Detector Requirements

Hadronic jets and jet pairs:

- excellent resolution for charged particles
- calorimetry with high granularity
- identification of *b* quarks, excellent vertexing

Lepton identification:

- excellent tracking resolution
- excellent electromagnetic energy resolution
- fine grain hadron calorimetry
- muon identification

Missing energy and momentum:

- excellent calorimetry
- redundancy tracker-calorimeter
- hermetic detector down to small angles wrt beam line
- energy flow methodology

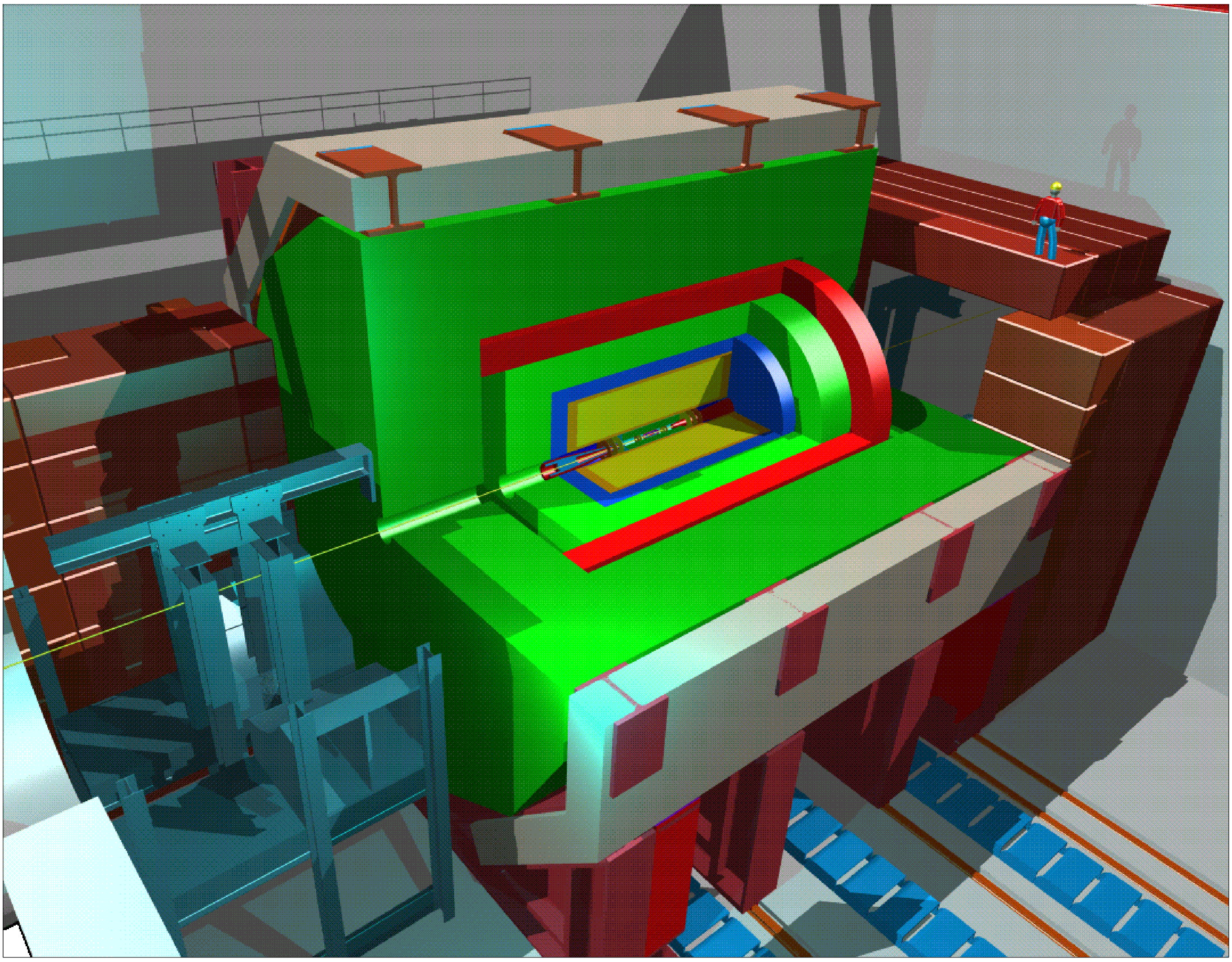
LEP Detectors vs LC Detectors

Difference LEP 2→LC	Possible Improvements to Detector
Smaller beam pipe	Instrumentation down to smaller radius with detectors having higher resolution
Higher multiplicities, more beam-associated background	Pixels essential in vertex detector; minimize mass in whole tracking volume; higher B field
Higher peak track energies (especially leptons)	Better point resolution; more measured points; higher B field
Higher e and γ energies	Thicker electromagnetic calorimeter ECAL
Higher hadron energies	Thicker hadronic calorimeter HCAL
Narrower and/or more jets	Better jet reconstruction; fine granularity; better HCAL; ECAL and HCAL inside coil

Vertexing	$\delta(IP_{r\phi}) \leq 10\,\mu m \oplus \frac{30\,\mu m\,\mathrm{GeV}/c}{p\sin^{3/2}\theta}$ $\delta(IP_z) \leq 20\,\mu m \oplus \frac{30\,\mu m\,\mathrm{GeV}/c}{p\sin^{5/2}\theta}$
Forward Tracking	$\frac{\delta p}{p} < 20\,\%$, $\delta_\theta < 200\,\mu$rad for 100–250 GeV particles down to lowest polar angle θ.
Tracking	$\frac{\delta p_t}{{p_t}^2} \leq 1 \cdot 10^{-4} (\frac{\mathrm{GeV}}{c})^{-1}$ Good particle identification.
Electromagnetic Calorimeter	$\frac{\delta E}{E} \leq 0.10 \frac{1}{\sqrt{E}} \oplus 0.01$ (E in GeV) Granularity $0.9° \times 0.9°$, at least 3 samples in depth.
Hadronic Calorimeter	$\frac{\delta E}{E} \leq 0.50 \frac{1}{\sqrt{E}} \oplus 0.04$ (E in GeV) Granularity $2° \times 2°$, at least 3 samples in depth.
Muon Detector	Fe yoke instrumented as tail catcher and muon tracker. Toroid momentum analysis for forward muons ($\theta < 15°$), $\frac{\delta p}{p} < 20\,\%$.
Energy Flow	$\frac{\delta E}{E} \simeq 0.3 \frac{1}{\sqrt{E}}$ (E in GeV)
Hermetic Coverage	$\lvert\cos\theta\rvert < 0.99$

