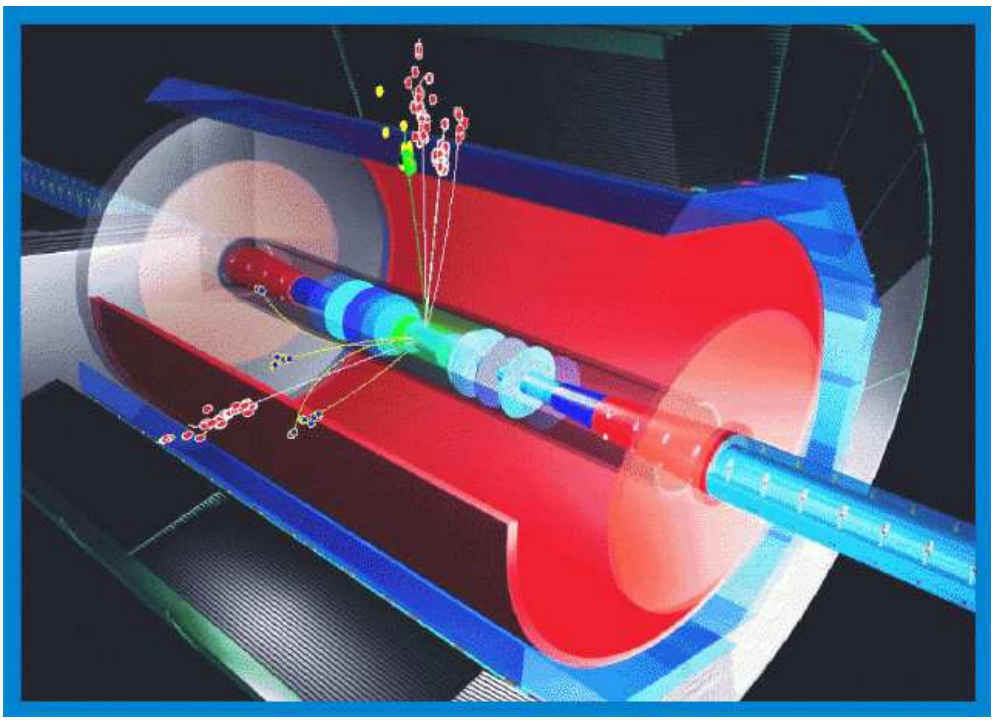
A detector for the TESLA project



- **Machine conditions**
- **Detector Concepts**
- **Tracking**
- **Calorimeters**
- **Magnet + μ Detectors**
- **Expected performance**

TESLA TDR Part IV (Detector):
Authors from 52 Institutes

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Machine conditions

DAQ

- Long time between bunch trains: 199 ms
- Bunch separation in a train: 337 ns
- Train length: 950 μs (2820 BX)
- $L = 3.4 \cdot 10^{34} \mathrm{cm}^{-2}\mathrm{s}^{-1}$, σ, background
  $\Rightarrow$ 220 MBytes/train

$$\Downarrow$$

- Hardware trigger unnecessary
- Data in pipeline for 1 ms, no dead time
- 200 ms for pipeline ready
- Software event selection
- Moderate throughput w.r.t. LHC

Beamstrhlung

- $\delta E \sim 3\%$

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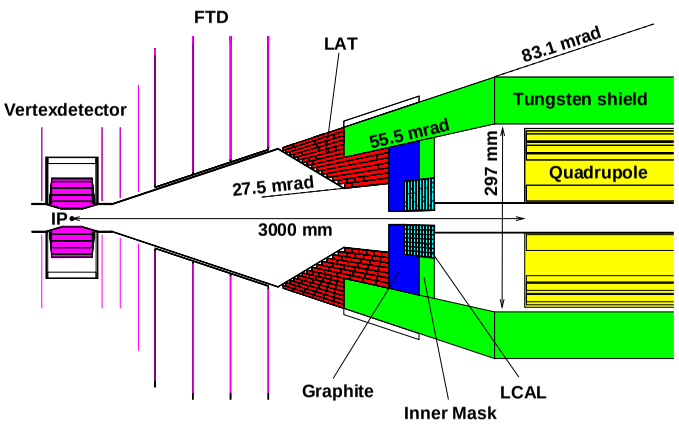
Background

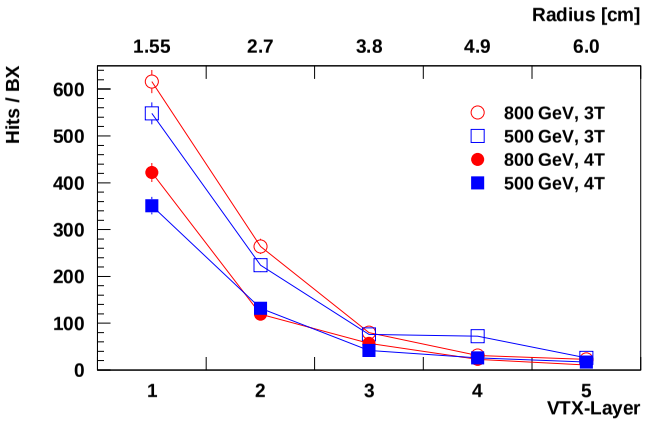
- Beamstrahlung photons ⇒ secondary effects:
  e^+e^- pairs (few GeV)
  hadronic interactions
- Radiative bhabhas
- Neutrons

The e^+e^- pairs in **B** move towards the quadrupoles creating a large number of secondaries.

⇓

- W mask system
- **B**field intensity
- Minimum radius for the vertex detector (VTX)





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Detector Concepts

- Excellent vertex resolution to identify heavy flavours (b,c,τ) $\Leftarrow g_{Hff}$

- Tracking system with good δp
  and high efficiency for multi-jet events
  $\Leftarrow HZ \to Hl^+l^-$

