4th Tracker Performance

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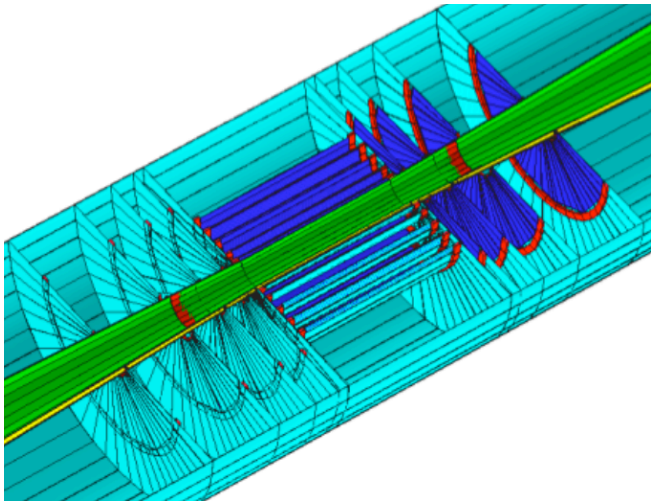
Vertex Detector



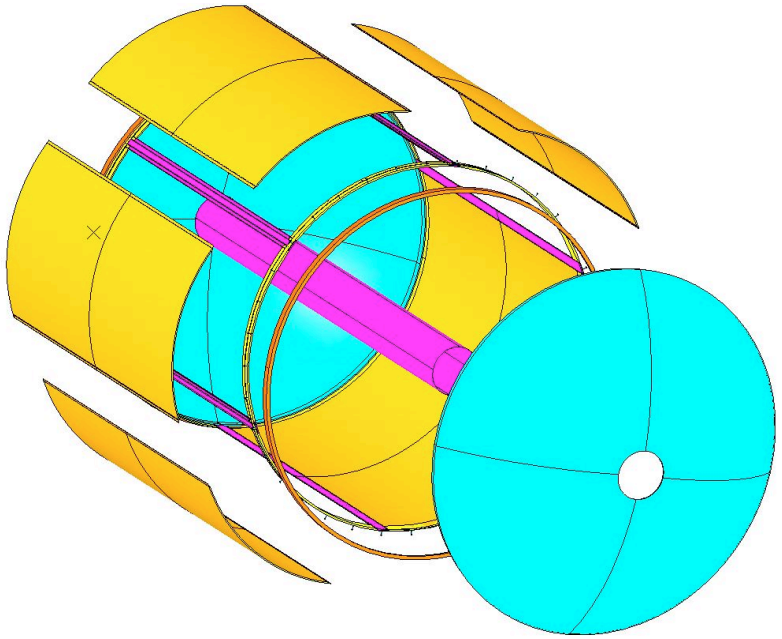
Vertex Detector:

multi Giga-pixel chamber with cylinders and disks according to SiD thin pixel design scaled up for B = 5T → 3.5T.

4th Concept is not currently working on a pixel chamber design.

VXD + Be beam pipe → 1.2% X_0

Central Tracker



Central Tracker:

CluCou

- **all stereo, cluster timing drift chamber**
- **light He based gas mixture**
- **mechanical structure entirely C-fibre**
- **max drift time contained in one BX**
- **total tracking volume (inner wall, gas and wires) < 0.5% X_0**
- **endplates (2.9% X_0), services (~5% X_0)**

$$\frac{\Delta p_\perp}{p_\perp} = \frac{\sqrt{320}\cdot\sigma_{xy}}{0.3\cdot B\cdot \ell^2\cdot\sqrt{n}}\cdot p_\perp \oplus \frac{5.4\times10^{-2}}{B\cdot\ell}\sqrt{\frac{\ell}{X_0}}$$

(transverse length ℓ, σ_{xy} and X_0 in [m], B field in [T], momentum in [GeV/c]).

Required performance at ILC: $3.\times10^{-5} \oplus 1.\times10^{-3}$

Central Tracker

For a given $B\ell^2$, the requirements are met with
50 μm resolution and ~150 measurements in a 1.5 m radius (drift chamber)
or, with
10 μm resolution and a few (5) measurement planes (silicon tracker).

Drift chamber over silicon tracker advantages

Lower **multiple scattering** contribution for momenta up to several tens of GeV/c (**0.5% X_0** vs **5% X_0**).

Redundancy: insensitivity to local inefficiencies and to spurious hits, due to background or to shared occupancy in dense regions.

Alignment and its temporal **stability** (e.g., before and after a push-pull operation) with the rest of the detectors and with the interaction point in a time short enough to control systematics.

Continuous seeding in the active volume for track finding, not relying on the vertex detector or the calorimeter, thus capable of detecting and fitting **kinks and neutral vertices** with high efficiency (hard to accomplish in a few planes silicon tracker).

Central Tracker

Drift chamber over TPC advantages

Lower **multiple scattering** contribution for momenta up to several tens of GeV/c (**0.5% X_0** vs **4% X_0**) in barrel region and (**8% X_0** vs **15% X_0**) in the endplates, without inner and/or outer blankets

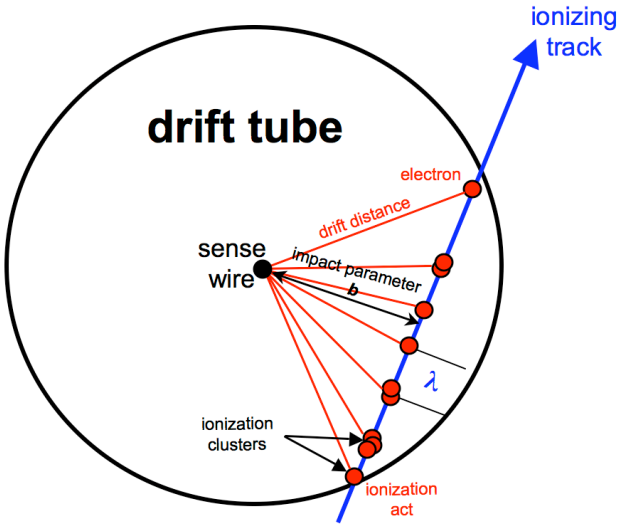
Single event per bunch crossing as opposed to the integration of at least **150 BX's**: **pattern recognition** more difficult and particularly severe because of the large integration of **backgrounds**.

