The 4th Concept Detector Status and Progress

Corrado Gatto
INFN Lecce
On behalf of the 4th Concept Collaboration

The 4th Concept Collaboration

4th Letter of Intent

Patrick Le Du
DAPNIA/SPP, 91191 Gif sur Yvette, France

Vito Di Benedetto, Franco Grancagnolo, Corrado Gatto, Fedor Ignatov,
Anna Mazzacane, Alessandro Miccoli, Giovanni Tassielli, Giuseppina Terracciano
Università & INFN di Lecce, via Arnesano, 73100 Lecce, Italy

Antonio Lamberto, Gaetana Francesca Rappazzo, Ada Anania
INFN di Messina, 98100 Messina, Italy

Gianluca Introzzi
Università di Pavia, via Bassi 6, 27100 Pavia, Italy

Franco Bedeschi, Roberto Carosi, Marco Incagli, Fabrizio Scuri
INFN di Pisa, Largo Bruno Pontecorvo 3, 56127 Pisa, Italy

Walter Bonvicini, Aldo Penzo, Irina Rashevskaya, Erik Vallazza, Gianluca Zampa
INFN di Trieste, Padriciano 99, 34012 Trieste, Italy

D. Cauz, C. Delpapa, G. Pauletta, M. Rossi, L. Santi
Università di Udine & INFN di Trieste, Viale delle Scienze, 33100 Udine, Italy

Kazuhiko Hara
High Energy Physics Laboratory, Institute of Physics, University of Tsukuba, Tsukuba, Ibaraki 305, Japan

Tae Jeong Kim, Hyeongseung Lee, Kyong Sei Lee, Minhee Lee, Sung Keun Park, Sungjoon Yoon
Department of Physics, Korea University, Seoul 136-701, Korea

Sorina Popescu, Laura Radulescu[3]
IFIN-HH, Bucharest, Romania

Fedor Ignatov, Boris Khazin, Alexander Popov, Alexander Ruban, Yury Yudin
Budker Institute of Nuclear Physics, 11 Prospect Lavrentyeva, Novosibirsk, 630090, Russia

Stanislav Tokar
Faculty of Mathematics, Physics and Informatics, Comenius University, 842 48 Bratislava, Slovakia

Jaroslav Antos
Institute of Experimental Physics, Watsonova 47, 043 53 Kosice, Slovakia

Sezen Sekmen, Efe Yazgan[2], Mehmet Zeyrek
Physics Department, Middle East Technical University, Ankara, Turkey

S.I. Bondarenko, A.N. Omeliyanchuk, A.A. Shablo, N.S. Scherbakova, N.M. Levchenko
Institute for Low temperature Physics and Engineering, Kharkov, Ukraine

Alexander Mikhailichenko
Cornell University, Ithaca, NY 14853-5001 USA

Muzaffer Atac, Marcel Demarteau, Dmitri Denisov, Ingrid Fang, Stephen R. Hahn,
Caroline Milstene, Masa Mishina, Adam Para, Robert Wands, Hans Wenzel, Ryuji Yamada, G.P. Yeh
Fermi National Accelerator Laboratory, Batavia, IL 60510 USA

Anatoli Frishman, John Hauptman, Jerry Lamsa,

Rapidly growing since EoI

Started @ Snowmass
8 / 2005

78 Members
19 Institutions
10 Countries

Regional Contacts

J. Hauptman (America)
S. Park (Asia)
F. Grancagnolo (Europe)

www.4thconcept.org

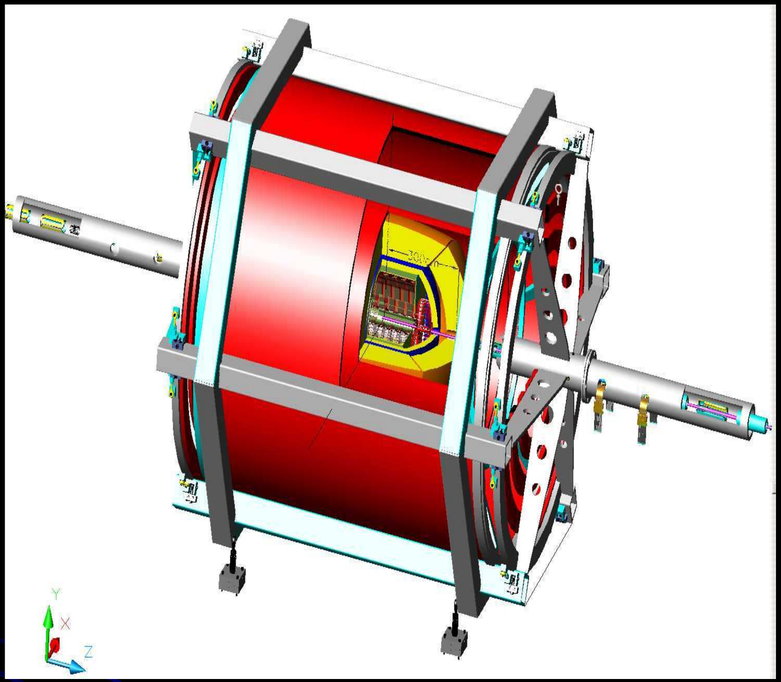
Detector Design Guidelines

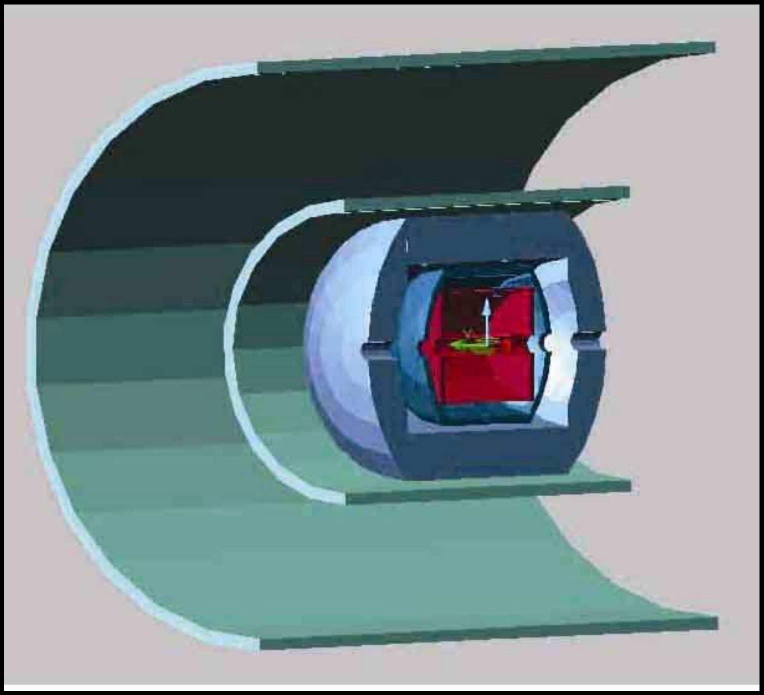
- Alternative to other Concepts
  - No PFA for Calorimetry
  - No TPC for Central Tracking
  - No range-based Muon Detector
- Low material budget in front of the Calorimeter
- Light -> no iron
  - Good for in the (unfortunate) case of push-pull
- Open mind toward the choice of technology
  - Define a baseline configuration
  - Work in parallel over (reasonable) alternatives

Detectors Comparison

	ILD	SiD	4-th
VTX	Si-pixels	Si-pixels	Si-pixels
Tracker	TPC + Si-strip	Si-strip	DC with Clust. Counting
Calorimeter	PFA Rin=2.1m	PFA Rin=1.27m	Multiple Readout Rin=1.5m
B	3-4T	5T	3.5T/-1.5T No return yoke
BR^2	10.2-13.2 Tm^2	8.1 Tm^2	(non-PFA)
E_{store}	1.6-1.6 GJ	1.4 GJ	2.7 GJ
Size	R=6.0-7.2m |Z|=5.6-7.5m	R=6.45m |Z|=6.45m	R=5.5m |Z|=6.4m

4th Concept Detector





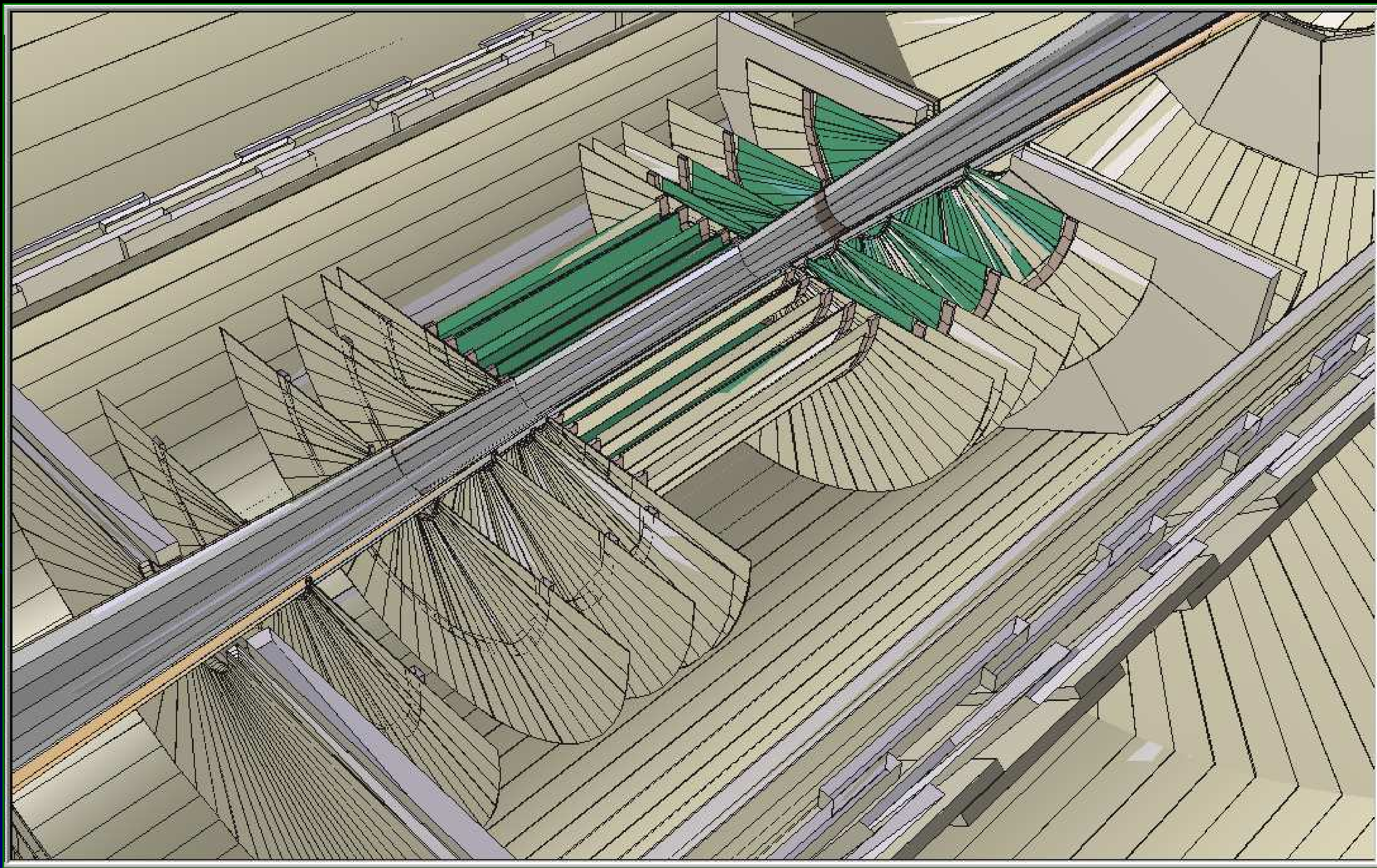
1. Vertex Detector 20-micron pixels (based on SLAC/FNAL design)
2. Drift Chamber with He gas and Cluster Counting
3. Double-readout calorimeter
4. Dual-solenoid with Muon Spectrometer

Motivations for Baseline Configuration

- **He-based Drift Chamber with Cluster Counting**
  - Continuous tracking and seeding from Central Tracker
  - Lowest material budget
  - $\mathcal{O}(10^4)$ channels
  - Consolidated technology (i.e. Kloe)
  - Cost
- **Dual readout with time history of all channels**
  - Resolution scales as 1/sqrt(E) at all energies
  - $\mathcal{O}(10^4)$ channels
  - Cost
- **Dual Solenoid Muon Spectrometer**
  - No iron (field is fully contained)
  - Precise determination of momentum
  - Tail catcher
  - Independent calibration for the calorimeter (i.e. via $\mu \to \mu\gamma$)

The 4th Concept Tracking Systems

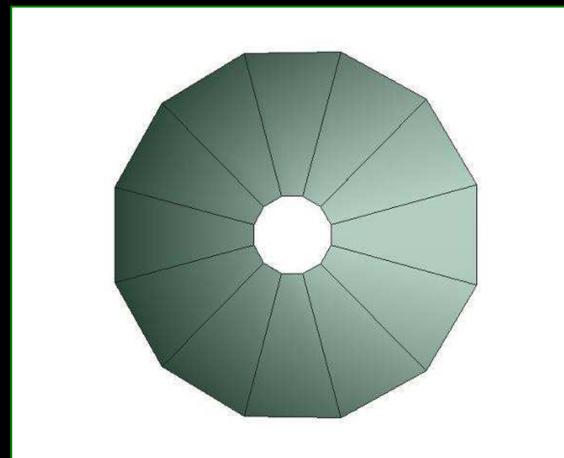
Beam Pipe and VXD layout

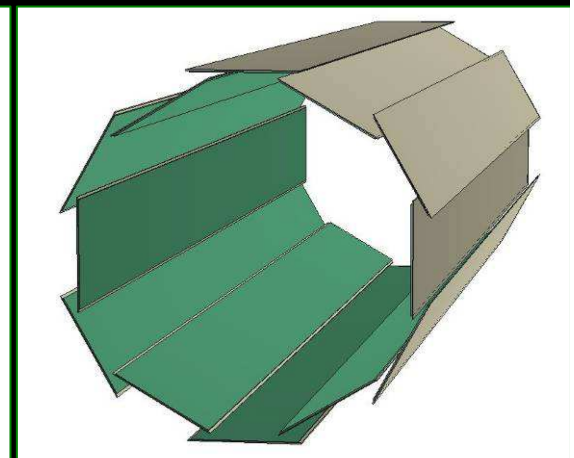


ILCRoot simulation

Beam Pipe and VXD layout

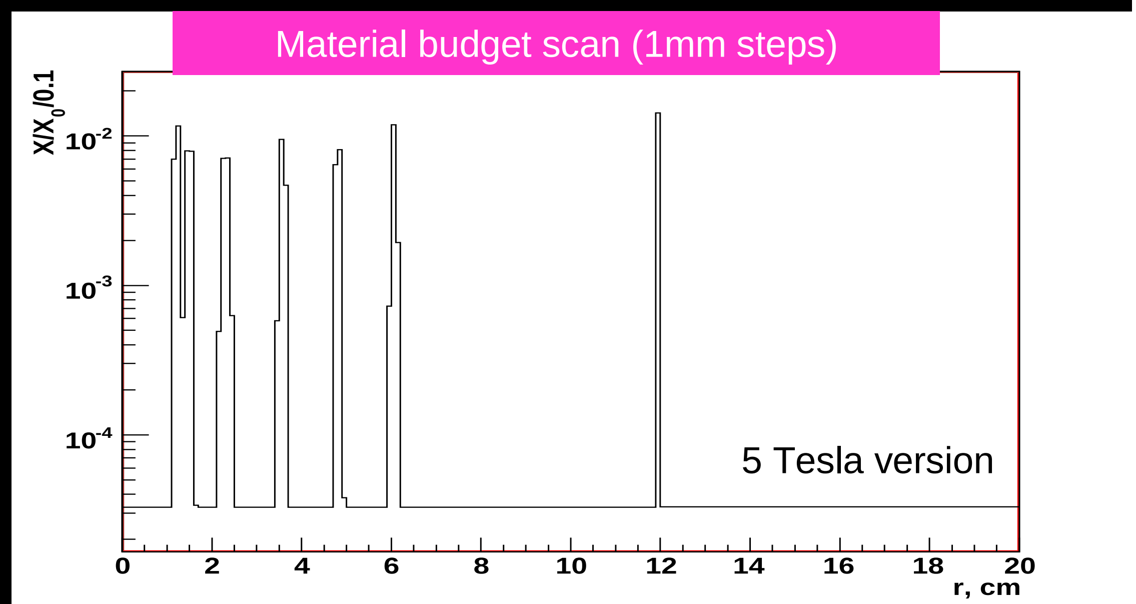
- Beam Pipe:
  - 400 μm Be
  - 25 μm Ti
- VXD: SiD layout (modified for 3.5 T)
  - 5 barrel layers (96 ladders) x 4 endcaps (96 sectors)
  - 20 μm x 20 μm pixel size
  - Total 4.3×10^9 pixels
  - (Total 2.5×10^9 pixels for 5 Tesla version)
  - Detector support: 100 μm CarbonFiber
  - Si modules: 100 μm Si





Material Budget

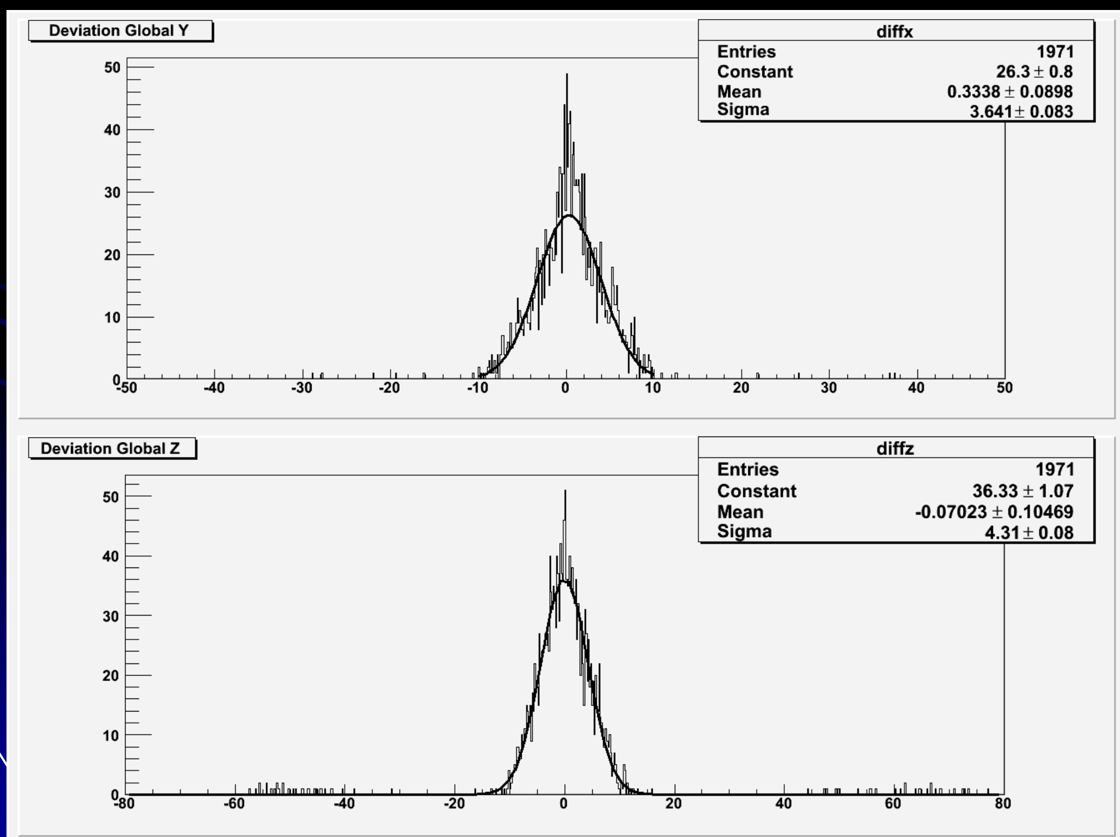
- Beam Pipe: 0.18% X/X_o
- VXD (including support & electr.): 0.8% X/X_o



Integrated over φ

VXD Single Cluster Residual (single track)

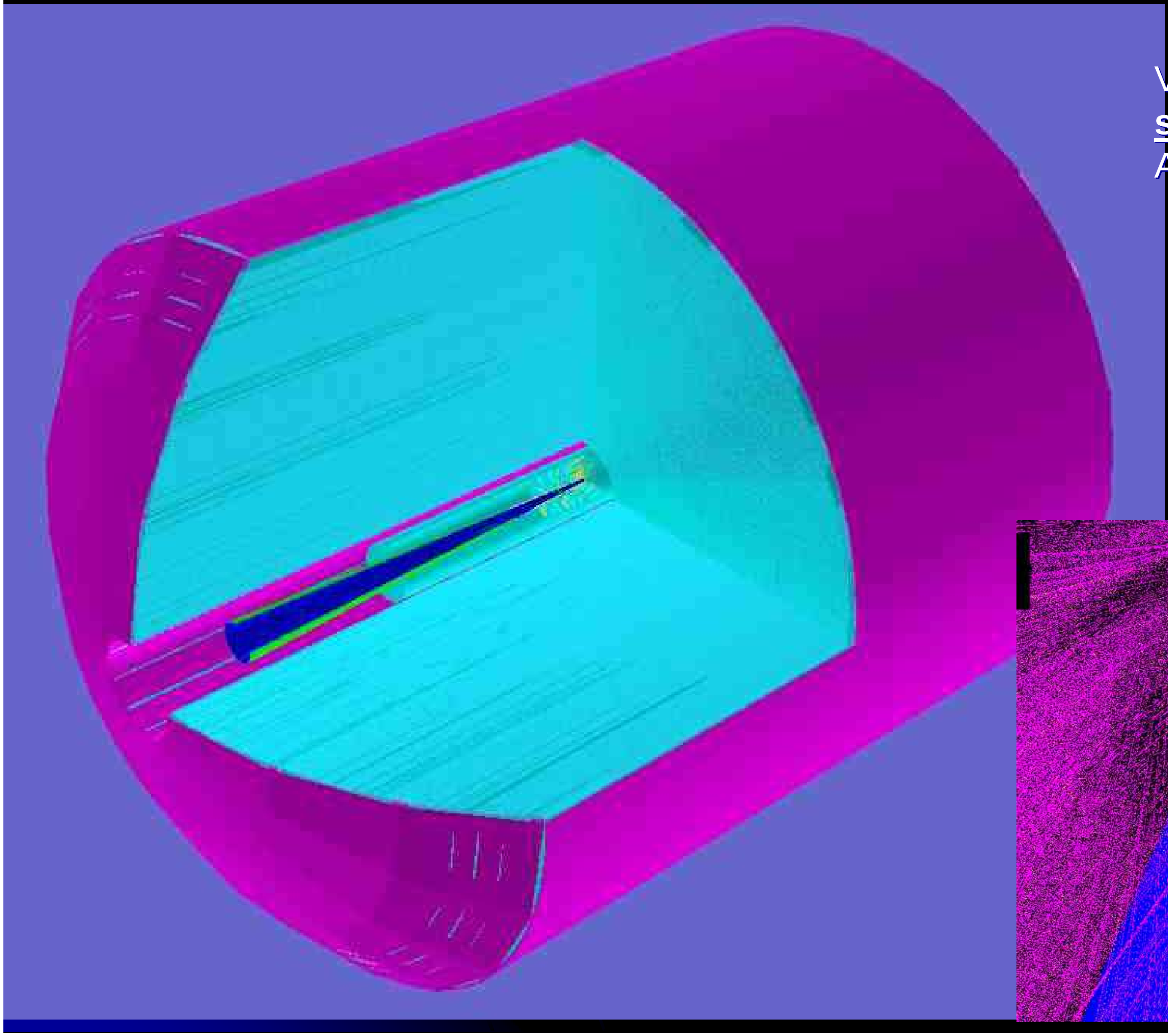
- FNAL/SLAC layout more than adequate for current requirements at ILC
- Main Issue is choice of technology
- Mostly driven by Montecarlo studies on beam background



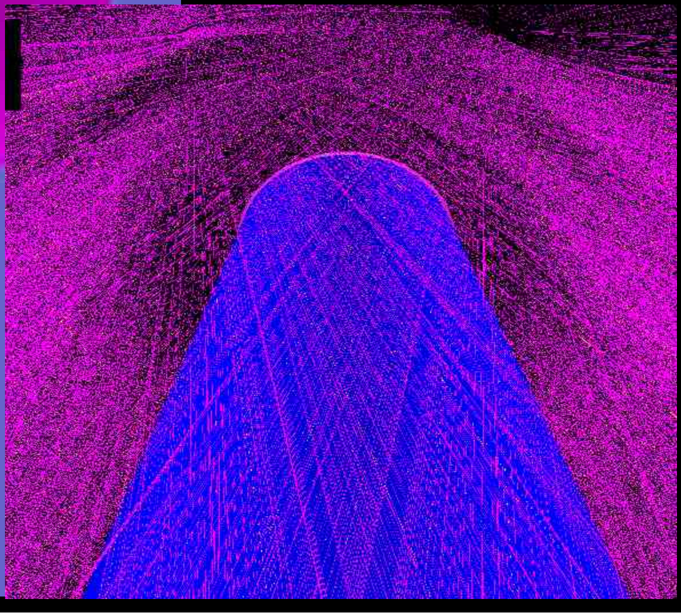
See F. Ignatov talk Wednsday afternoon

ILCRoot simulation

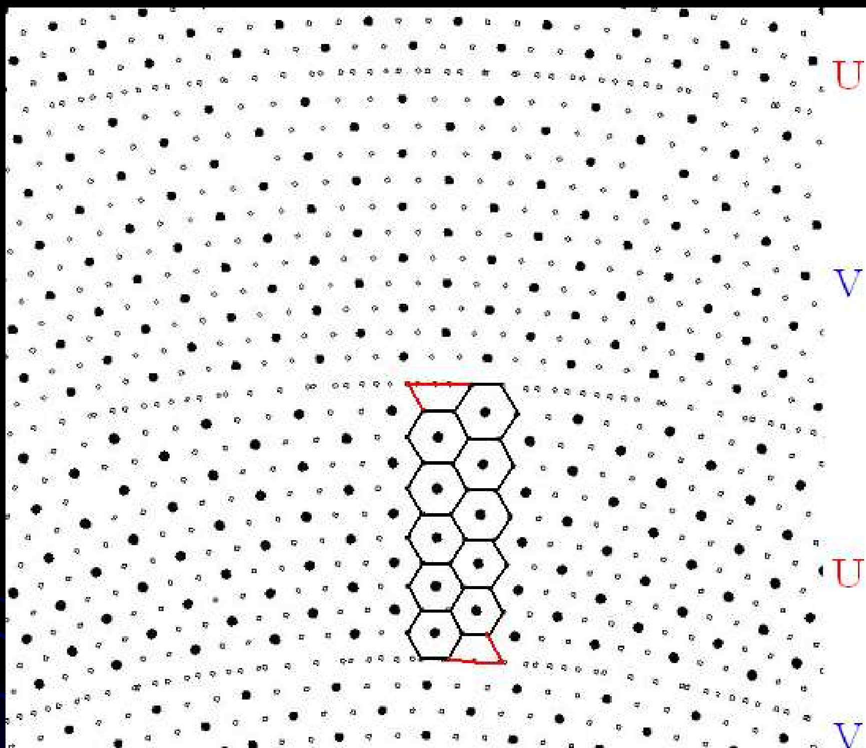
The 4th Concept Drift Chamber



Vessel: 18-150 cm
spherical Endcaps
Active volume: 19-147 cm



Drift Chamber Layout



Hexagonal cells f.w./s.w.=2:1

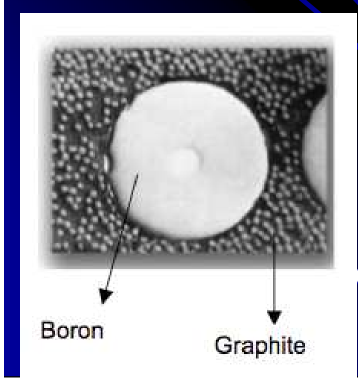
cell height: 1.00 ÷ 1.20 cm
cell radius: 4.5 ÷ 6.00 mm

24 superlayers, in 240 rings
10 cells each (7.5 in average)
at alternating stereo angles
±72 ÷ ±180 mrad
(constant stereo drop = 2 cm)

66000 sense w. 20 μm W
152000 field w. 80 μm Al

"easy" t-to-d r(t) (few param.)

>90% sampled volume



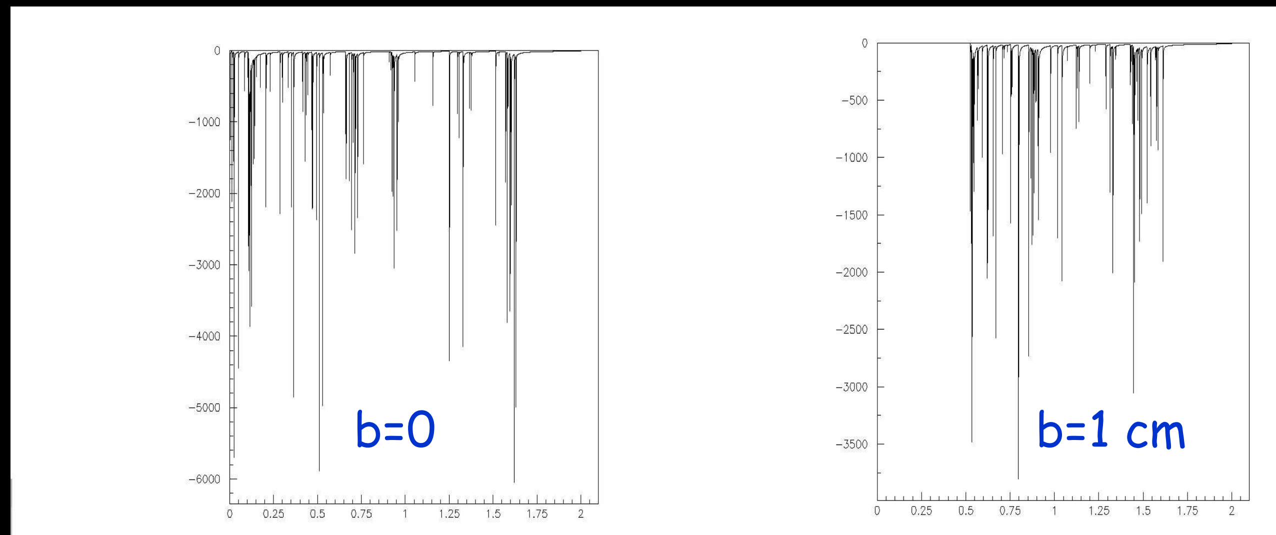
Under test
PET Field wires 25 μm
(end plate thickness reduced by a factor 2)

further reduction (30%÷50%) with
use of Boron loaded Carbon fibers

(max. drift time < 300 ns !)

