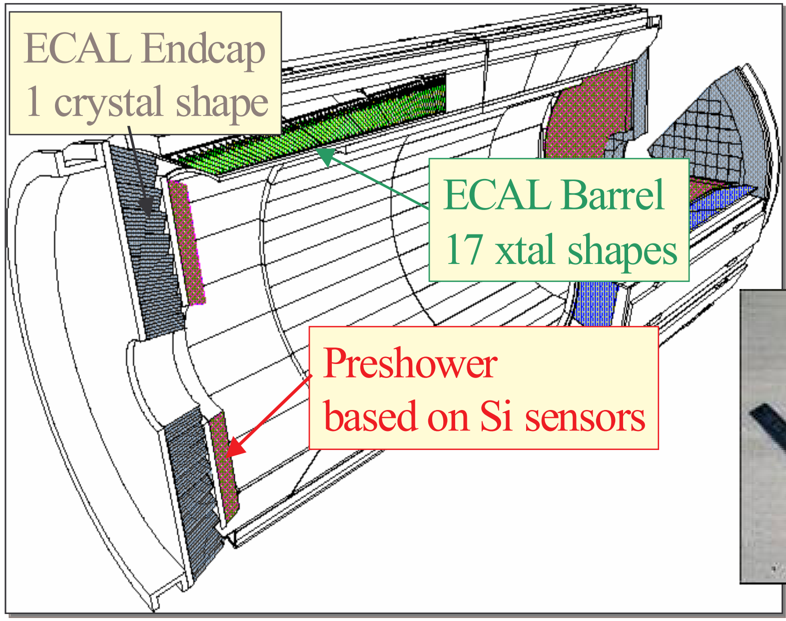




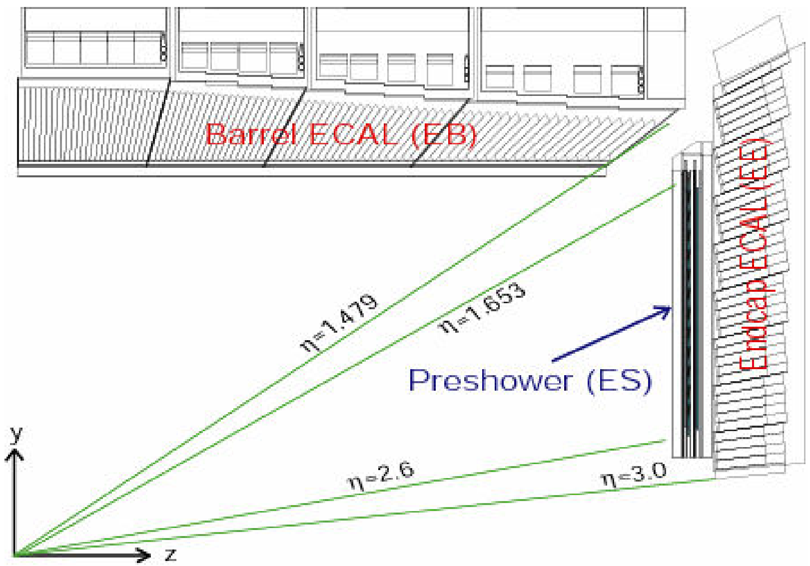
Pixel endcap disks

207m² of silicon sensors
10.6 million silicon strips
65.9 million pixels in final configuration!