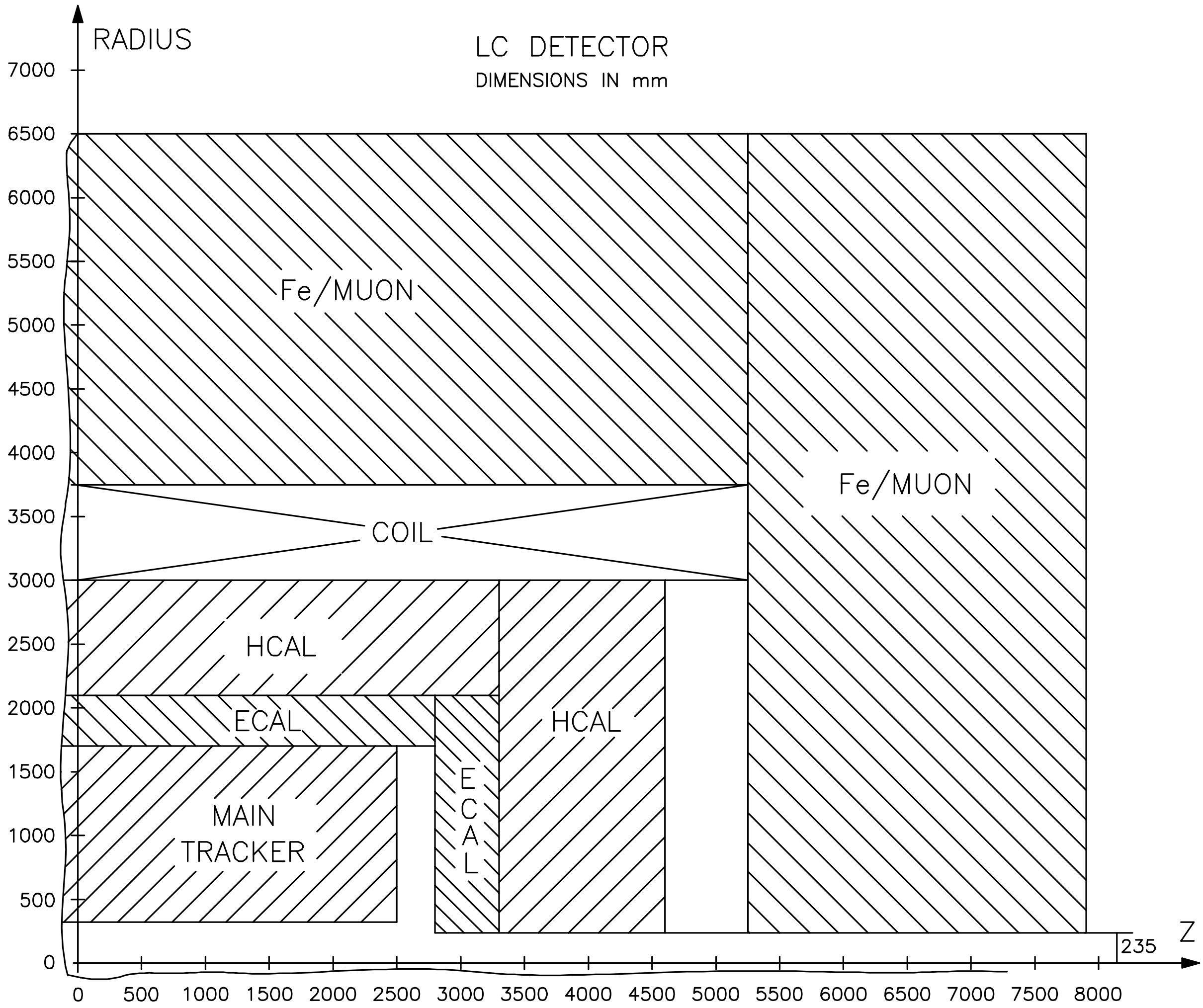
A Detector for TESLA

Detector layout described in Conceptual Design Report DESY 1997-048



Conceptual choices of detector technologies, optimisation in progress

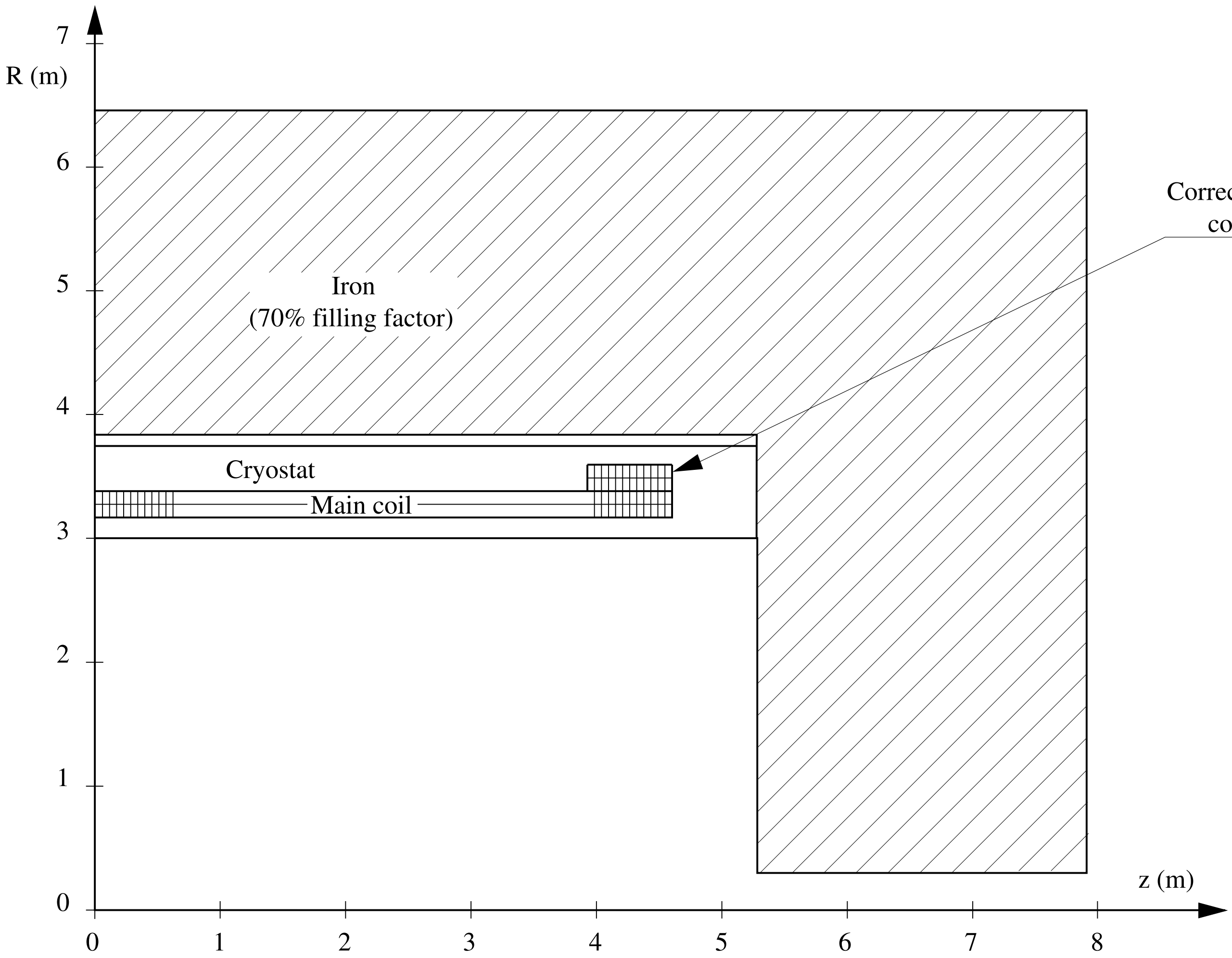
Detector Schematics



- Superconducting detector magnet
- Vertex detector for detection of long lived particles
- Full solid angle spectrometer for charged particles
- Sampling calorimeter for electromagnetic and hadronic showers
- Small angle detector for luminosity measurement

Detector Magnet

CDR: Superconducting magnet, 3T field, 1300 MJ



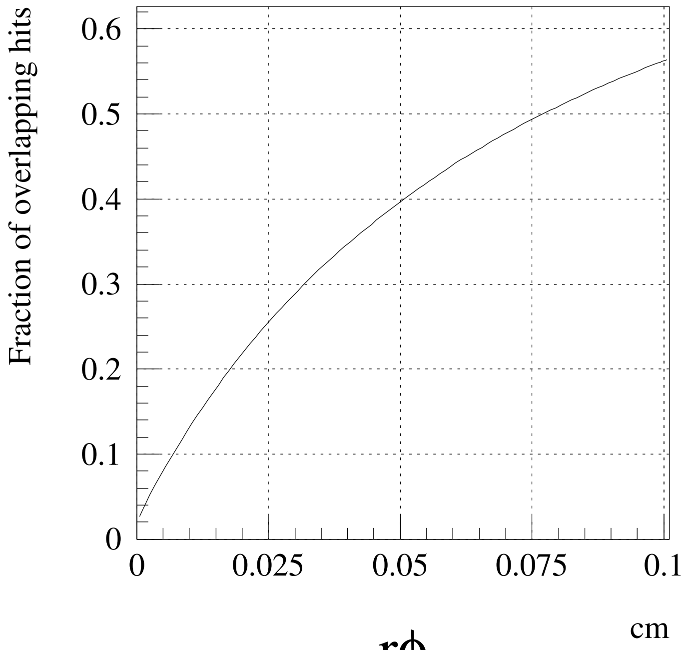
Increase field to 4T

Optimisation under study

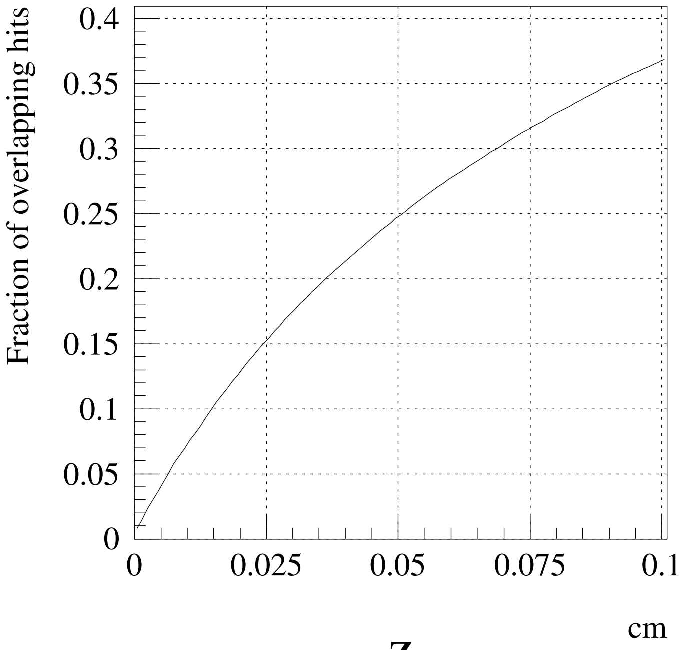
- implications on TESLA machine
- stored energy 2500 MJ (cf. CMS)
- more spiralling tracks, tracker occupancy, resolution