- Good Energy flow
  $\Leftarrow W, Z \to q\bar{q}(\prime)$,SUSY

- Hermeticity and good forward E determination
  $\Leftarrow$ SUSY

- Luminosity spectrum (beamstrahlung)
  $\Leftarrow \sigma$ at threshold

- Excellent lepton identification

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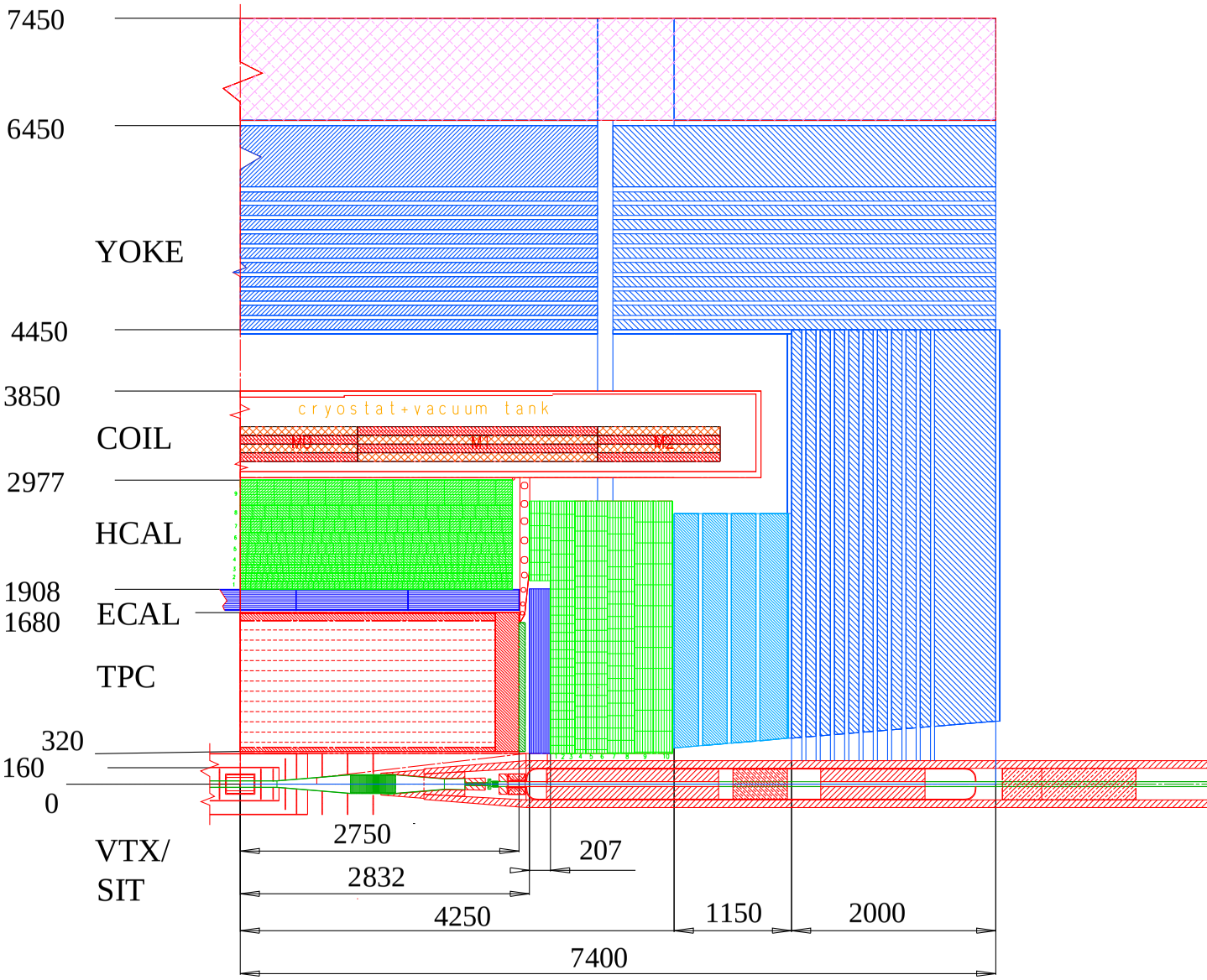

VTX $\Rightarrow \delta(I.P.) \leq 5\mu m \oplus \frac{10\mu m}{psin^{3/2}\theta}$

TPC $\Rightarrow \delta\frac{1}{p_t} < 2 \cdot 10^{-4}$, Tracking $\delta\frac{1}{p_t} \leq 5 \cdot 10^{-5}\frac{GeV}{c}^{-1}$

ECAL $\Rightarrow \frac{\delta E}{E} \leq 0.10\frac{1}{\sqrt{E(GeV)}} \oplus 0.01$, granularity

HCAL $\Rightarrow \frac{\delta E}{E} \leq 0.50\frac{1}{\sqrt{E(GeV)}} \oplus 0.04$, granularity

COIL $\Rightarrow$ 4 T, uniformity$\leq 10^{-3}$

EFLOW$\Rightarrow \frac{\delta E}{E} \sim 0.3\frac{1}{\sqrt{E(GeV)}}$

Low Angle + Lumi CAL down to $\sim$ 5 mrad (veto)

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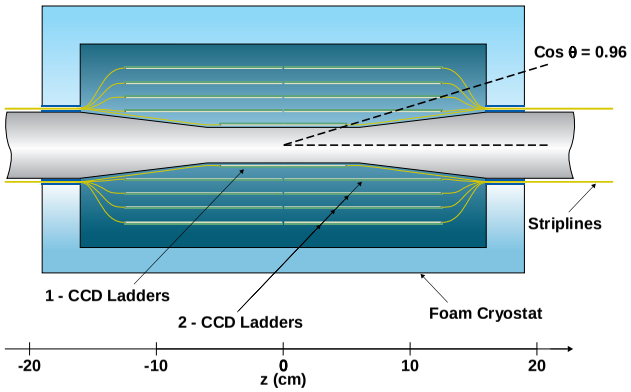
Tracking system

Vertex Detector



- Impact parameter optimization:
  minimize R $\Leftrightarrow$ machine background
  if B=4 T R_1=1.5 cm possible <0.1 hit/mm^2
  minimal multiple scattering $\Rightarrow$ thickness
- Maximal solid angle:
  forward region $|cos\theta|$
  geometry dipends on thickness (conical end-caps)
- Tecnologies:
  CCD
  CMOS
  Pixels

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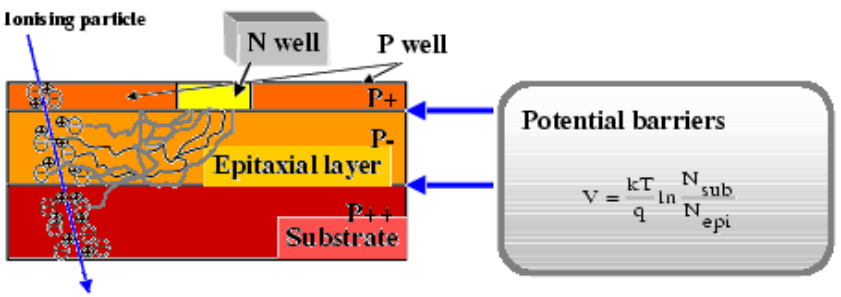
- CCD
  needs R&D:
  reduction of material with unsupported Silicon
  improving of the clocking rate
  improving the radiation hardness

Layer	Radius	CCD L×W	CCD size	Ladders and CCDs/lddr	Row clock fcy & Readout time	Bgd occupancy	Integrated bgd
	mm	mm^2	Mpix			$Hits/mm^2$	KHits/Train
1	15	100×13	3.3	8/1	50 MHz/50 μs	4.3	761
2	26	125×22	6.9	8/2	25 MHz/250 μs	2.4	367
3	37	125×22	6.9	12/2	25 MHz/250 μs	0.6	141
4	48	125×22	6.9	16/2	25 MHz/250 μs	0.1	28
5	60	125×22	6.9	20/2	25 MHz/250 μs	0.1	28