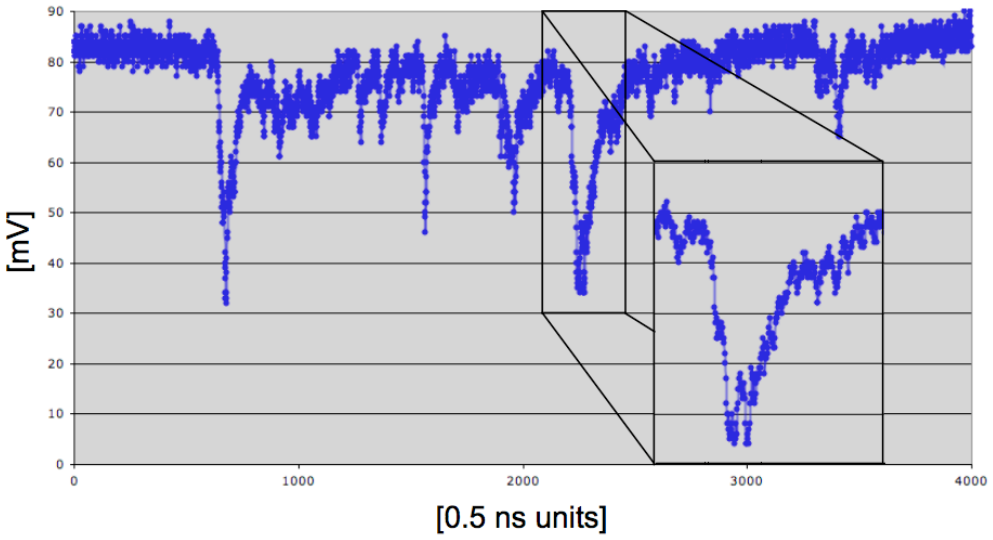
Particle identification using **dN/dx**, in principle, down to **2.5%**, as opposed to **dE/dx at 5-6%** at best.

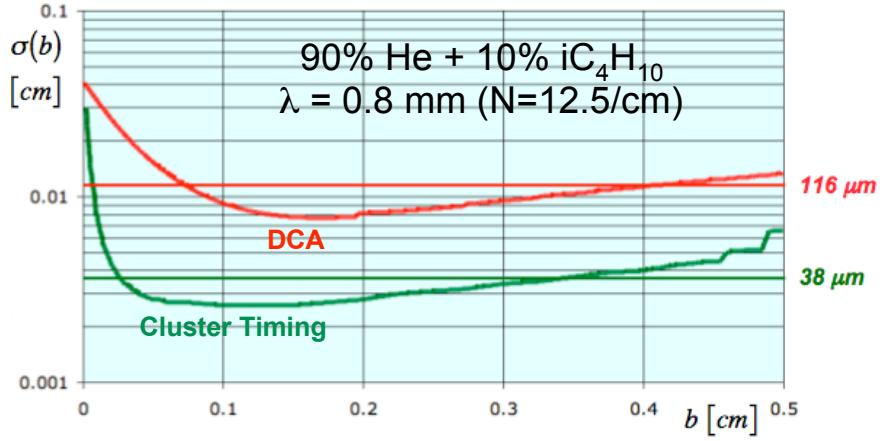
High concern about the problem of the **positive ion feedback in a TPC** causing trajectory distortions (affecting resolution) and drifting electrons recombination (affecting efficiency).