Strips vs Pixels

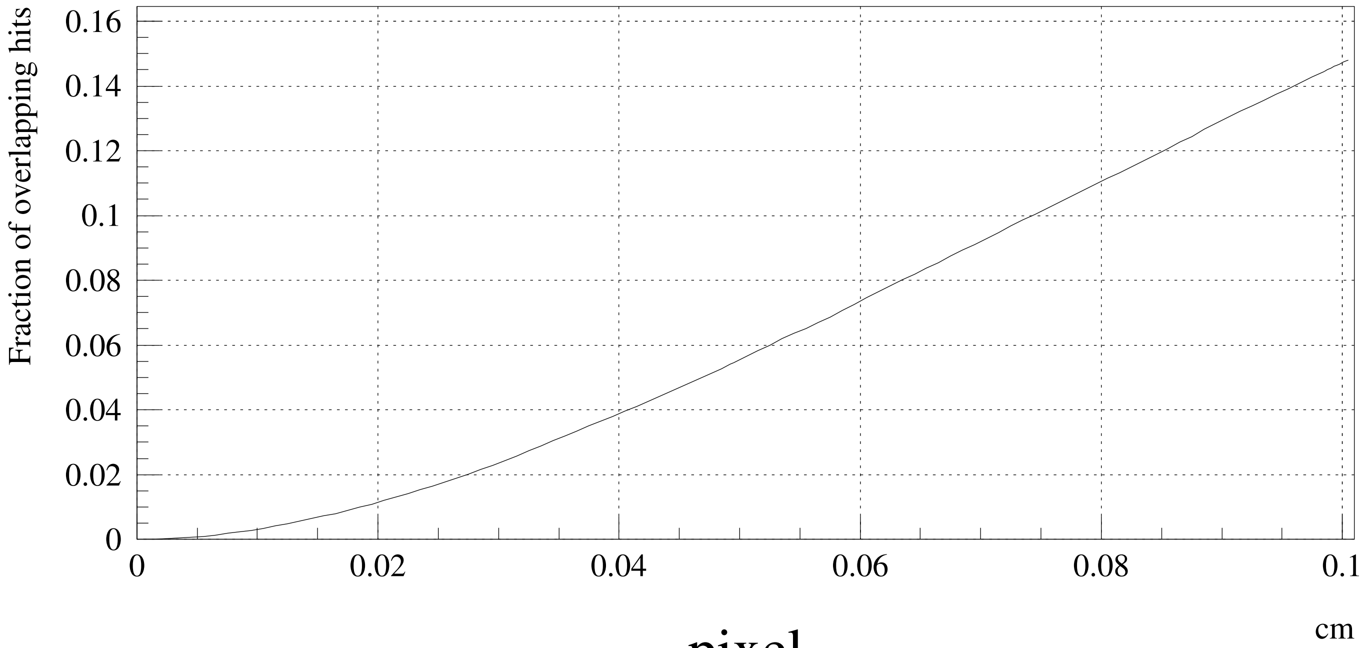
↑ Fraction of overlapping hits at R=2.5 cm