CLUster COUnting

MC generated events:
2cm diam. drift tube
gain = few x 10
gas: 90%He-10%iC_4H_{10}
no electronics simulated
vertical arbitrary units



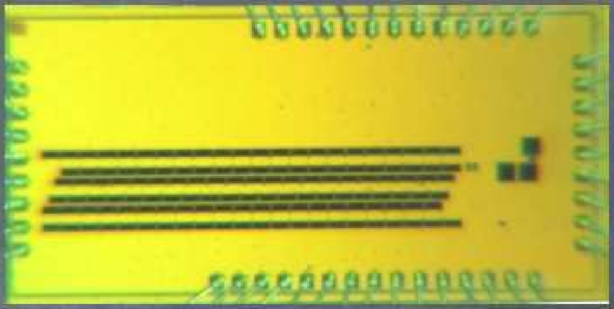
cosmic rays triggered by scintillator telescope and readout by:
8 bit, 4 GHz, 2.5 Gsa/s digital sampling scope through a 1.8 GHz, x10 preamplifier

Front end VLSI chip

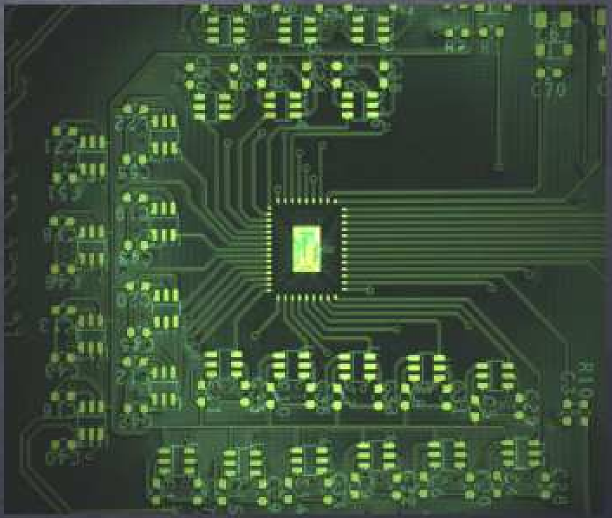
- Integrated 0.13μm CMOS technology provided by UMC though Europractice;
- 3 costitutive blocks:
  - 500MHz bandwidth amplifier with programmable DC-gain;
  - 6-bit@1Gsa/s ADC;
  - 6-bit@1Gsa/s to 30bits@200Msa/s buffer;
- Very low power consumption (~40 mW)
- Fully differential architecture

72 chips delivered as of today

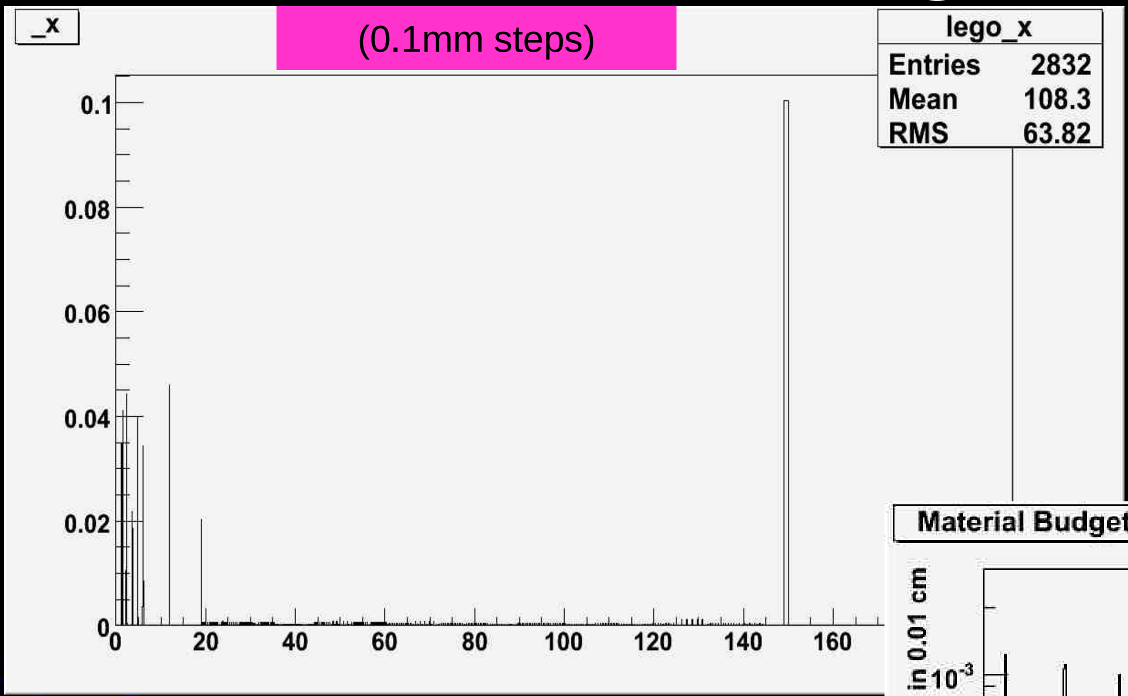
chip microphotography



test board



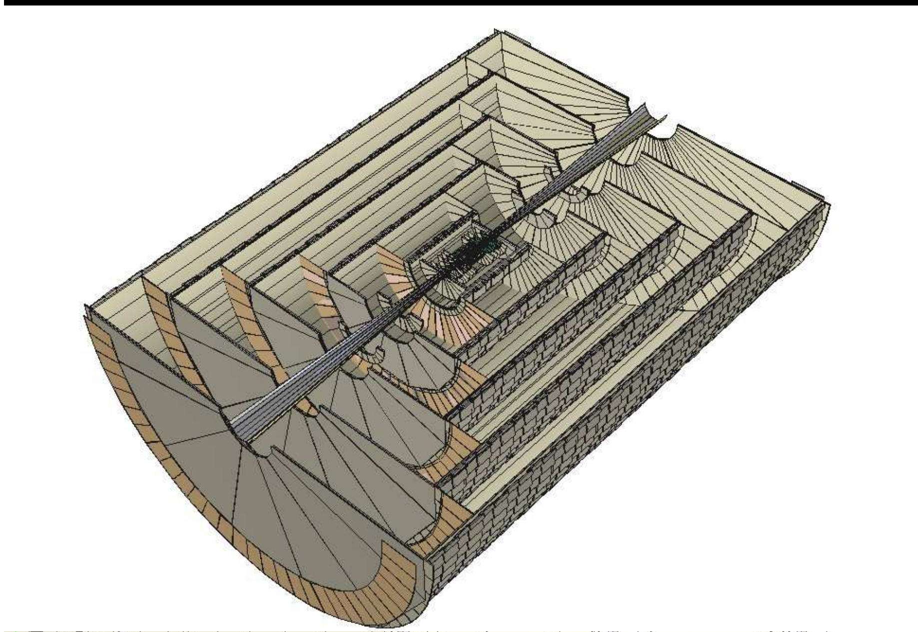
Material Budget at θ= 90˚

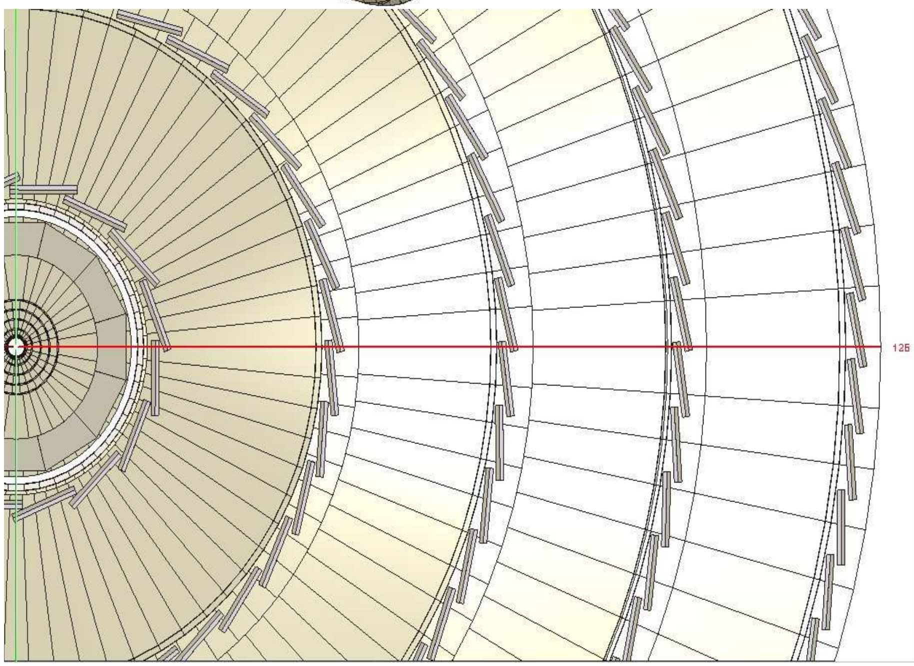


- Gas [He-C4H10/90-10]: 0.15%
- Wires: 0.4%
- Vessel:
  - Inner wall: 0.1% X/Xo
  - Outer wall: 2% X/Xo
  - Endcaps (wires, pads,electronics & services included): 8% X/Xo

Integrated over φ

Tracking Option #1: Si-Strip Tracker

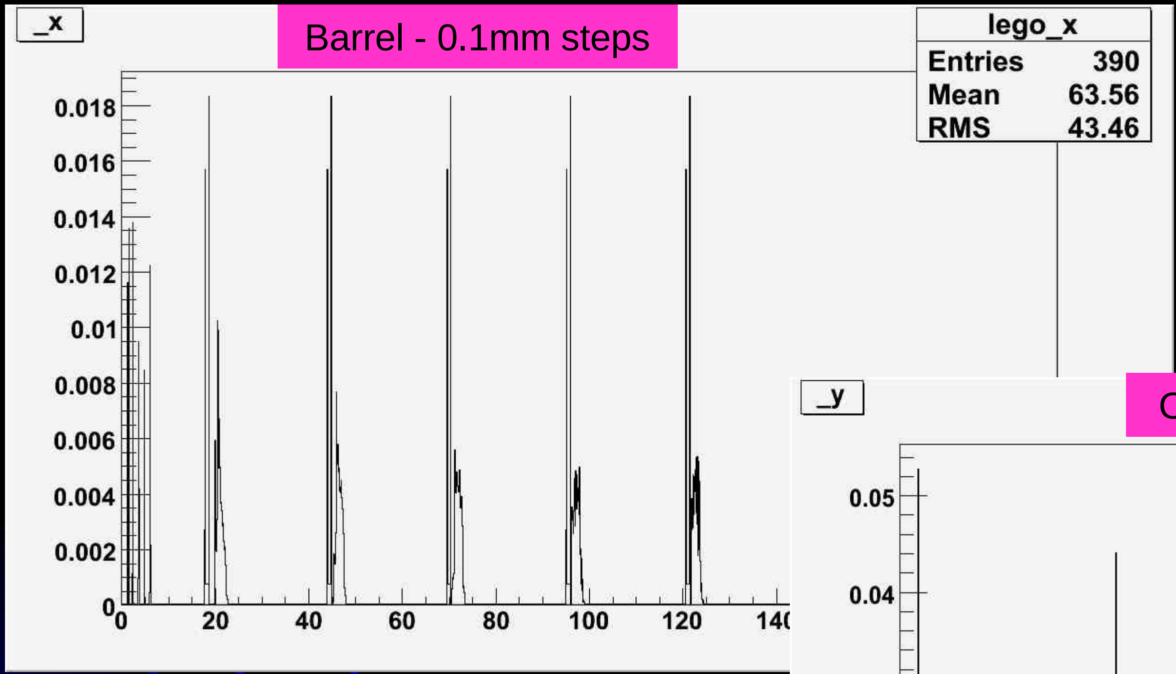


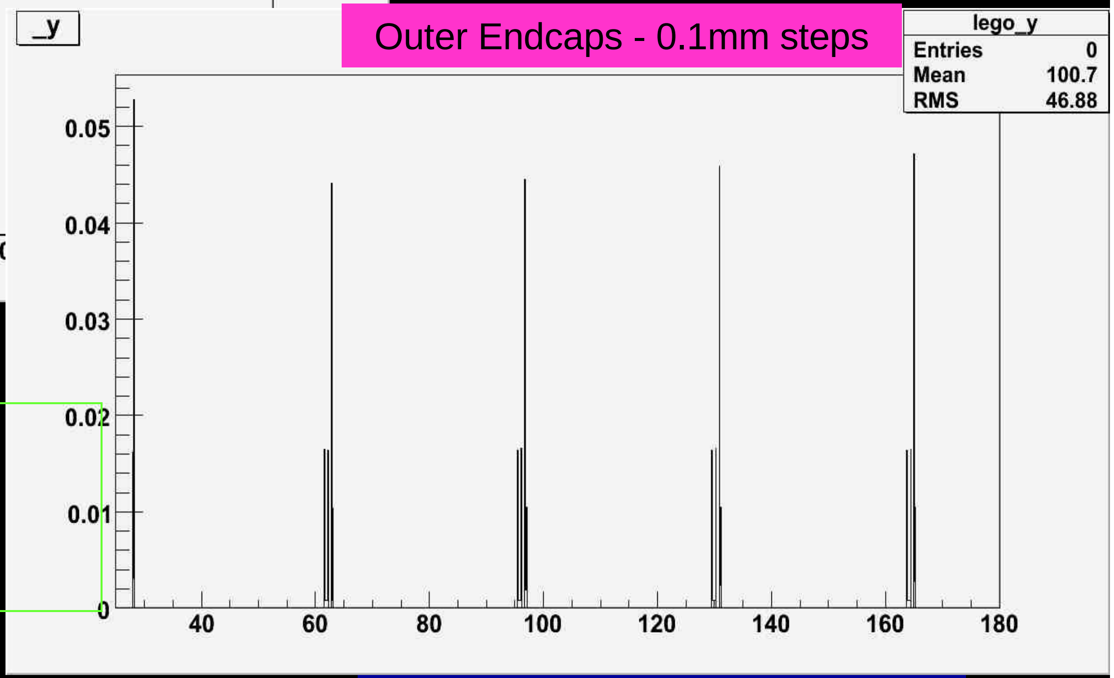


- Support
  - Double-walled CF cylinders
  - Allows full azimuthal and longitudinal coverage
- Barrels
  - Five layers, 300 µm wafer thickness
  - 25µm x 10 cm strips
  - Read alternate strips
  - Eighty-fold phi segmentation
  - rin= 18cm; rout=127cm
- Disks
  - Four double-disks per end
  - Stereo strips **17.5 mrad**
  - Measure R and Phi
  - varying R segmentation
  - Disk radii increase with Z
- **Total strips: 5.5x10^{7}**

ILCRoot simulation
Based on SID May01/Polyhedra

Si-Strip Tracker Material Budget





Si Strip Tracker

Barrel :6.21% (Si= 3.98% + Support=2.23%)

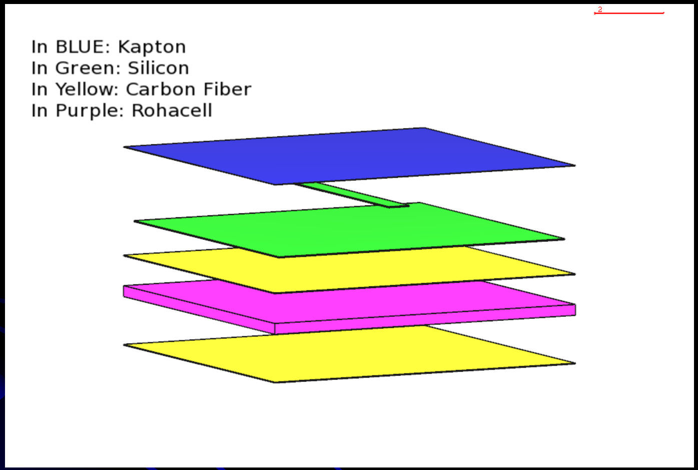
Endcap Inner Disks: 2.93 % X/Xo

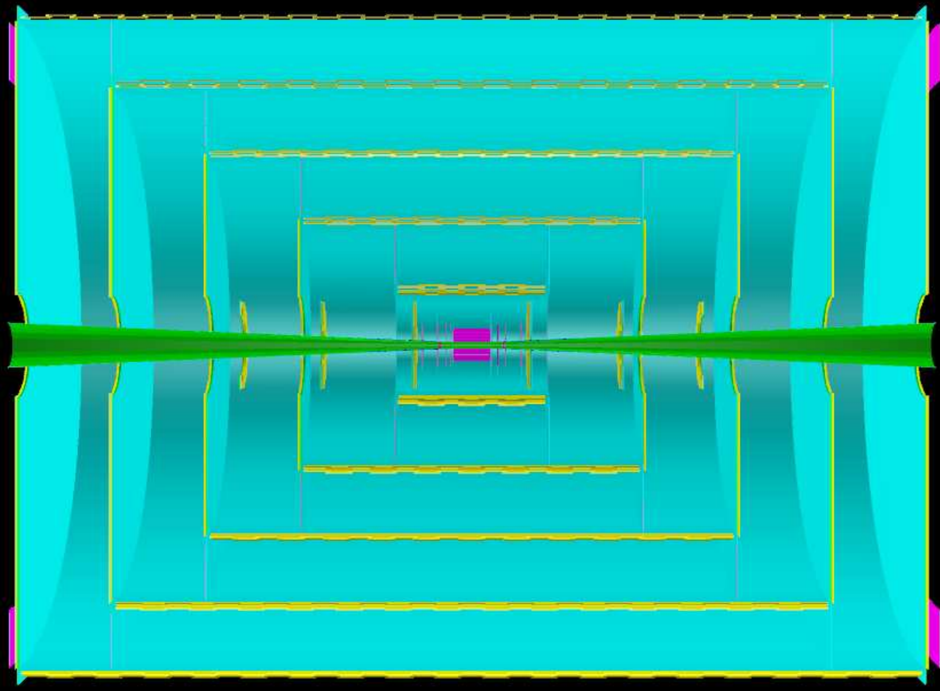
Endcap Outer Disks: 4.39-5.39% (with supports) X/Xo

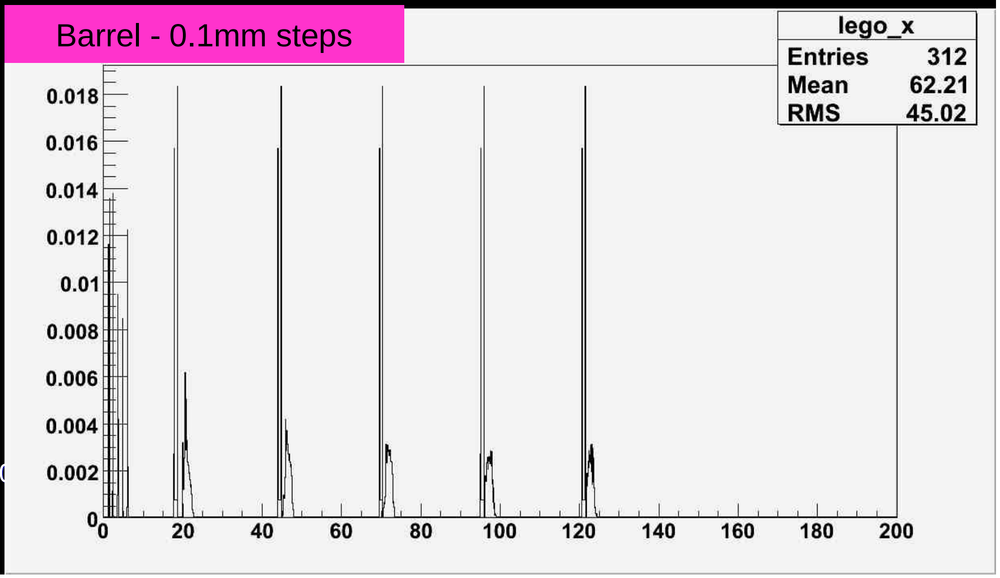
Integrated over φ

Tracking Option #2: Si-Pixel Tracker

- Same layout as Si Strip
- 100µm thikness Si detectors
- 50µm x 50µm pixels
- $\mathcal{O}(5\times10^{10})$ channels







Si Pixel Tracker

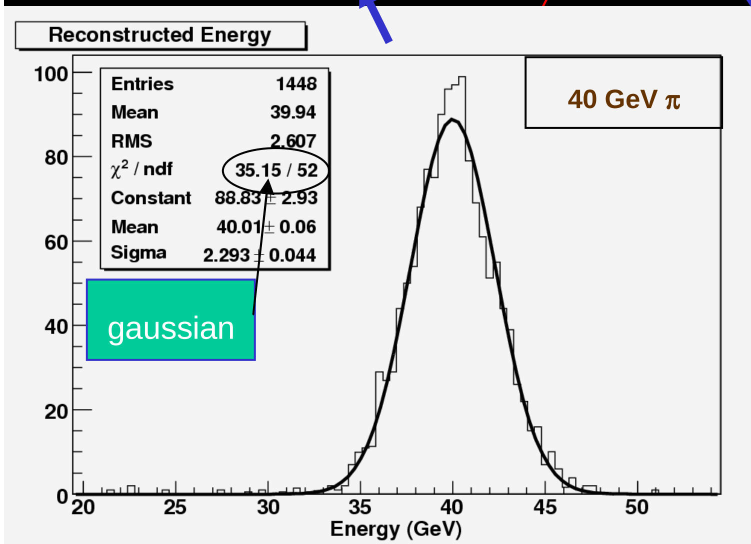
- Barrel : 4.8% (Si= 2.6% + Support=2.2%)
- Endcap Inner Disks: 2.22 % X/Xo
- Endcap Outer Disks: 3.78-4.28% (with supports) X/Xo

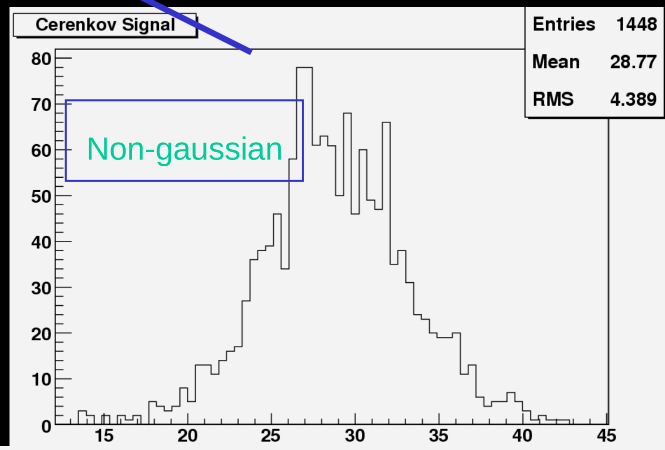
The 4th Concept Dual/Triple Readout Calorimeter

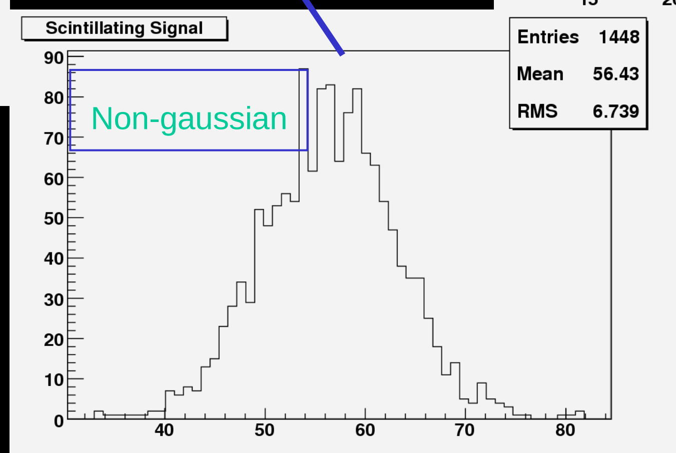
Dual Readout Calorimetry

Total calorimeter energy: use two measured signals and two, energy-independent, calibration constants

$$E_{HCAL} = \frac{\eta_S \cdot E_S \cdot (\eta_C - 1) - \eta_C \cdot E_C \cdot (\eta_S - 1)}{\eta_C - \eta_S}$$







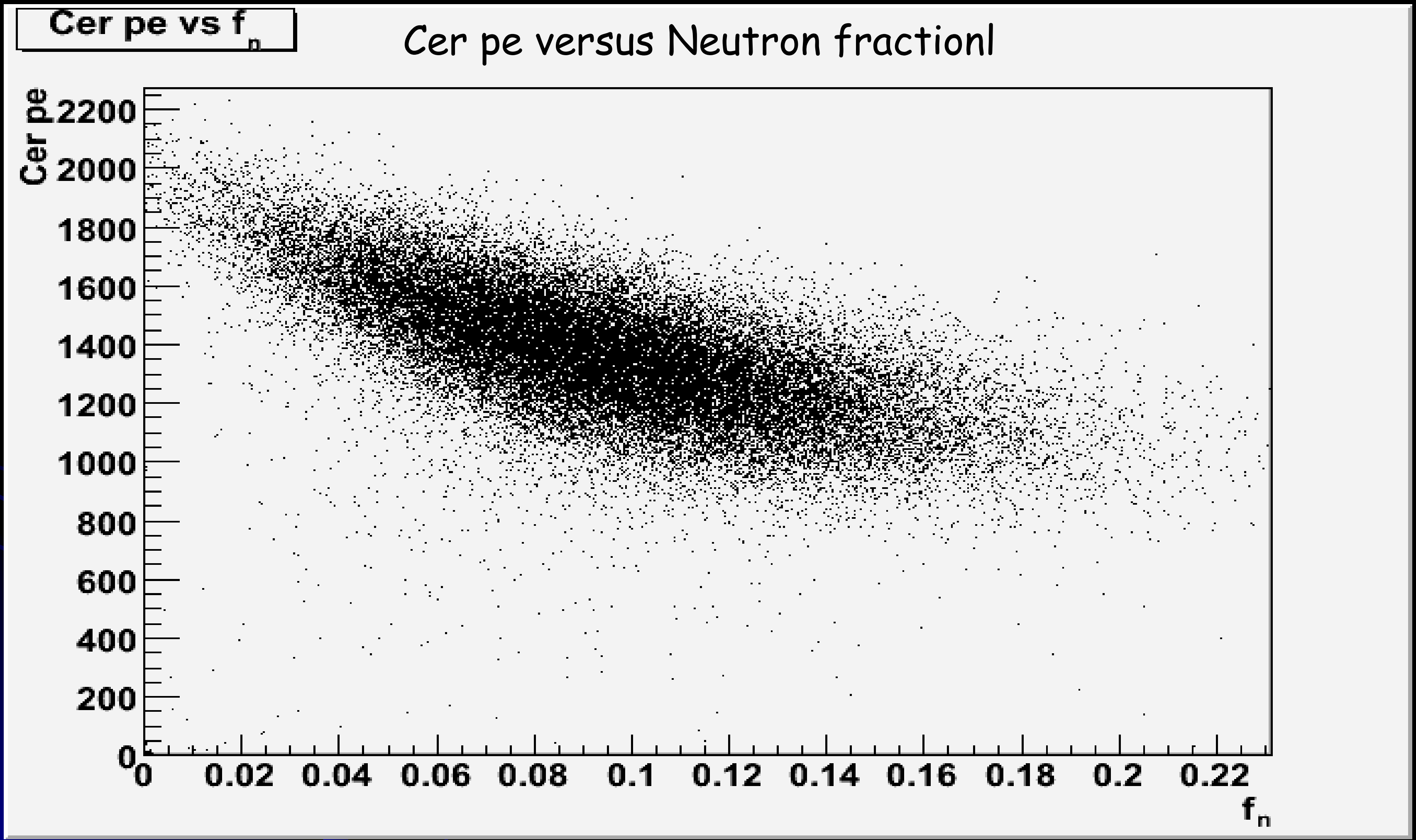
$$\eta_c = \left(\frac{e}{h}\right)_C \qquad \eta_S = \left(\frac{e}{h}\right)_S$$

From calibration

@ 1 Energy only

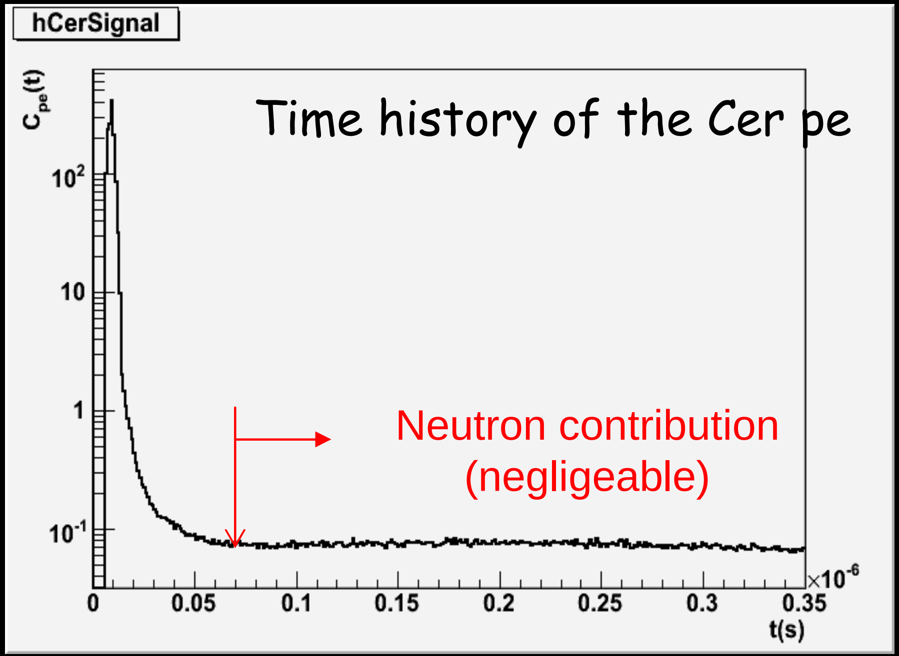
Improving the Energy Resolution: The Effect of Neutrons

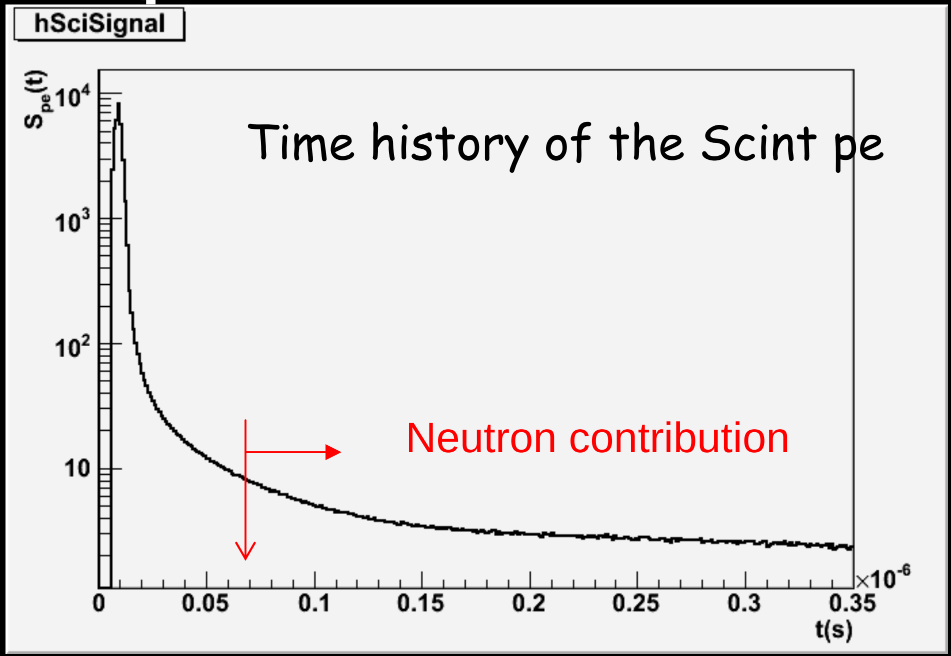
45 GeV π^-



ILCRoot simulation

From Dual to Triple Readout





45 GeV π⁻

$$E_{HCAL} = \frac{\eta_S \cdot E_S \cdot (\eta_C - 1) - \eta_C \cdot E_C \cdot (\eta_S - 1)}{\eta_C - \eta_S} + \eta_n \cdot E_{neutrons}$$