ECAL



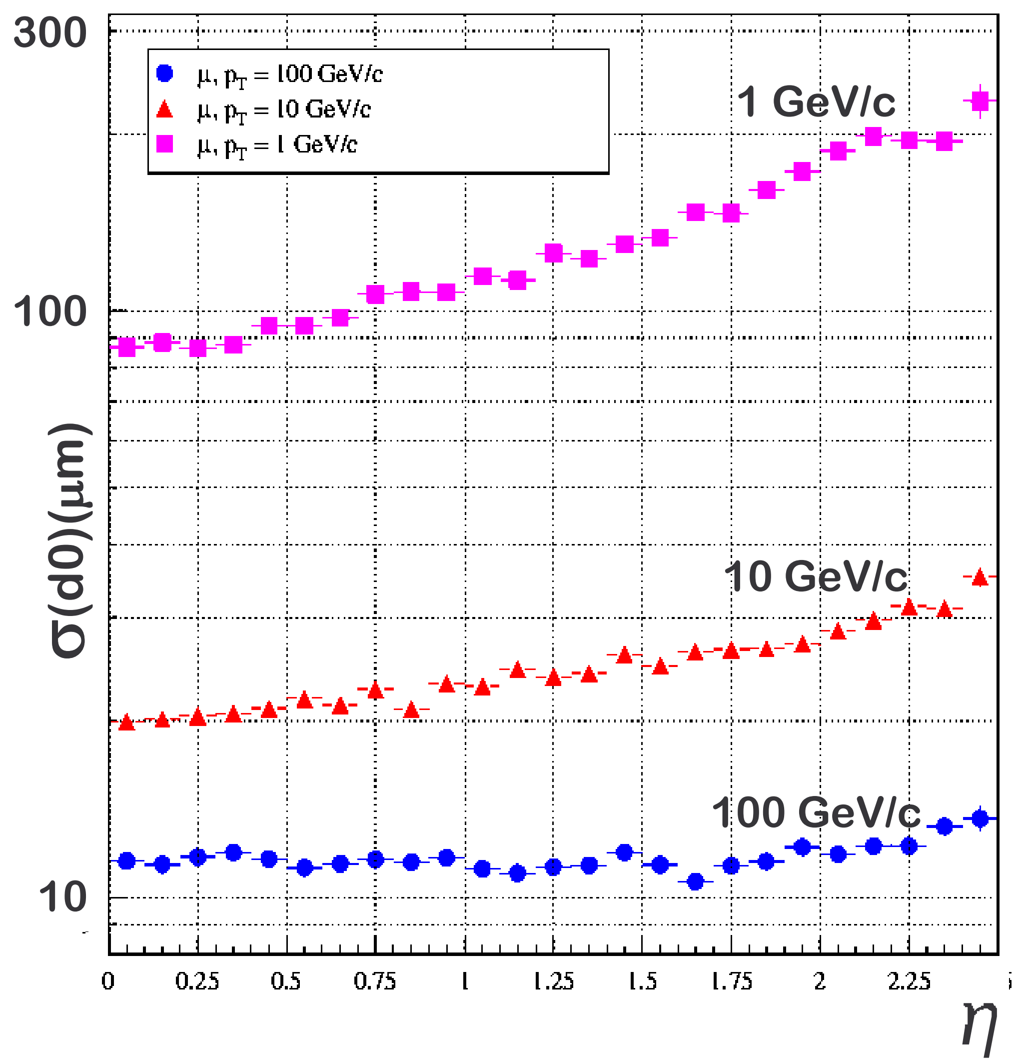
Characteristics of $PbWO_4$
$X_0 = 0.89$cm
$\rho = 8.28$g/cm^3
R_M (Molière radius) = 2.2cm



Parameter	Barrel	Endcaps
Coverage	$\|\eta\|<1.48$	$1.48<\|\eta\|<3.0$
$\Delta\phi \times \Delta\eta$	0.0175 x 0.0175	0.0175 x 0.0175 to 0.05 x 0.05
Depth in X_0	25.8	24.7
# of crystals	61200	14648
Volume	8.14m^3	2.7m^3
Xtal mass (t)	67.4	22.0