rϕ



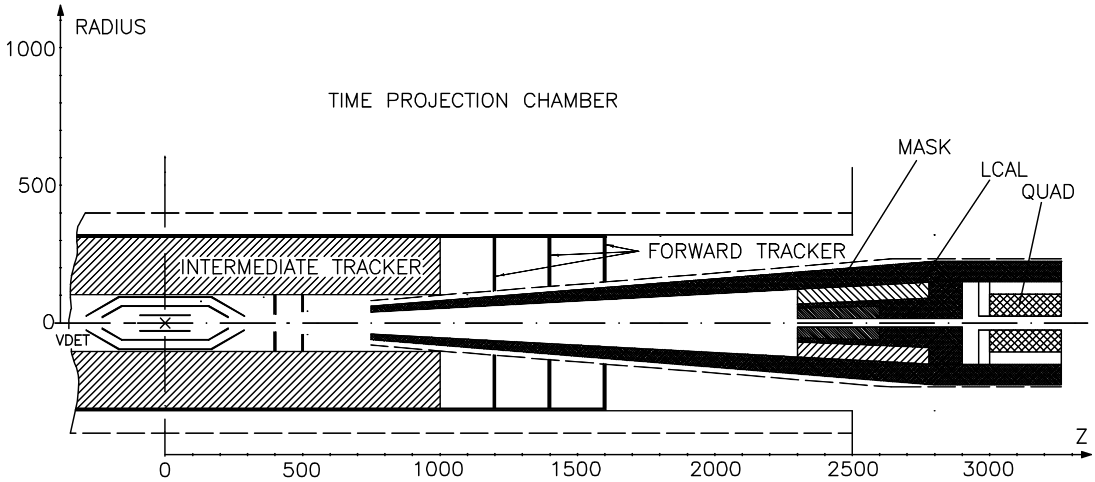
z



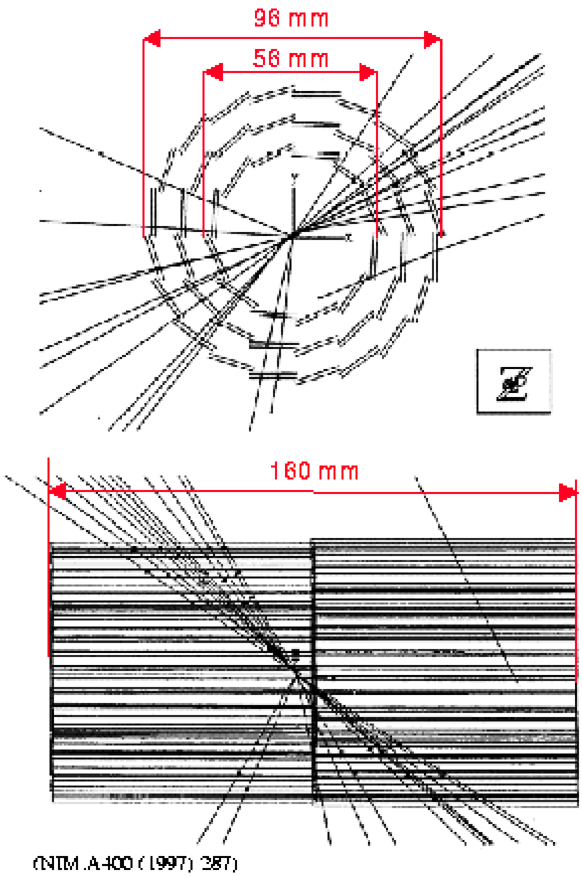
pixel

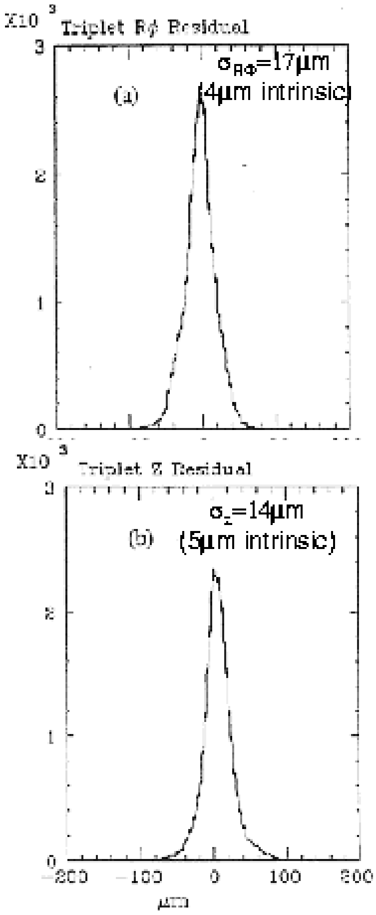
Double track resolution →

CCD Vertex Detector

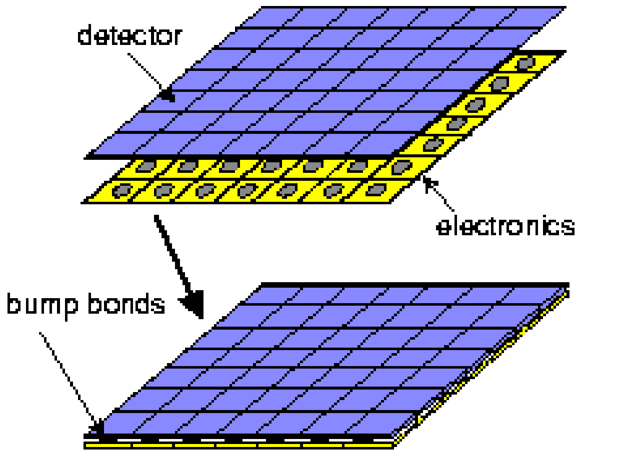


Pioneered by SLD

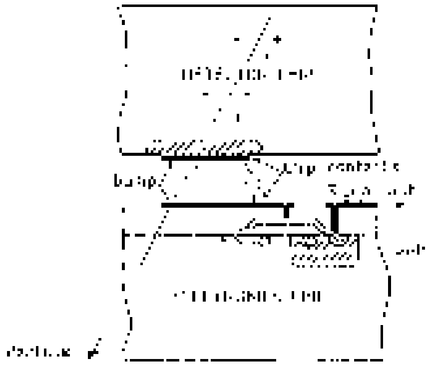


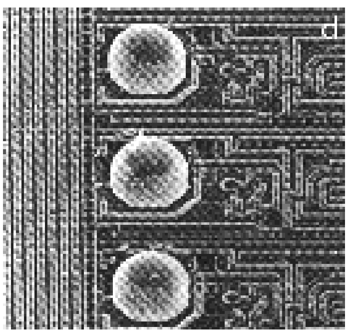


Alternative: Active Pixel Detector

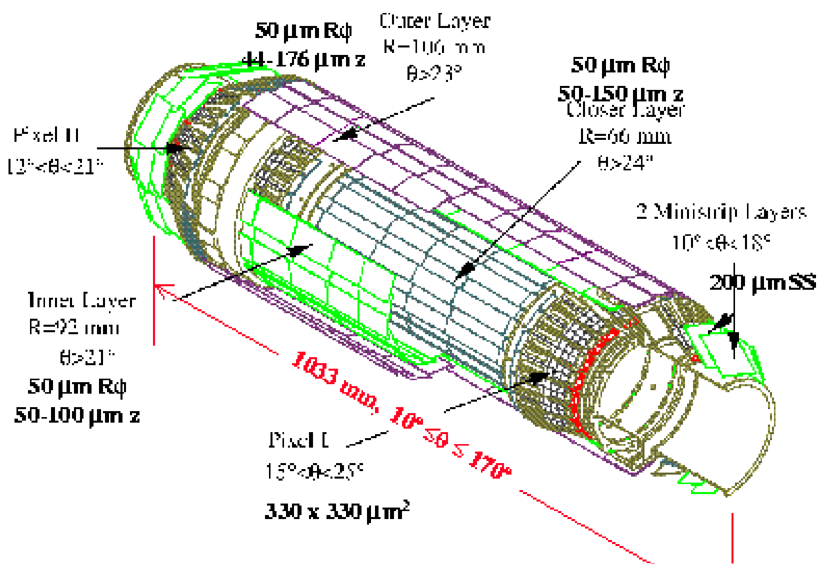


RD 19, E. Heijne et al., NIM A 384 (1994) 399



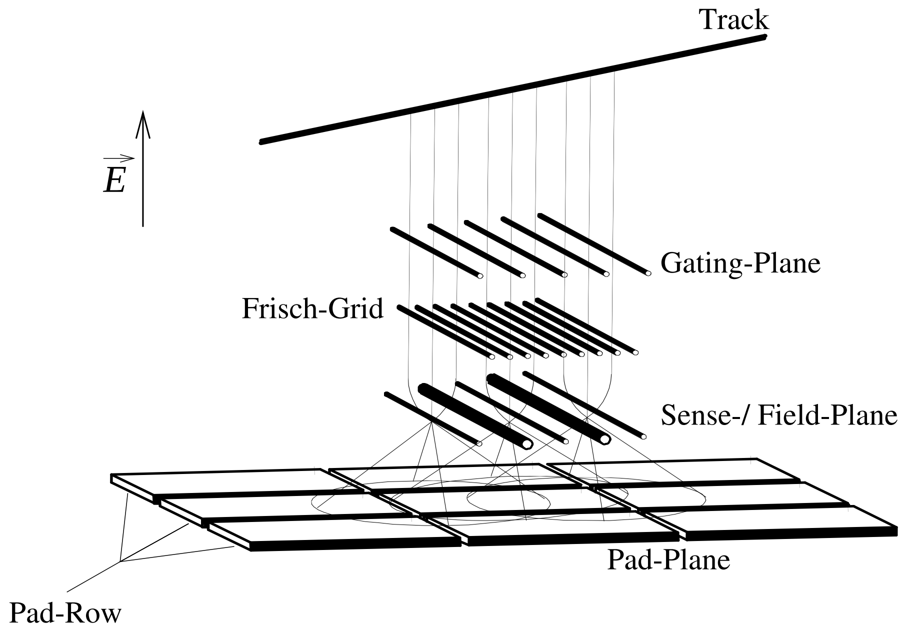


Pioneered by DELPHI

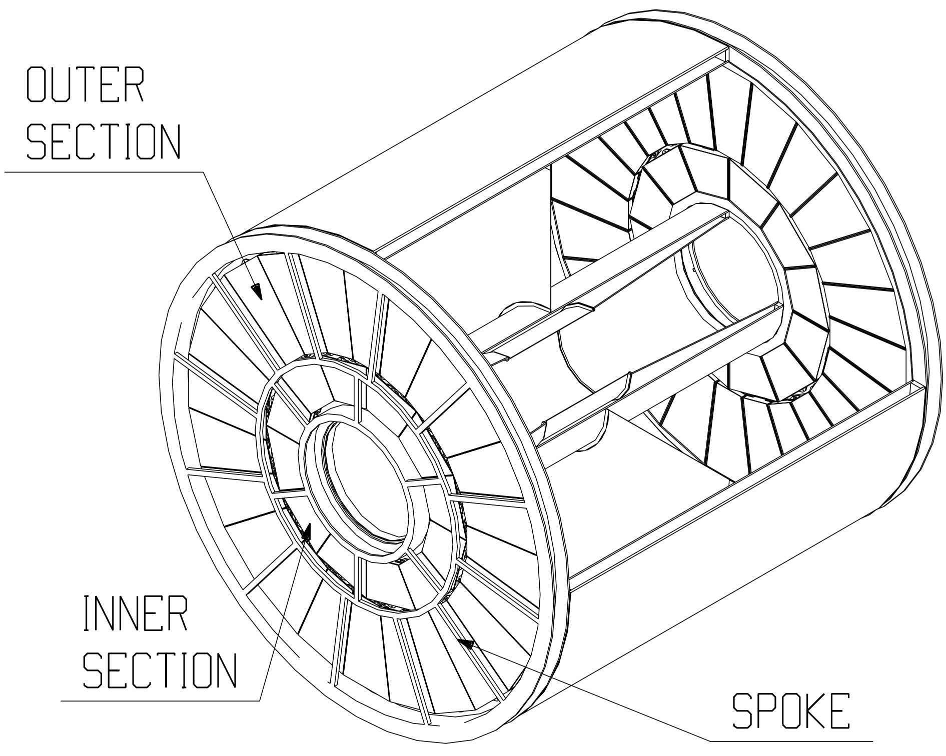