Key parameters of the CCD-based vertex detector design

- CMOS
  - Charge collection by diffusion in undepleted epitaxial layer
  - Fill factor 100%
  - Detector inseparable from RO electronics
  - Low cost
  - Test results: ϵ>99%, 20μm pitch $\Rightarrow \sigma \sim 2\mu$m



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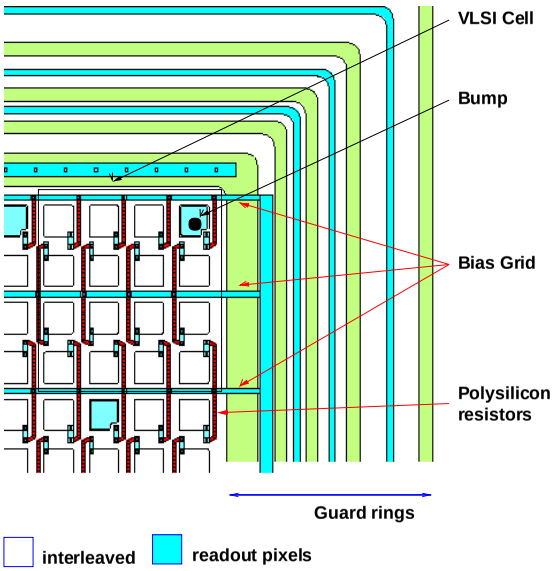
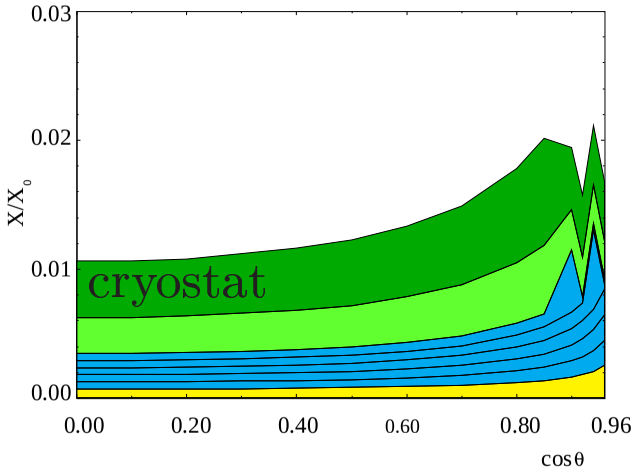
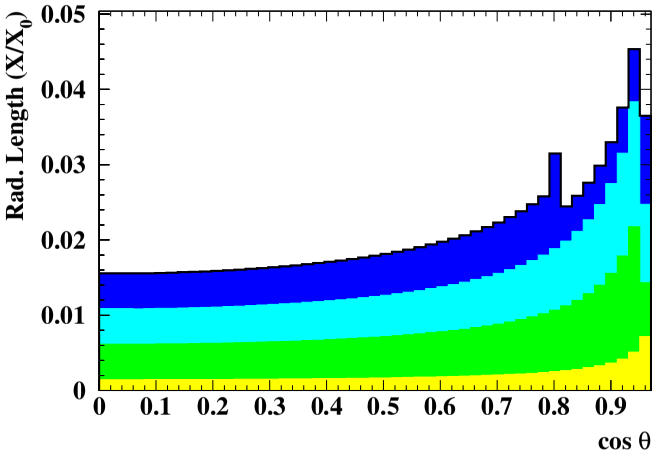
- Hybrid Pixels
  in use (DELPHI + LHC)
  capacitive coupling: goal $\sigma < 7\mu$m

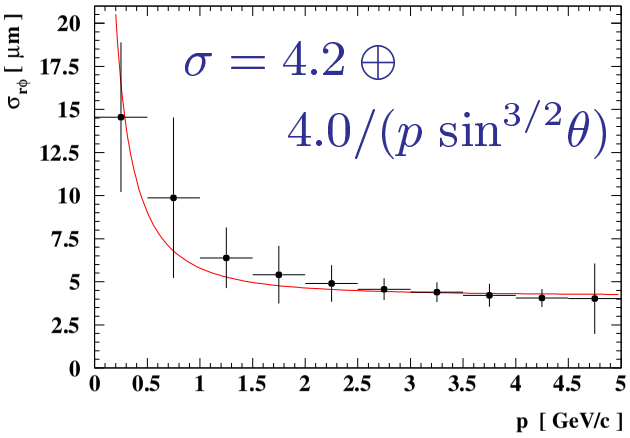


CCD



Pixels





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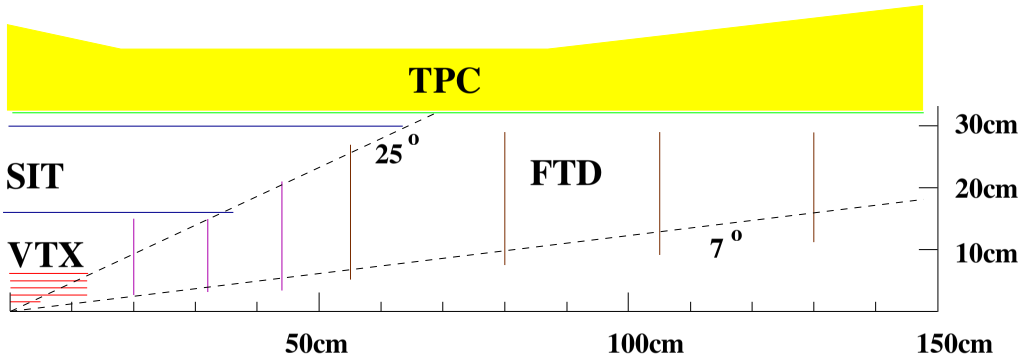
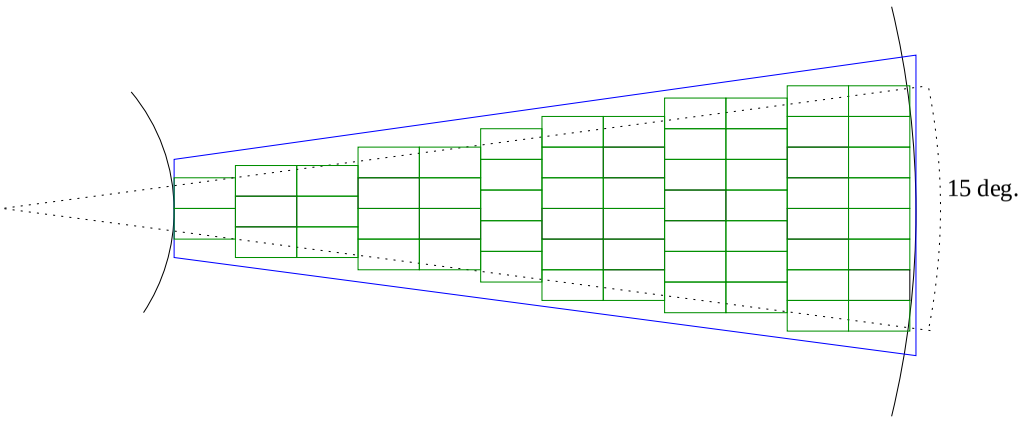
Intermediate Detector