Central Tracker

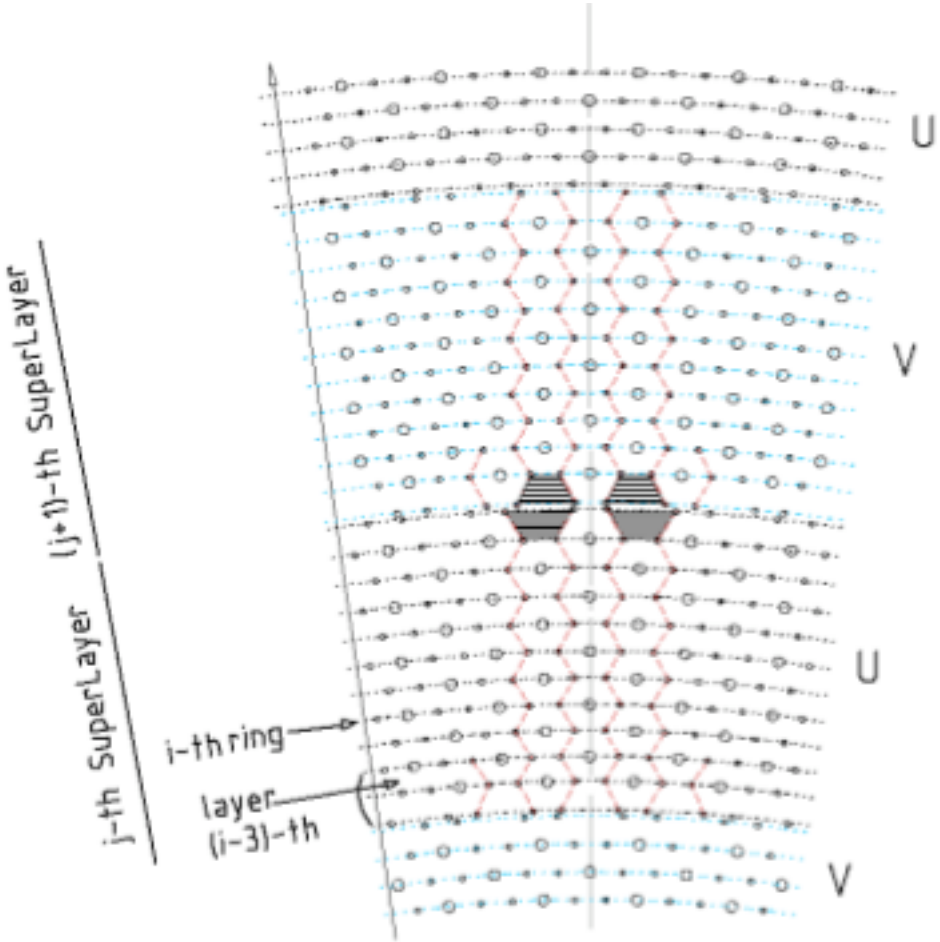
Cluster timing in drift chambers consists in recording the drift times of all individual ionization electrons collected on a sense wire and due to the passage of an ionizing track in the active gaseous medium.
This leads to spatial resolutions like







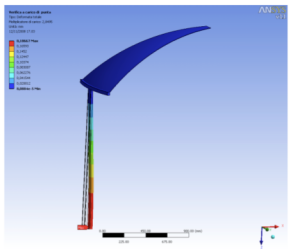
Central Tracker



General layout based on successful operation of KLOE drift chamber

R_{in} = 19 cm
R_{out} = 150 cm
R_{dome} = 242 cm

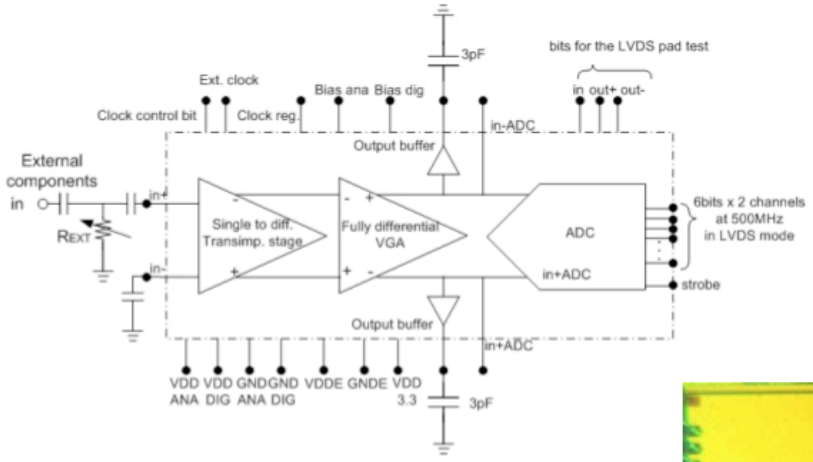
Cell size from 0.4 cm to 0.7 cm side
160 axial measurements (on average)
Stereo angles from 55 mrad to 220 mrad
sense wires = 66000 (5X KLOE)
field wires = 150000 (4X KLOE)



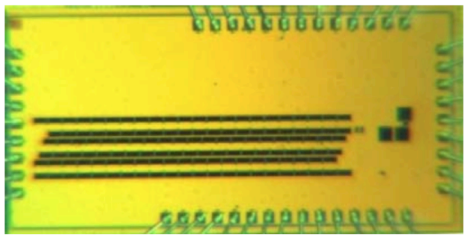
Design, structural stability, types of carbon fiber and other component materials are given in a mechanical engineering thesis, together with a strategy for the wiring procedure, taking into account the deformation of the structure while the wires are tensioned.

Central Tracker

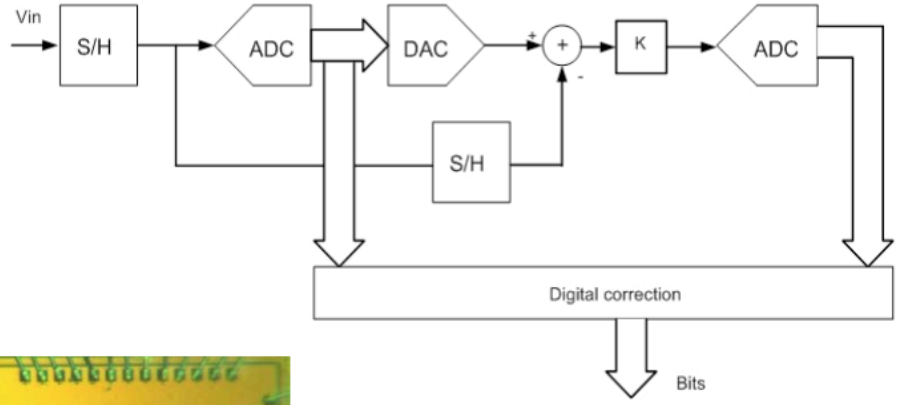
The implementation of the cluster timing technique requires a **low cost**, **high-speed**, **low-power** electronic interface able to process the drift signals. We have designed a **CMOS 0.13μm** integrated readout circuit, including a **fast preamplifier** (with a -3dB bandwidth of **700 MHz**) and **1 GSa/s-6bit ADC** to fulfill all the requirements for cluster timing. (2nd version by June 2009)



preamplifier



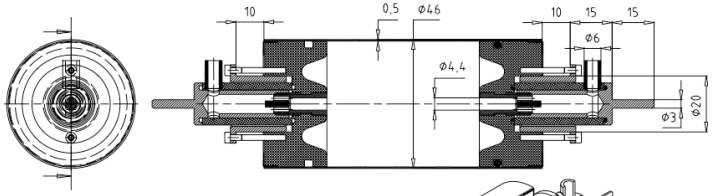
microphotography (1st version)