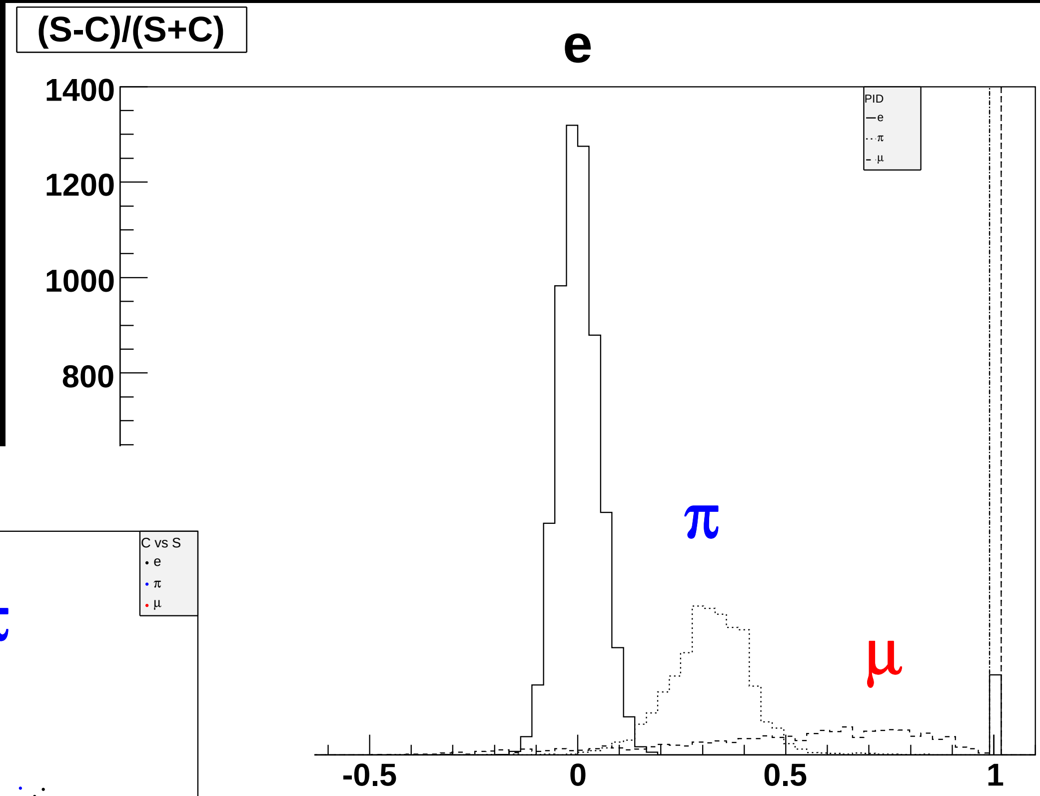
Triple readout aka Dual Readout with time history readout

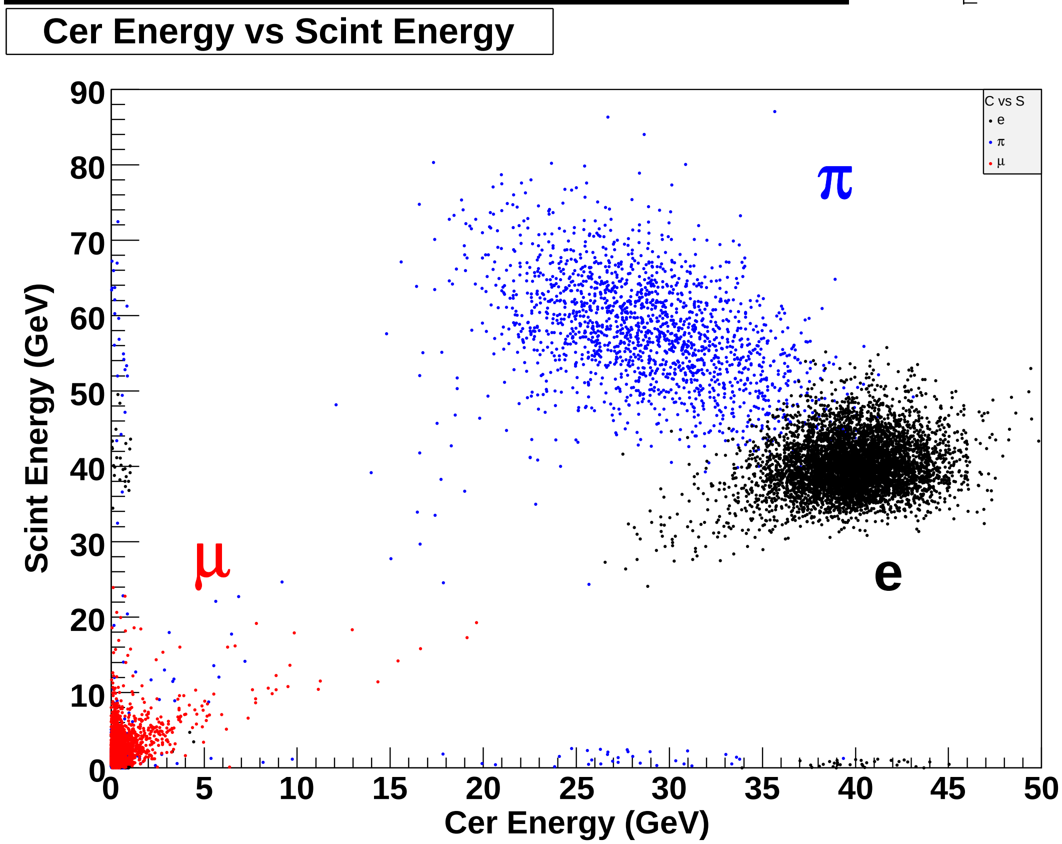
ILCRoot simulation

Particle Identification with Dual Readout

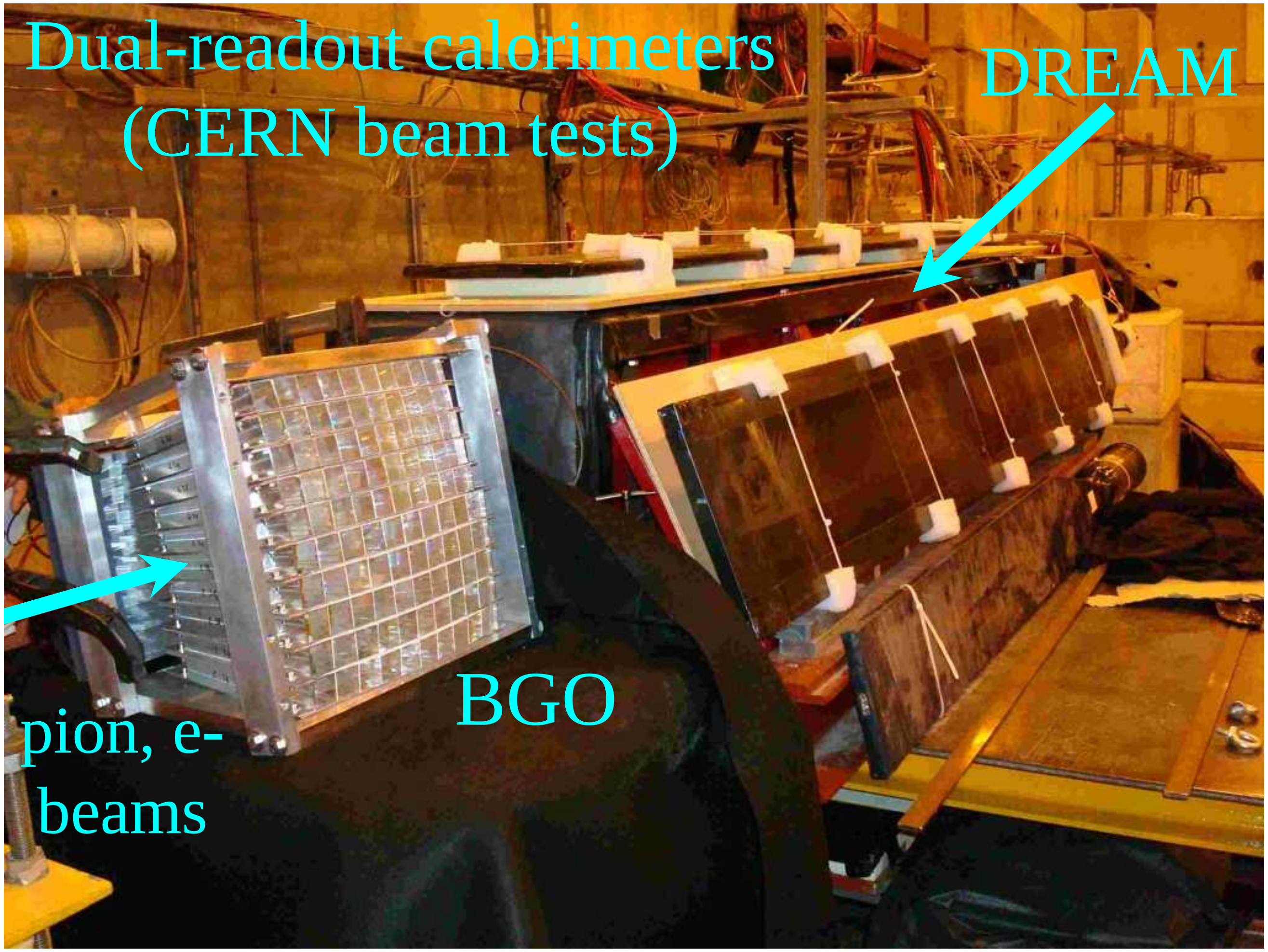
See J. Hauptman talk Monday morning

- 40 GeV particles

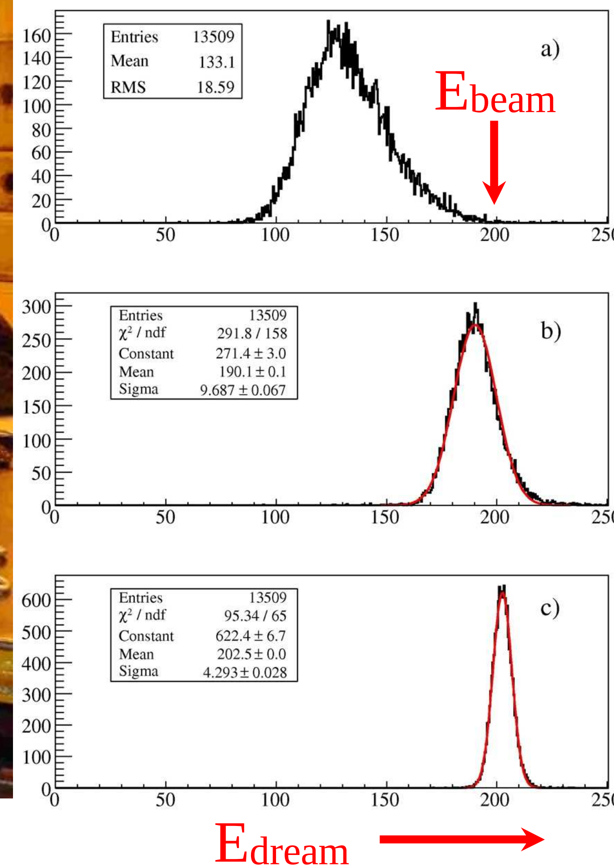


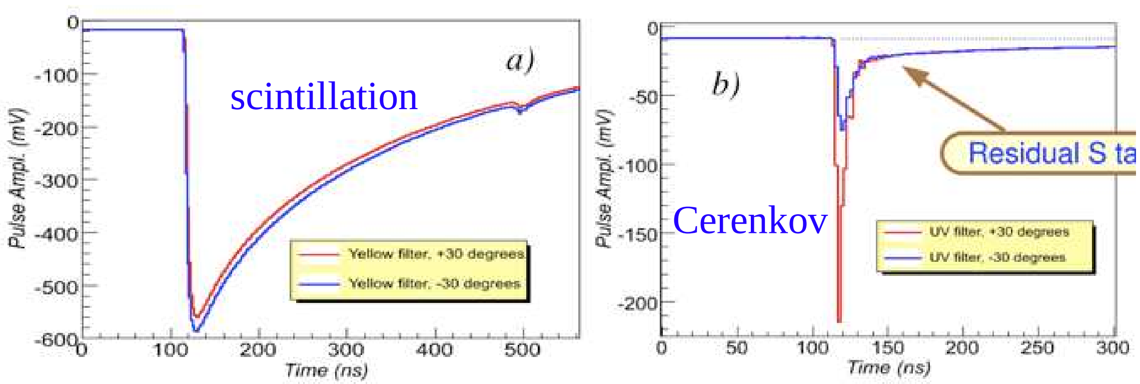


ILCRoot simulation



Hadronic energy resolution (fibers)





Dual-readout in BGO:
scintillation and Cerenkov
lights separated

The 4th Concept Calorimeter

Cu + scintillating fibers + Ĉerenkov fibers

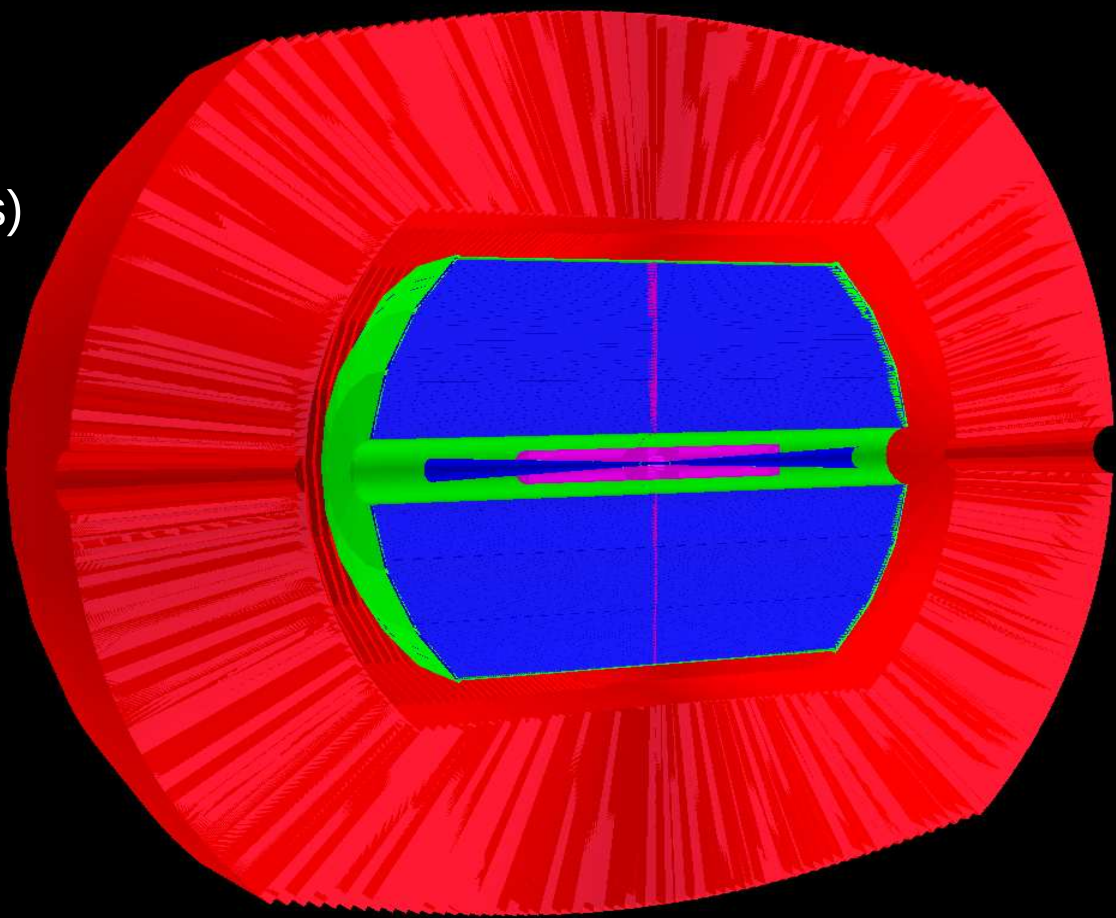
Fully projective layout

~1.4° aperture angle

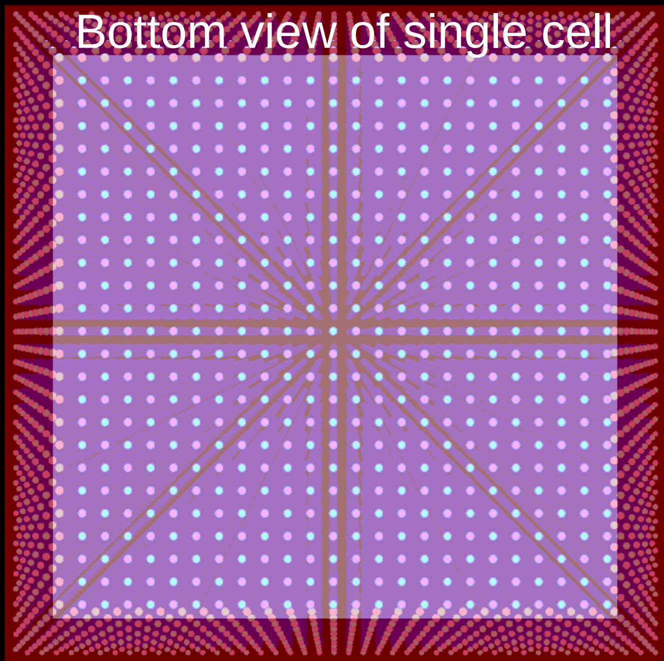
~ 7.3 <λ_{int}> (Fibers)

~ 8.3 <λ_{int}> (Crystal+Fibers)

- Azimuth coverage
  down to 2.8°
- Barrel: 16384 cells
- Endcaps: 7450 cells



Hadronic Calorimeter Cells



Prospective view of clipped cell

1 mm diameter

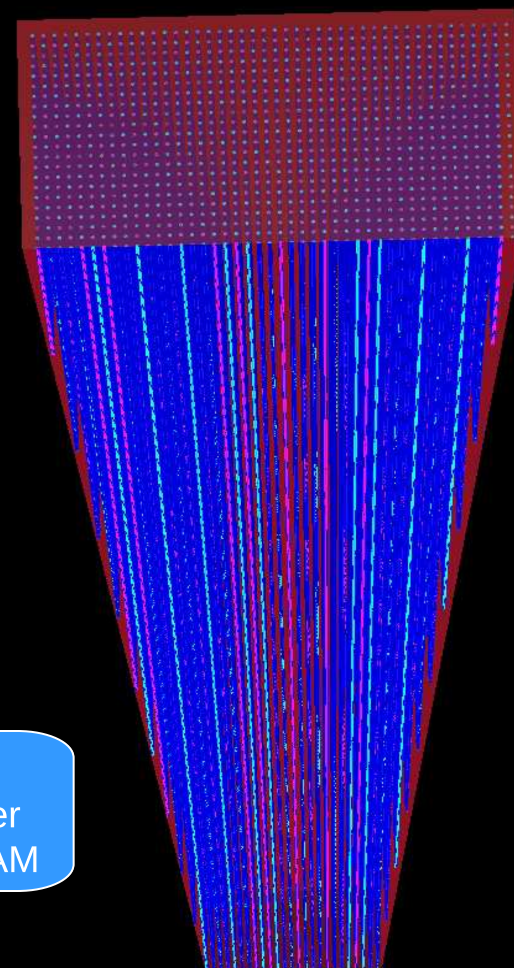
Plastic/Quartz fibers

Aperture Numb r=0.50

(C fibers

Same absorber/fiber ratio as DREAM

Top cell size:~ 8.1 × 8.1 cm^2



Bottom cell size: ~ 4.4 × 4.4 cm^2

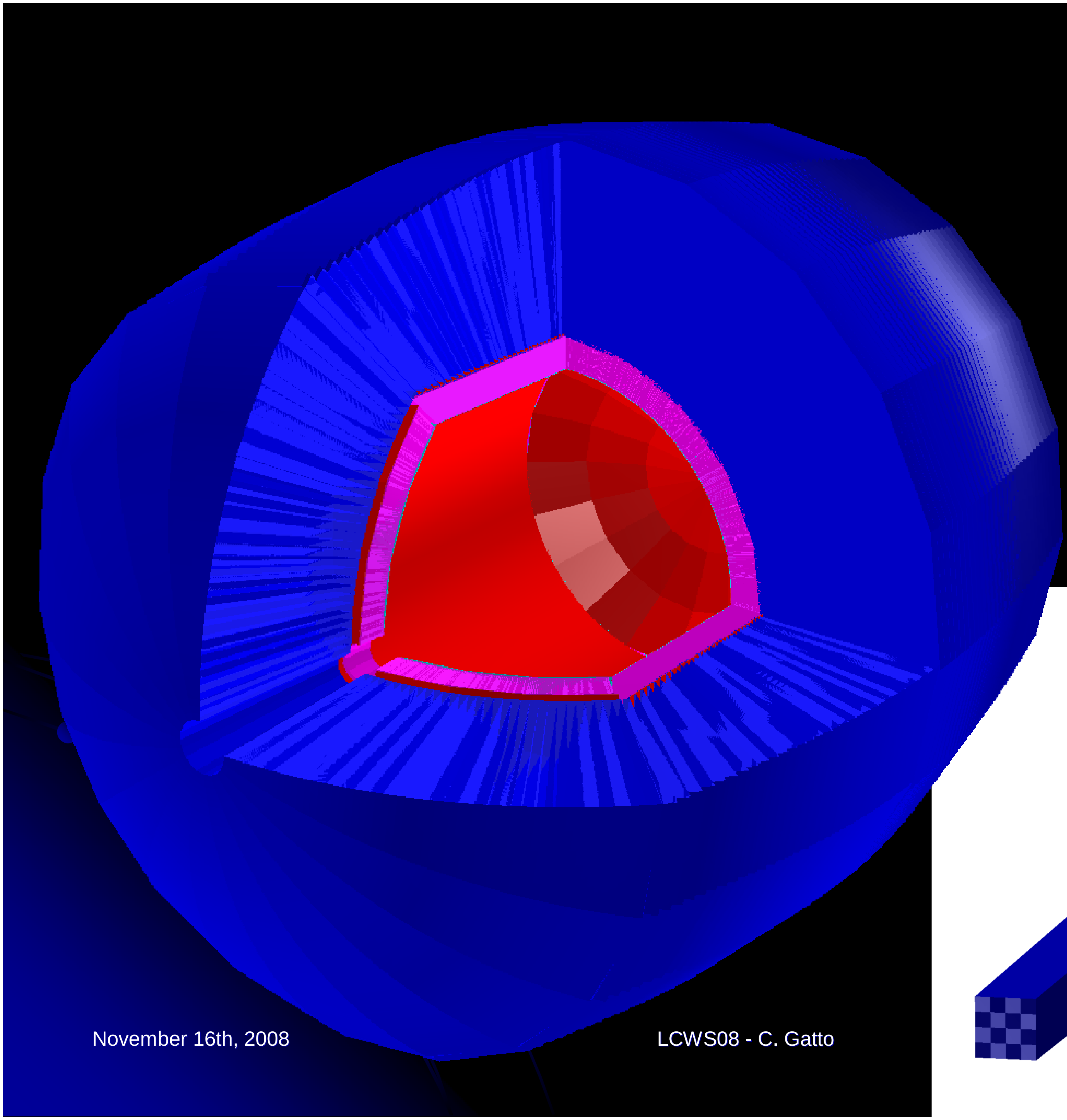
Number of fibers inside each cell: ~1600 equally subdivided between Scintillating and Cerenkov

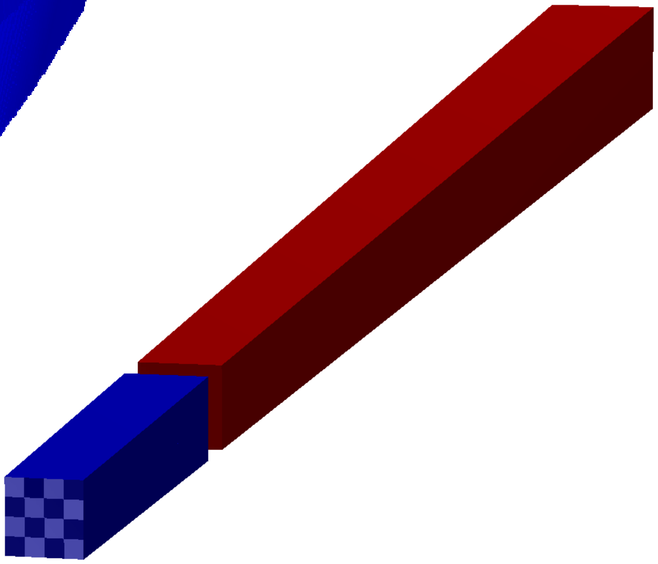
Fiber stepping ~2 mm

Cell length: 150 cm

Each tower works as two independent towers in the same volume

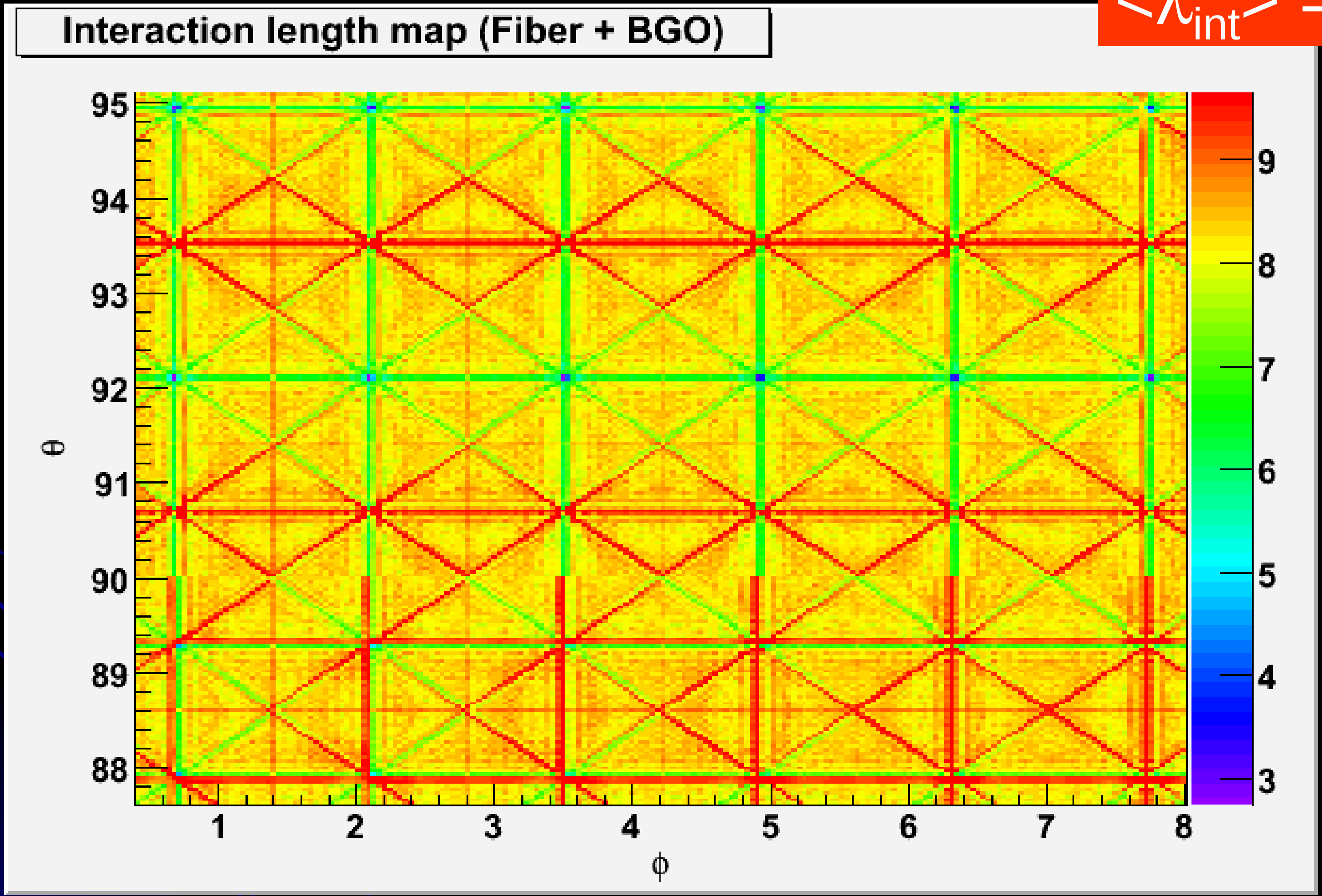
ECAL + HCAL





Material Budget Map (Crystal+Fibers)

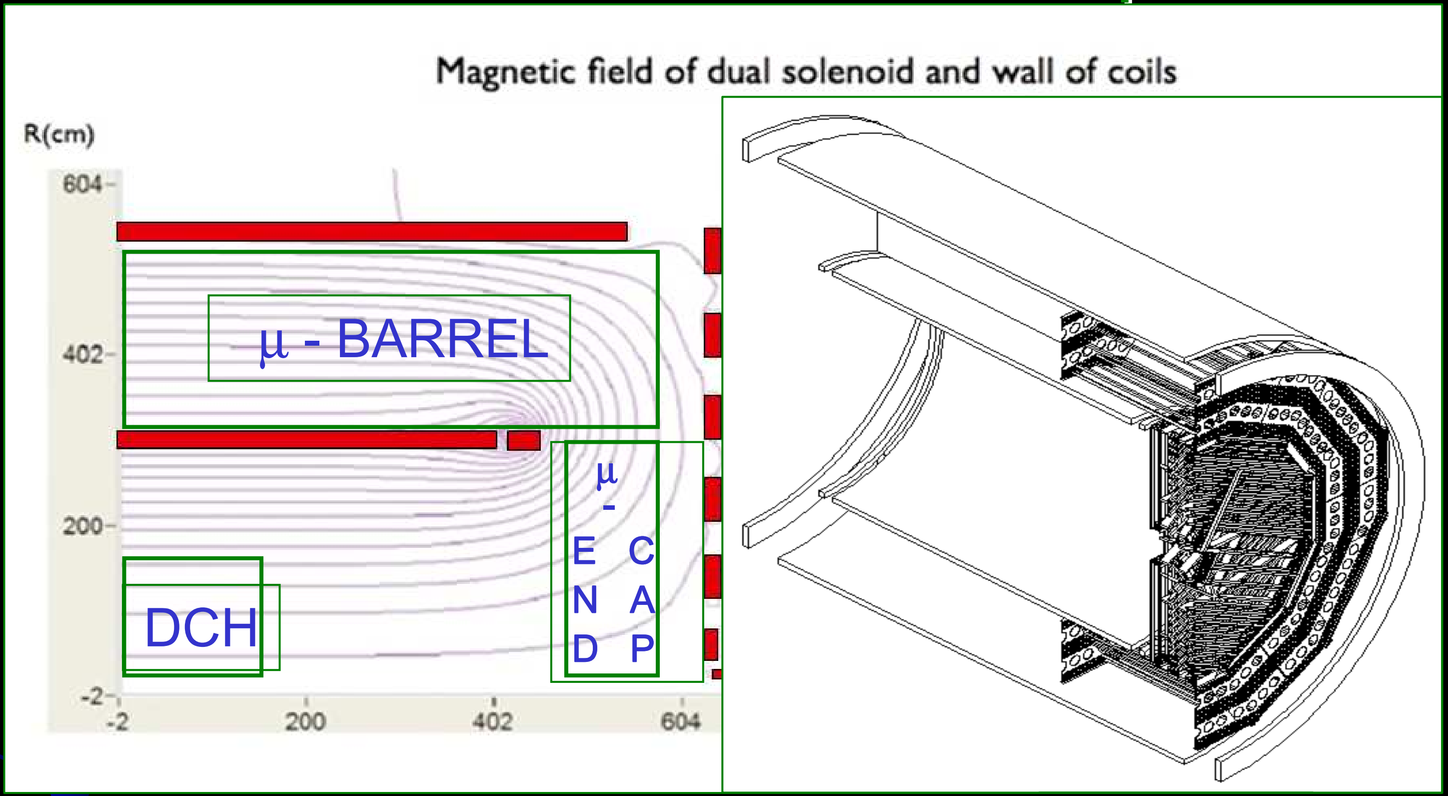
$<\lambda_{int}> = 8.3$



ILCRoot calculation

The 4th Concept Muon Spectrometer

Dual Solenoid B-field & Muon Spectrometer



radius 2.3 cm
filled with 90% He – 10% iC_4H_{10} @ NTP
gas gain few × 10^5
total drift time 2 μs
primary ionization 13 cluster/cm ⇒ ≈ 20 electrons/cm total
both ends instrumented with:

- > 1.5 GHz bandwith
- 8 bit fADC
- > 2 Gsa/s sampling rate
- free running memory

for a

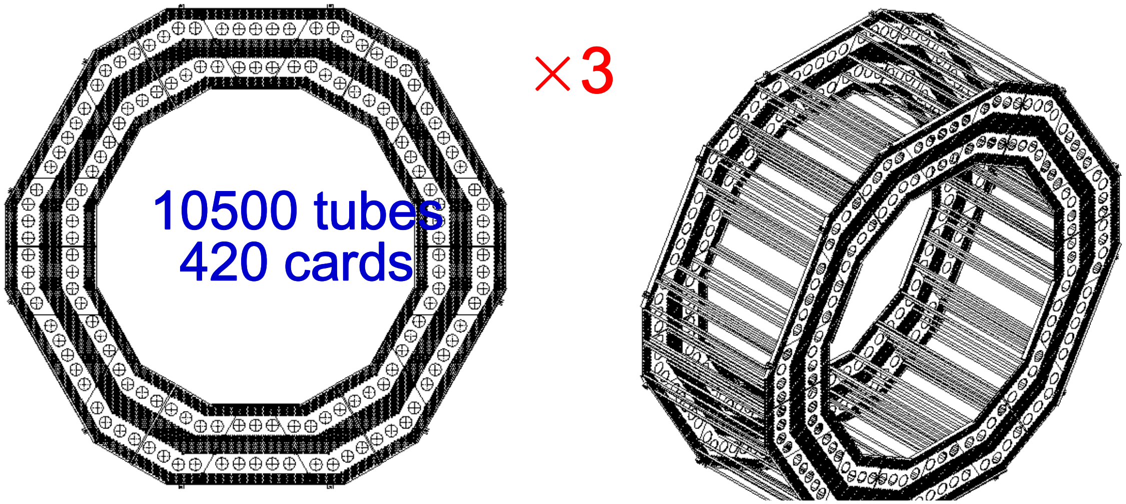
- fully efficient timing of primary ionization: cluster counting
- accurate measurement of longitudinal position with charge division
- particle identification with dN_{cl}/dx

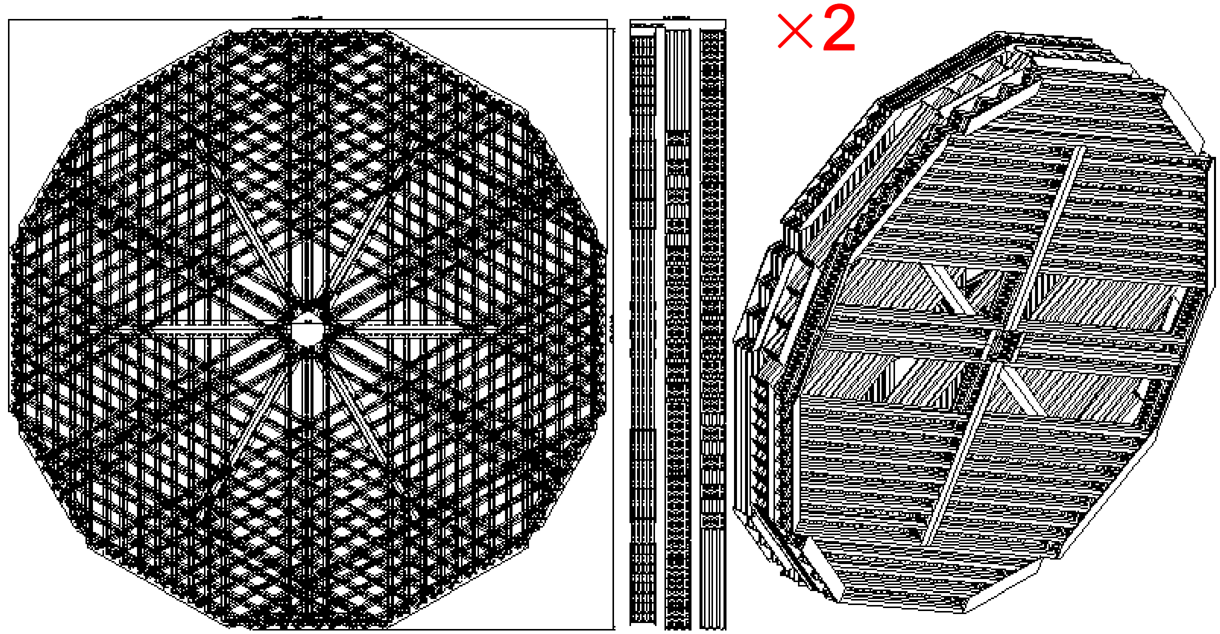
Barel:
31500 tubes
21000 channels
840 cards

End caps:
8640 tubes
9792 channels
456 cards

Total:
40140 tubes
30792 channels
1296 cards

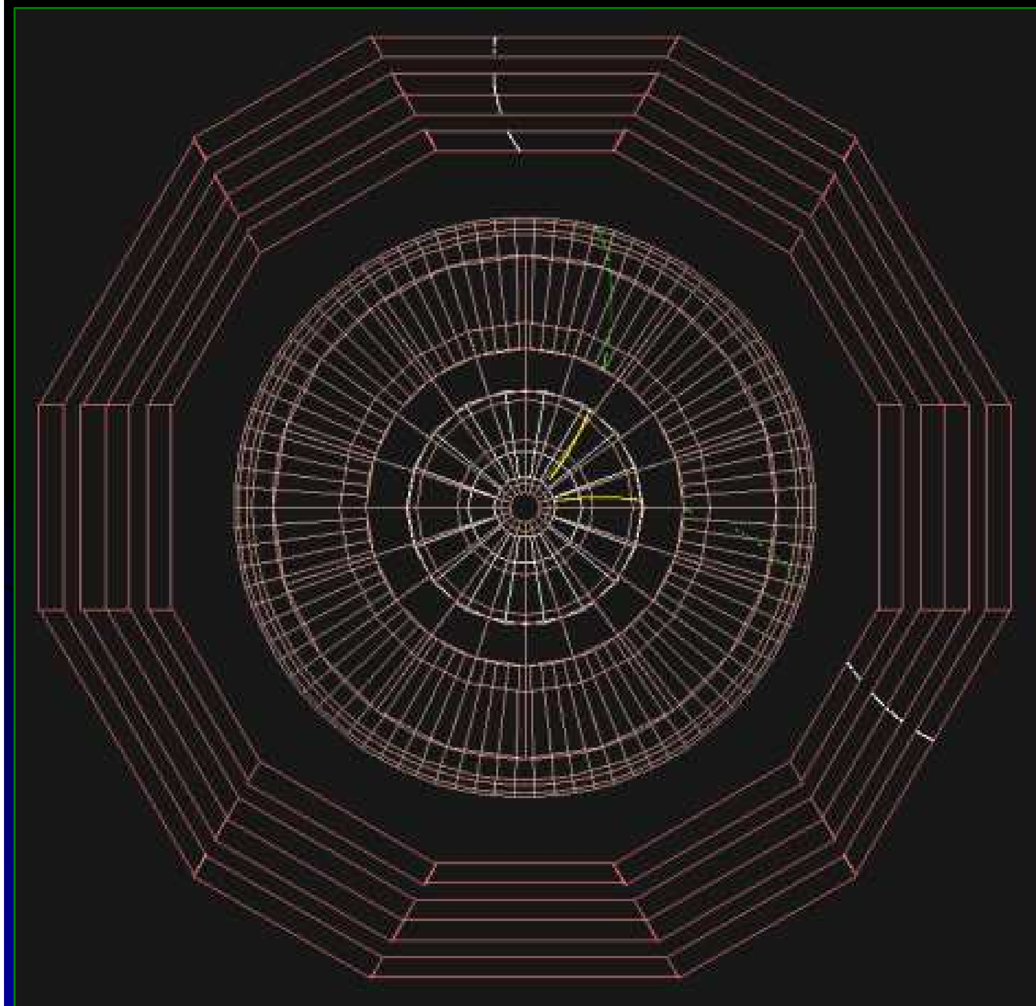
MUD Barrel (1/3)+Endcap





November 16th, 2008

$\mu^+ \mu^-$ at 3.5 GeV/c



ILCRoot simulation

4^{th} Concept Detector Performance Studies

See also the following talks:

J. Hauptman on Monday morning on Particle ID
F. Ignatov on Tuesday afternoon on tracking with beam background
M. Rucco on Tuesday afternoon on tracking performance
A. Mazzacane on Wednsday afternoon on Performance with jets
V. Di Benedetto on Tuesday morning on Performance of Dual Readout

4th Concept Software Strategy: ILCroot

- **CERN** architecture (based on Alice's Aliroot)
- Full support provided by Brun, Carminati, Ferrari, et al.
- Uses ROOT as infrastructure
  - All ROOT tools are available (I/O, graphics, PROOF, data structure, etc)
  - Extremely large community of users/developers
- TGenerator for events generation
- Virtual Geometry Modeler (VGM) for geometry
- Based on Virtual Montecarlo
- Could it ever evolve into a general purpose entity for the HEP community (as ROOT)?
- Growing number of experiments have adopted it: Alice, Opera, CMB, (Meg), Panda, 4th Concept
- Six MDC have proven robustness, reliability and portability

Do not Reinvent the wheel

Concentrate on Detector studies and Physics

The Virtual Montecarlo Concept

- Virtual MC provides a virtual interface to Monte Carlo
- It allows to run the same user application with all supported Monte Carlo programs
- The concrete Monte Carlo (Geant3, Geant4, Fluka) is selected and loaded at run time
  - Compare Montecarlo performance and possible flows
  - Choose the optimal Montecarlo for the study

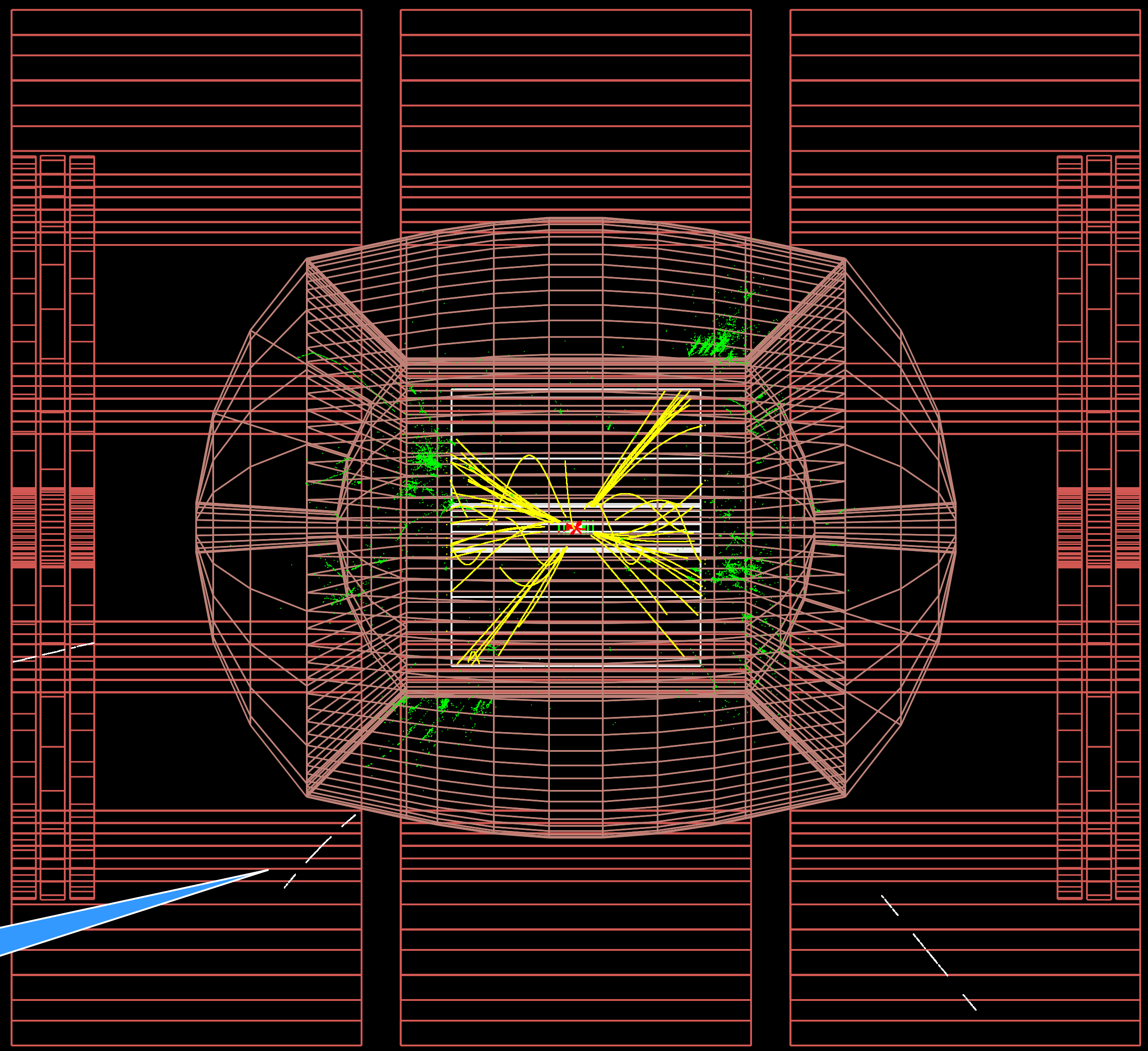
Perfect Tool for Designing/Optimizing new Detectors

Detectors in ILCroot

- VTX Detectors: 4th Concept,SiD, FTD (from SiLC)
- Central Trackers: TPC, Drift Chamber (3 versions), Si-Strips (SID01), SPT (Pixel Tracker)
- HCAL: DREAM (3 versions)
- ECAL: 4th Concept (2 versions)
- Muon Spectrometer: 4th Concept
- **Total: 10 subdetectors (15 versions), most of them with full simulation**

Event Display in ILCroot

e^+e^- -> $H^oH^oZ^o$ –> 4 jets 2 muons ECM = 500 GeV

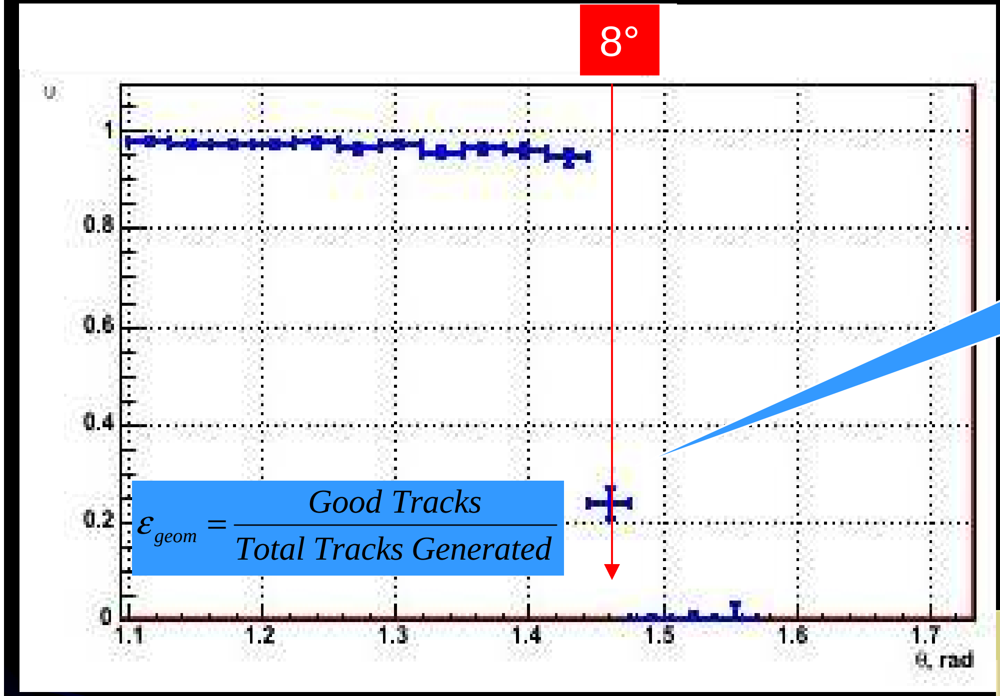


Low pt secondary muon

Single tracks
No beam bkg

Tracking Performance

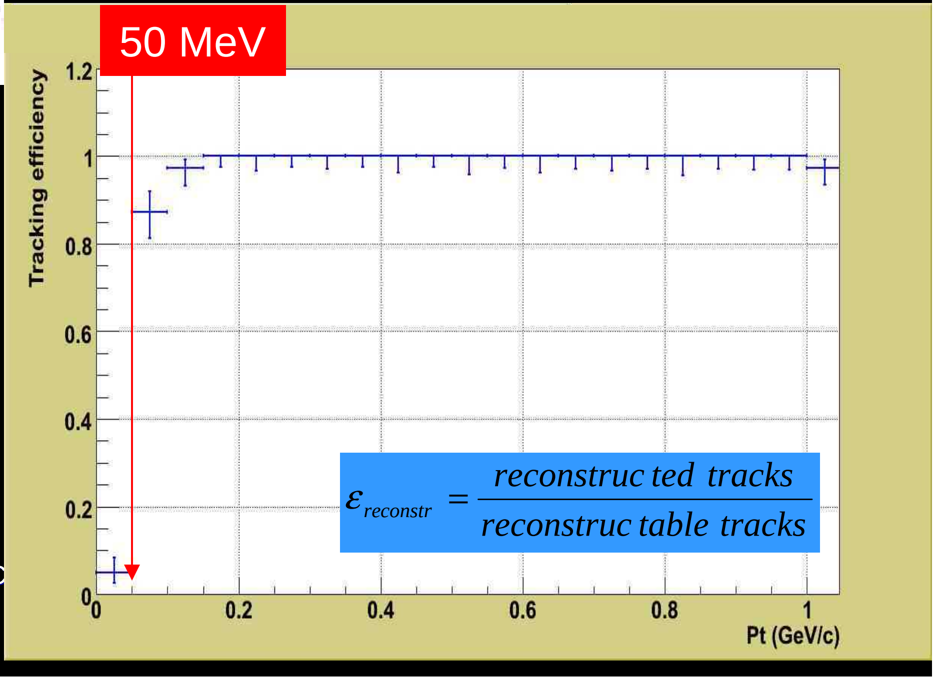
10 muons



Tracking efficiency at low angle will improve with addition of Si in the fwd regions

Defining "reconstructable tracks"

I. DCA(true) < 3.5 cm
AND
II. (At least 10 hits in DCH
OR
III. At least 4 hits in VTX)

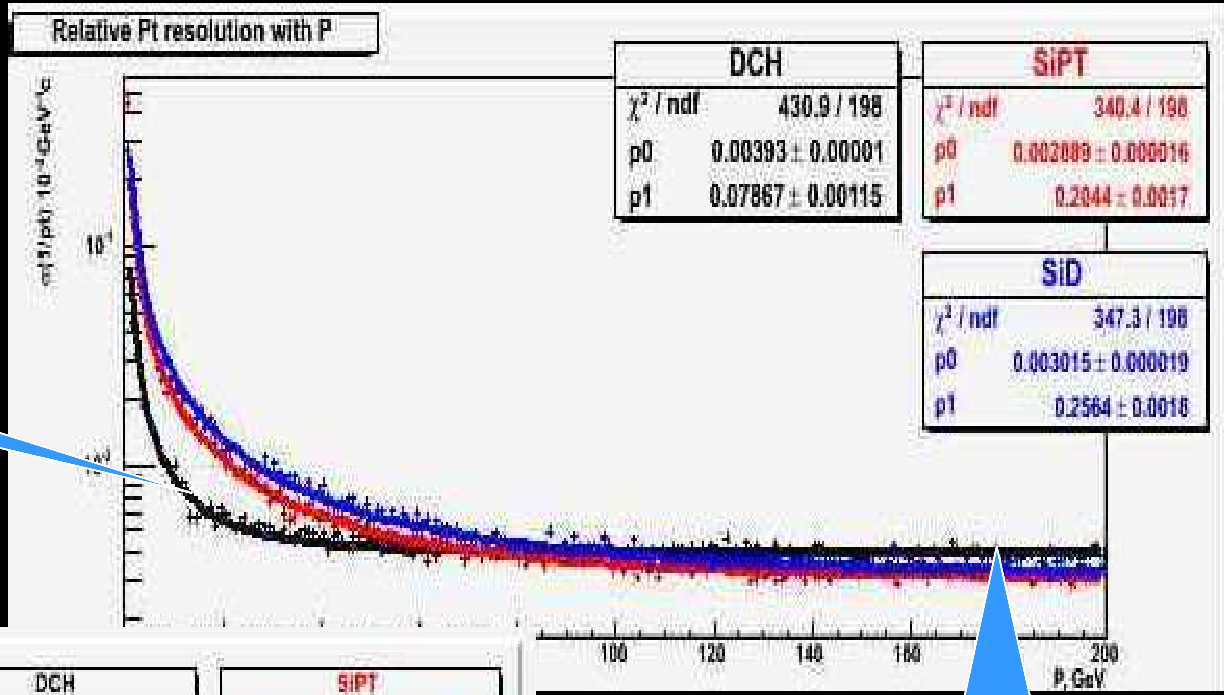


See M. Rucco talk
Tuesday afternoon

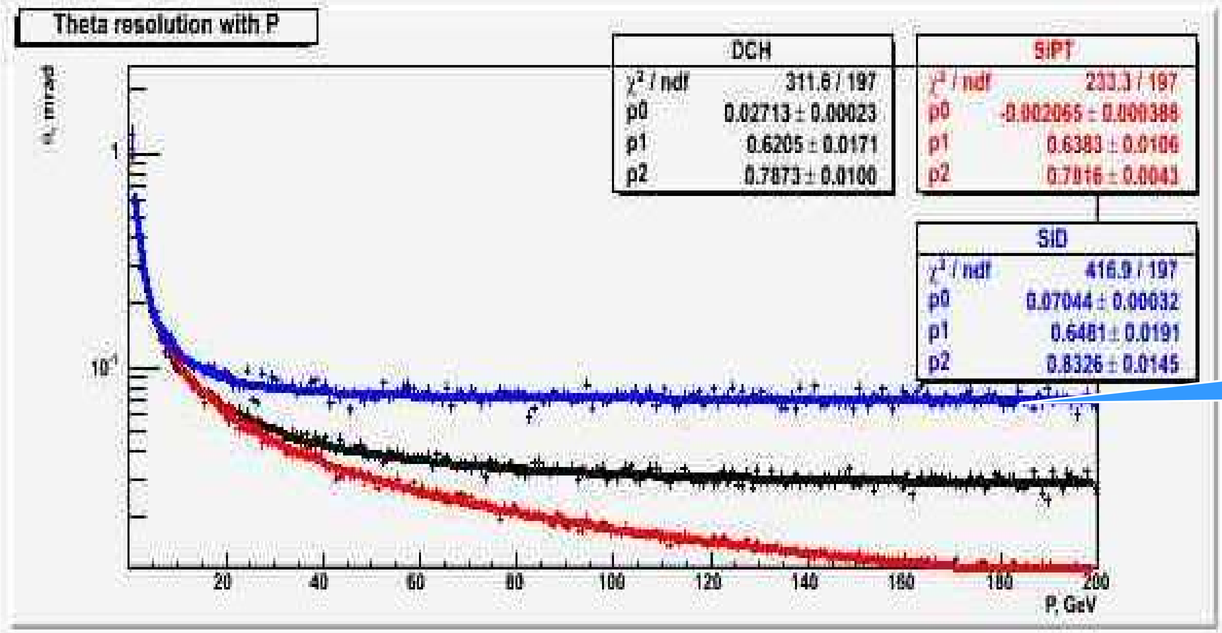
10 muons

Comparing Central Trackers Performance

DCH with 3.5 T field
SID/SIPT with 5 T field



Lower multiple scattering



Lower B field

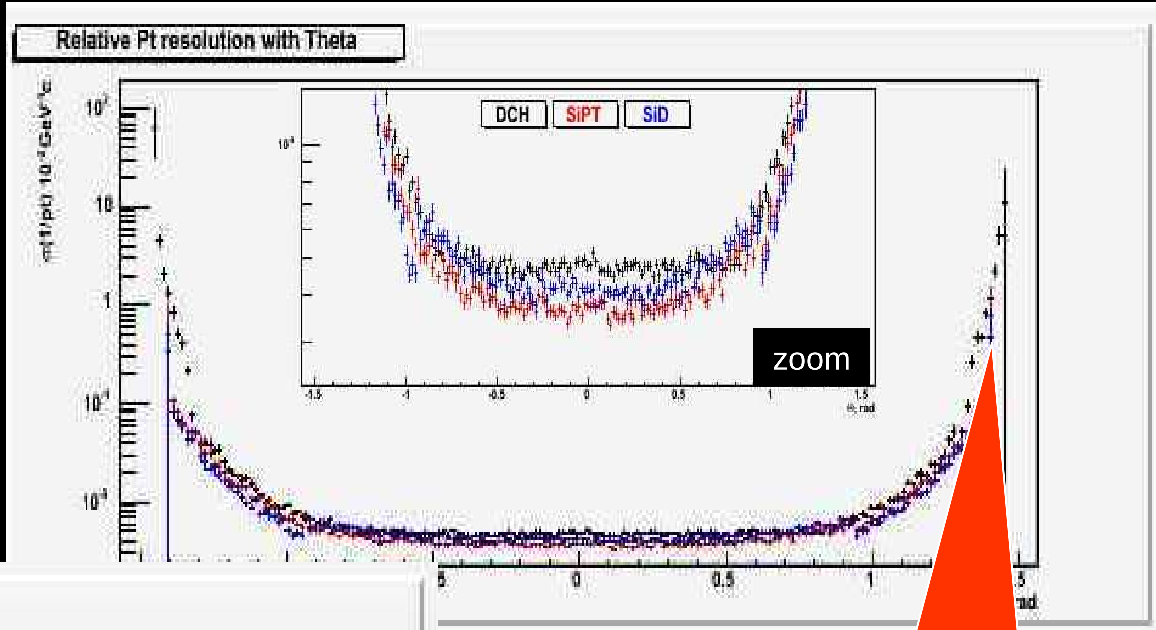
Single sensors in barrel

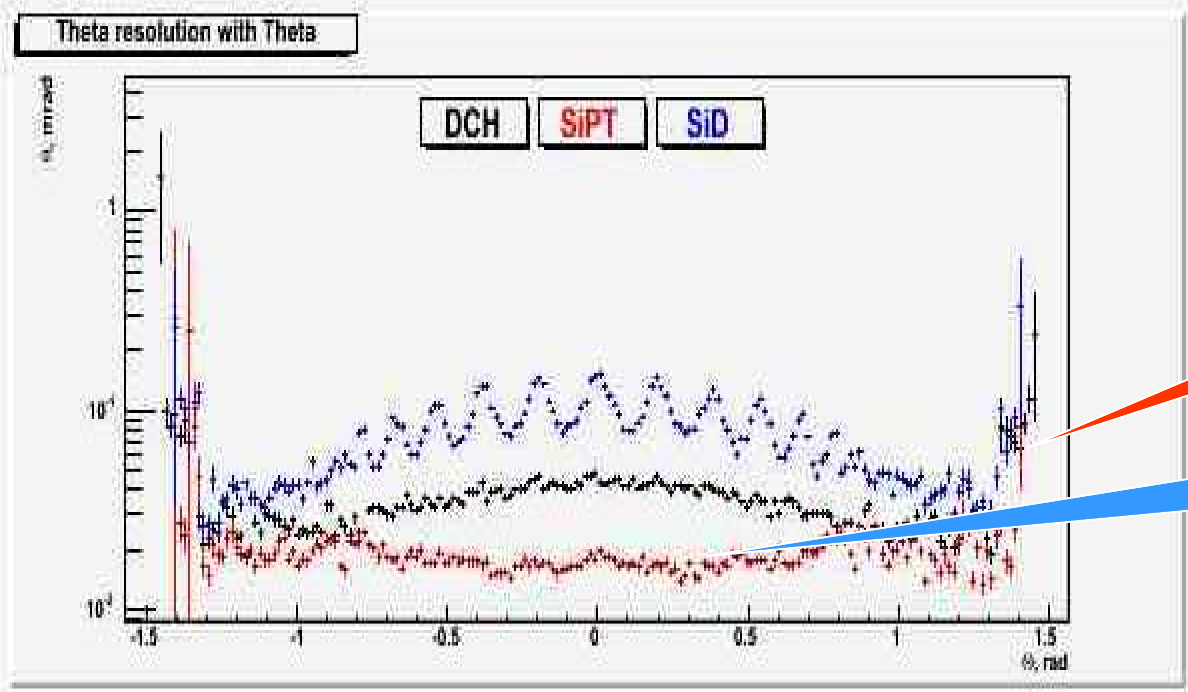
See M. Rucco talk
Tuesday afternoon

10 muons

Comparing Central Trackers Performance

DCH with 3.5 T field
SID/SIPT with 5 T field





Silicon in fwd/bwd region is mandatory

Pixels excels in θ reconstruction

See M. Rucco talk Tuesday afternoon

Tracking Performance for Single Tracks (P=[0.02,200] GeV) in 5 Tesla

CluCou

$$\sigma(P_t^{-1}) = 7.9/P \oplus 0.39 \times 10^{-4}\, GeV^{-1}c$$
$$\sigma(\vartheta) = 0.62/P^{0.79} \oplus 0.027\ mrad$$
$$\sigma(\varphi) = 1.30/P \oplus 0.031\ mrad$$
$$\sigma(D_o) = 12.8/P^{0.46} \oplus 2.1\ \mu m$$
$$\sigma(Z_o) = 15.7/P^{0.58} \oplus 2.9\ \mu m$$

Pixel Tracker

$$\sigma(P_t^{-1}) = 20.4/P \oplus 0.29 \times 10^{-4}\, GeV^{-1}c$$
$$\sigma(\vartheta) = 0.64/P^{0.78} \oplus 0.002\ mrad$$
$$\sigma(\varphi) = 1.41/P \oplus 0.027\ mrad$$
$$\sigma(D_o) = 12.7/P^{0.61} \oplus 2.1\ \mu m$$
$$\sigma(Z_o) = 13.5/P^{0.57} \oplus 2.1\ \mu m$$

SiD Tracker

$$\sigma(P_t^{-1}) = 24.1/P \oplus 0.31 \times 10^{-4}\, GeV^{-1}c$$
$$\sigma(\vartheta) = 0.6/P^{0.83} \oplus 0.07\ mrad$$
$$\sigma(\varphi) = 1.4/P \oplus 0.029\ mrad$$
$$\sigma(D_o) = 12.2/P^{0.55} \oplus 2.1\ \mu m$$
$$\sigma(Z_o) = 16.8/P^{0.84} \oplus 4.4\ \mu m$$

3.5 – 5 Tesla effect

Tracking Performance for Single Tracks (P=[0.02,200] GeV) in 5 Tesla

CluCou

$$\sigma(P_t^{-1}) = 7.9/P \oplus 0.39\times10^{-4}\,GeV^{-1}c$$
$$\sigma(\vartheta) = 0.62/P^{0.79} \oplus 0.027\ mrad$$
$$\sigma(\varphi) = 1.30/P \oplus 0.031\ mrad$$
$$\sigma(D_o) = 12.8/P^{0.46} \oplus 2.1\ \mu m$$
$$\sigma(Z_o) = 15.7/P^{0.58} \oplus 2.9\ \mu m$$

Pixel Tracker

$$\sigma(P_t^{-1}) = 20.4/P \oplus 0.29\times10^{-4}\,GeV^{-1}c$$
$$\sigma(\vartheta) = 0.64/P^{0.78} \oplus 0.002\ mrad$$
$$\sigma(\varphi) = 1.41/P \oplus 0.027\ mrad$$
$$\sigma(D_o) = 12.7/P^{0.61} \oplus 2.1\ \mu m$$
$$\sigma(Z_o) = 13.5/P^{0.57} \oplus 2.1\ \mu m$$