- Barrel:
  2 μ strip planes doble read-out



- Forward:
  pixel and strip disks (DELPHI)
  complete Ω and measure radiative bhabhas



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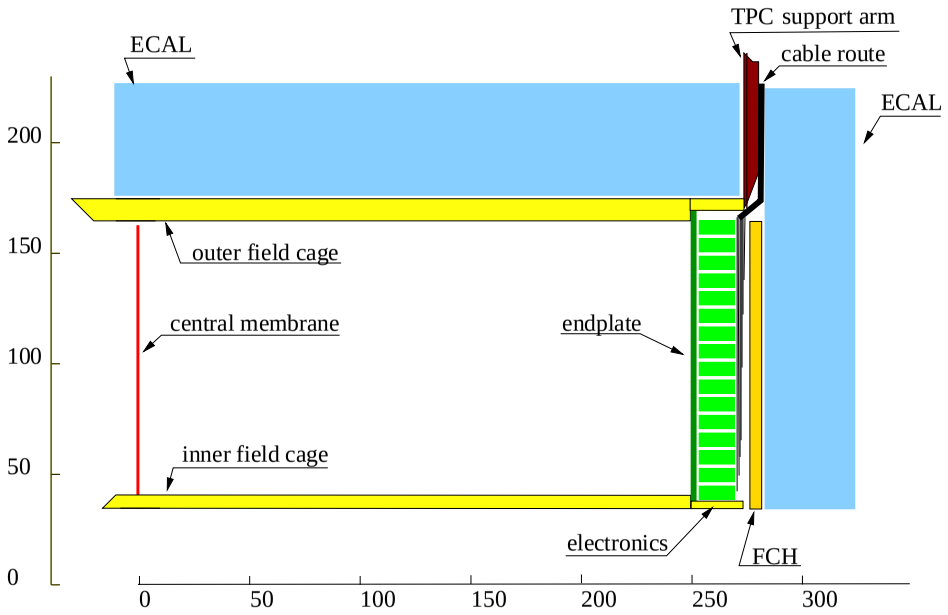
Central Tracking: TPC



- In use (LEP + STAR , ALICE)
- much less tracks
- event pile-up from many BX
  $\Rightarrow$ good time information
- continuous operation during a train
  $\Rightarrow$ ReadOut system
  gating scheme
- minimize end-plate material
- Internal Radius $\Leftarrow$ mask system
- External Radius $\Leftarrow \delta\frac{1}{p_t} < 2 \cdot 10^{-4}(\mathrm{GeV/c})^{-1}$
- RO: GEM, Micromegas, w. ch.$\Leftarrow$ B=4 T

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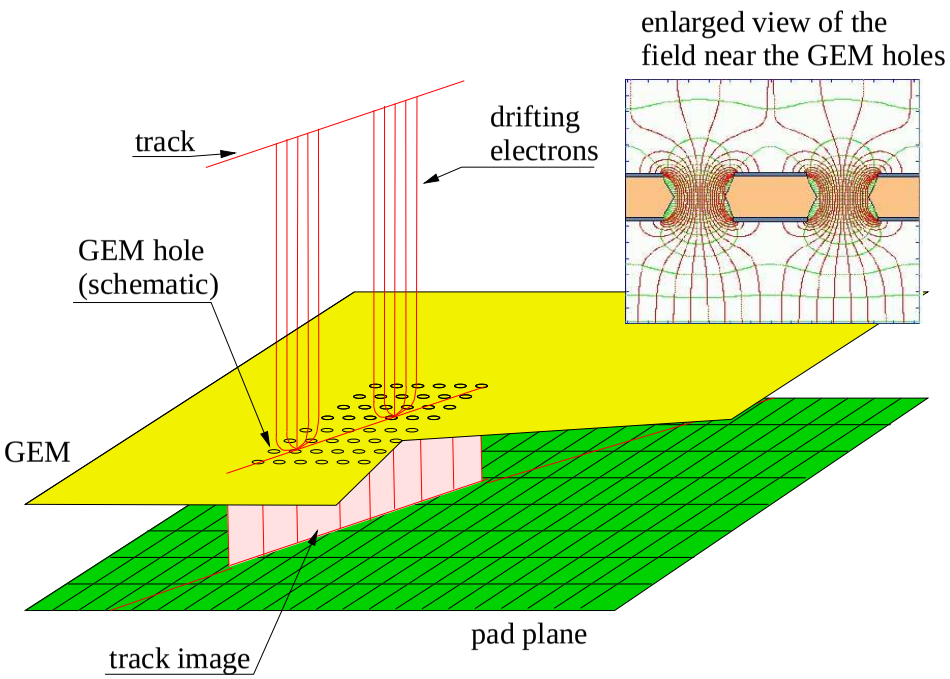
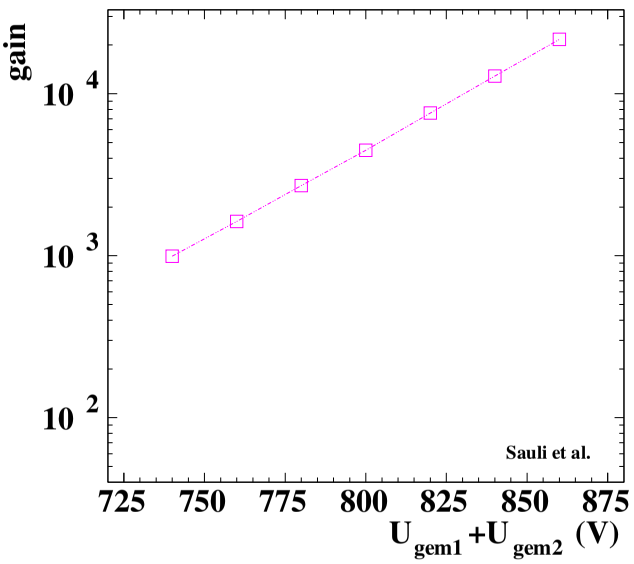
GEM

Thin polymer foil with metal coating on both sides
holes $\sim 100\mu m$ apart,
$\Delta V \Rightarrow \mathbf{E} \sim 80\text{kV/cm}$