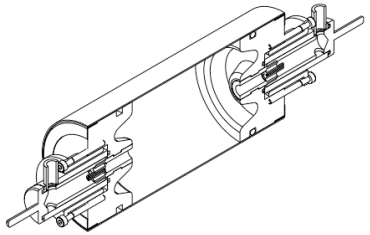


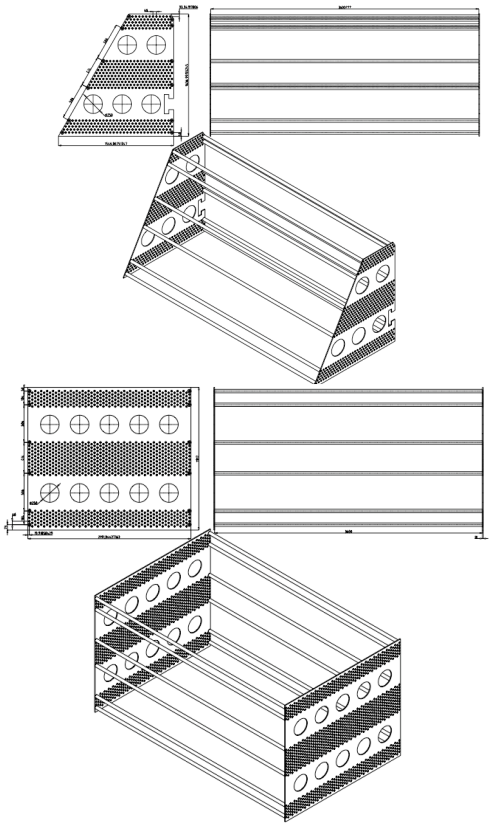
Flash ADC

Muon Spectrometer

The basic building block is a **4.6 cm drift tube** using the **same He gas mixture** and the **same front end electronics** as **CluCou**.





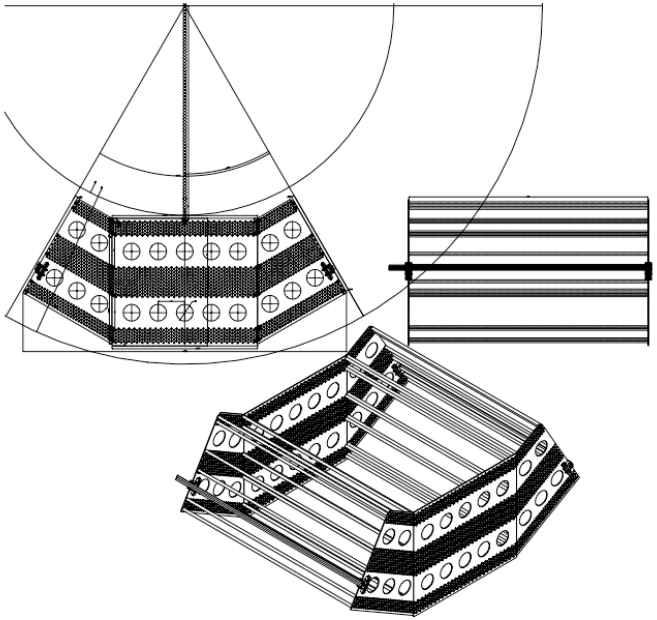


Precision positioning plates are used to align the tubes.

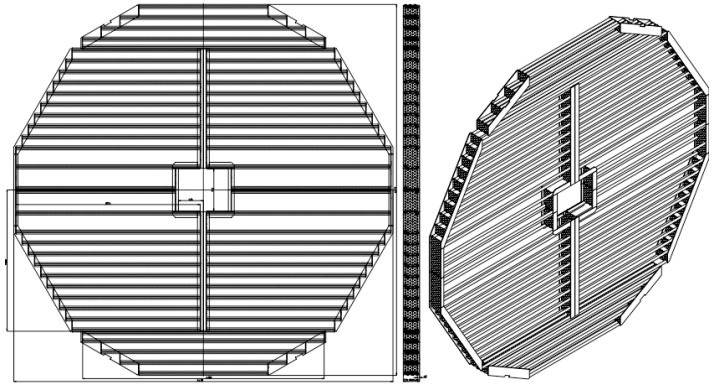
Only two different muduli, 4 m long, 460 and 1100 tubes each, are necessary to build 1/6 of 1/3 of the whole barrel.