Tracking performance studies

Transverse
impact parameter
resolution

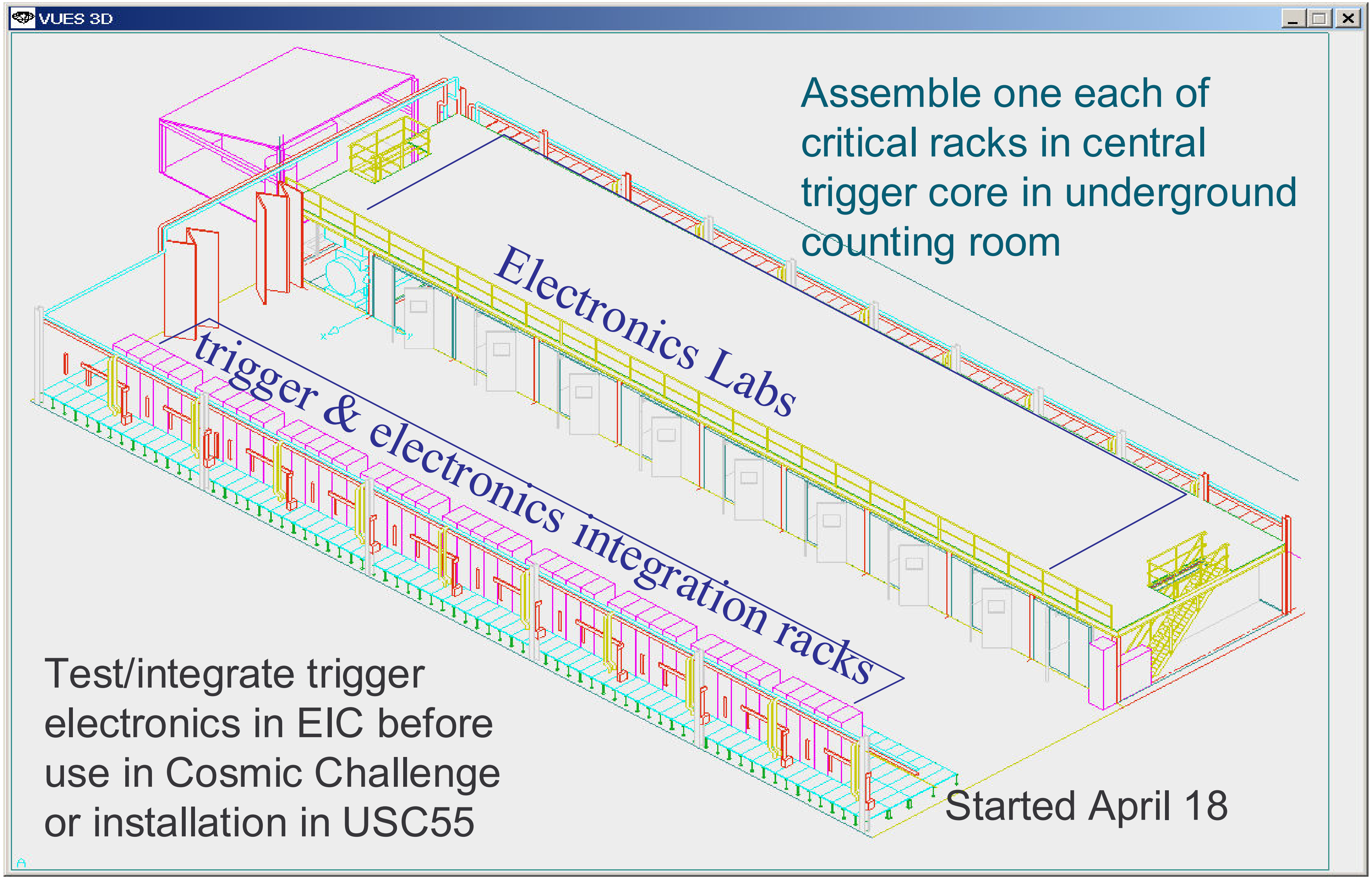


HLT Trigger tables

TRIGGER OBJECT			THRESHOLD (GeV)	RATE (Hz)
ISOLATED MUONS			19	25
DI-MUONS			7	4
ISOLATED ELECTRONS			29	33
ISOLATED DI-ELECTRONS			17	1
ISOLATED PHOTONS			80	4
ISOLATED DI-PHOTONS			40, 25	5
SINGLE JET, 3 JET, 4 JET			657, 247, 113	9
JET + MISSING ENERGY			180,123	5
TAU+ MISSING ENERGY				
INCLUSIVE TAU JET			86	3
DI-TAU JET			59	1
ELECTRON + JET			19, 45	2
INCLUSIVE B-JET			237	5
B-PHYSICS				
OTHERS (pre-scales, calibration)				10
TOTAL				105