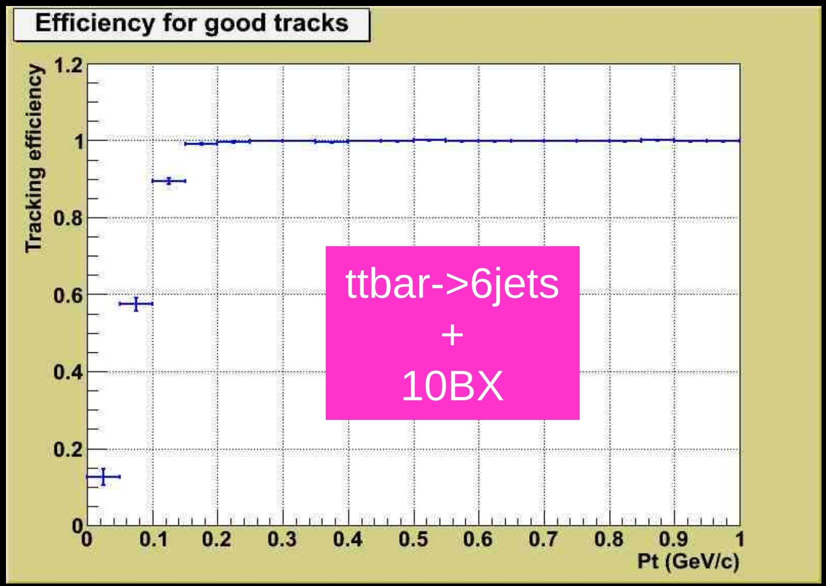
SiD Tracker

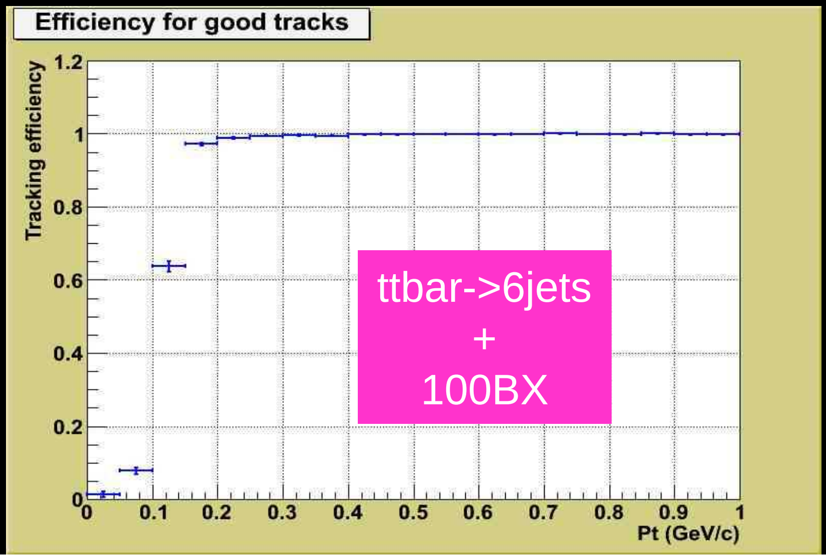
$$\sigma(P_t^{-1}) = 24.1/P \oplus 0.31\times10^{-4}\,GeV^{-1}c$$
$$\sigma(\vartheta) = 0.6/P^{0.83} \oplus 0.07\ mrad$$
$$\sigma(\varphi) = 1.4/P \oplus 0.029\ mrad$$
$$\sigma(D_o) = 12.2/P^{0.55} \oplus 2.1\ \mu m$$
$$\sigma(Z_o) = 16.8/P^{0.84} \oplus 4.4\ \mu m$$

MS effect

Single sensor effect

Tracking Efficiency with Beam Background in CluClou Tracker



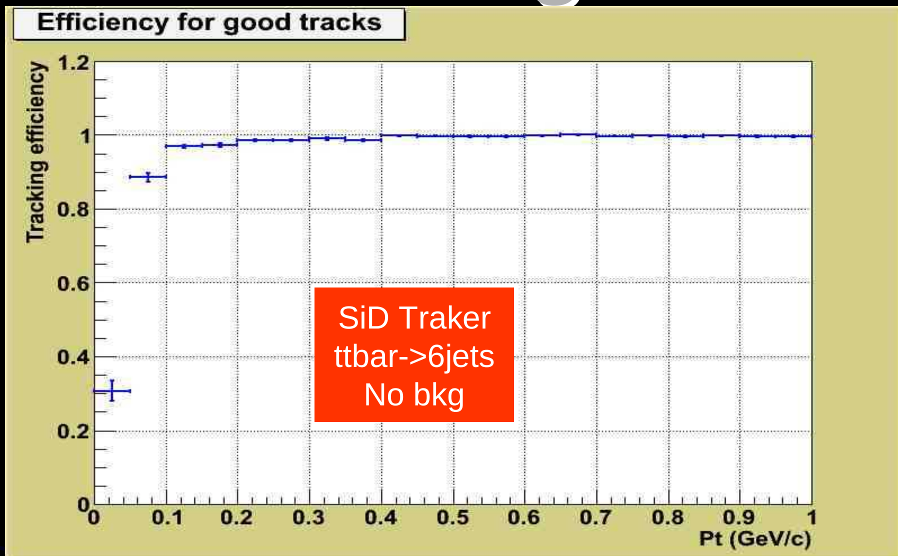


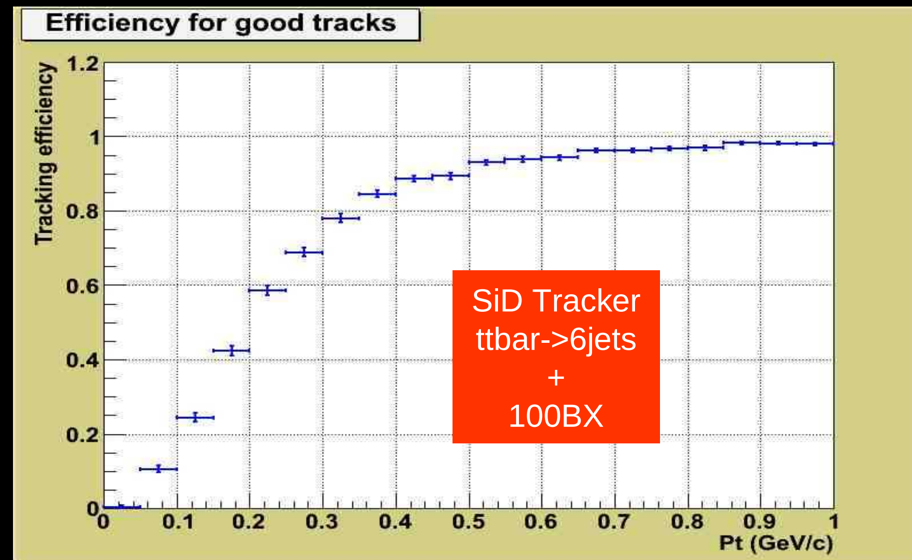
- ttbar->6jets
- Drift chamber + VTX
- Full simulation/reconstruction
- 3.5 Tesla B-field

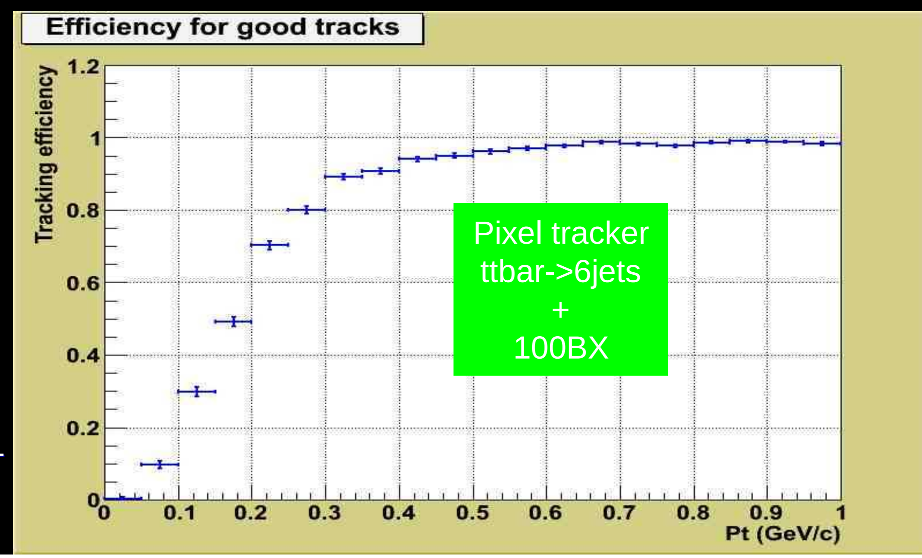
See F. Ignatov talk Tuesday afternoon

ttbar->6jets

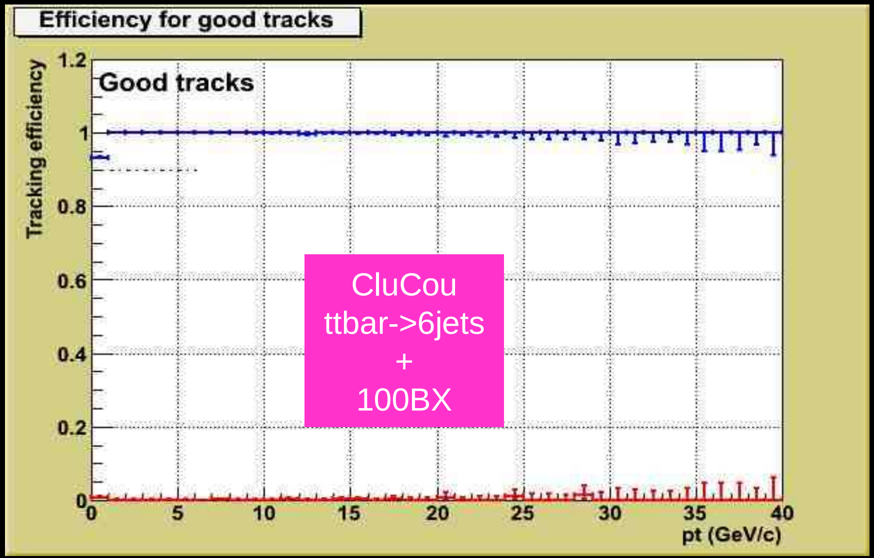
Tracking Efficiency with Beam Background in Si-Trackers

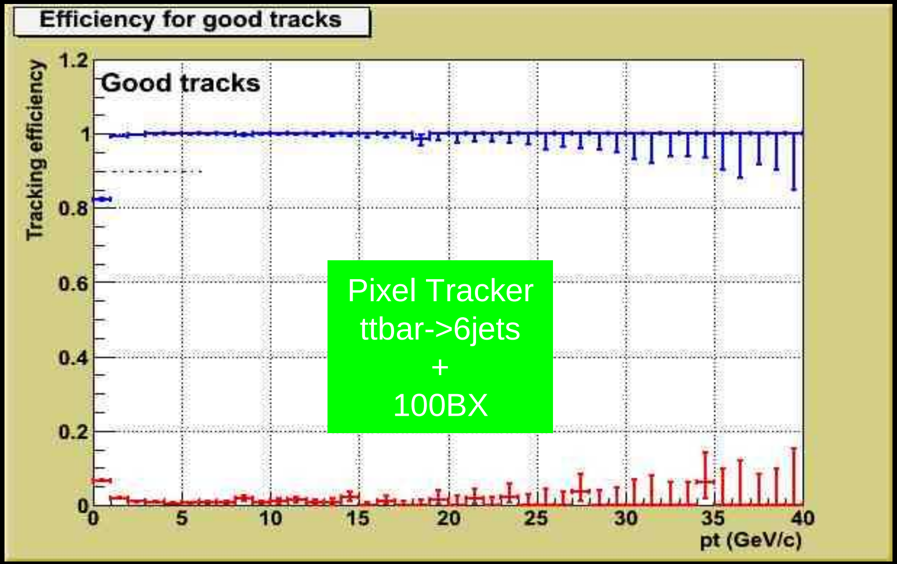


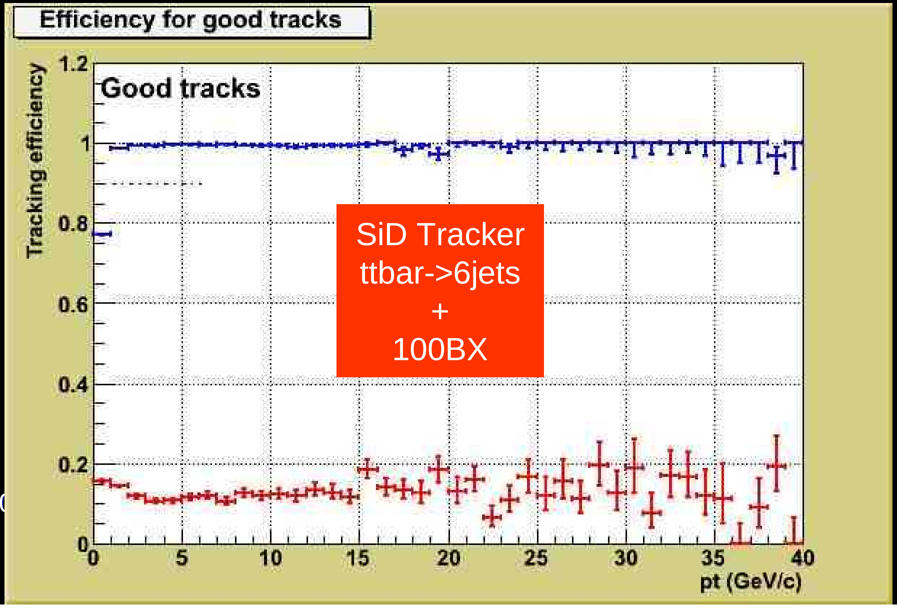




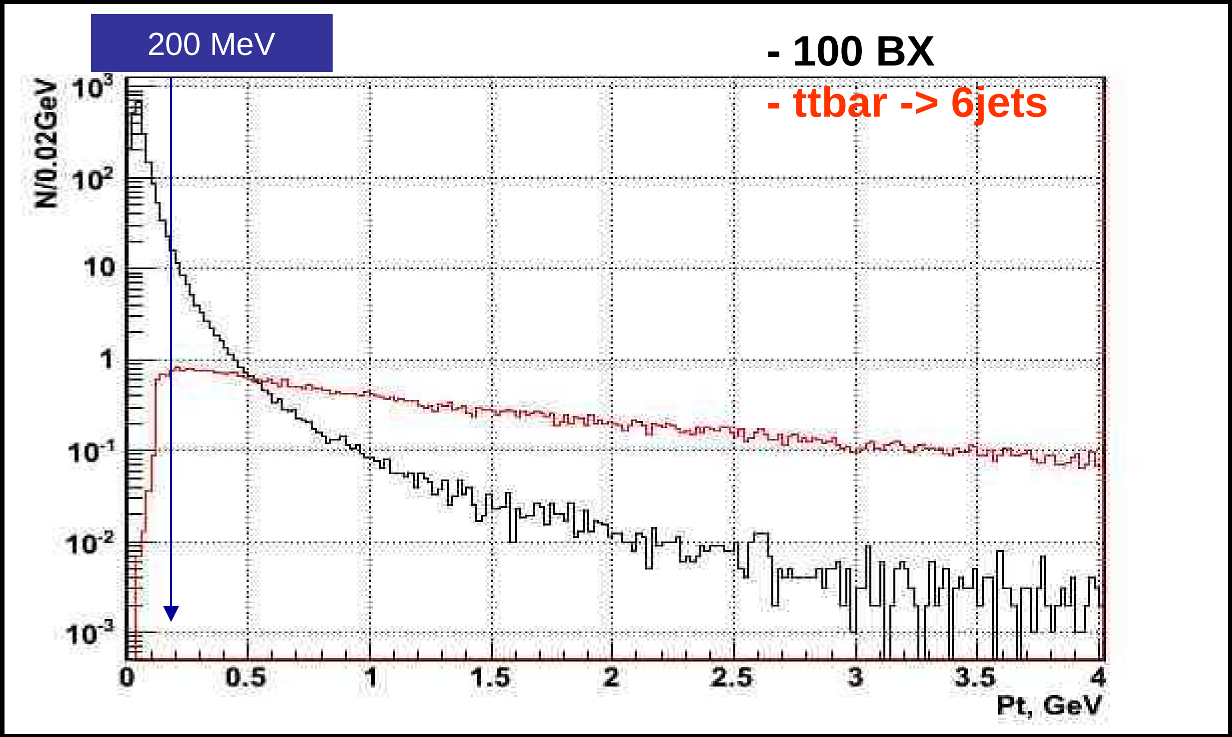
Efficiency vs Fake Clusters with Beam Background

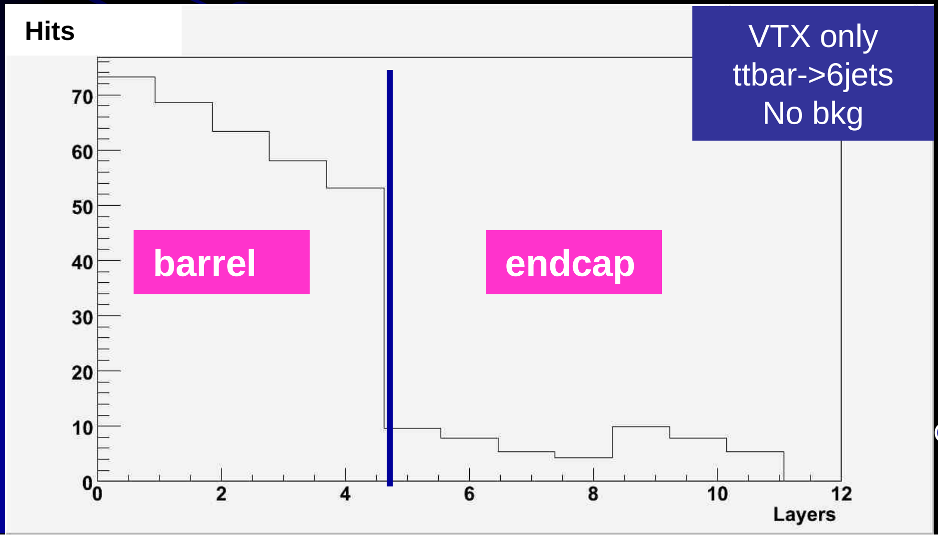


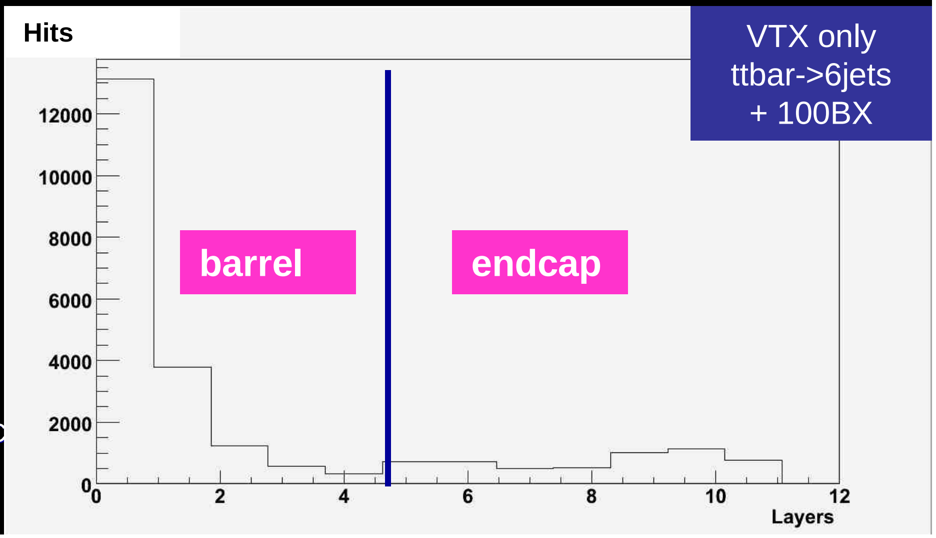




P_t Spectrum of Reconstructed Tracks



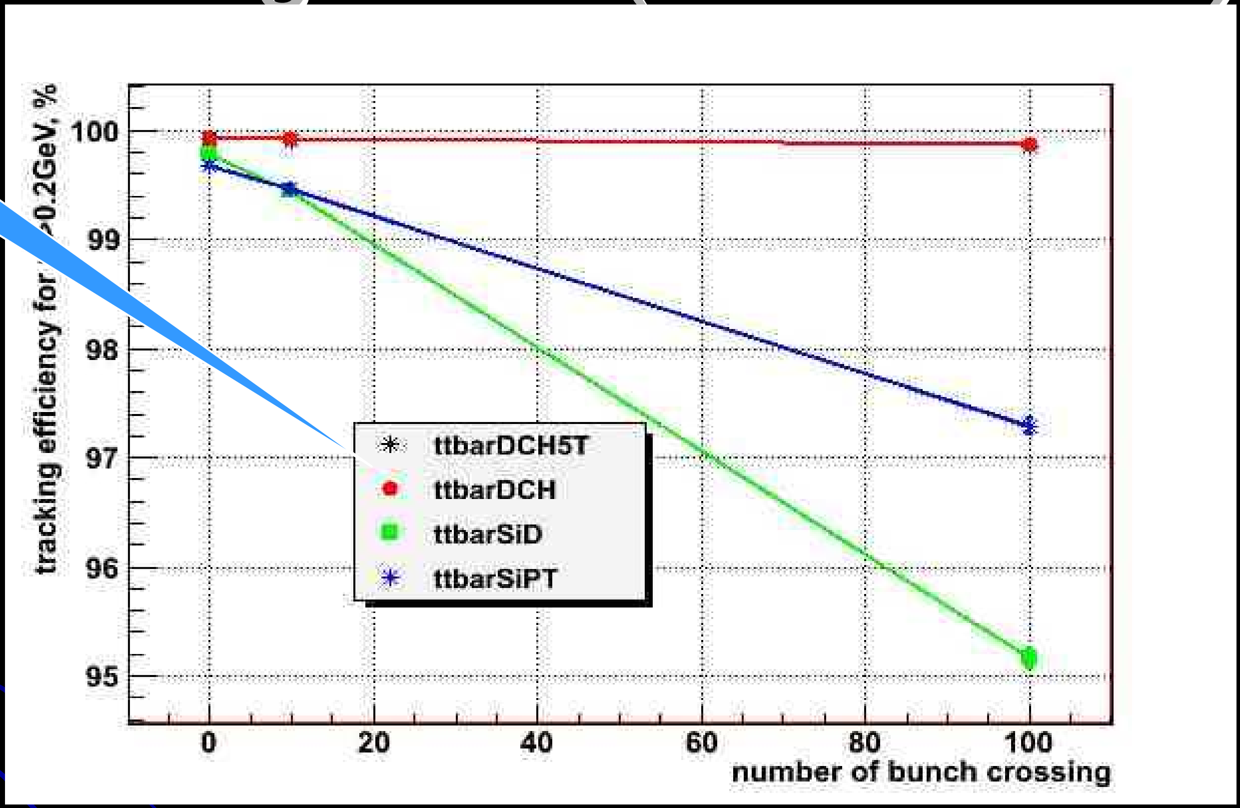




ttbar->6jets

Tracking efficiency with Beam Background (Pt>0.2 GeV)

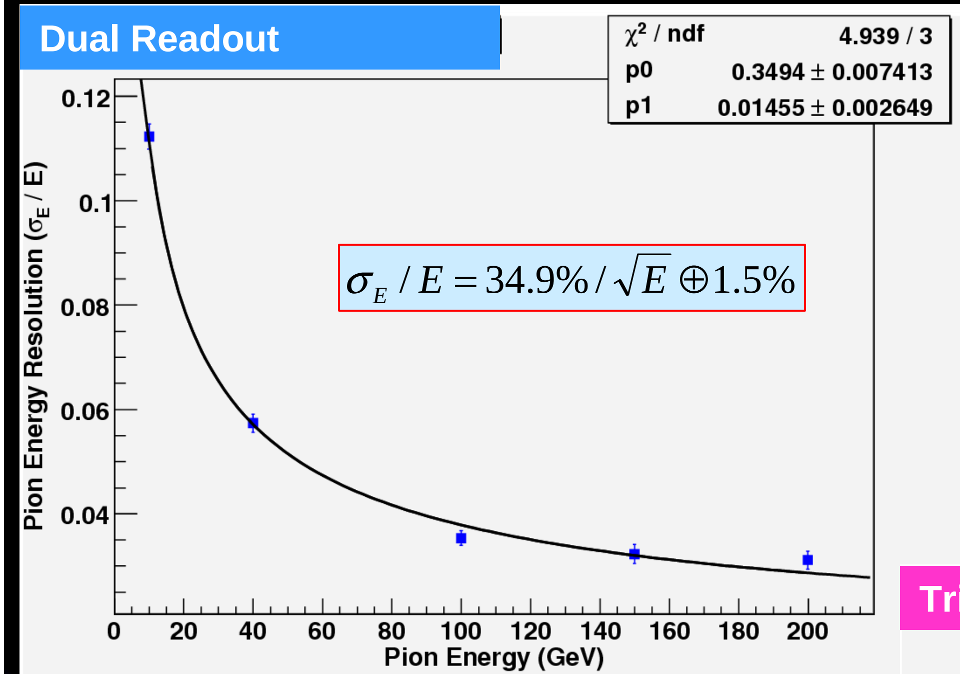
B-Field has no effect on efficiency

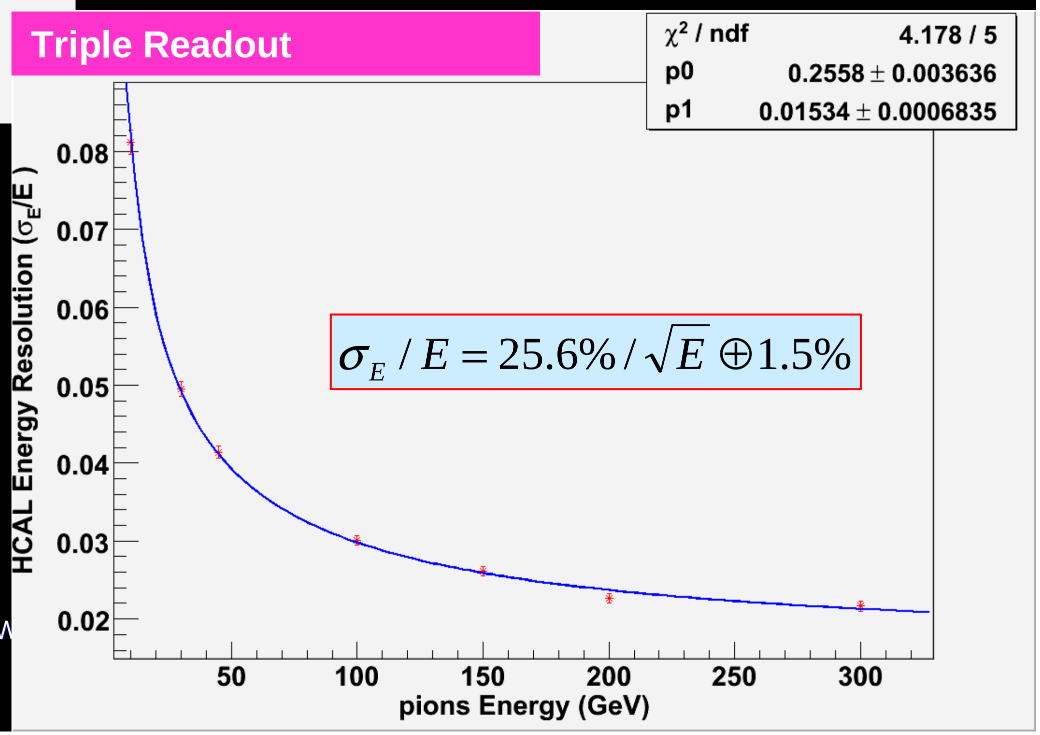


Sources of inefficiency

- Gas detector: seeding for low Pt & Kalman filter with fake clusters
- Strip detector: seeding from barrel with no z-coordinate (endcaps are OK)
- Pixel detector: seeding for low Pt & Kalman filter with fake clusters