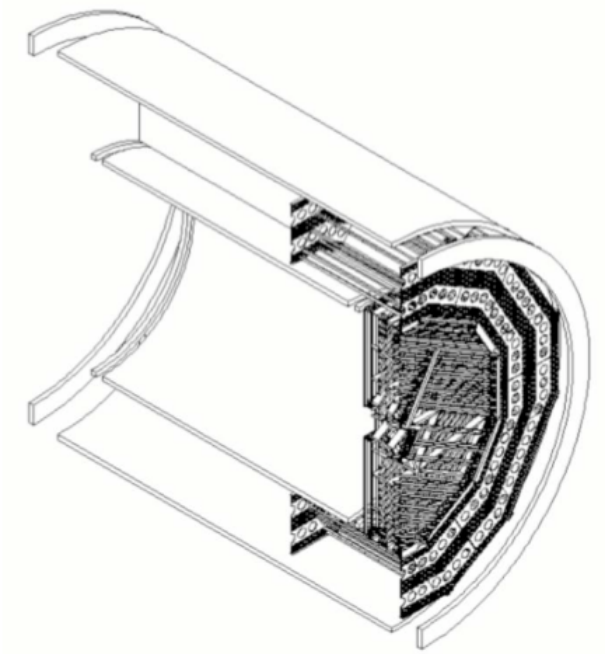
The three corresponding tubes along *z* are ganged together for a more precise *z*-coordinate measurement with current division.

20 layers of tubes radially.



Muon Spectrometer





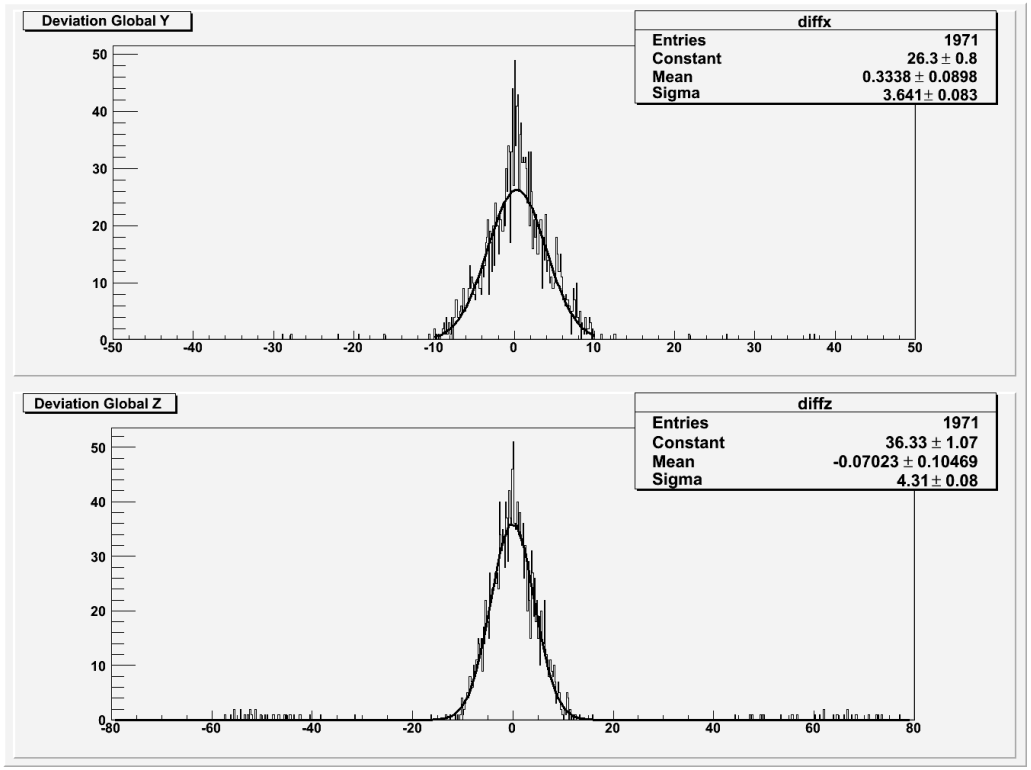
Each end cap plane is made of three basic moduli.
One end cap is made of three planes rotated by 120º.

6 tubes per projection, 18 per end cap.

Total number of tubes: 45000.
Total number of electronics channels: 34000.

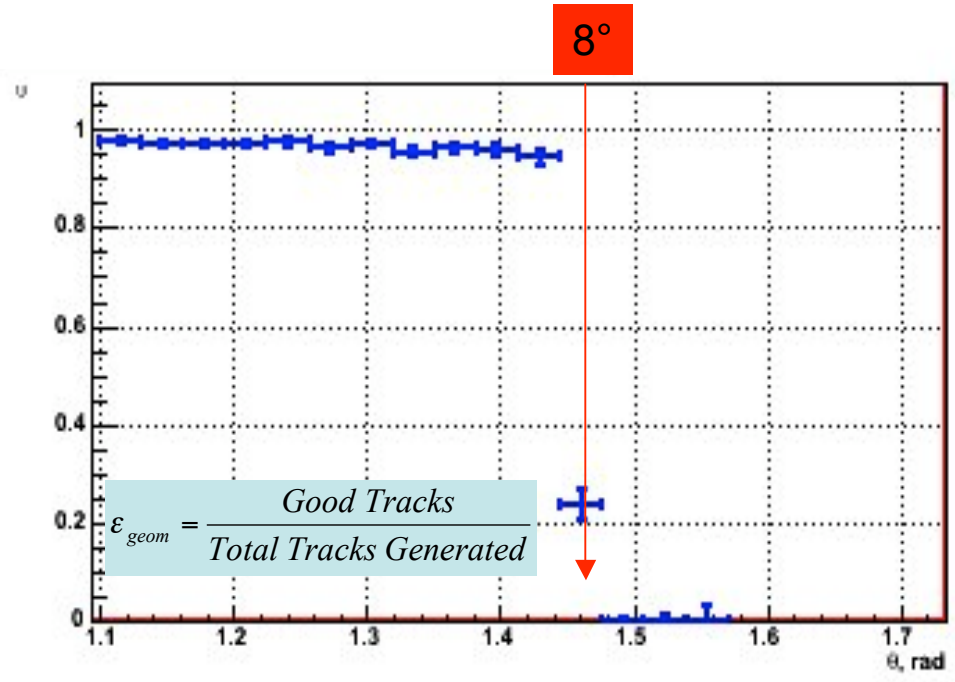
VXD Single Cluster Residual (single track)