Trigger Install/Commission:

Electronics Integration Center: Prevessin 904



DAQ 05-07: milestones

- √ **Dec 2004 Pre-series: installed DAQ integration started**
- √ **Jan 2004 Data to Surface (D2S): Production&Procurement started**
- √ **Apr 2005 Online software: DAQkit 3.0 released**
  - –XDAQ 3, RC2, FF, DCS, DB, for **904** and **Cosmic Challenge**
- **May 2005 Cosmic challenge: start of FED-Detector integration**
- **Nov 2005 D2S: end of production, start of installation in USC**
- **Jan 2006 FRL-FED readout and DCS commissioning**
  - –USC, GTPe and FRL installation, FED-FRL DAQ commissioning, USC-miniDAQ (8x8)
  - –SCX and DAQ fibers: SCX FED builders and SCX-miniDAQ (8x8)
- **Oct 2006 Start of Trigger&DAQ commissioning**
  - –Central Trigger & DAQ integration, DBs and Connection with remote data storage
  - –Multiple Readout Builders and multiple TTC/DAQ Partitions
  - –DAQ Slices and Farms PC procurement for first run
- **Jun 2007 Ready for first collisions**

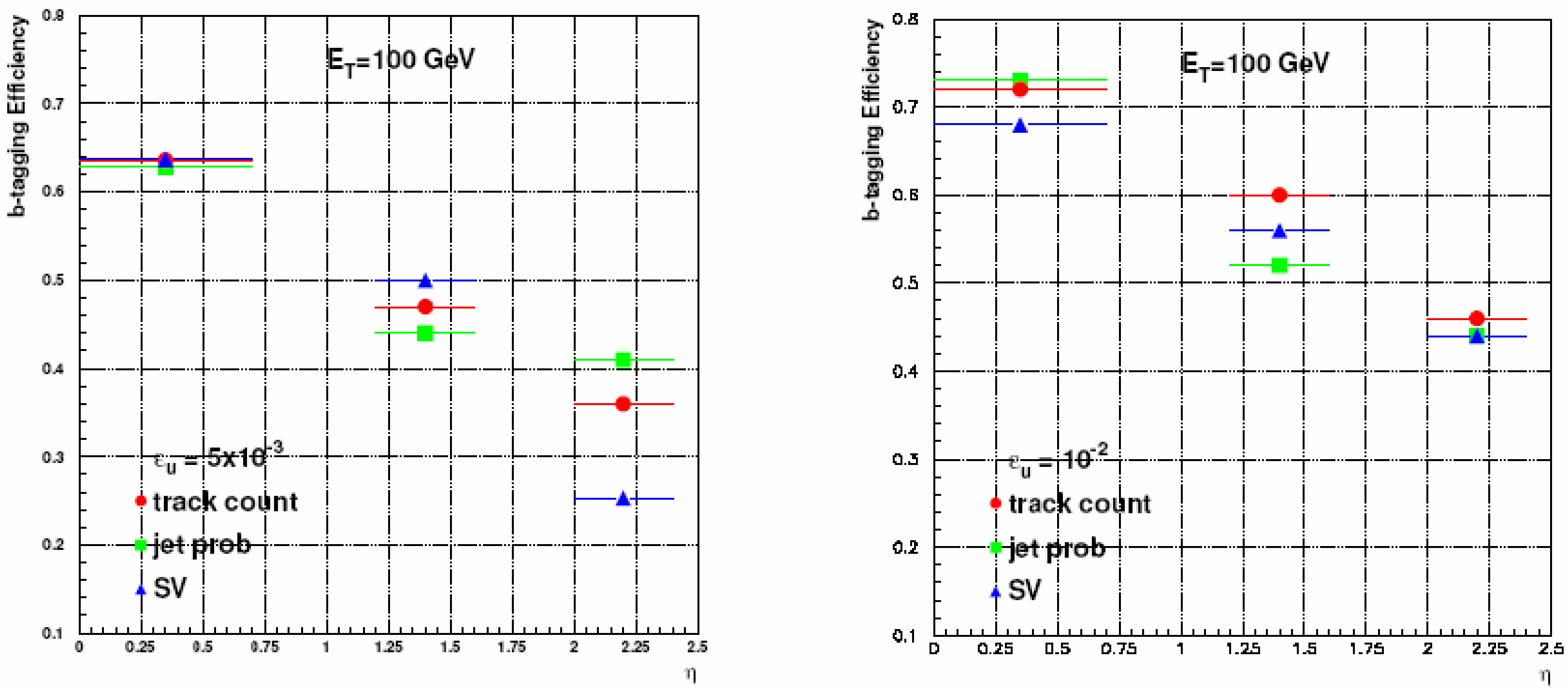


Figure 33: b-tagging efficiencies that can be achieved at 5×10^{-3} (left) and 10^{-2} (right) mistagging rate as a function of η for the algorithms based on track counting, jet probability and secondary vertices for $E_T = 100$ GeV jets.