HCAL resolution with single π



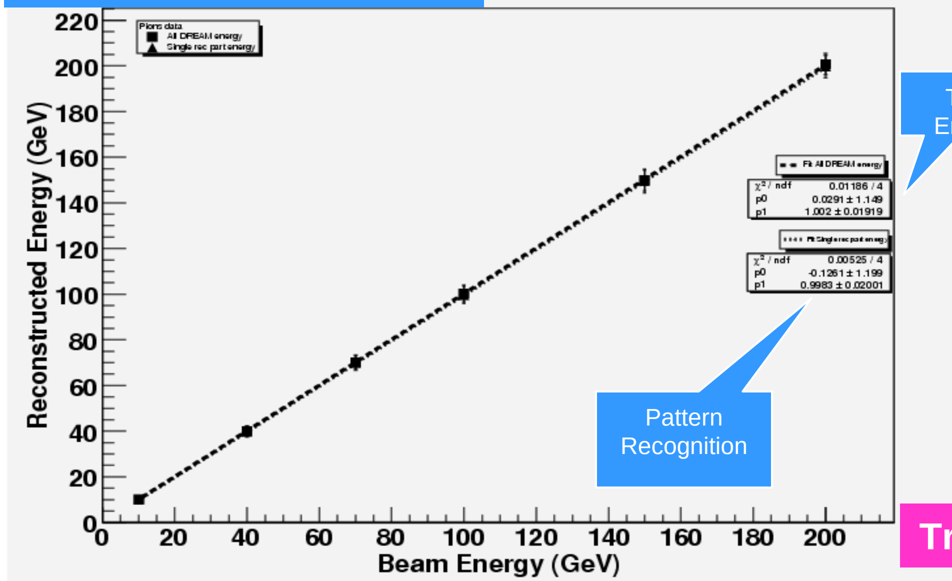


See V. Di Benedetto talk Tuesday morning

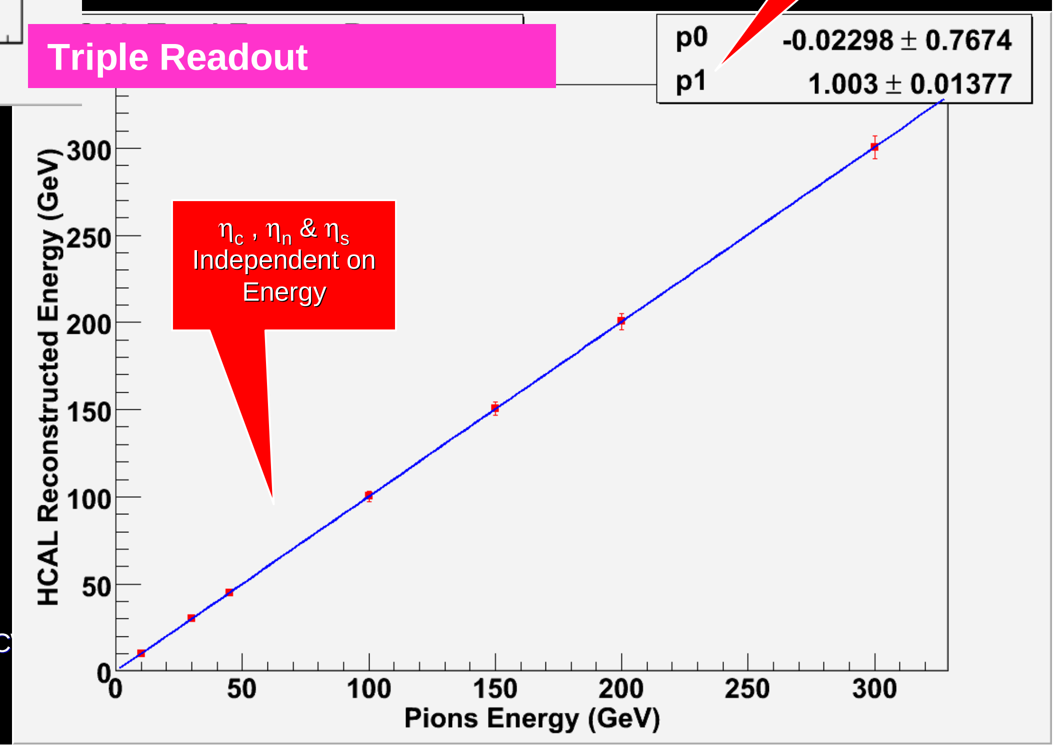
LCW

Reconstructed vs Beam Energy

Dual Readout

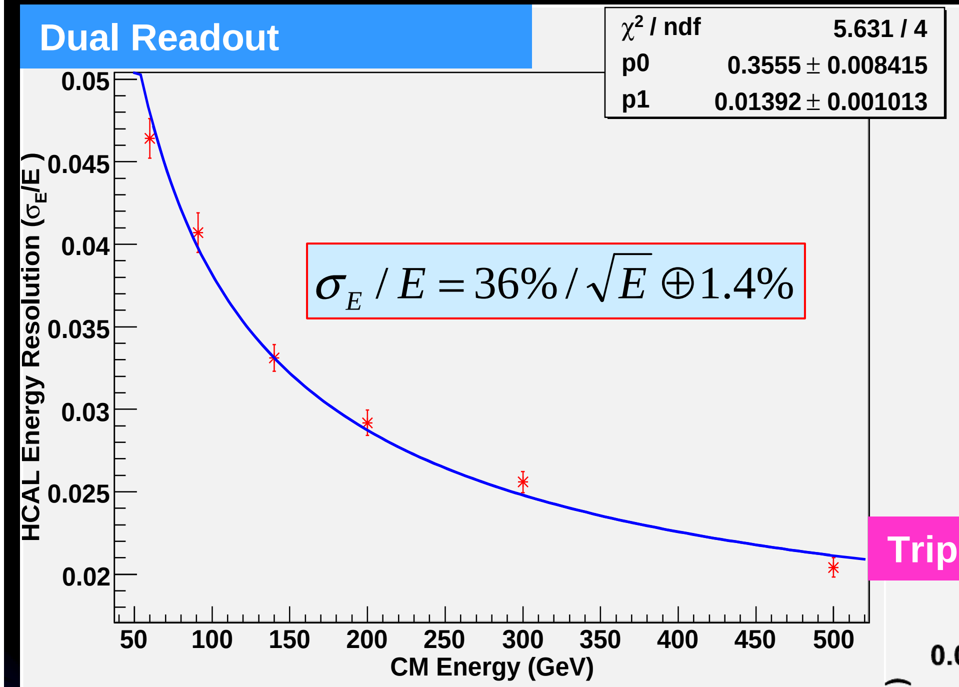


Triple Readout

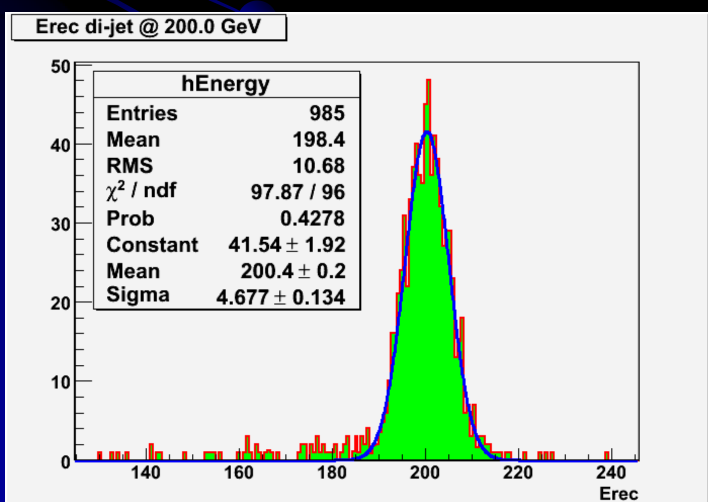


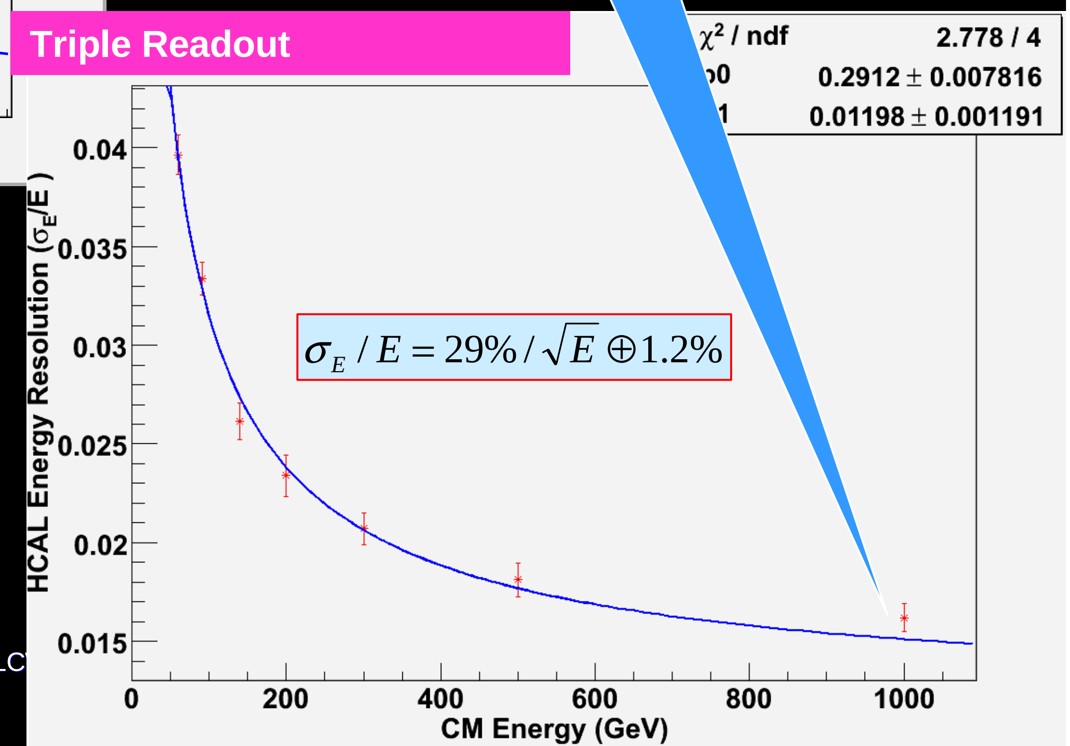
Di-jets events

Total Energy Resolution for di-jets



Sizeable Punch-through

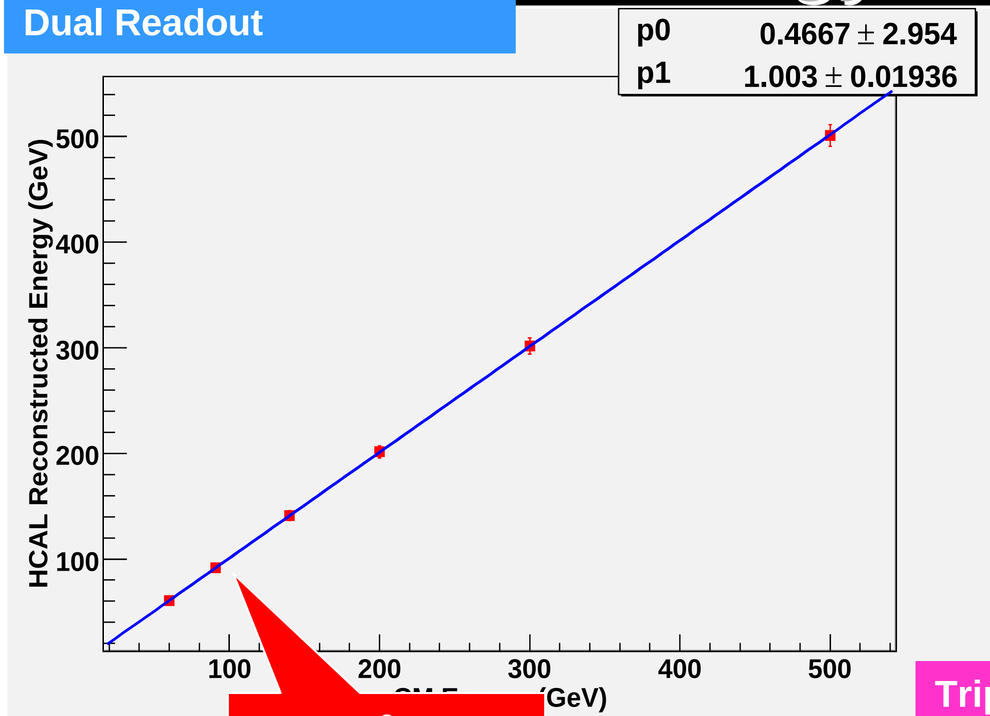




Energy Response

Di-jets events

Dual Readout



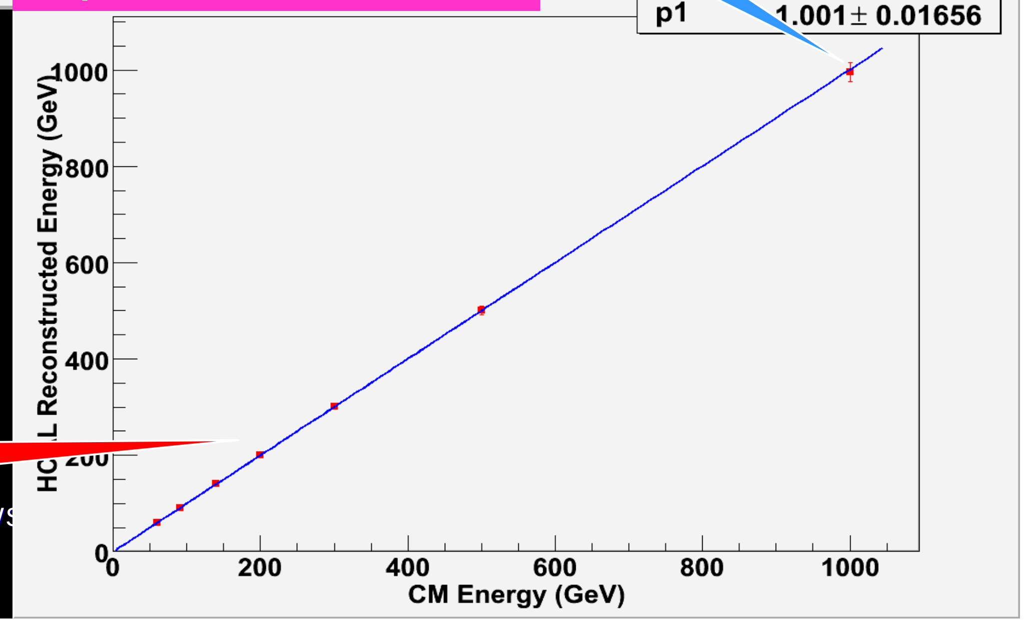
η_c & η_s Independent on Energy

Sigma from Gaussian fit on the Total Energy Distribution

Mean from Gaussian fit on the Total Energy Distribution

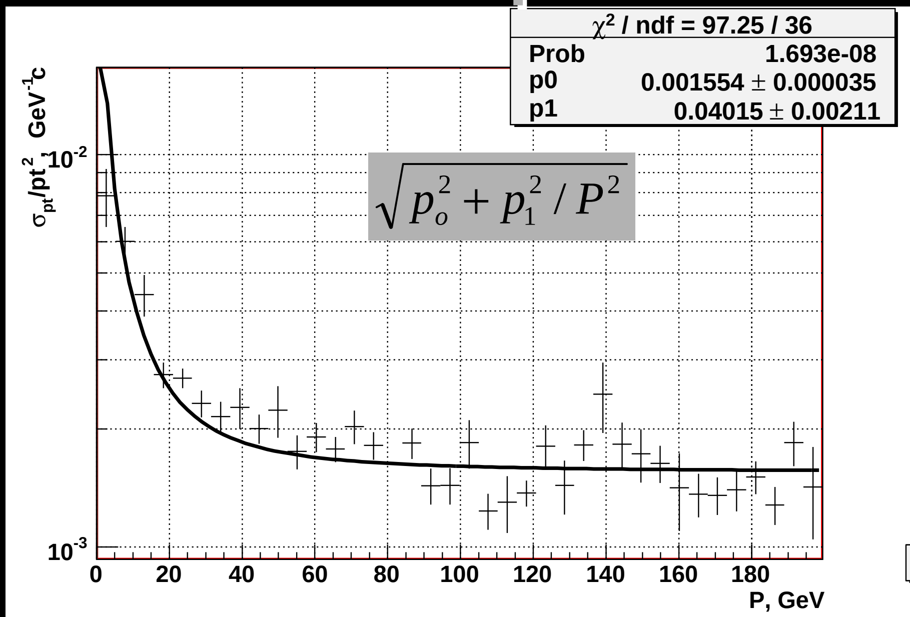
Skewed distribution: Sizeable Punch-through

Triple Readout



η_c , η_n & η_s Independent on Energy

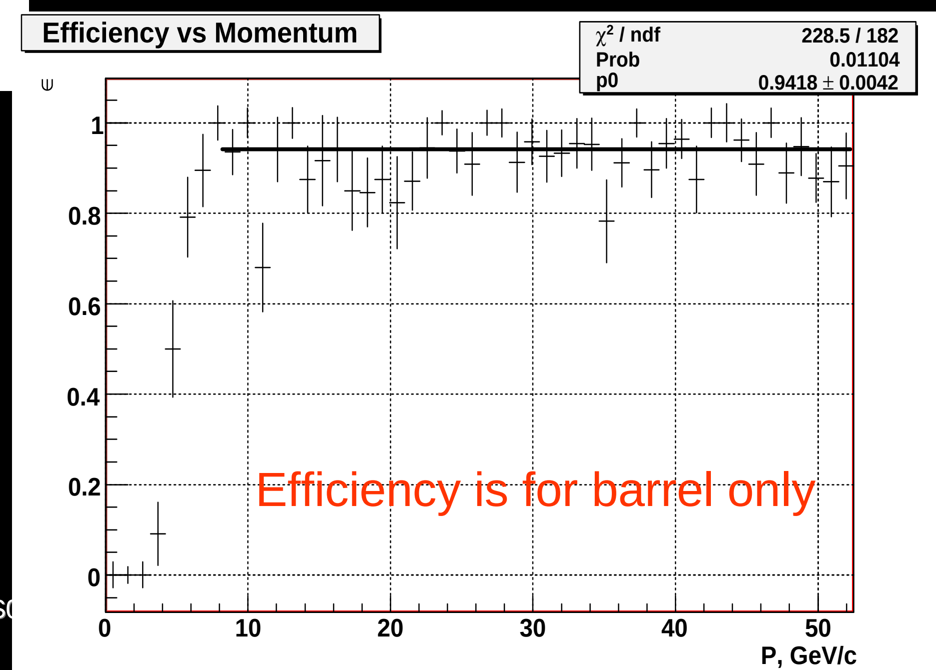
Muon Spectrometer Performance



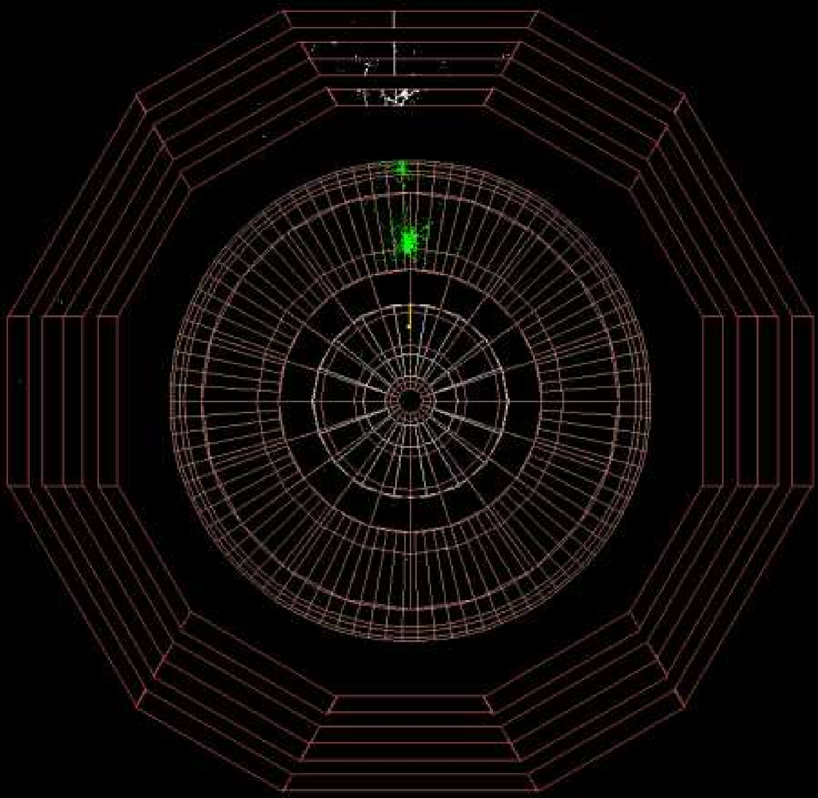
Cracks excluded

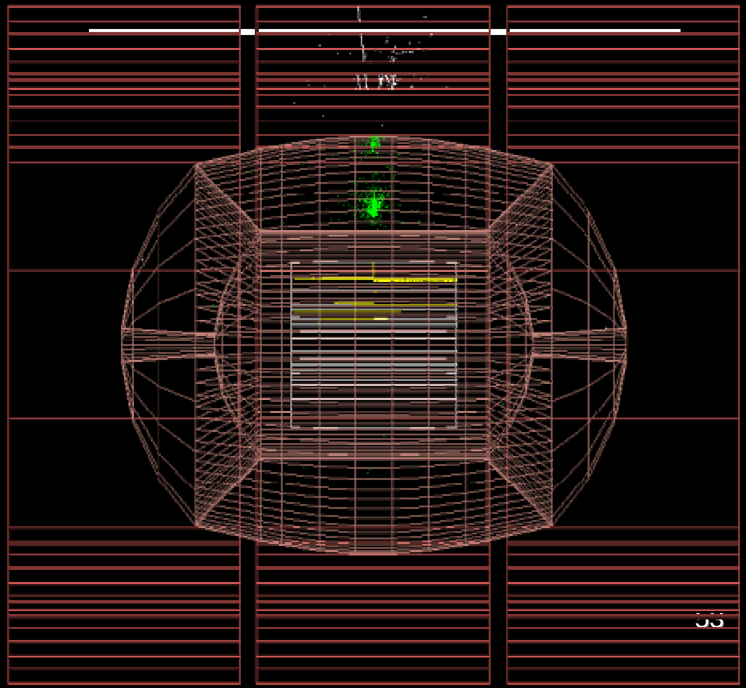
Requires tracks already reconstructed in DCH

$$\sigma(P_t^{-1}) = 40/P \oplus 1.5\times10^{-3} GeV^{-1}c$$



80 GeV jet with escaping particles



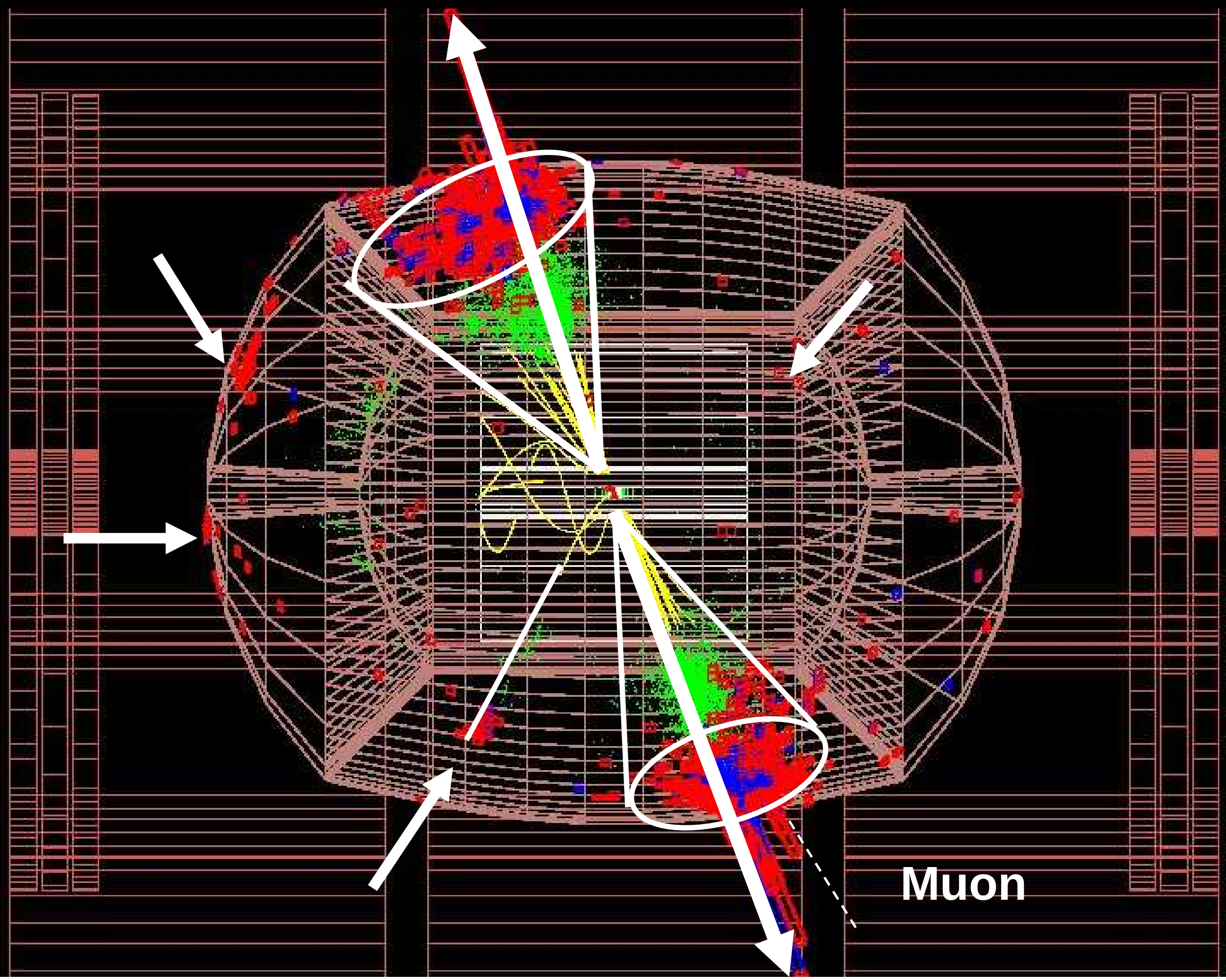


Jet reconstrucion: combine calorimetric and tracking informations

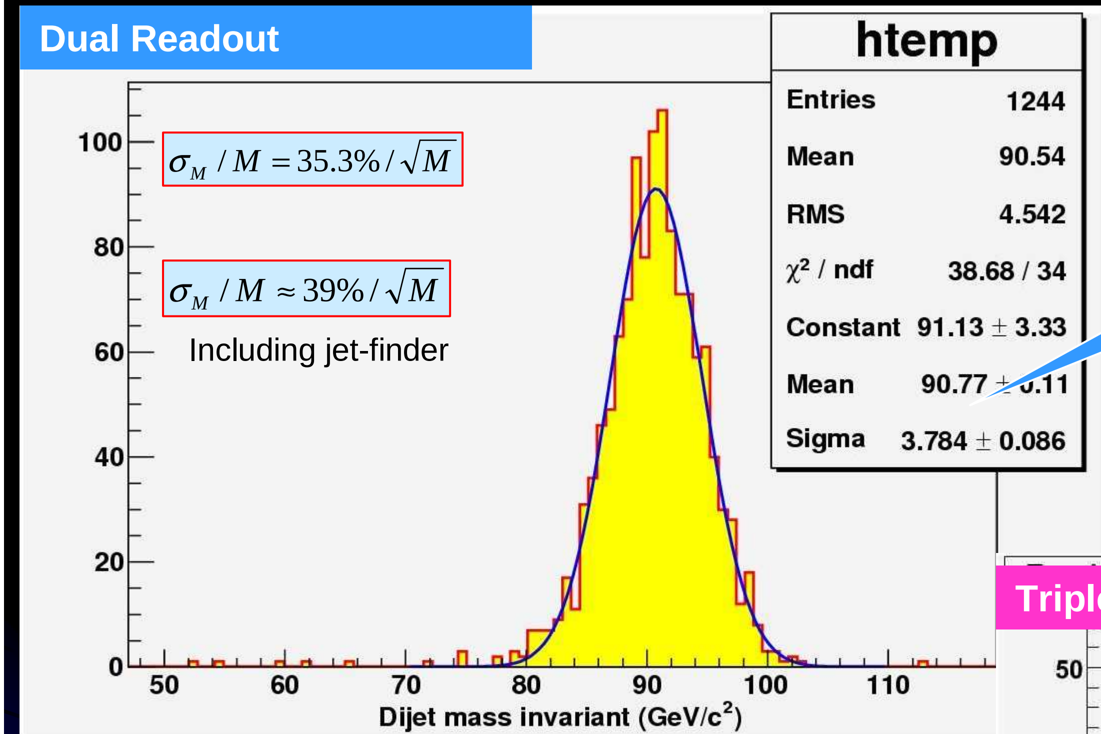
(work in progress)

See A. Mazzacane talk Wednsday afternoon

Jet Reconstruction Strategy



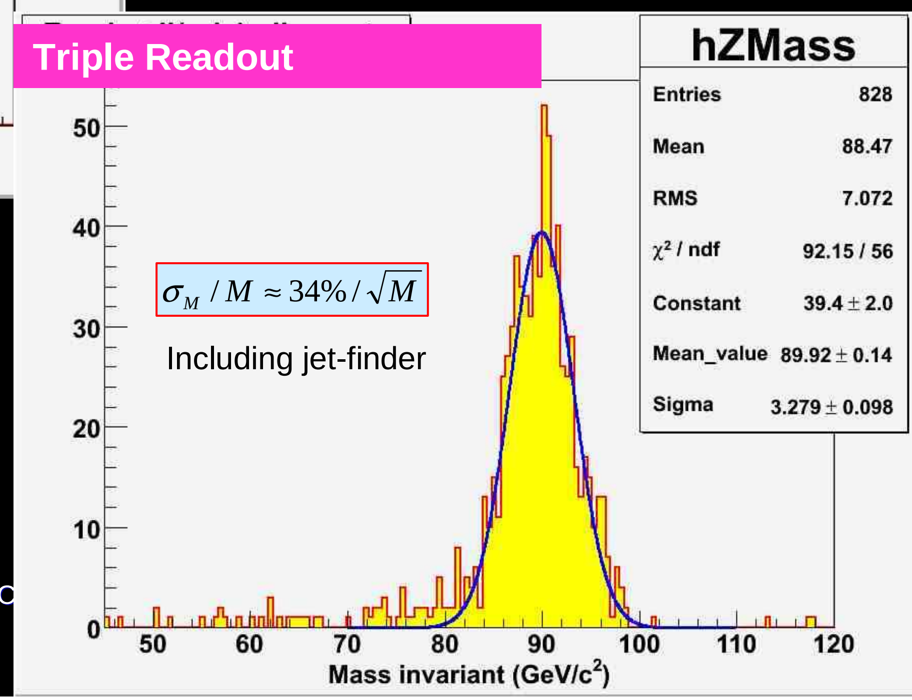
Z° Mass with Dual Readout



Presented at ALCPG07
By A. Mazzacane

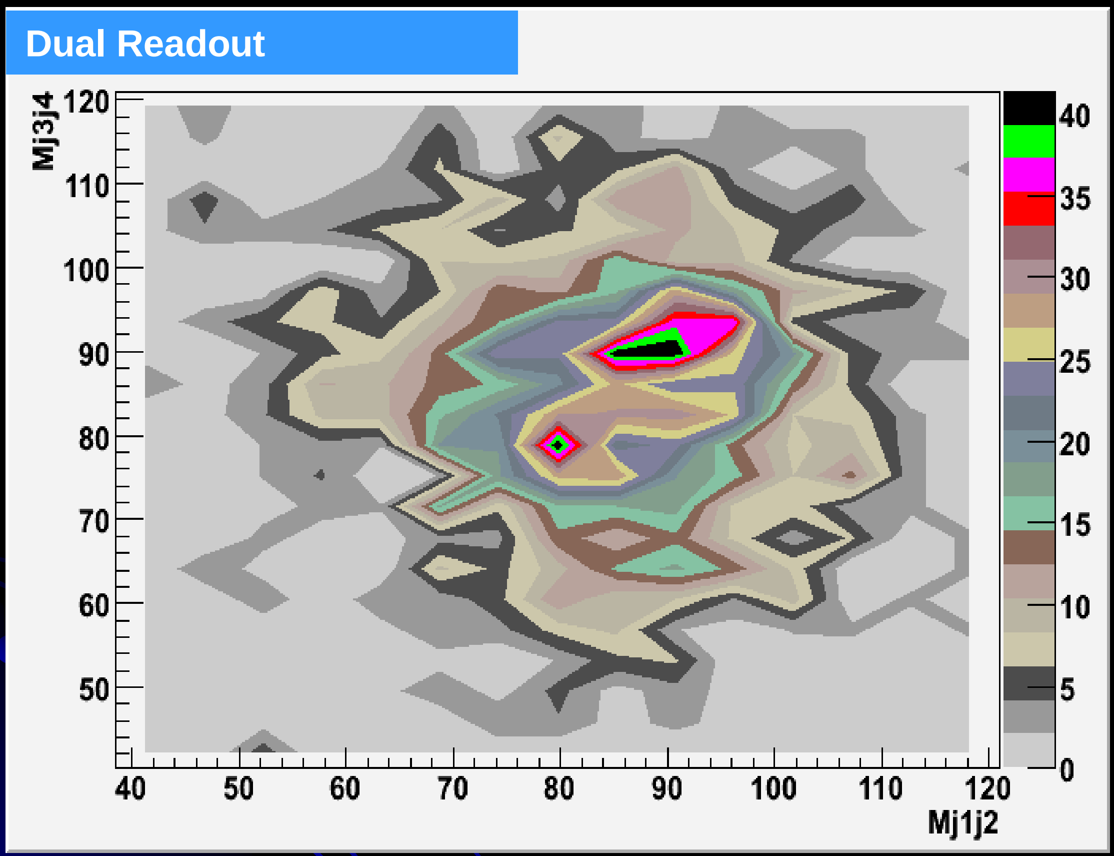
All events, no cuts

Jet axis resolution
$\sigma_\theta = 1.7°$
$\sigma_\phi = 1.9°$



$$e^{+}e^{-} \rightarrow W^{+}W^{-}\nu\bar{\nu}, Z^{o}Z^{o}\nu\bar{\nu}$$

W/Z Mass Separation

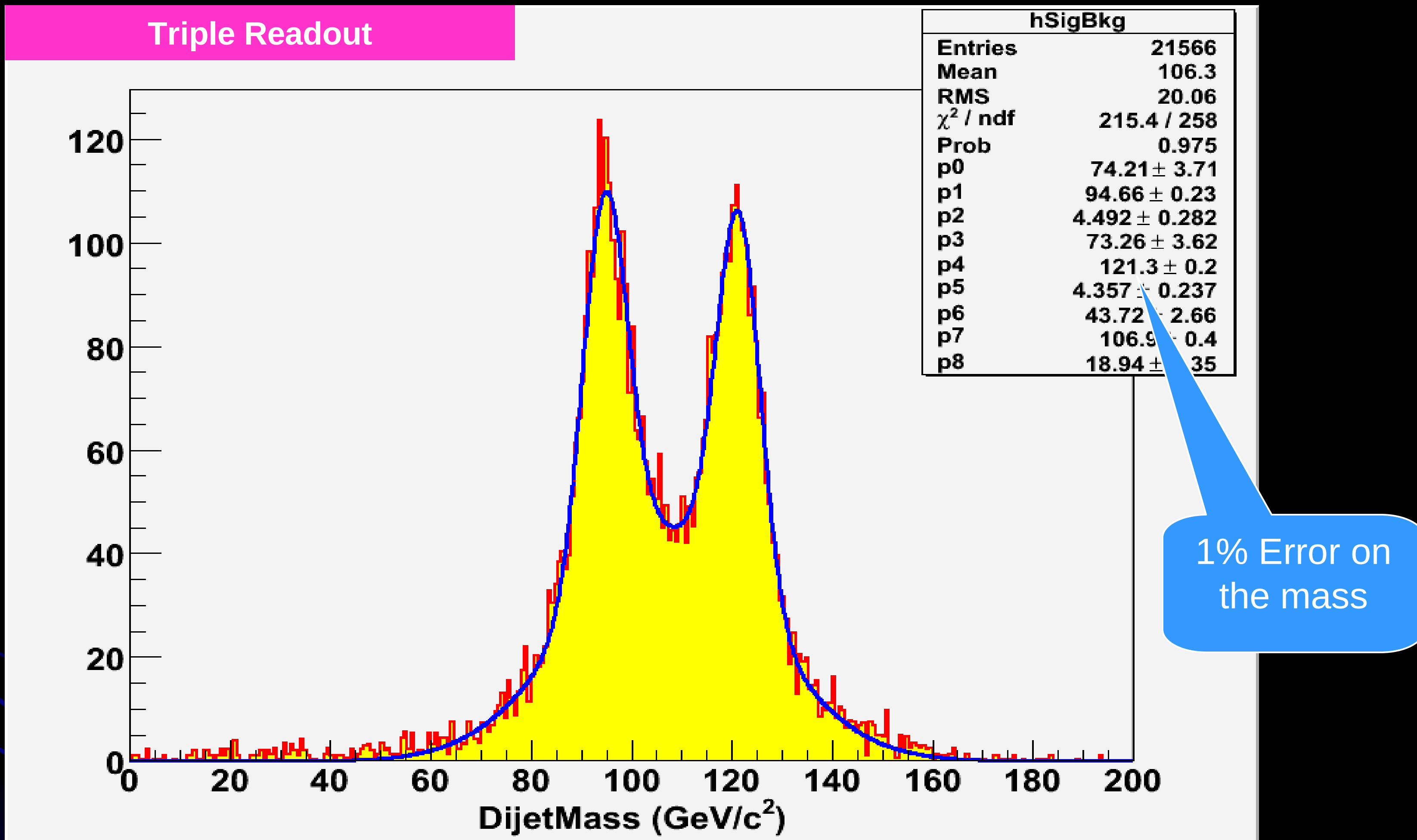


- Simple Durham jet-finder a la L3 (fixed/variable ycut) used for this analysis
- No combined information with tracking yet
- 4-jets finding efficiency: 95%