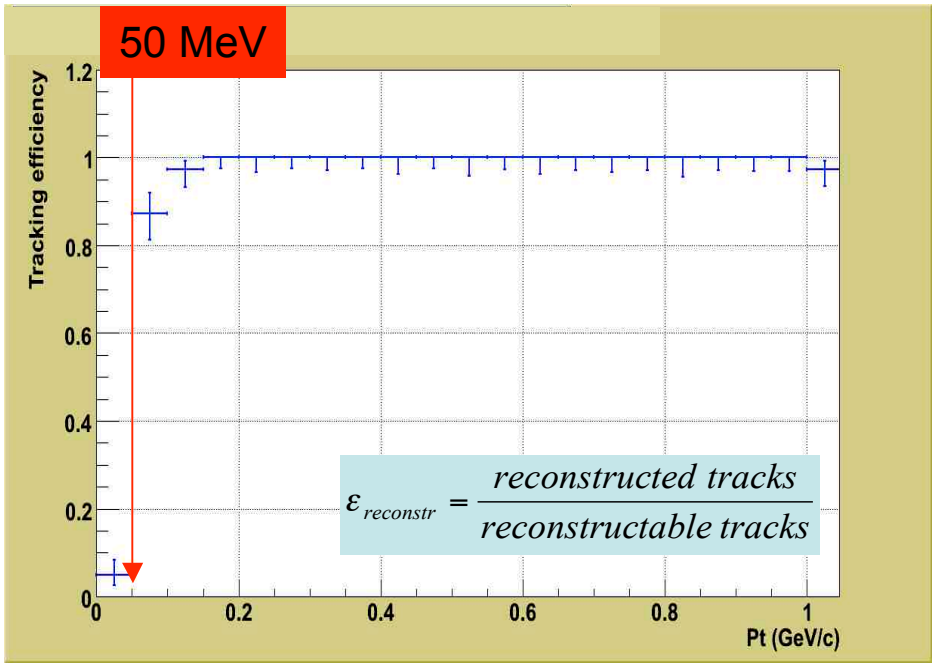
- FNAL/SLAC layout more than adequate for current requirements at ILC
- Main issue is choice of technology
- Choice driven by Montecarlo studies on beam background



Single muons
No beam bkg

Tracking Efficiency



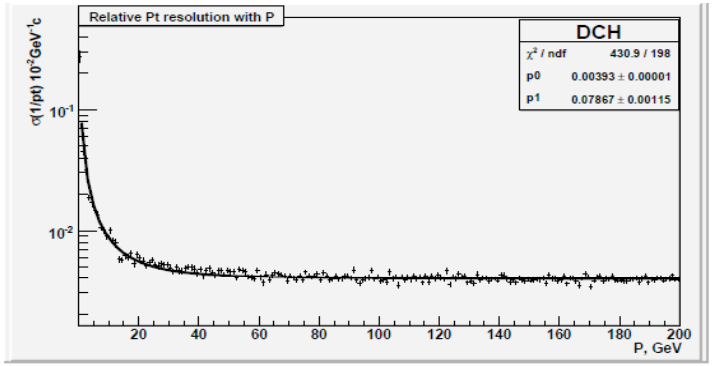


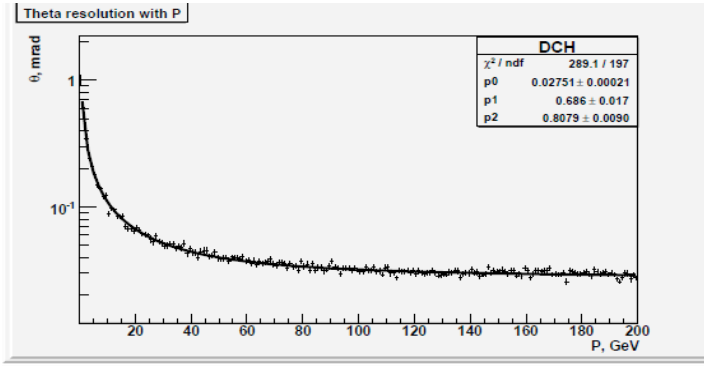
Defining "reconstructable tracks"

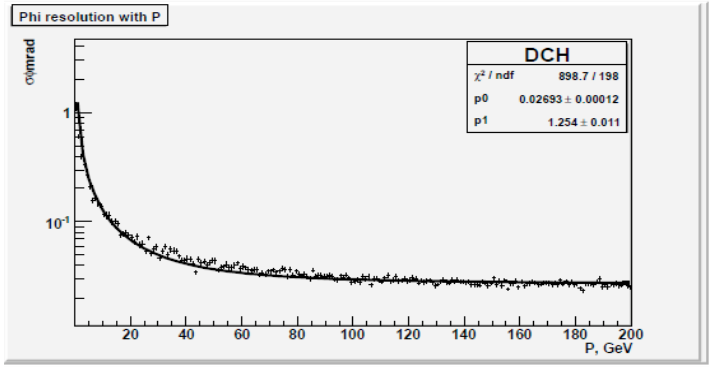
- DCA(true) < 3.5 cm
  AND
- (At least 10 hits in DCH
  OR
- At least 4 hits in VTX)