- Gain $\mathcal{O}(10^3)$
- 2 GEM cascade



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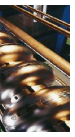
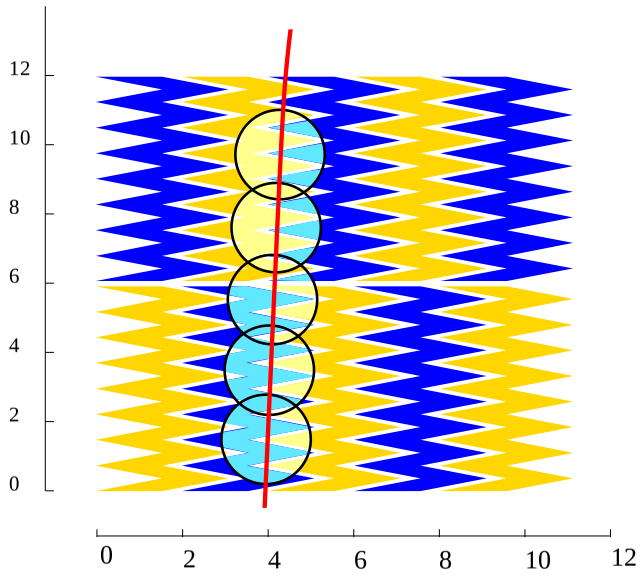
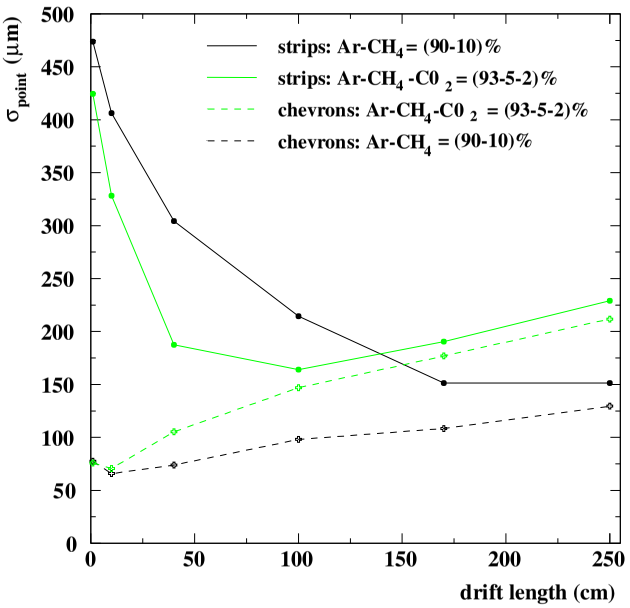


- Resolution optimization $\Rightarrow$ *Chevron* pad
  200 points/track



- 2×6 mm^2 $\Rightarrow$ 0.6 M channel/side
  $\sigma_{\frac{dE}{dx}} = 4.3\%$ $\quad$ $\delta\frac{1}{p_t} \sim 1.5 \times 10^{-4}(\mathrm{GeV/c})^{-1}$



- Calibration: local distortions$\leq 10\mu m$

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Calorimeters

General Overview

- From Physics:
complex hadronic final states (i.e. $t \to bW$)
missing energy (i.e. ν, $i\tilde{n}i$)

- hermeticity down to low angles
- lepton id
- angular resolution
- jet 4-vector reconstruction (partons)
  strategy: *energy flow* algorithms as
  $E = \Sigma_{ch} p^{tk} + \Sigma_{\gamma} E^{ecal} + \Sigma_{neut.} E^{hcal}$
  $\Downarrow$
  high granularity to disentangle contributions
  calorimeters inside the coil

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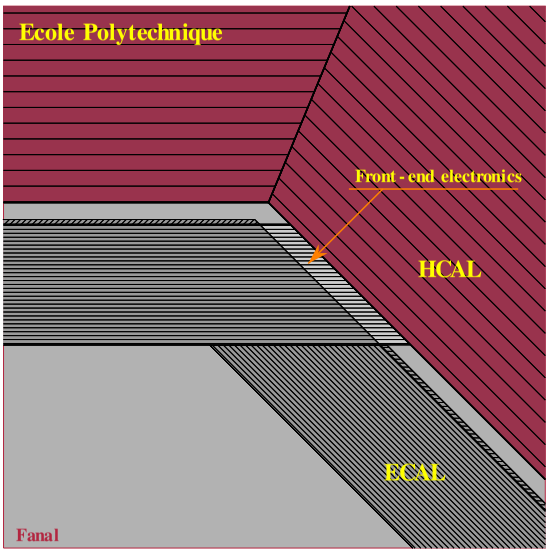
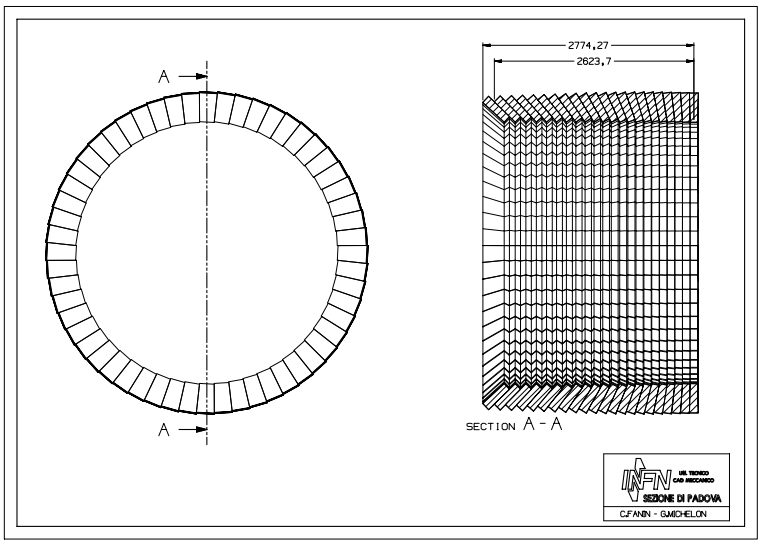
Electromagnetic Calorimeter

- Where granularity has the largest importance

  - TDR: 2 solutions

	SiW	Shashlik
Absorber (X_0/layer)	W $0.4 \div 1.2$	Pb 0.18
Detector	Si 500μm	Scintillator 1 mm
# of layers	30+10	140
Transv. Dim. (cm^2)	$\sim 1 \times 1$	$\sim 3 \times 3$
Longit. Segm.	40(20?)	$2 \div 3$
# of channels	$\sim$ 30(15) M	$\sim$ 58 k
Geometry	flat	pointing
Total thickness (X_0)	$\sim$ 24	$\sim$ 25





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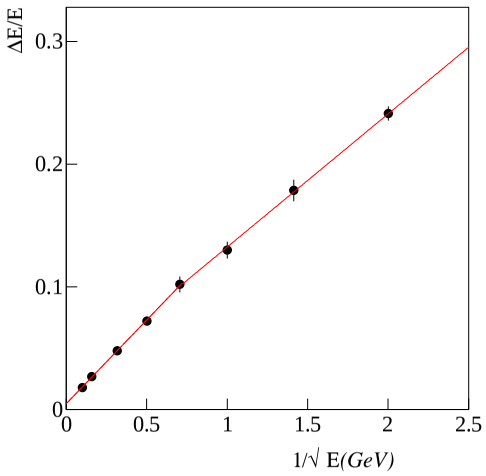
SiW