More interesting: Monolithic APS

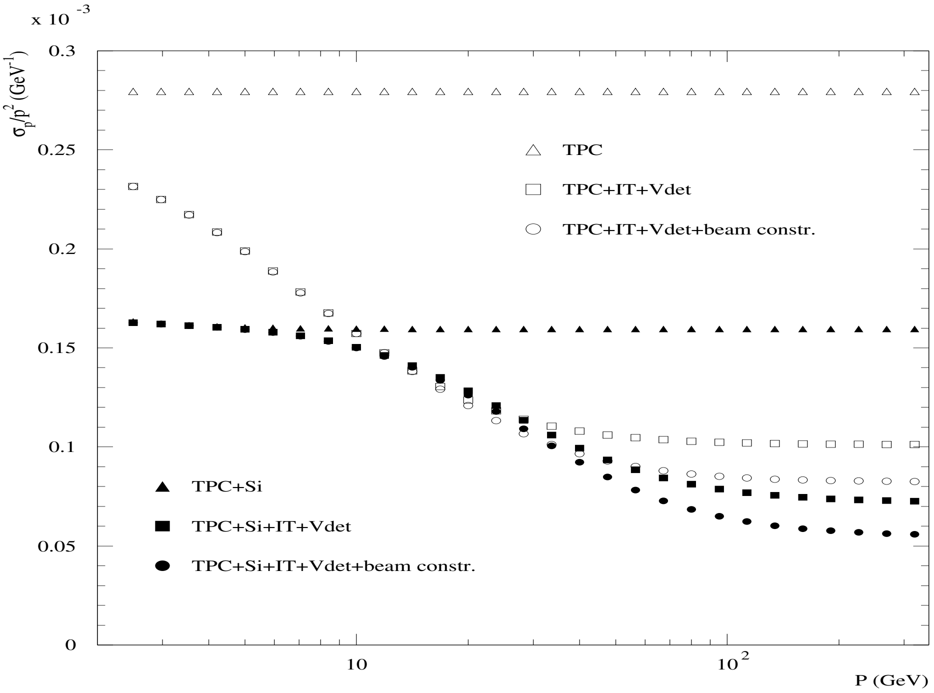
Time Projection Chamber

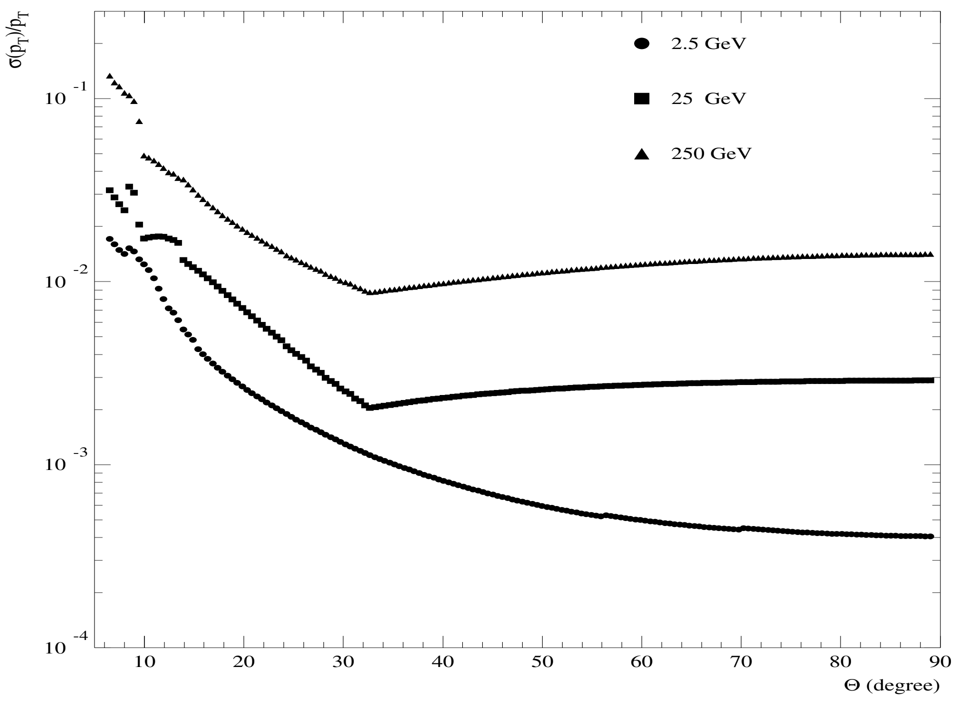


Full 3D reconstruction, electronic bubble chamber



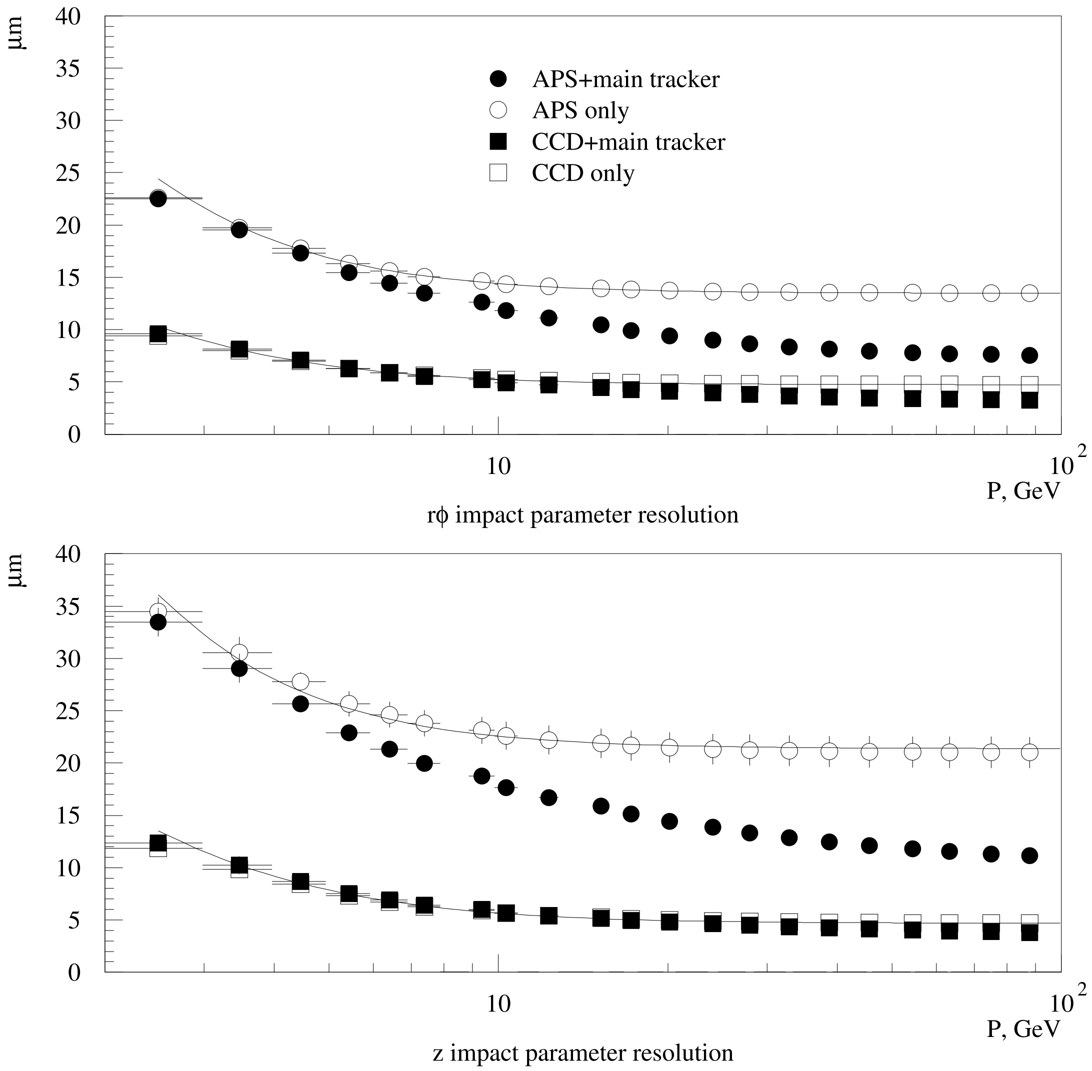
Momentum Resolution





Impact Parameter Resolution

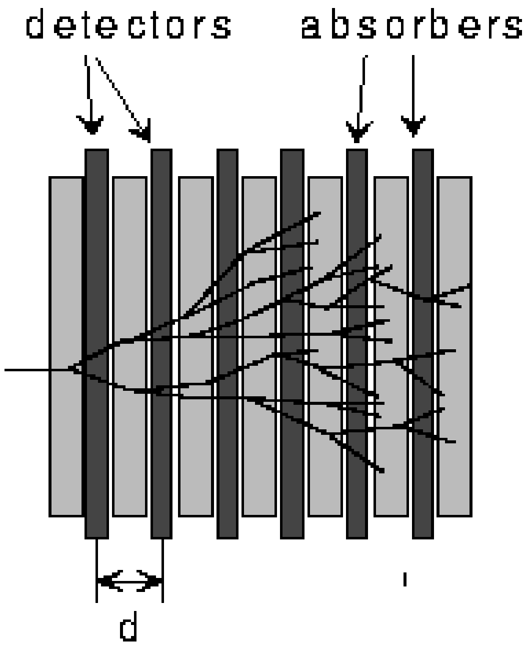
Even at R=2.5cm: substantial extrapolation error



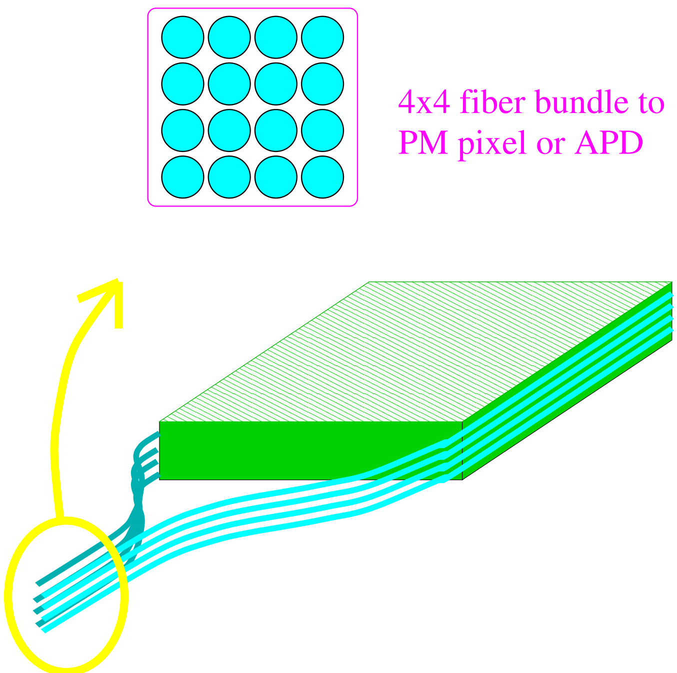
	$\sigma_{r\phi}$ [μm]	σ_z [μm]
CCD	$4.7 \oplus 22.8/p$ [GeV/c]	$4.7 \oplus 31.6/p$ [GeV/c]
APS	$13 \oplus 51/p$ [GeV/c]	$21 \oplus 72/p$ [GeV/c]