Study by A. Mazzacane

See A. Mazzacane talk Wednsday morning

$e^+e^- \rightarrow Z^oH^o \rightarrow \nu\bar{\nu}\, c\bar{c}$ + ZZ Background



- Signal + ZZ background
- Requires 2 jets from jet-finder
- Evis > 130 GeV

- **No flavor tagging**
- Fit with three gaussians
- Selection Efficiency = 80.2%

Summary of Detector Studies

- Resolutions with multi-jets are dominated by multiple scattering in VTX + Central Tracker
- Redundancy of measurements and **seeding in central tracker** is fundamental for good/safe performance
- Small drift cell (drift time<= time between BXs) relax the requirements on the VTX
- VTX resolution likely not an issue (for pixels about 20 μm x 20 μm)
- VTX material budget of 1% X/X_o is OK
- Jet Energy resolution is better than 30%/sqrt(E) with Triple Readout Calorimeter
- Constant term is 1.2%
- Dual Solenoid Muon Spectrometer nice complement to Tracking + Calorimeter

Status of LoI

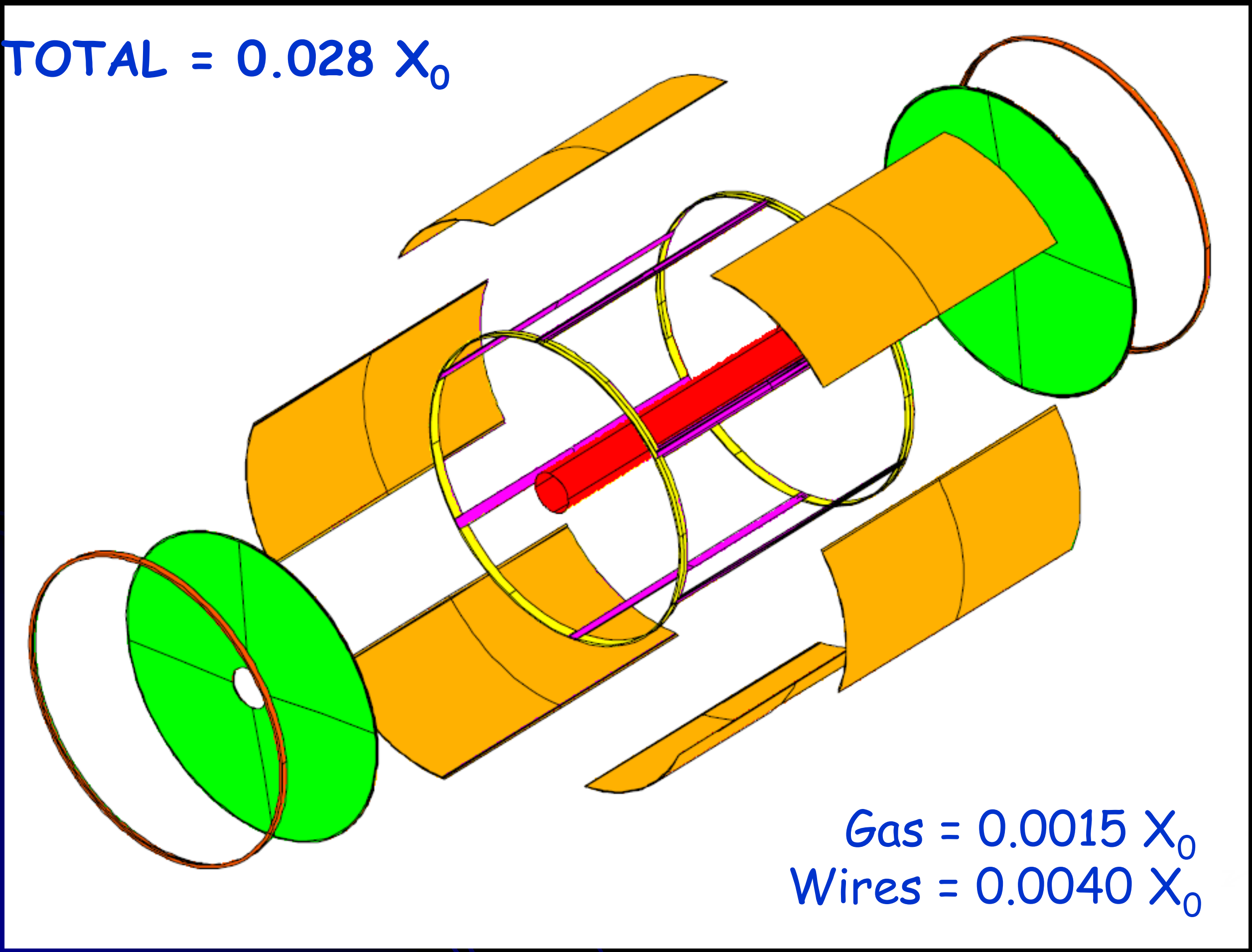
- Organization of LoI of 4th Concept has been finalized
- All tasks have been assigned
- Mass production of events has been planned after ECFA2008 (July 2008)
- Mass production of events started in August.
- All computing resources for the mass production of events are from Fermilab

Status and Perspectives

- Detector R&D is conducted by independent collaborations (CLUCOU, DREAM, SiLC, SIDET, 3D-Pixels, etc)
- Most critical issues have been pinpointed:
  - DCH needs Si in fwd region: CLUCOU + SiLC (A. Savoy-Navarro, F. Grancagnolo)
  - Crystal Calorimeter: Collaboration with DREAM/Pavia, Fermilab (A. Para)
- Performance of Dual/Triple Readout is very good in data and simulation:
  - need much more work to go from Technique R&D to a Detector design
  - many good ideas on the market (fibers, crystals, fiber-crystals)
  - **It should be an independent, worldwide effort (for future colliders as well)**
- Software framework (ILCroot) runs smoothly at FNAL. It allows quick test of new ideas and efficient optimization work
- It is continuously upgraded, with newer versions of the detectors
- Present effort is for the Letter of Intent (March 2009)
- Personal thanks go to Fermilab for their support and collaboration over the last two years (especially M. Demarteau and B. Tschirhart)

Backup slides

Layout and assembly technique (based on Kloe)



Length:
3.4 m at r = 19 cm
3.0 m at r = 147.0 cm

Spherical end plates:
C-f. 12 mm + 30 mm Cu
(0.047 X_0)

Inner cylindrical wall:
C-f. 0.2 mm + 30 mm Al
(0.001 X_0)

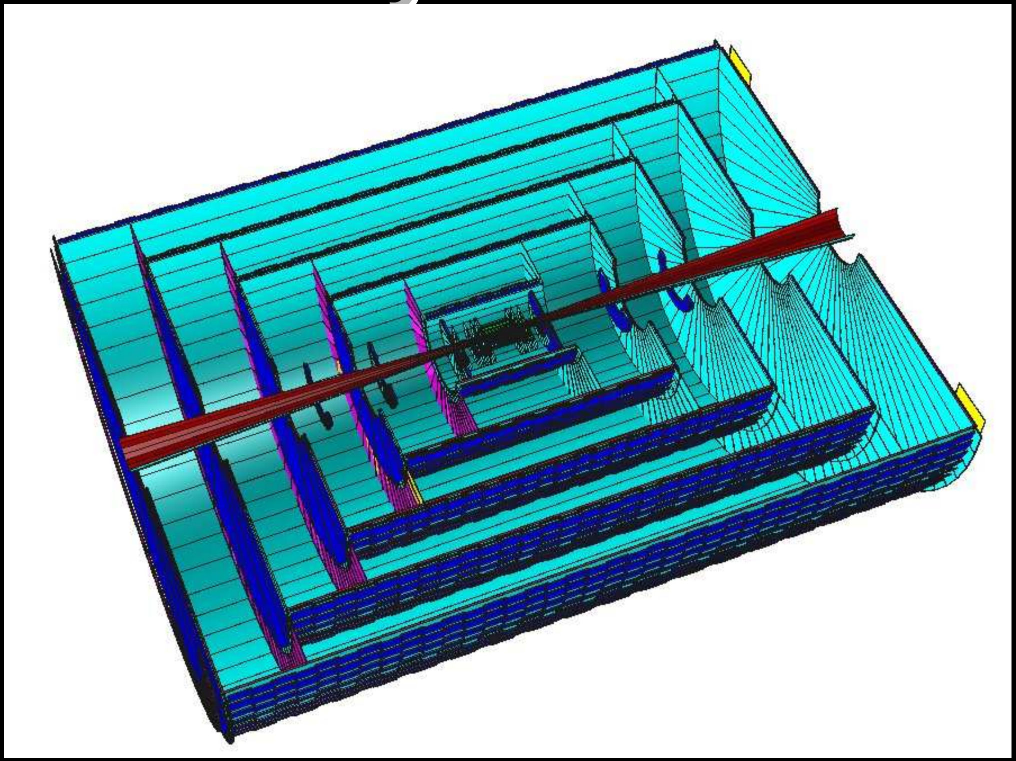
Outer cylindrical wall:
C-f./hex.cell. sandwich
held by 6 unidir. struts
0.020 X_0)

Retaining ring

Stiffening ring

SiD Tracker Layout

- Version SiD01-Polyhedra + SiD01
- Guard ring: mm 0.07
- Barrel Layers: 5
- Total Tiles Barrel 7312
-
- **Wafer layout**
- Strip pitch 50 µm
- Strip thickness (Si wafer) 300 µm
- Strip length 93.31 mm
- Tile width 93.531 mm
- Carbonfiber in 0.228 mm
- Rohacell tickness 3.175 mm
- Carbonfiber out 0.228 mm
- Si support 300 µm x 6.667 mm x 63.8 mm
- Kapton Layer 0.1 mm
-
- **Support layout**
- Carbon Fiber 500 µm
- Rohacell 8.075 mm
- Carbon Fiber 500 µm
-
- **Barrel Layer layout**
- Radial position (Barrel) cm 18.5-24.5; 44.1-50.1; 69.6-75.6; 95.2-101.2; 120.8-126.5
- Z-length cm 53.4; 121.6; 189.6; 257.8; 326



- **Endcap rmin rmax z position in cm**

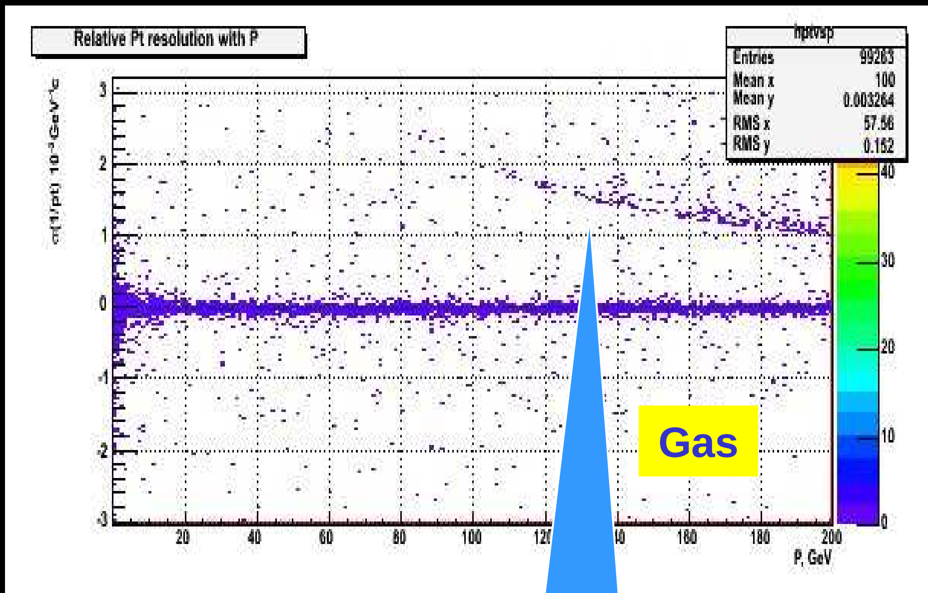
Endcap	rmin	rmax	z position in cm
1	18.5	48.6	62.9148
2	18.5	74.1	96.915515
3	18.5	99.7	131.016285
4	19.5	125.3	165.117005
5	2.78	16.67	20.59408
6	7.51	16.67	54.04408
7	11.65	16.67	83.14408

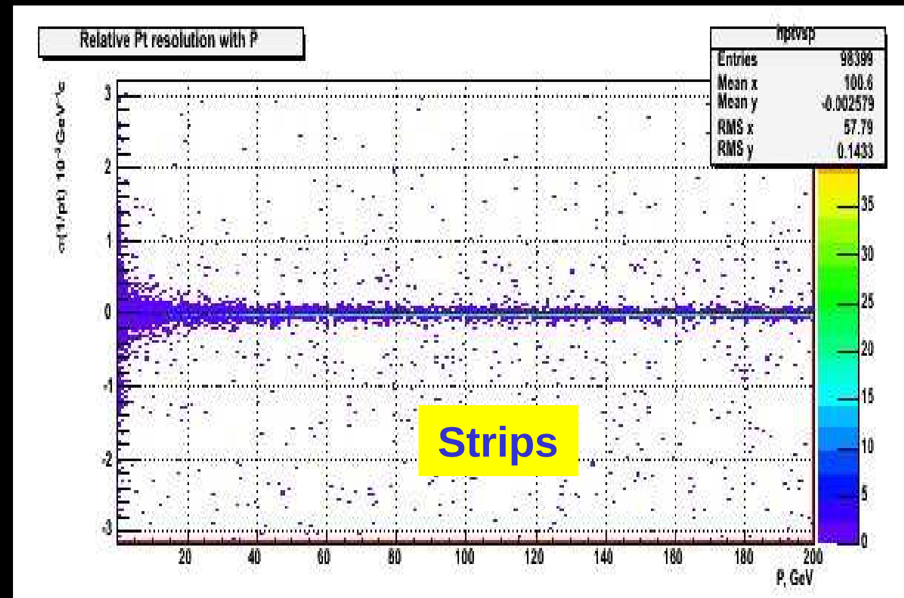
Barrel has single sensor strips

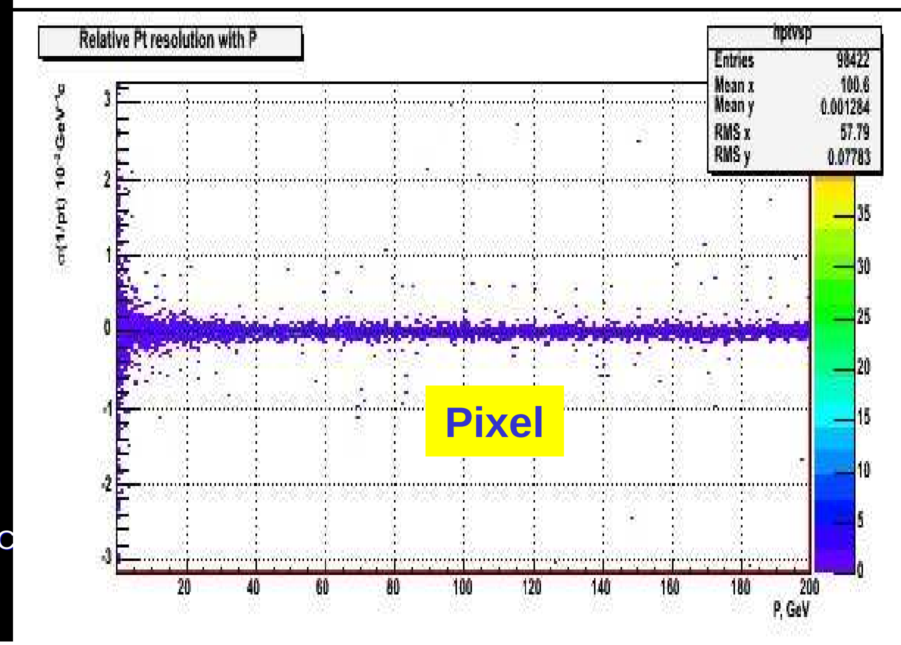
Endaps have double sensor strips with 17.5 mrad stereo angle

10 muons

DCH Resolution vs P



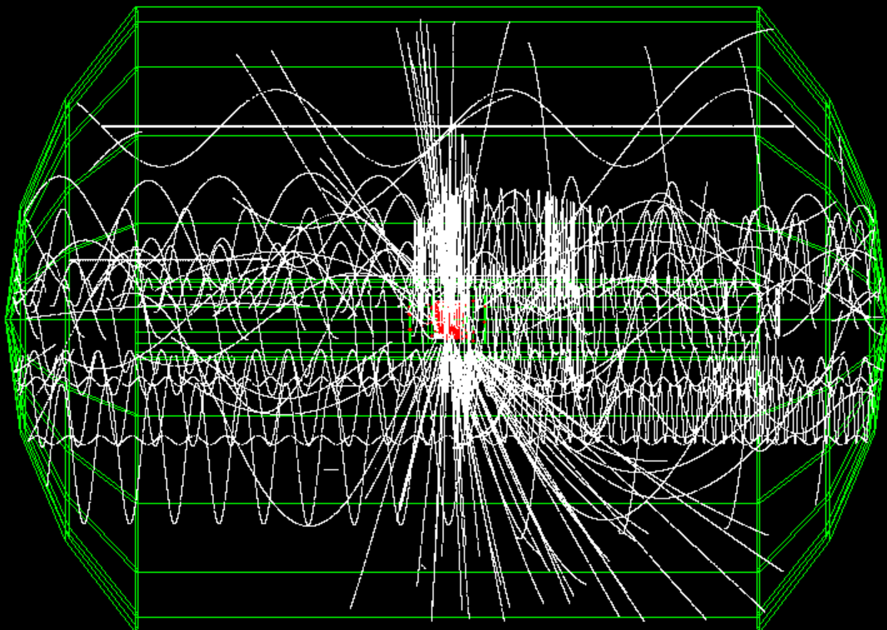


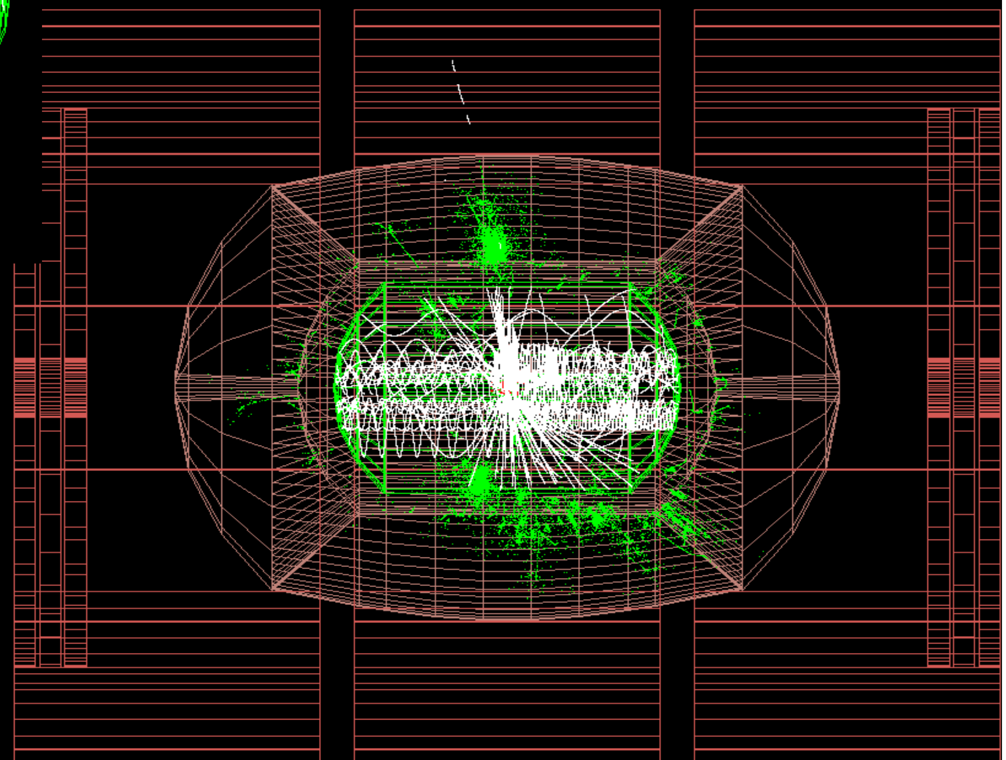


Left-right ambiguity for 0.5% of the tracks.

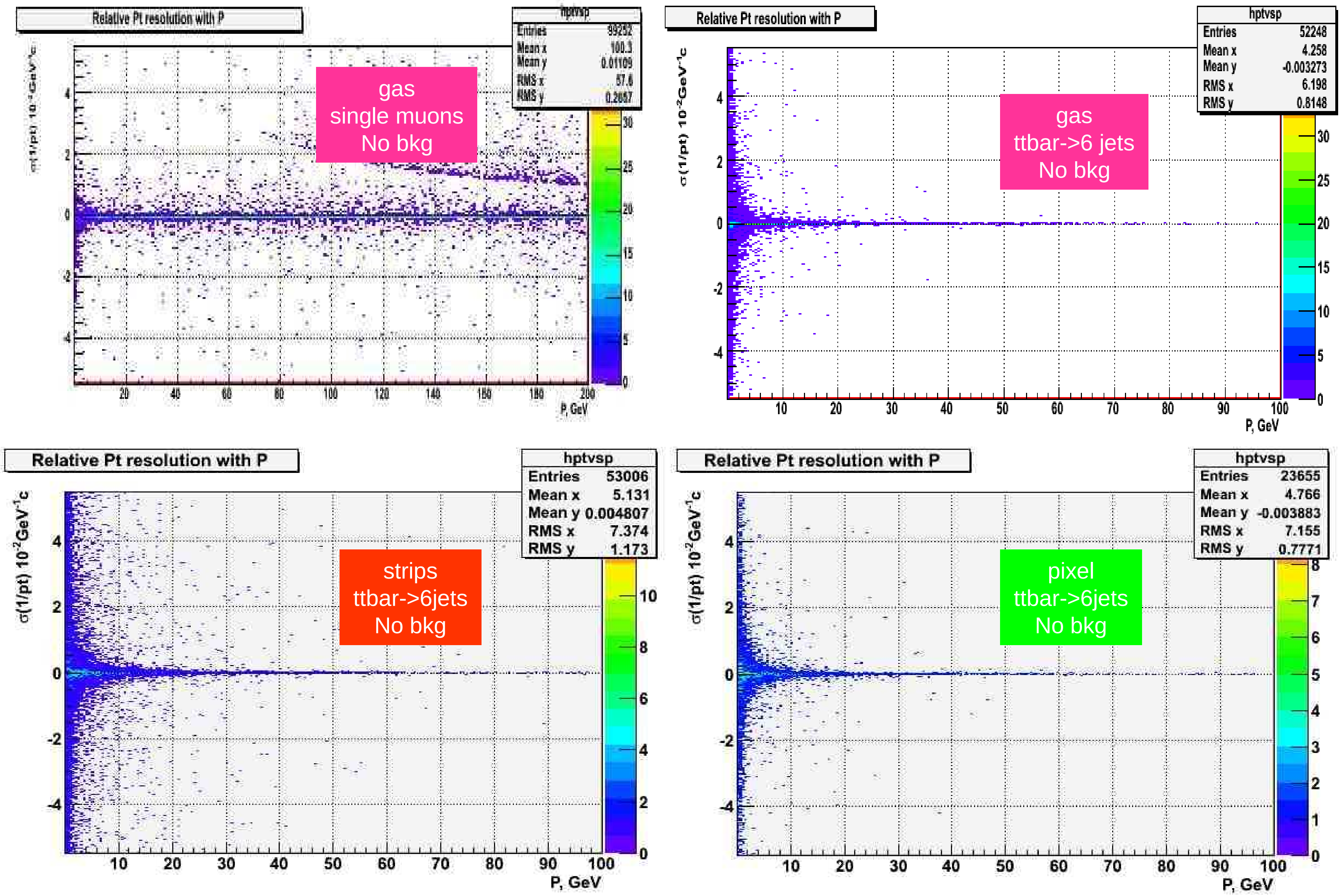
ttbar->6 jets events

Ecm = 350 GeV
B = 3.5 T



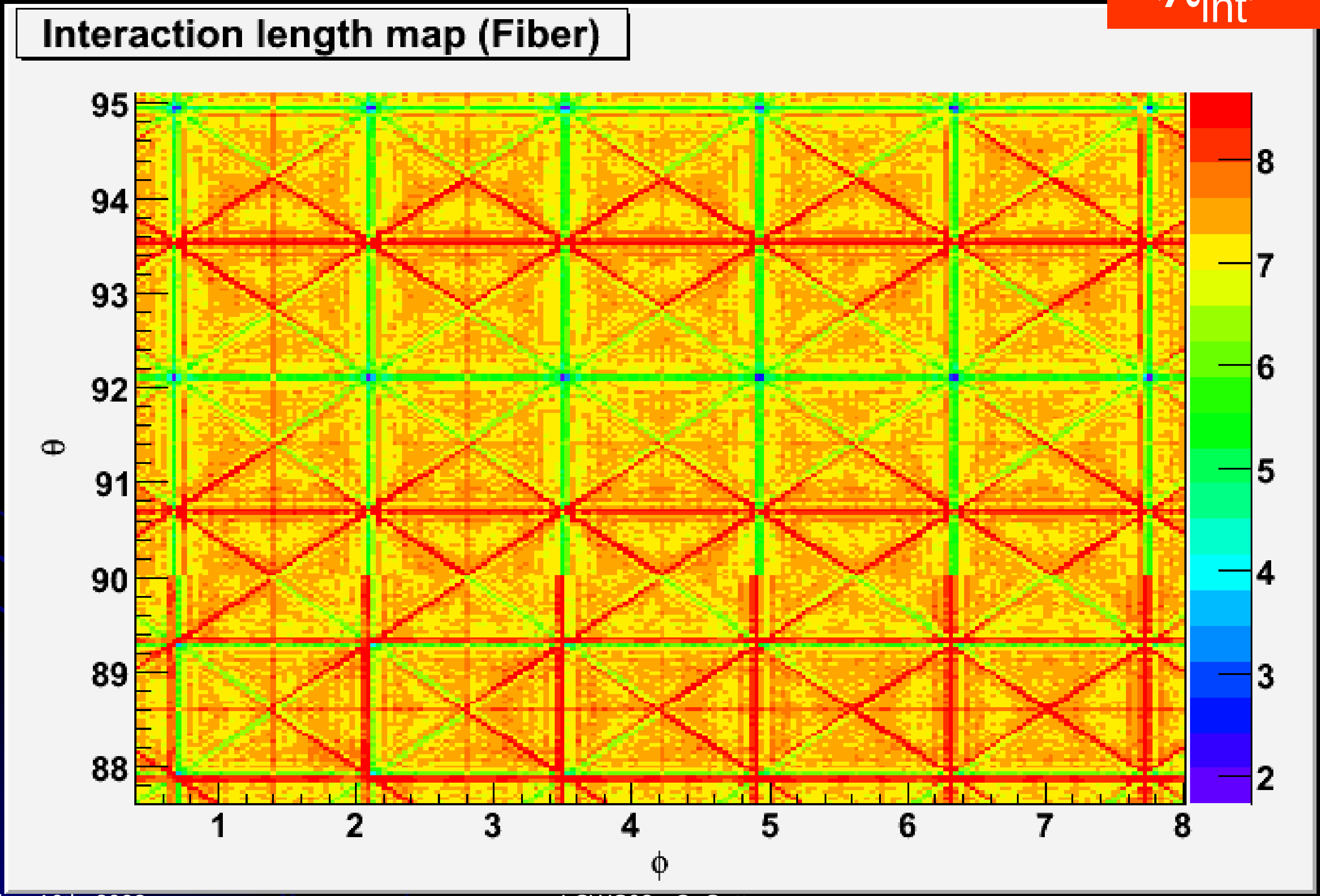


Resolution in Real Life: ttbar->6jets



Material Budget Map (Fibers)

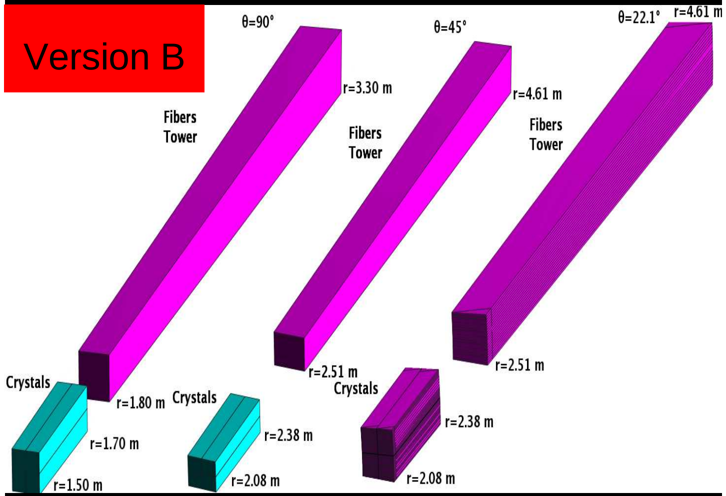
$<\lambda_{int}> = 7.3$



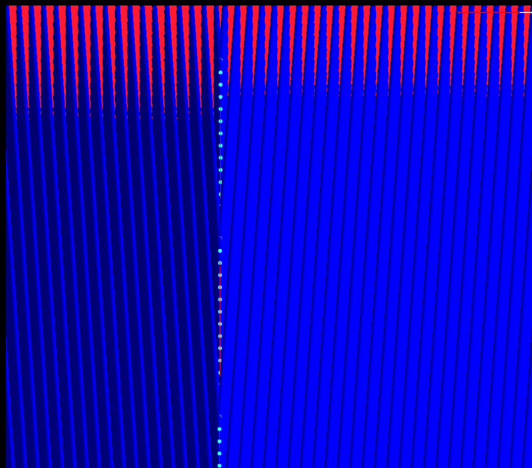
ILCRoot calculation

4th Concept Crystal Calorimeter

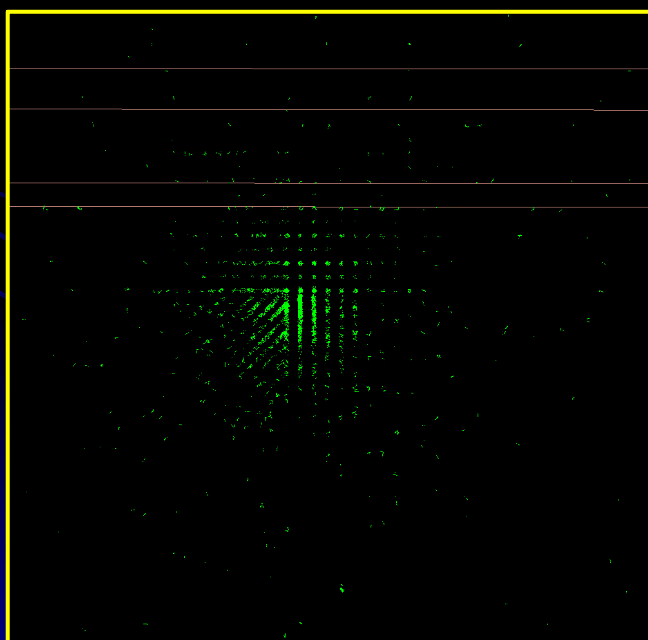
	Version A	Version B
Crystals	BGO (20 cm)	PbF_2 with 0.15% Gd doping 25 cm
Scintillation yield	5 pe/MeV	4.5 pe/MeV
Cerenkov yield	0.6 pe/MeV	1.4 pe/MeV
Dimensions	1 x 1 x 20 cm	2 x 2 x 25 cm
Rin, Rout cm	155,175	155, 180
material in front	5% X/Xo + tracking	None + tracking
Depth (X/X_o)	~ 17.9 X/X_o	~ 27.7 X/X_o
Depth (λ)	~0.88 λ	~1.25 λ
Granularity	~0.38°	~0.76°
Coverage in θ	3.4 °	3.4°
Total cell barrel	222784	55696
Total cell endcaps	2*50624	2*25312