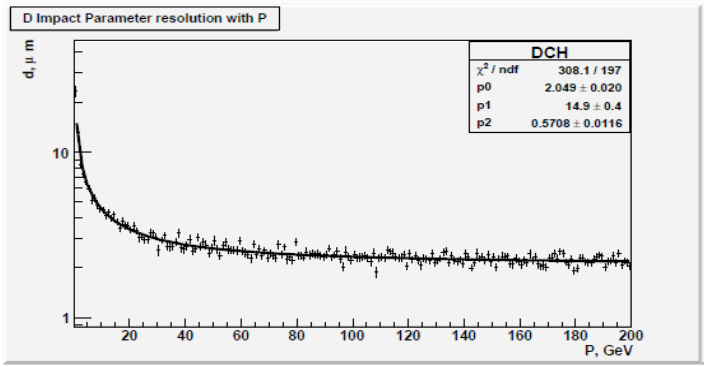
Single muons
No beam bkg

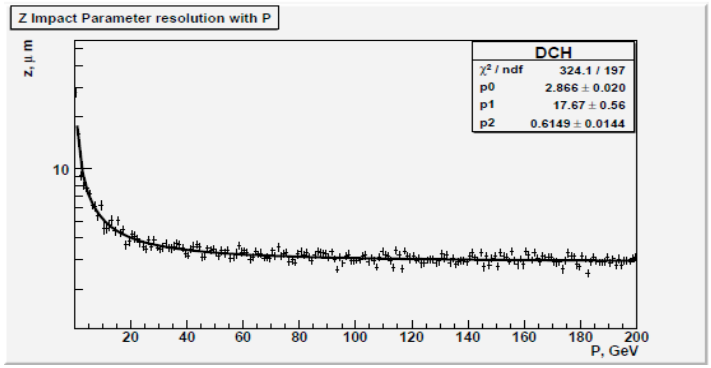
Tracking resolution vs P







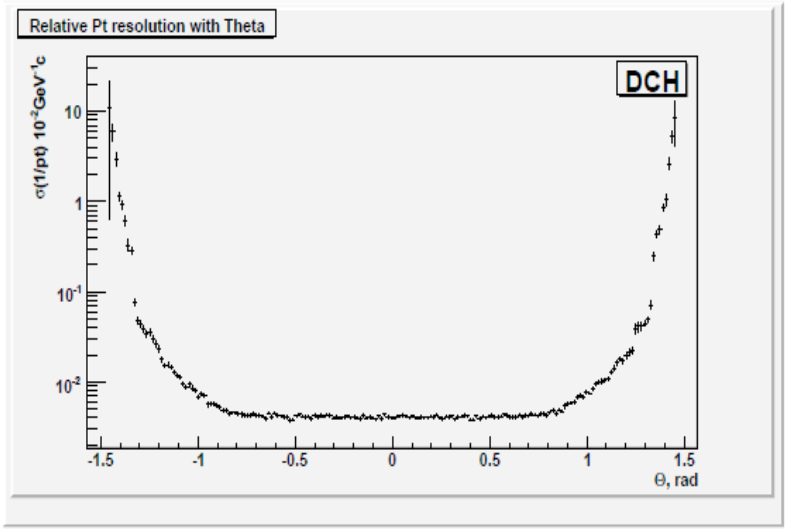


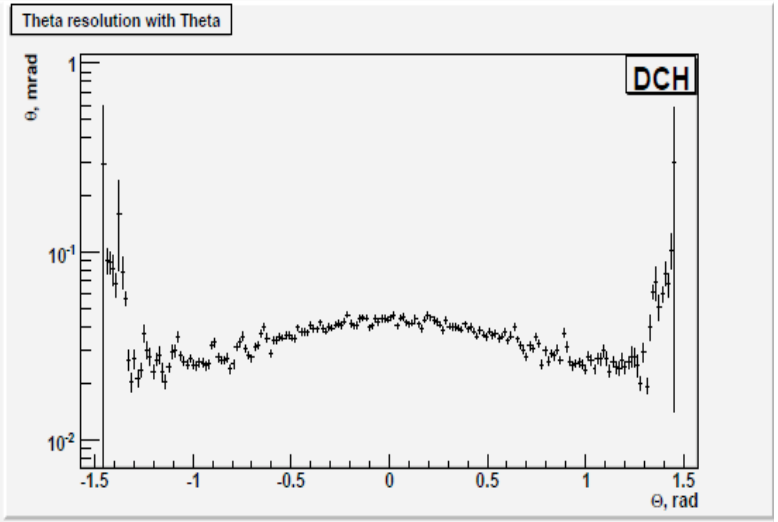


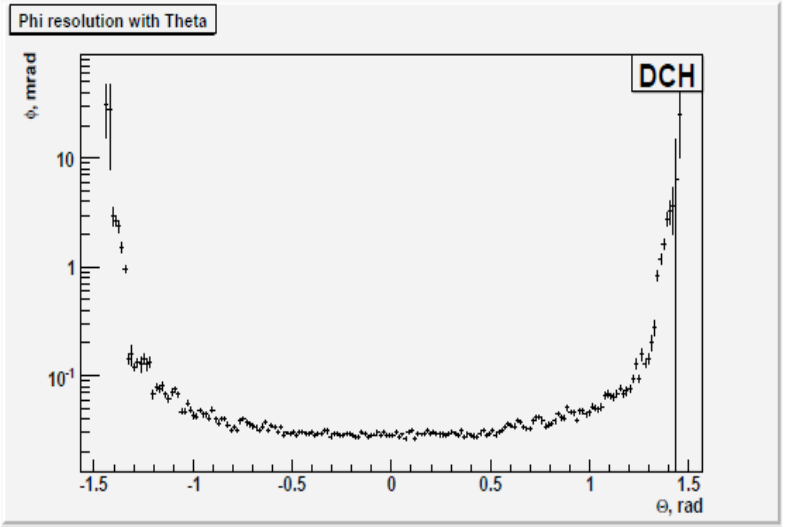
track parameter	fit results stochastic term	multiple scattering term
$\sigma(1/p_T)$	3.9×10^{-5} (GeV/c)$^{-1}$	$\oplus$ $7.9 \times 10^{-3}/p_T$