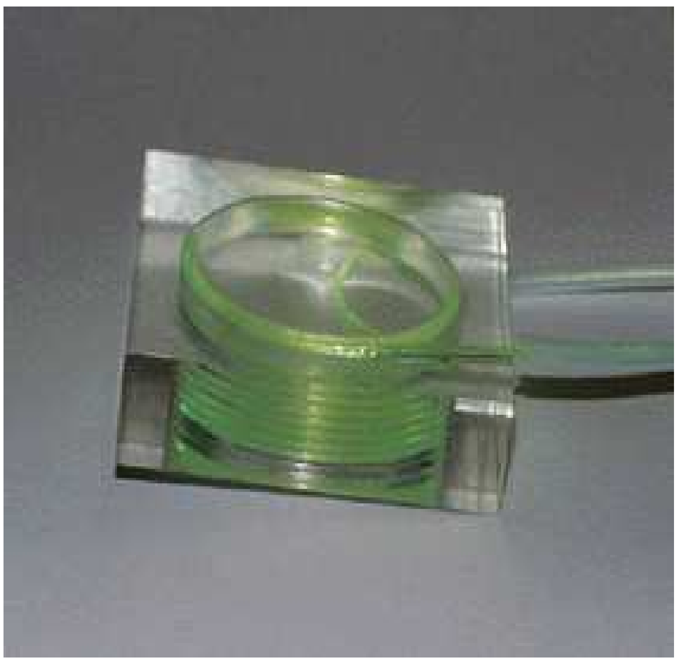
Shashlik or Tile Calorimeter

Sampling Calorimeter: Metal/Scintillator sandwich

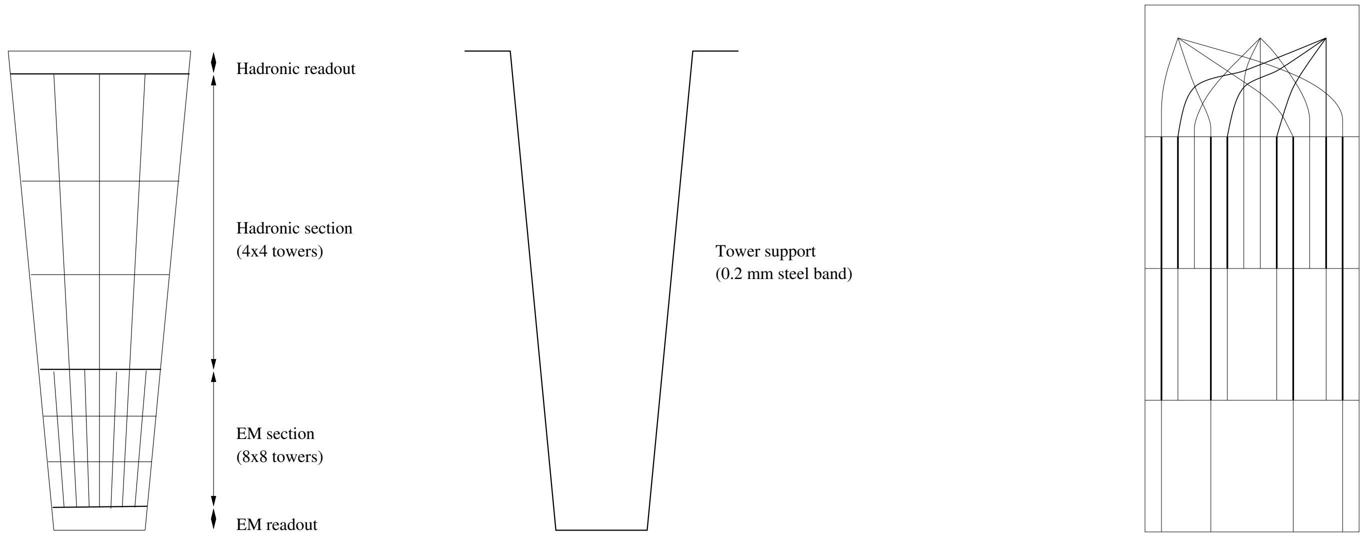


Wave length shifter fibers for light transport to PM

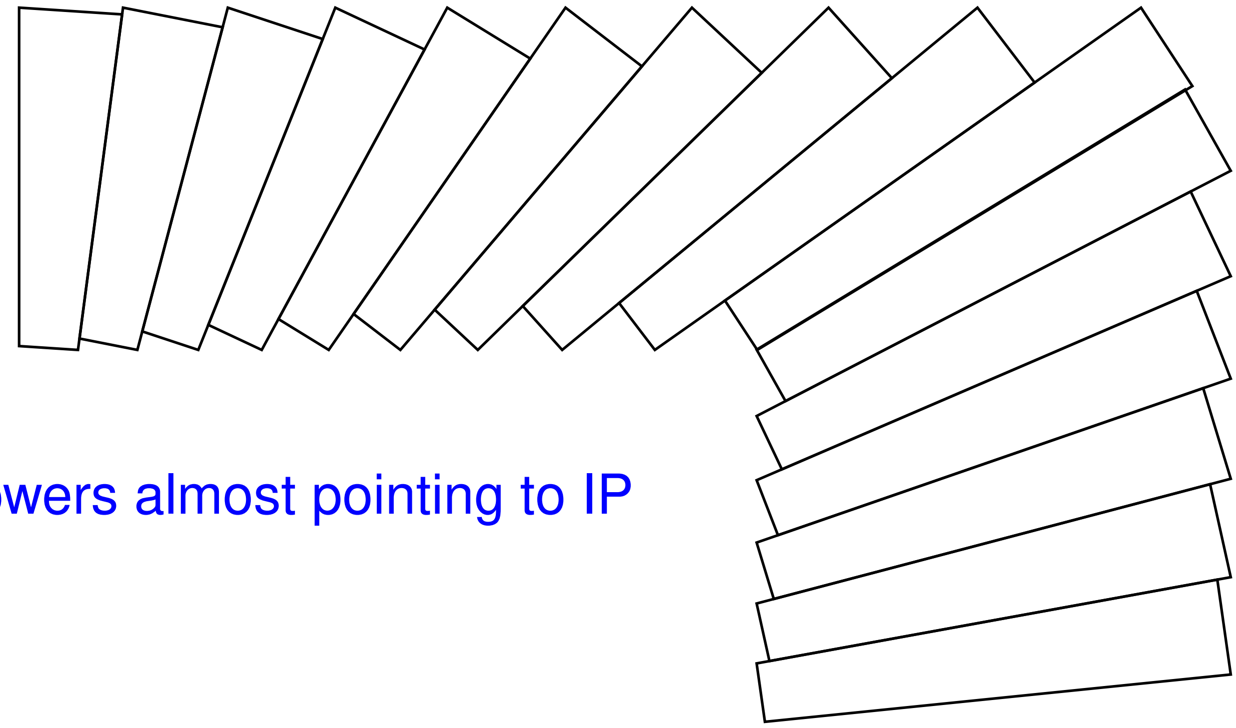




Calorimeter Tower Structure



Granularity: $1^\circ \times 1^\circ$ and fine sampling in ECAL,
$2^\circ \times 2^\circ$ and coarse sampling in HCAL