- Problems with the project dimension

SiW MC

$$\frac{\Delta E}{E} \sim \frac{11 \div 14\%}{\sqrt{E}}$$

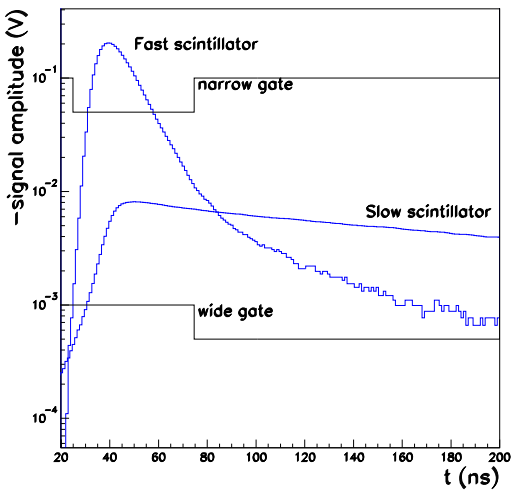


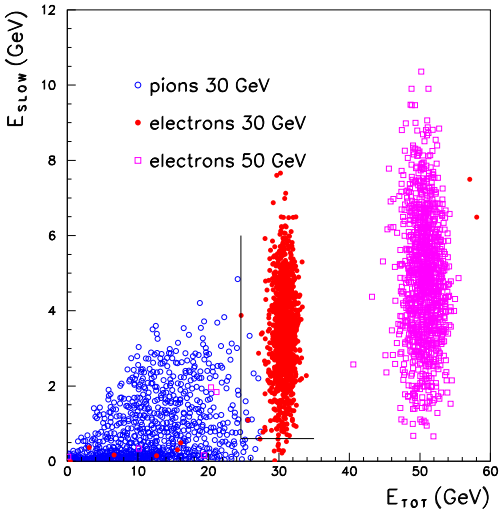
Shashlik

- R&D for long. segm. done

  CALEIDO: thin vacuum photodiodes or

  Scintillators with different decay times





- $\Delta E/E \sim 10 \div 15\%/\sqrt{E} + 1\%$

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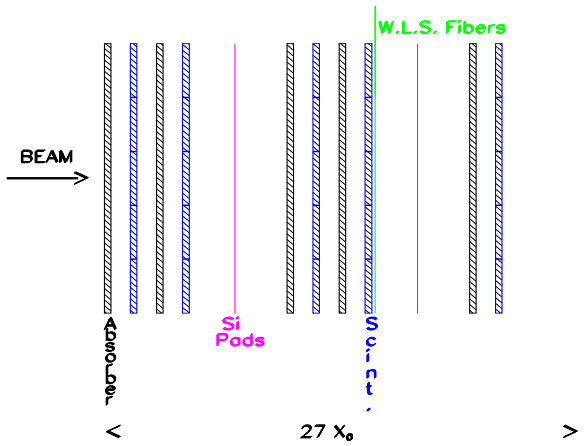
R&D for alternative solutions

Prototype Pb(W)/Sc + Si:



- 50 layers:
- $25 \times 25 \times 0.3(0.2)$ cm^3 Pb (W)
- $25 \times 25 \times 0.3$ cm^3 Scint.:
  25 Cells 5×5 cm^2, WLS σ tail fibers.....

- 3 planes:
- 1×1 cm^2 Si Pads
- at: 2, 6, 12 X_0

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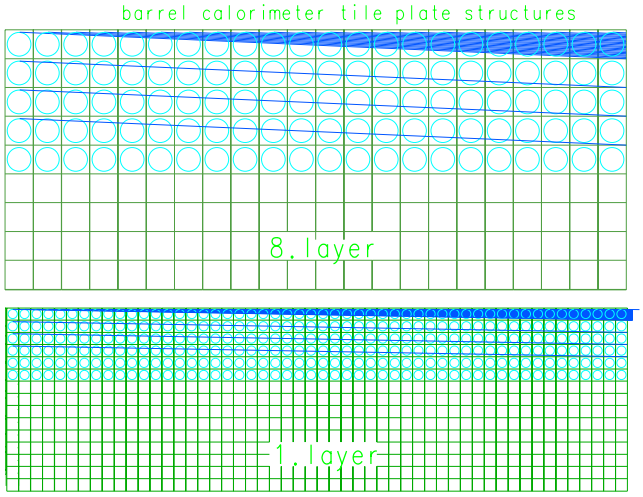
Hadronic Calorimeter

- 2 solutions 4.5λ

- σ tail
  38 layers Fe/Sc/fibers (mm) 20/5/1.5
  Transv. Dim (cm^2) $5 \times 5 \div 25 \times 25$
  Long. Segm. 9
  Layers per segm. $3 \div 7$



- digital (binary)
  38 layers Fe/RPC- limited Geiger w. ch.- w. ch.
  Dim. Transv. (cm^2) 1×1
  Long. Segm 38
  Saturation?

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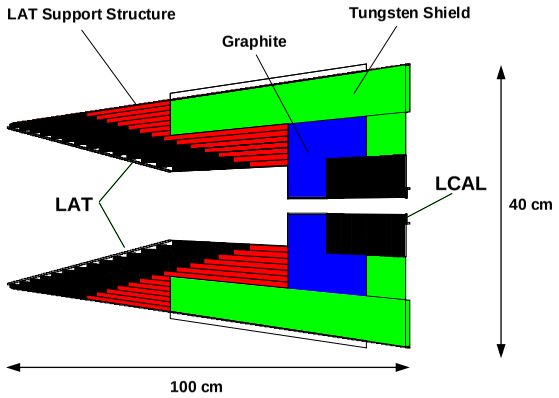
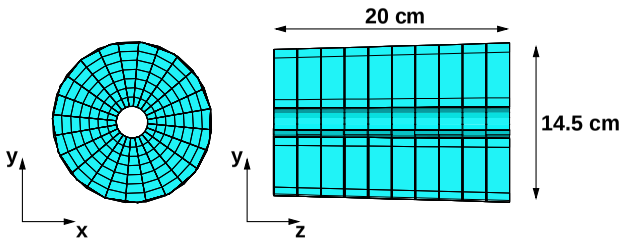
Forward Region



- Low Angle Tagger
  83.1 ÷ 27.5 mrad
  63 layers W/Si (mm) 2.6/0.5 $\Rightarrow\sim 47X_0$
  14 segments r, 24 ϕ
  $\Delta E \sim 20 \div 25\% \times \sqrt{E}$
  up to E=E_{beam}
- Luminosity CALorimeter
  $\theta_{min} = 4.6$mrad
  63 layers W/Si(C) (mm) 2./0.5 $\Rightarrow\sim 36X_0$
  7 segments r, 24 ϕ
  Integrate 20 TeV/BX
  background subtract. dominates resolution
  $e^{\pm}$ with E> 50 GeV from $\theta_{min} = 5$mrad