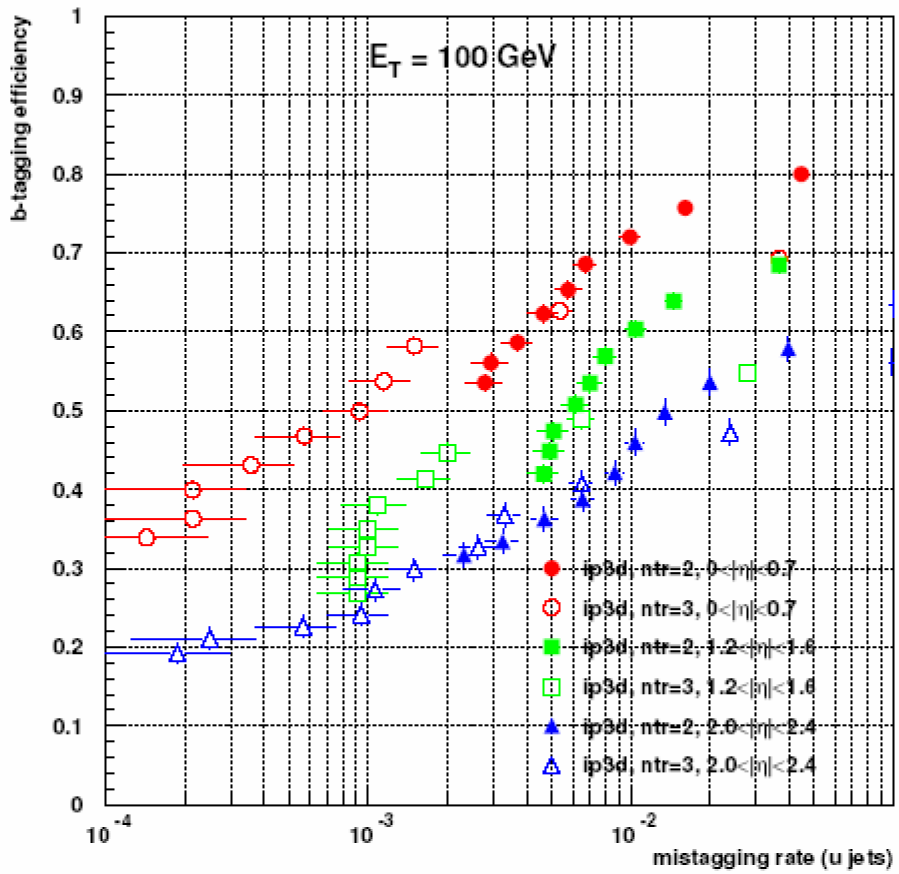
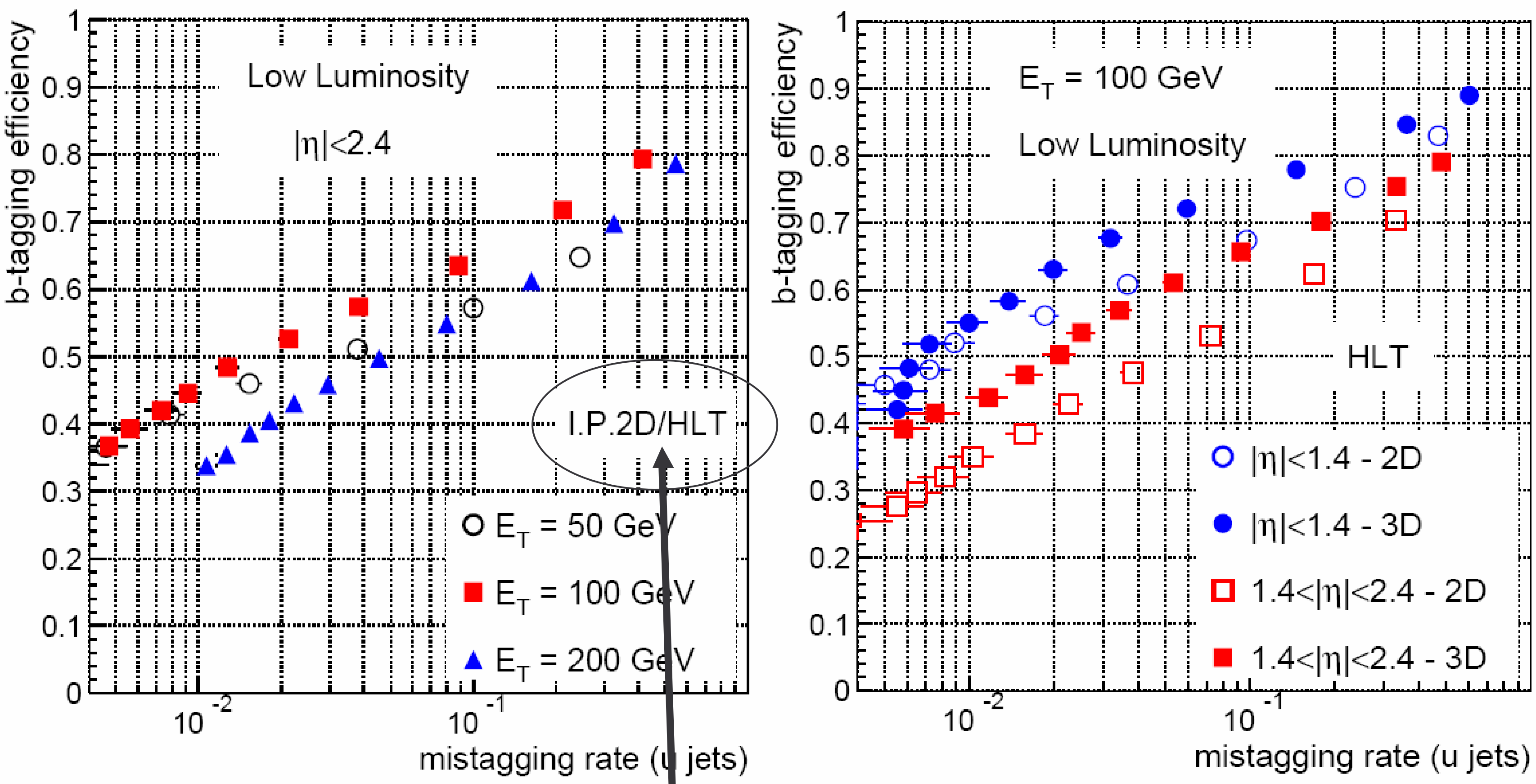


Figure 24: b-tagging efficiency vs mistagging rate from u-jets, obtained with the track counting algorithm based on the three-dimensional impact parameter (ip3d) with the requirement of at least two and three tracks with a significance over threshold for $E_T = 100$ GeV jets in different pseudorapidity regions.



igure 15-70 Efficiency for *b*-tagging versus the mistagging rate for different jet energies (left) and for 3D vs 2D ıpact parameters (right).

Nota Bene! 2-dim impact parameter