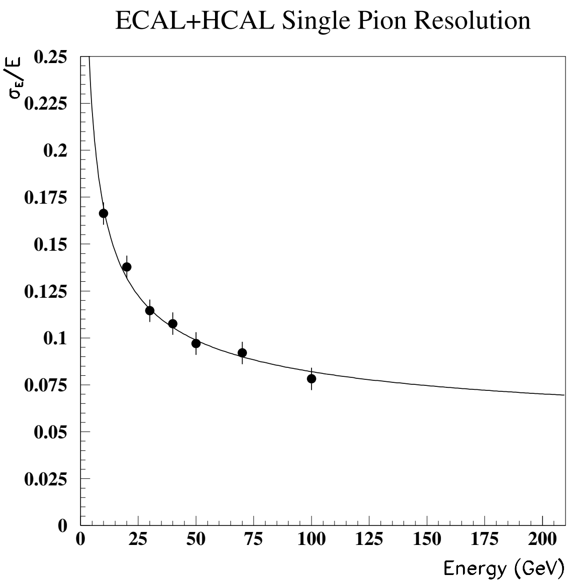


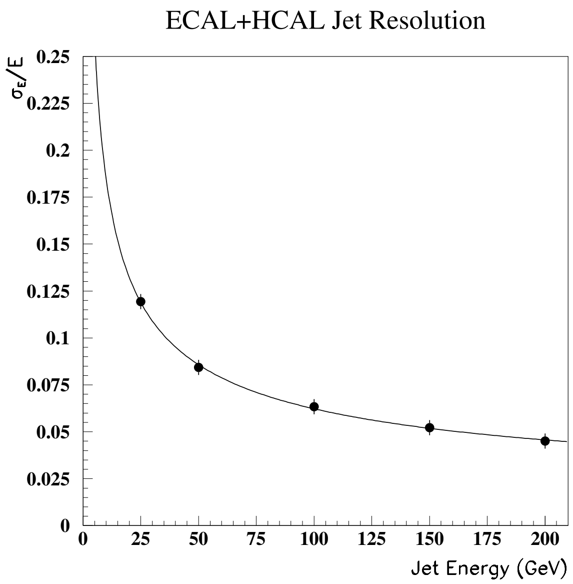
Towers almost pointing to IP

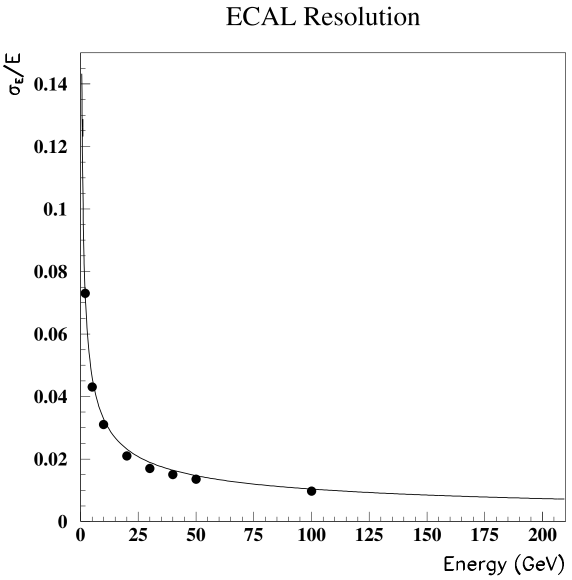
More interesting: SiW calorimeter

TDR Calorimeter Resolution

$\pi^{\pm}$: $\frac{\sigma}{E} = \frac{0.41}{\sqrt{E}} + 0.04$ Jet: $\frac{\sigma}{E} = \frac{0.57}{\sqrt{E}} + 0.01$





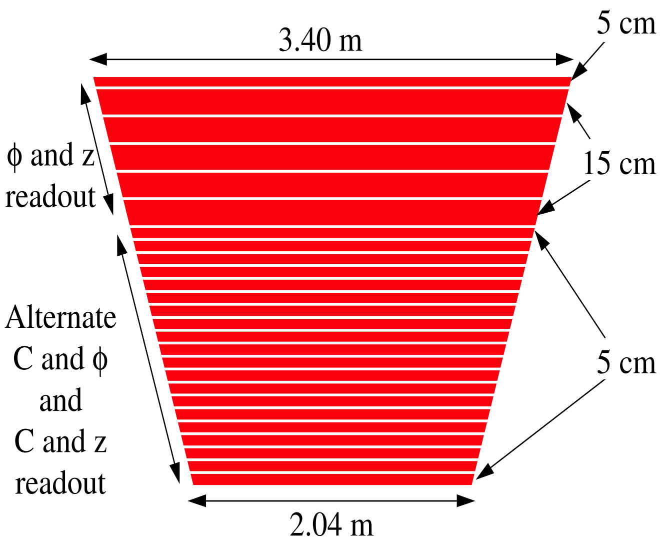


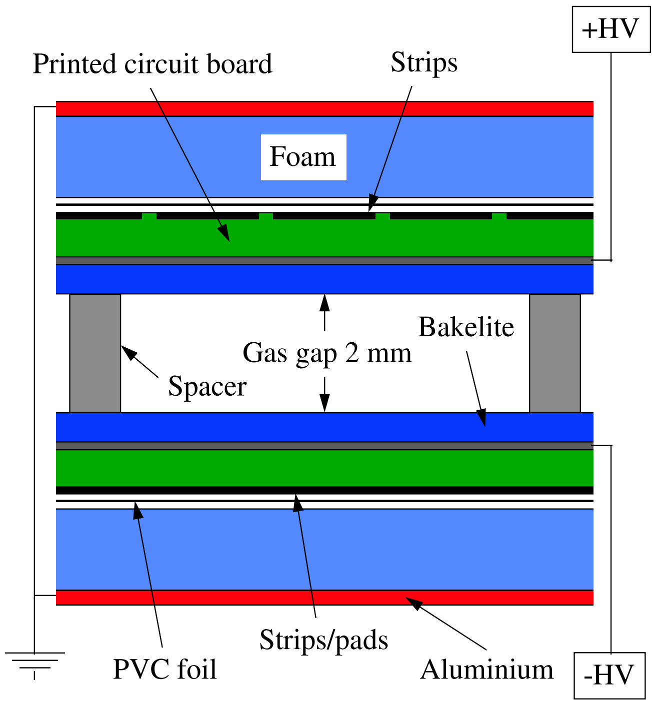
$e^{\pm}$: $\frac{\sigma}{E} = \frac{0.10}{\sqrt{E}} + 0.01$

CDR optimistic, more details coming

Muon Detector

Simple, large surface detector: Resistive Plate Chamber

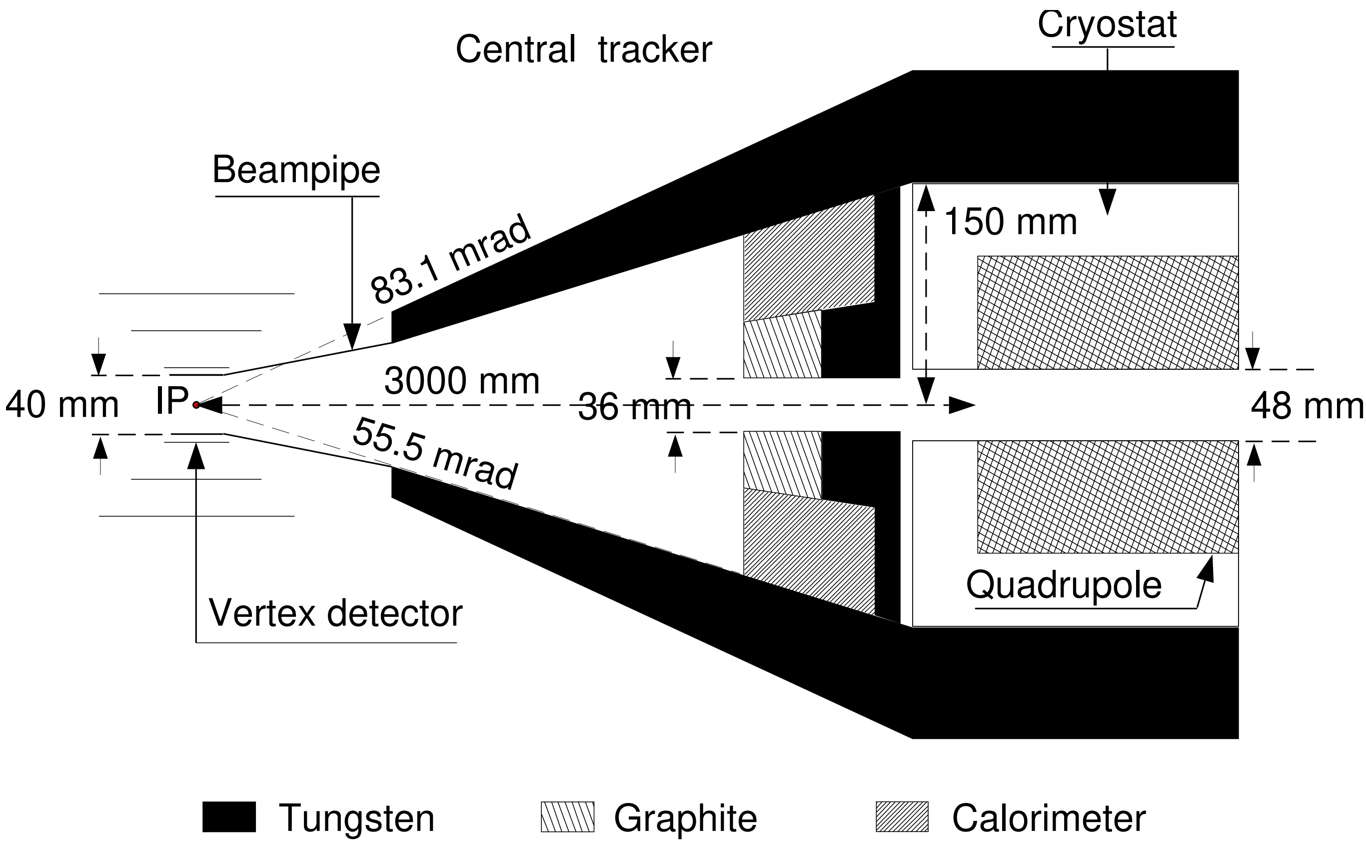




Iron of magnet return yoke as absorber for showering particles

Instrumented Mask

Monitoring of luminosity by small angle Bhabha scattering $e^+e^- \rightarrow e^+e^-$