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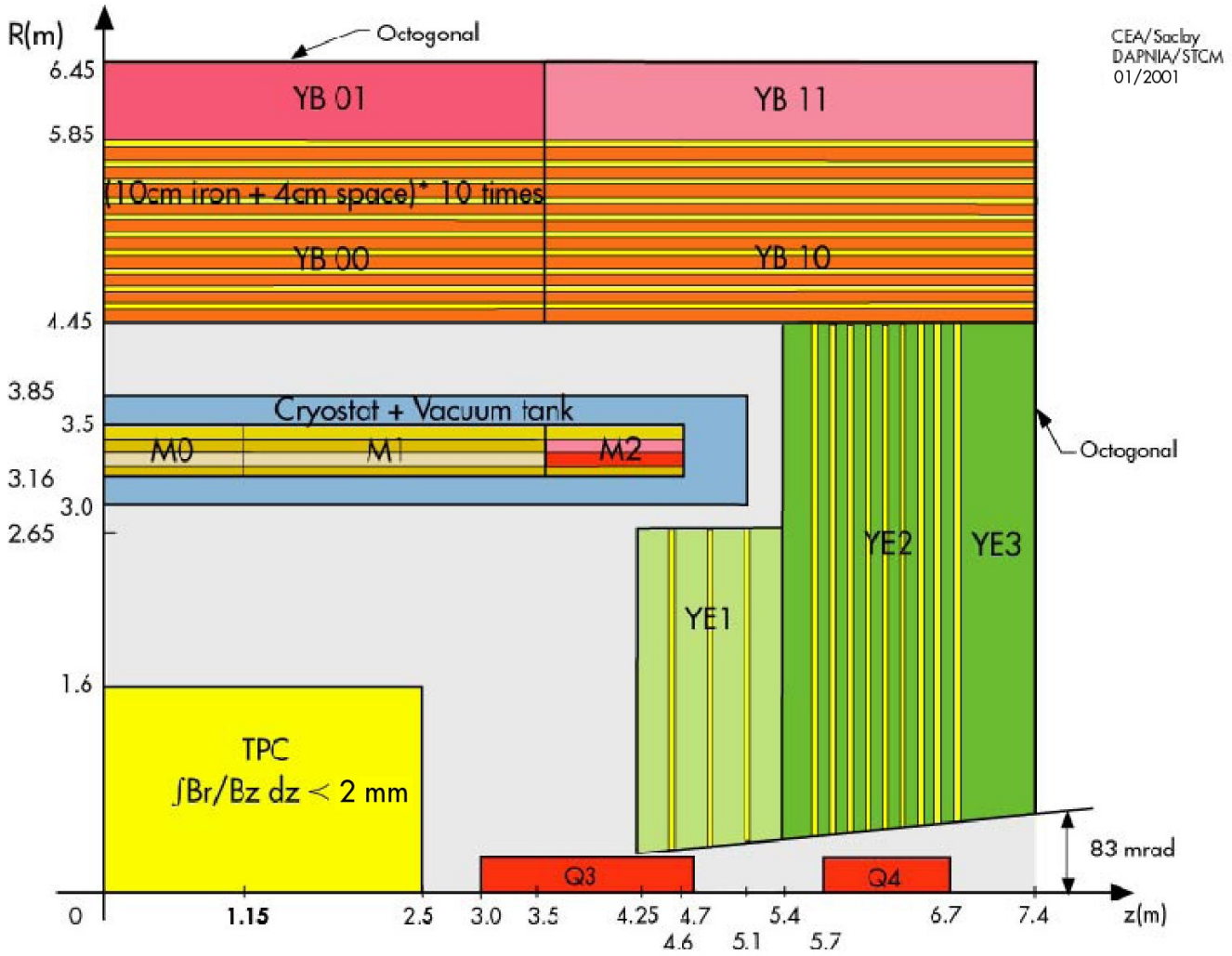
Magnet + μ



- Based on CMS design
- **B**=4 T in 6 m diameter di, 9.2 m length
- high omogeneity (TPC)
- Coil: 5 modules, 4 windings
- Correction in the external modules
- Yoke: 10 layers Fe/μch 10/4 cm

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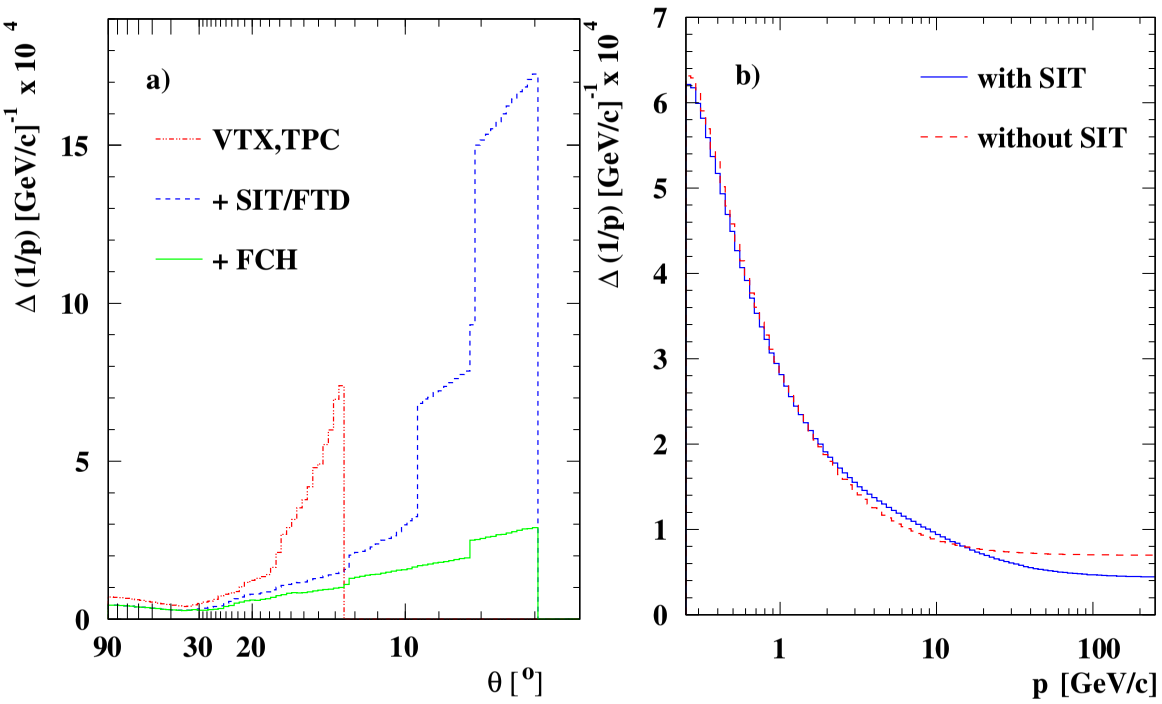
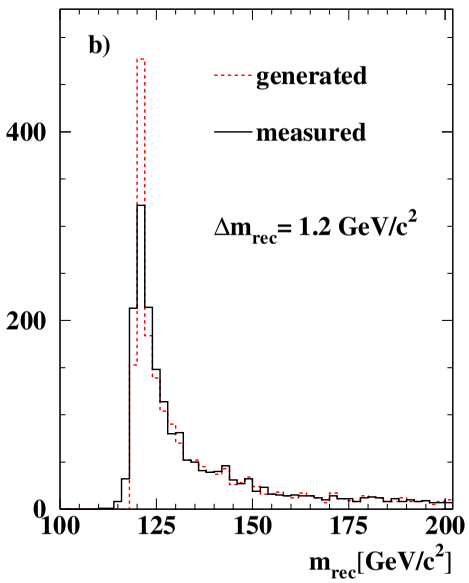
Performance

- Momentum resolution



$e^+e^- \rightarrow ZH \rightarrow l^+l^-H$

BRAHMS + fit: complete simulation/recostr.