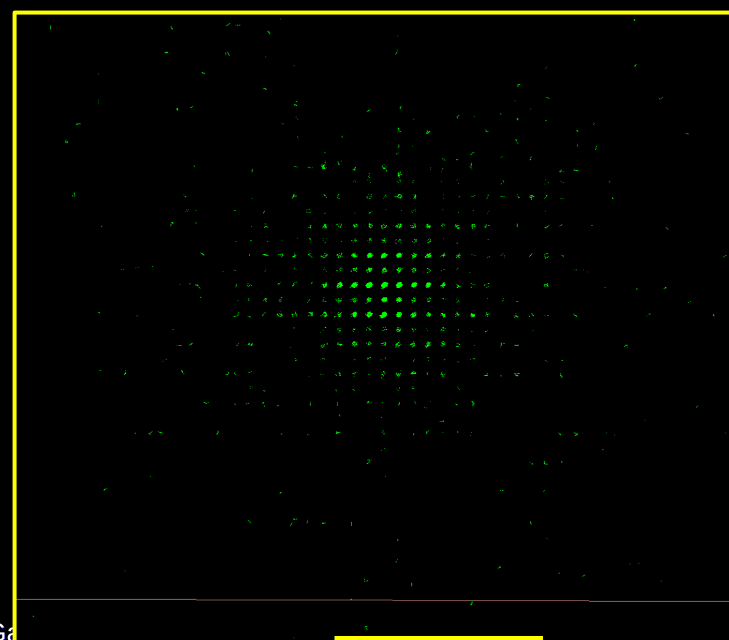
Main Source of Constant Term: tower shape



Top view of the shower of a 45 GeV e⁻

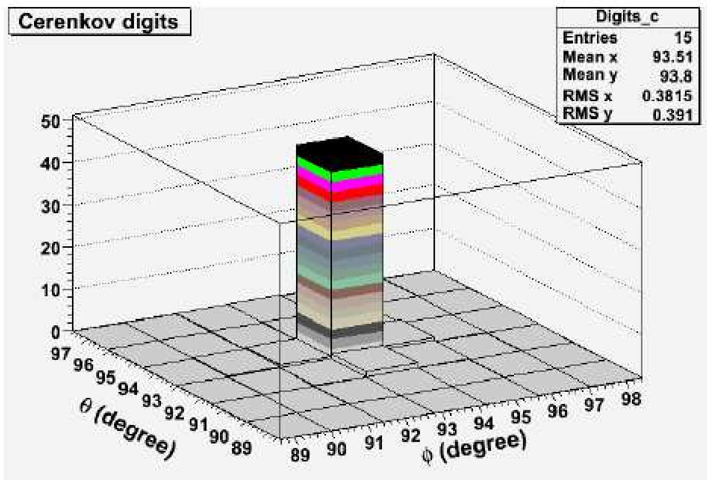


boundary

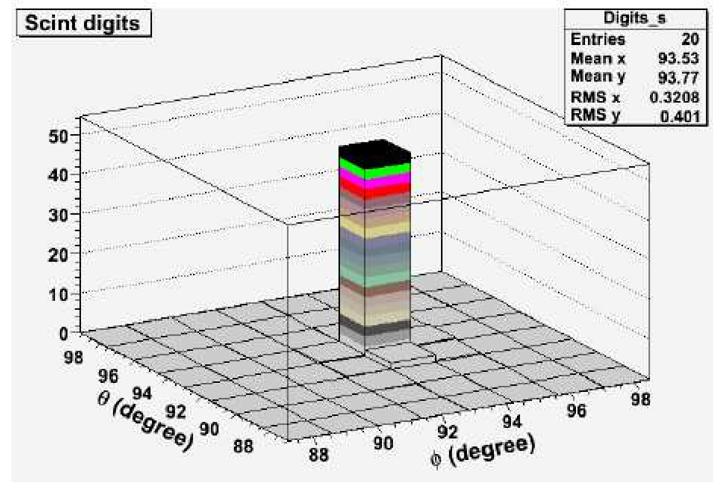


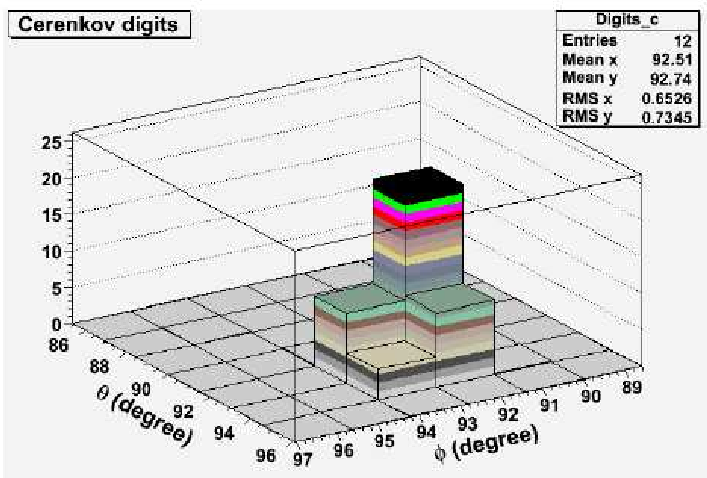
core

Calorimeter Response for 40 GeV e^-

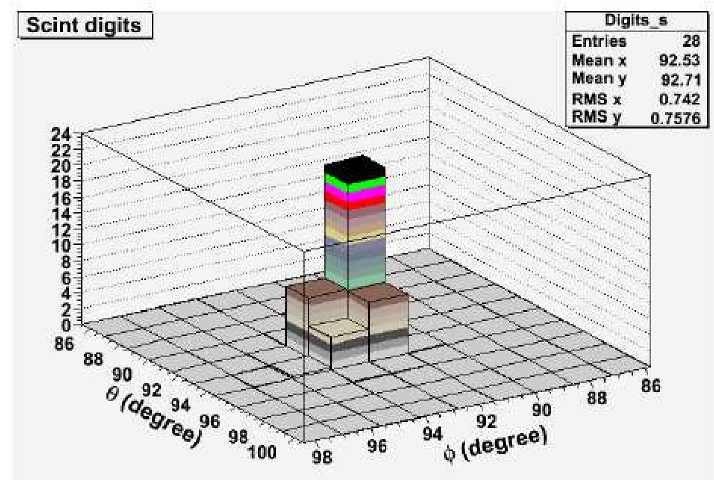


core

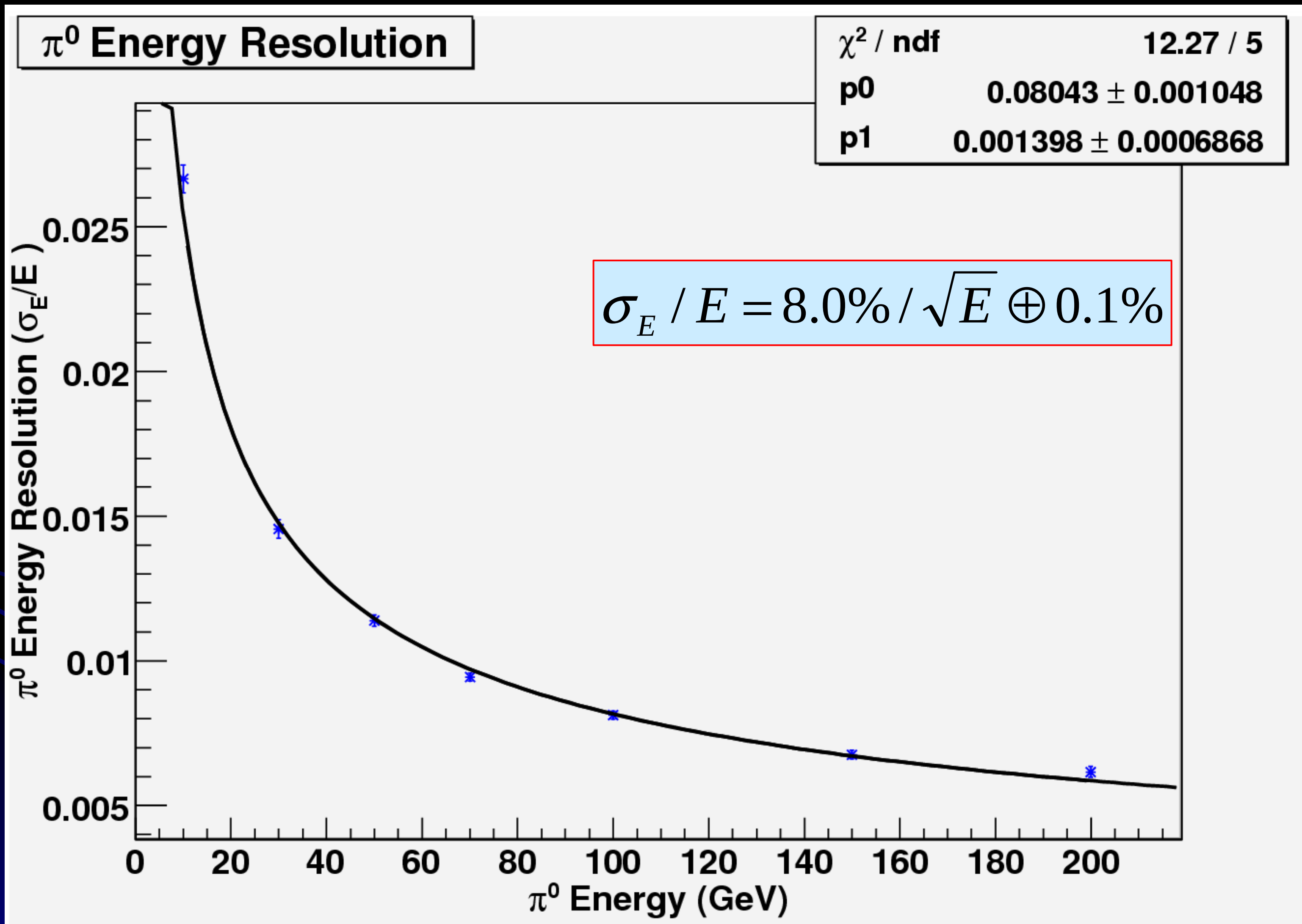




boundary



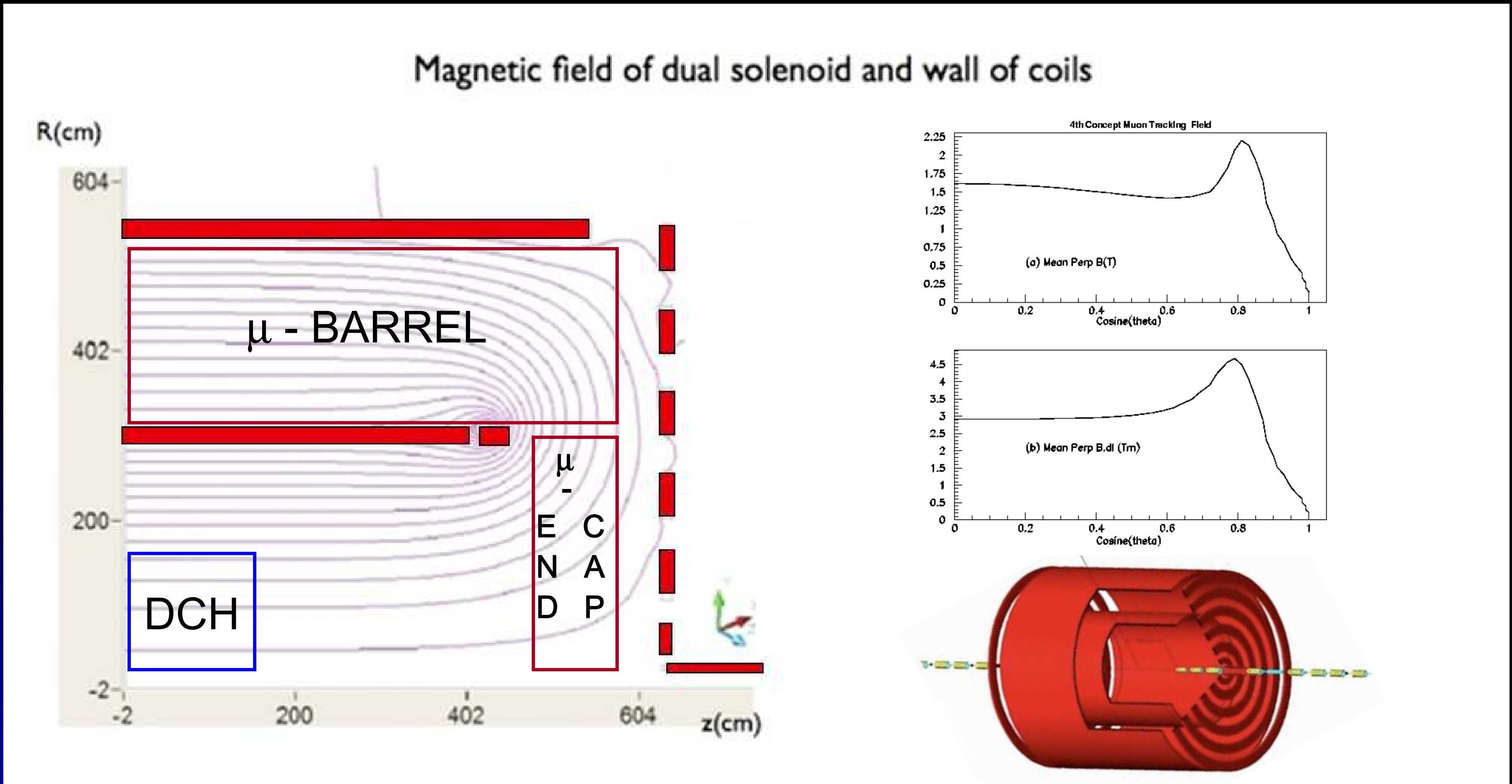
Resolution for π⁰ in ECAL+HCAL



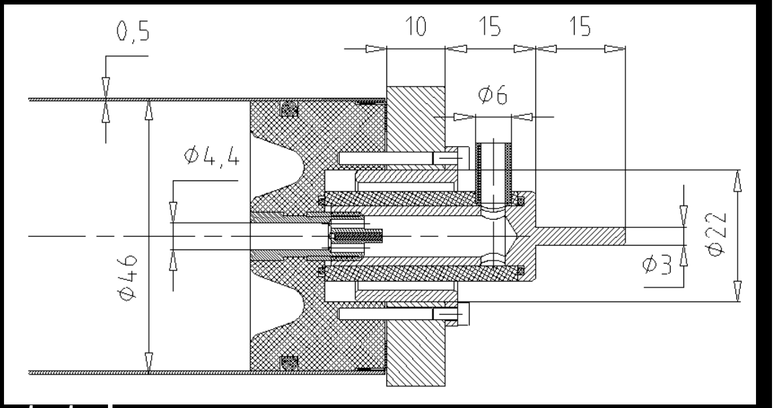
ECAL+HCAL Issues

- Preliminary studies on ECAL+HACAL for hadronic showers and jets
- Making ECAL and HCAL working together is not trivial
- Simple merging of the two showers is not working
- Need a more involved calibration
- Otherwise need to give up the crystals or make a purely crystal calorimeter
- **Ongoing collaboration with Fermilab on simulation of crystals in ILCroot**

Dual Solenoid B-field & Muon Spectrometer



μ-System basic element: drift tube



radius 2.3 cm
filled with 90% He – 10% iC_4H_{10} @ NTP
gas gain few × 10^5
total drift time 2 μs
primary ionization 13 cluster/cm ⇒ ≈ 20 electrons/cm total
both ends instrumented with:

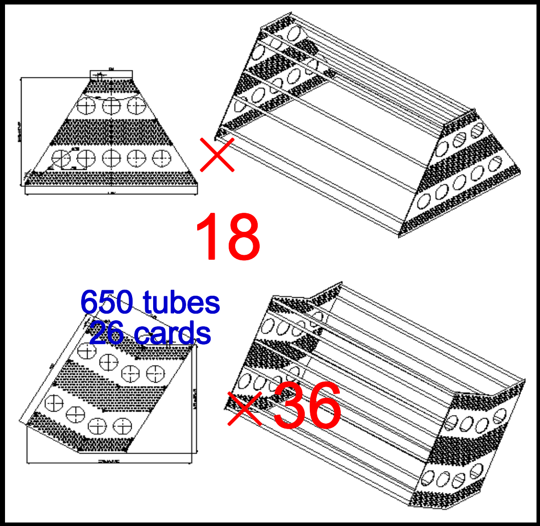
- > 1.5 GHz bandwith
- 8 bit fADC
- > 2 Gsa/s sampling rate
- free running memory

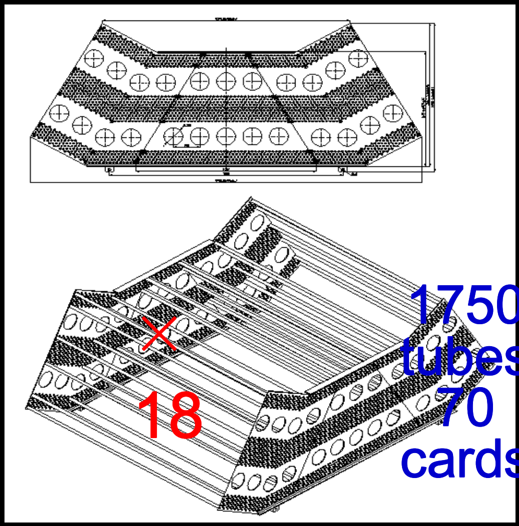
ASIC chip under development at INFN-LE

for a

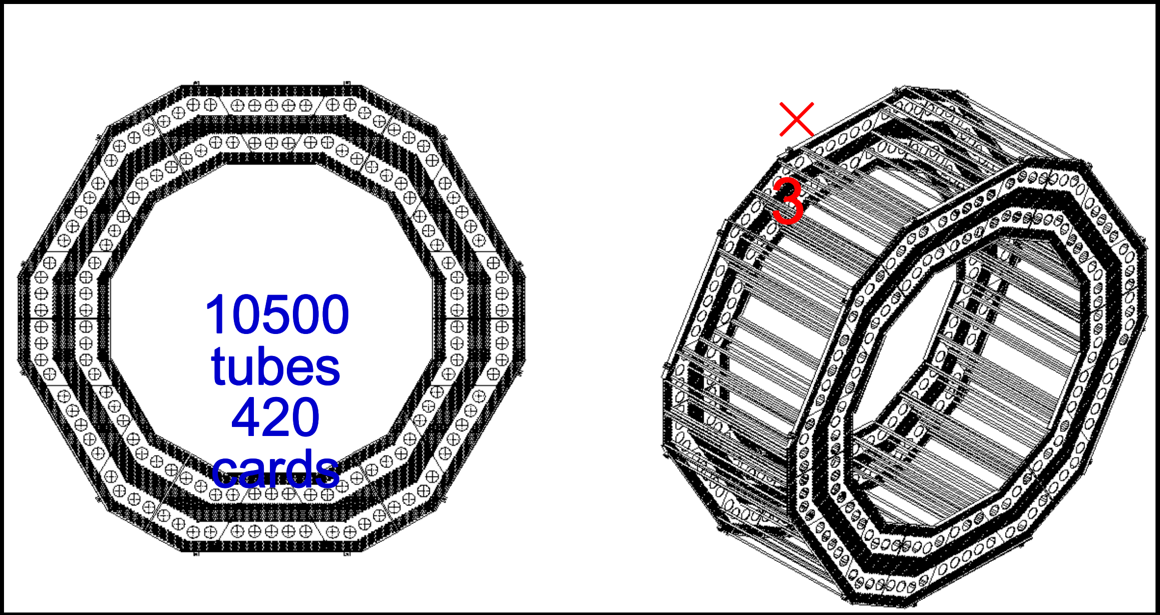
- fully efficient timing of primary ionization: cluster counting
- accurate measurement of longitudinal position with charge division
- particle identification with dN_{cl}/dx

Modular Design

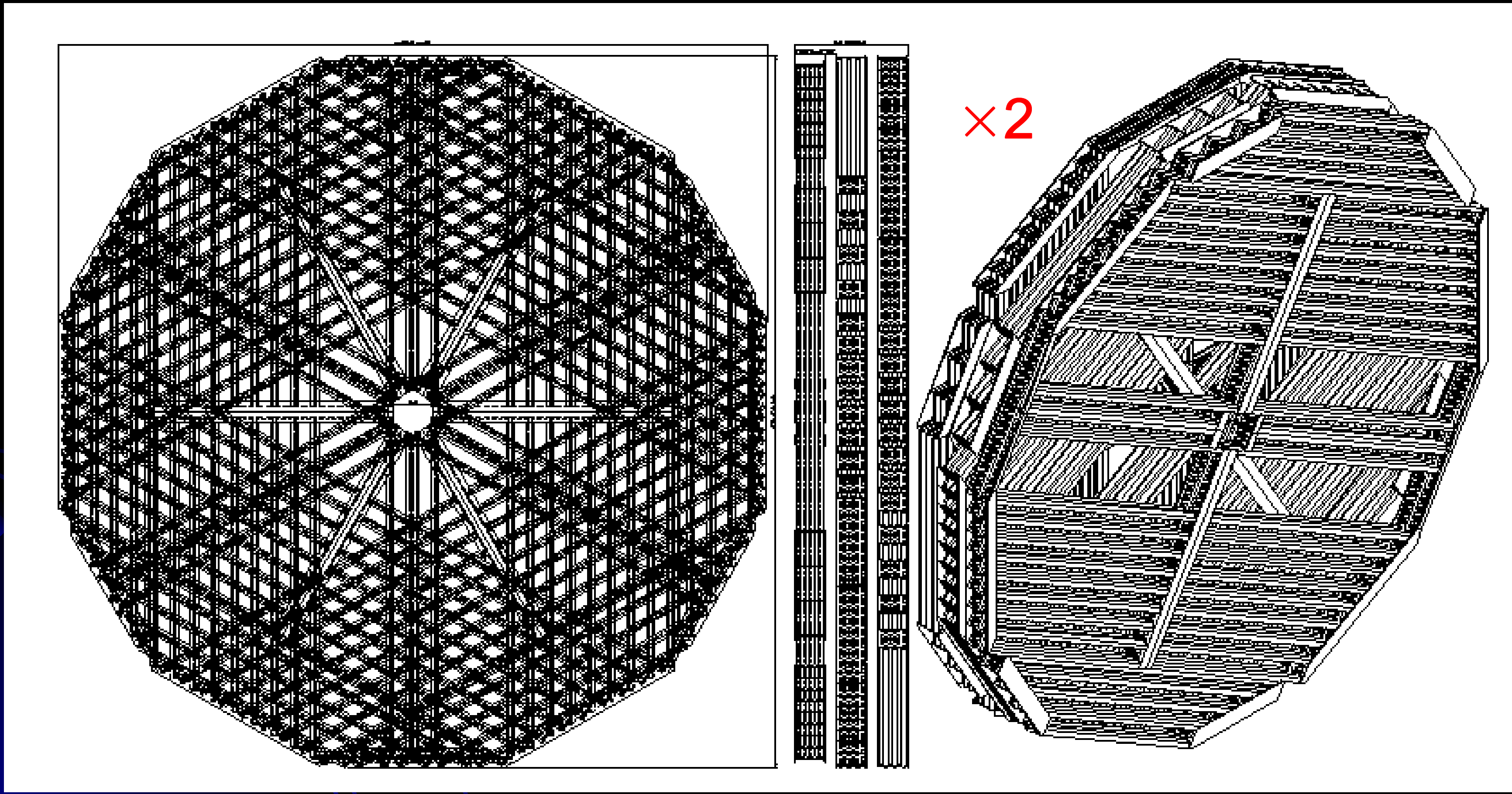




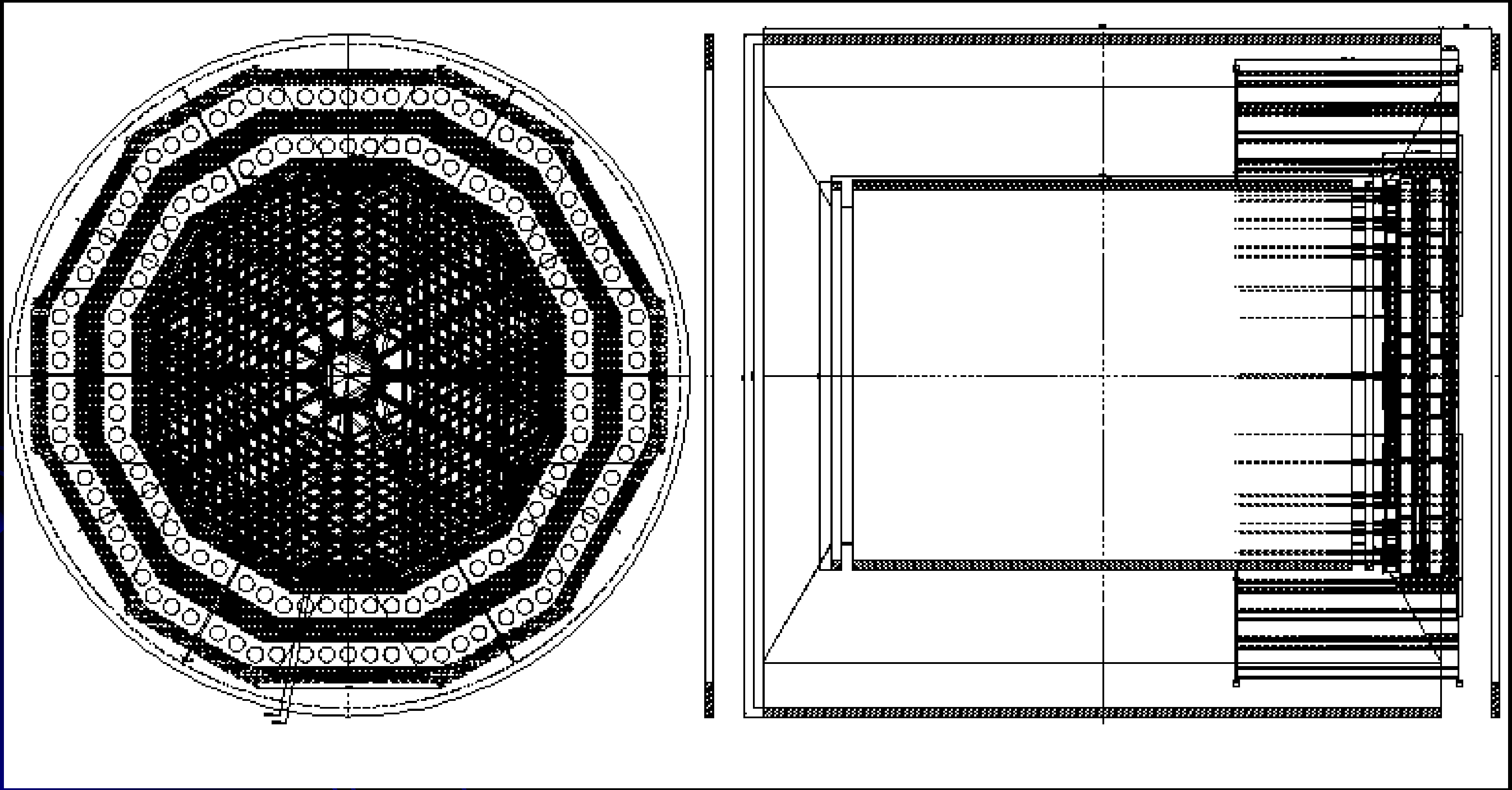
550 tubes
22 cards



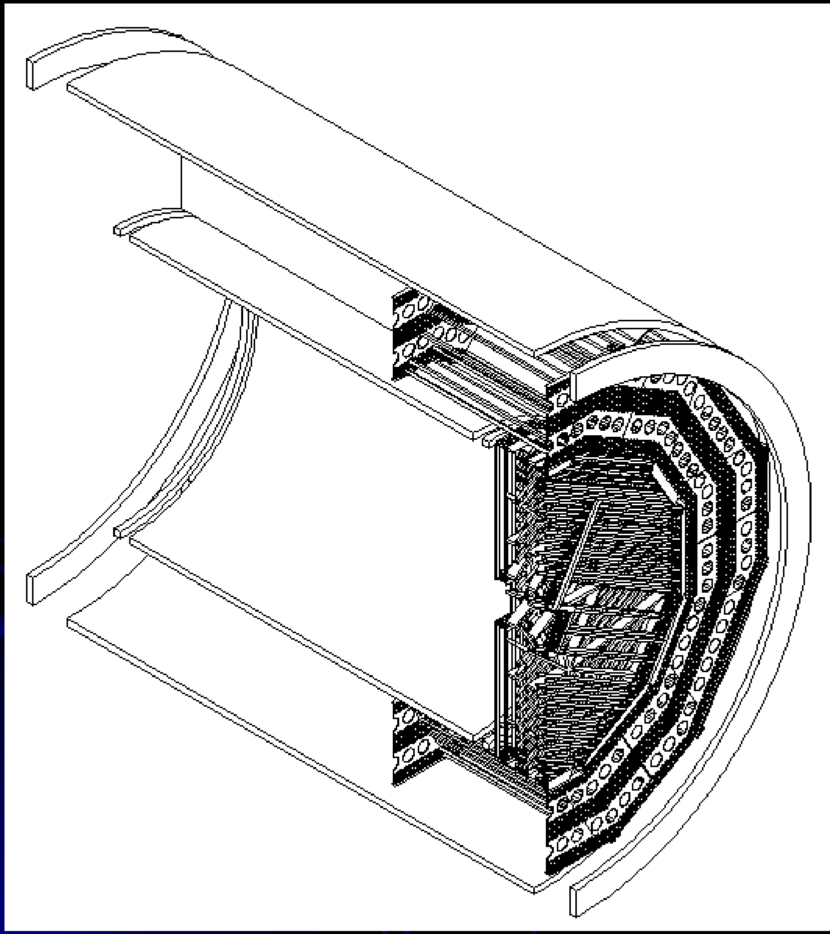
End cap



Full μ-system



Channel count



Barrel:
31500 tubes
21000 channels
840 cards

End caps:
8640 tubes
9792 channels
456 cards

Total:
40140 tubes
30792 channels
1296 cards