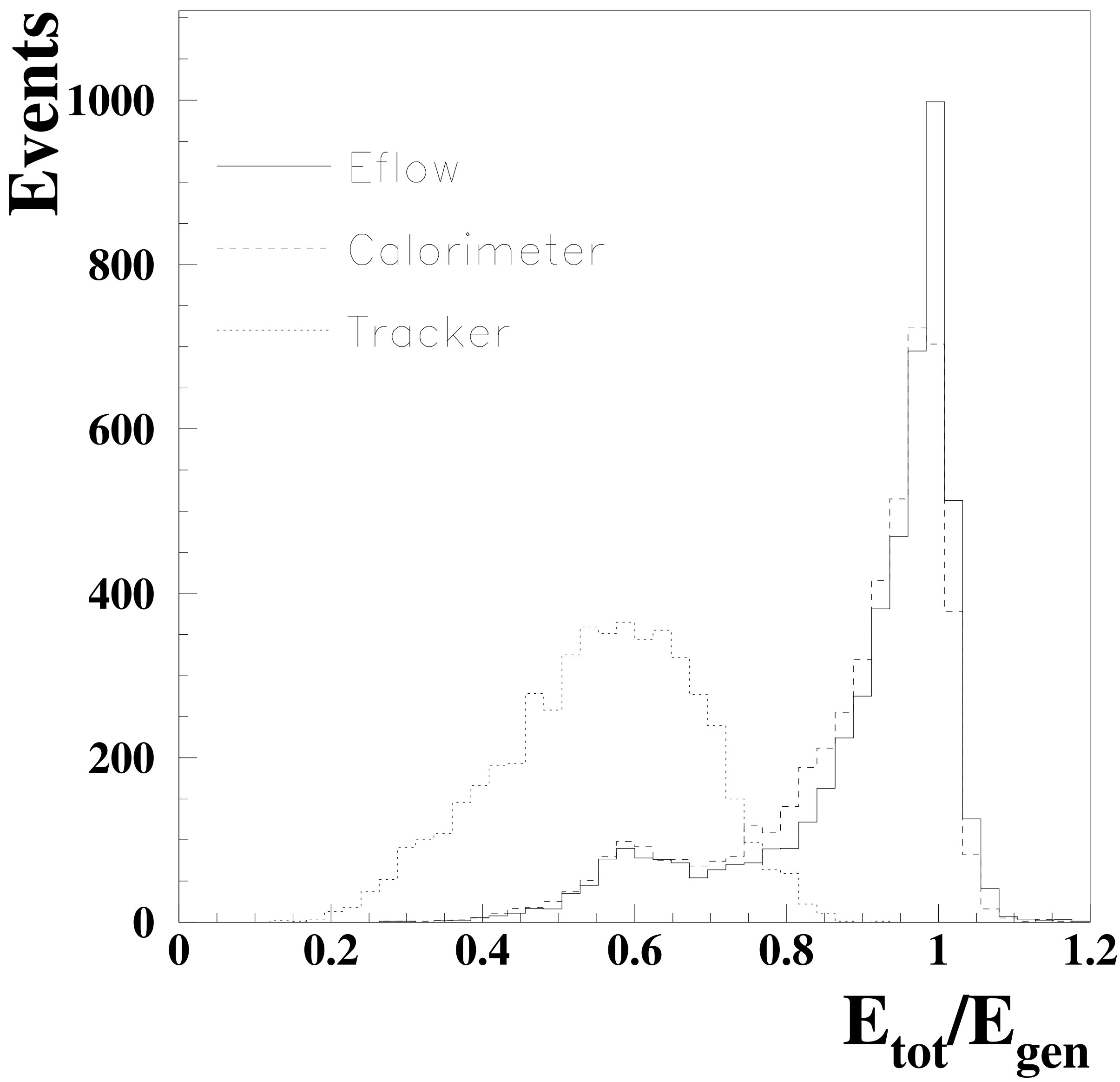


Smallest possible angle: Detector inside beam pipe

System's Aspect: Energy Flow

Subdetector performance is important, but what matters is how they work together

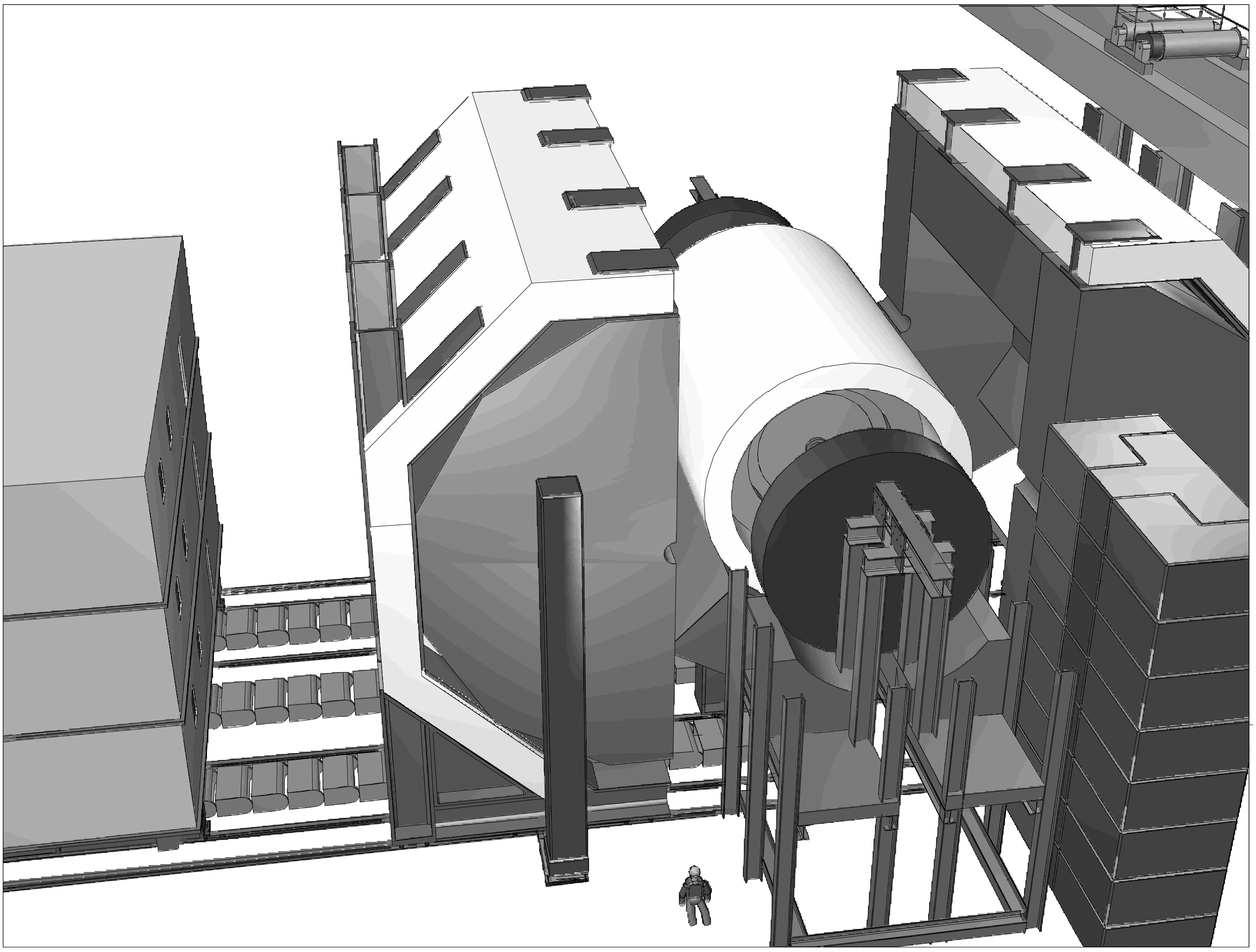
Pohl, Schreiber, DESY 99-030



Total detector better than the sum of its pieces

Installation Scheme

First round engineering study of support structure and installation scheme



Experimental hall and infrastructure comparable to current LEP experiments.

Trigger and Readout Scheme

	BaBar	LHC	LC
Bunch crossing time	4 ns	25 ns	4-708 ns
Level-1 accept rate	2 kHz	100 kHz	<0.1 kHz
Event building	0.4 Gbit/s	20-500 Gbit/s	1 Gbit/s
Processing power	10^3 MIPS	10^6 MIPS	10^5 MIPS