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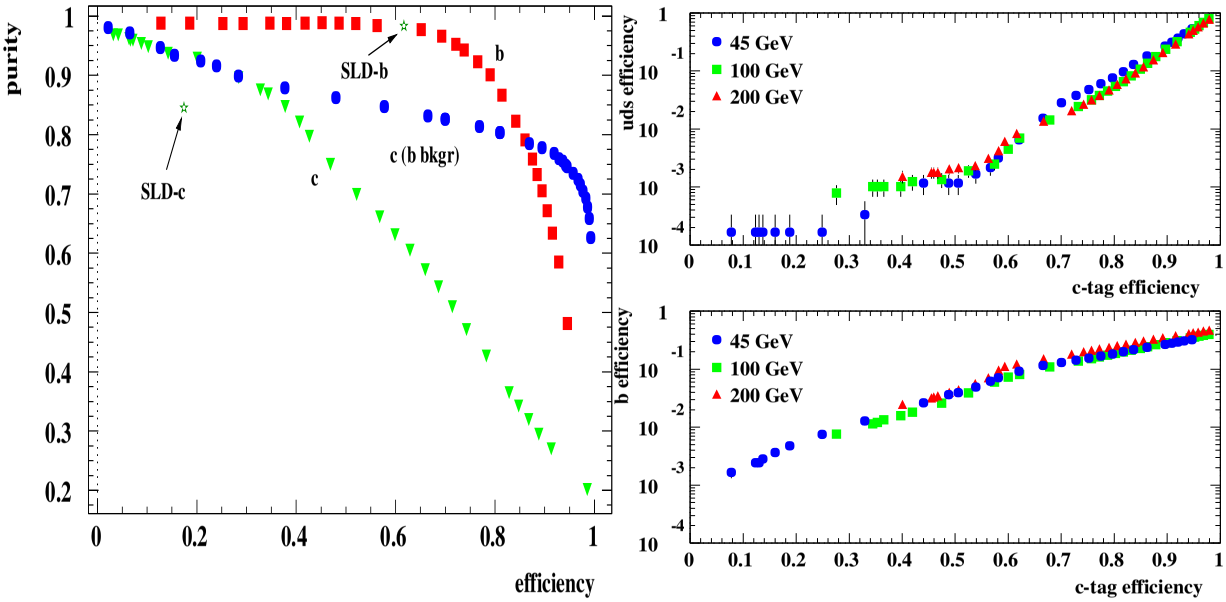
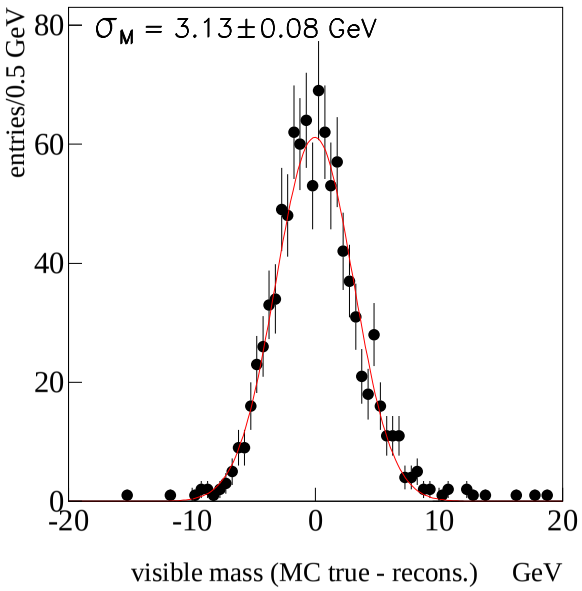
- Heavy flavour Id.



- Jet energy

  $\Delta E/E = 33\%/\sqrt{E}$

$Z^0 \rightarrow q\bar{q}$ at rest



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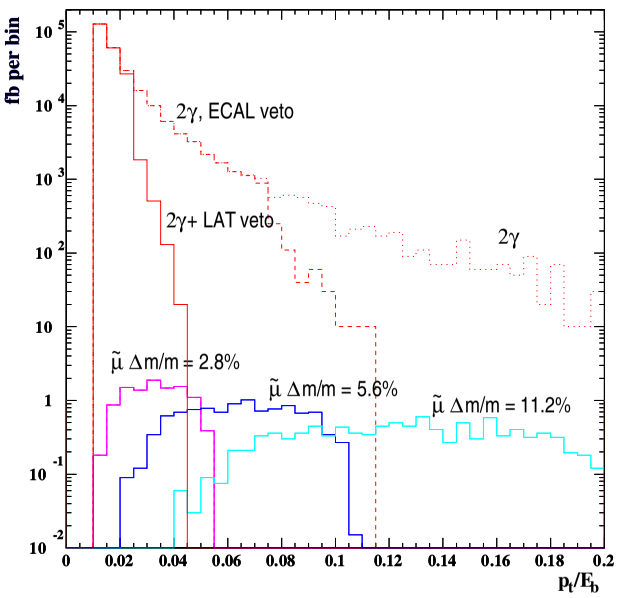
- Hermeticity

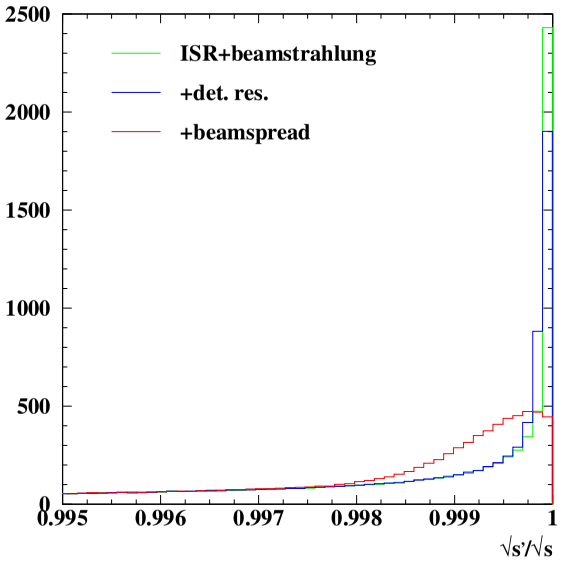
  p_t with mask calorimeters

$$\tilde{\mu}\tilde{\mu} \to \mu^- \tilde{\chi}_1^0 \mu^+ \tilde{\chi}_1^0$$



- Luminosity spectrum

  Bhabha events in FTD



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Conclusions

- High precision Physics requires

- High precision Detector

- which may need R&D...

- ... but which could be builded tomorrow

- No big principle problems:

- excellent momentum resolution

- impact parameter precision

- and jet energy reconstruction

- No doubts on the Physics program:

We simply need the Machine

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