σ_θ	0.69 mrad$/p_T^{0.80}$	$\oplus$ 0.027 mrad
σ_ϕ	1.25 mrad$/p_T$	$\oplus$ 0.027 mrad
σ_d	14.9 μm$/p_T^{0.57}$	$\oplus$ 2.0μm
σ_z	17.7 μm$/p_T^{0.58}$	$\oplus$ 2.9μm

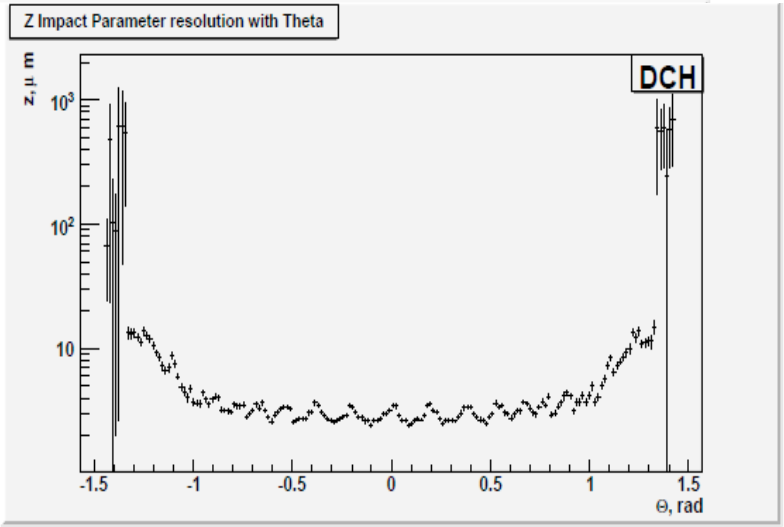
Single muons
No beam bkg

Tracking resolution vs θ





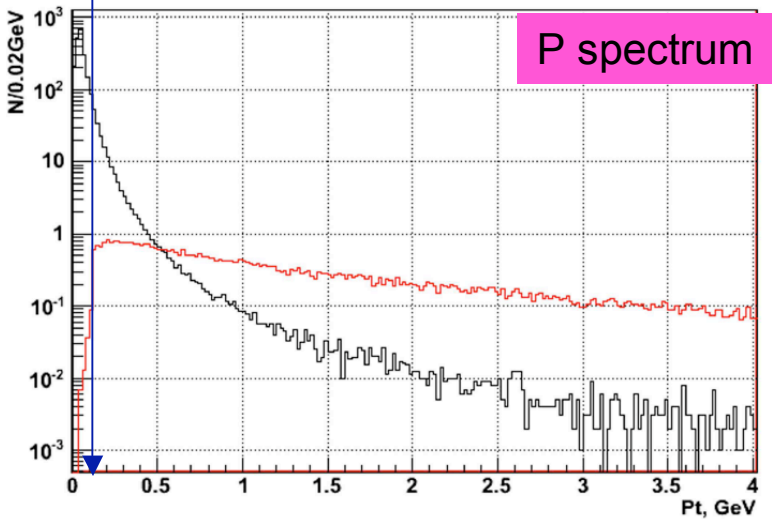




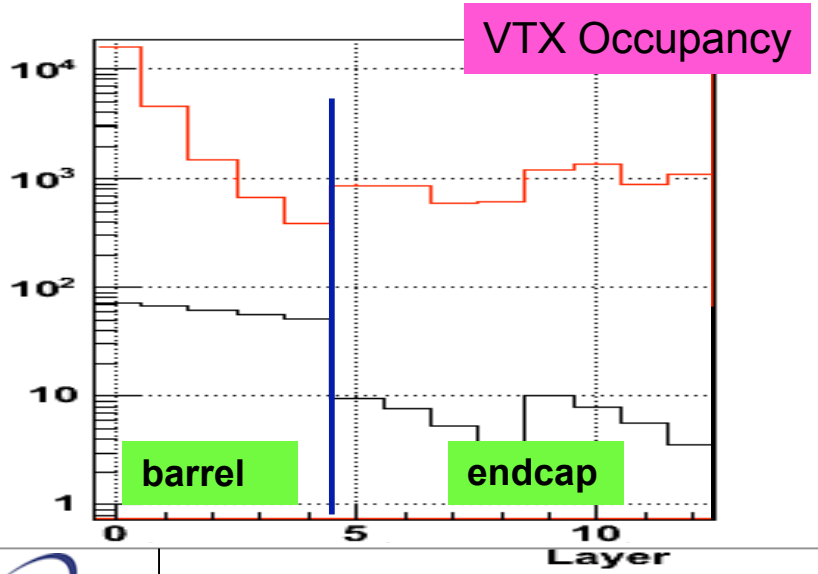
ttbar –> 6 jets
100 BX beam bkg

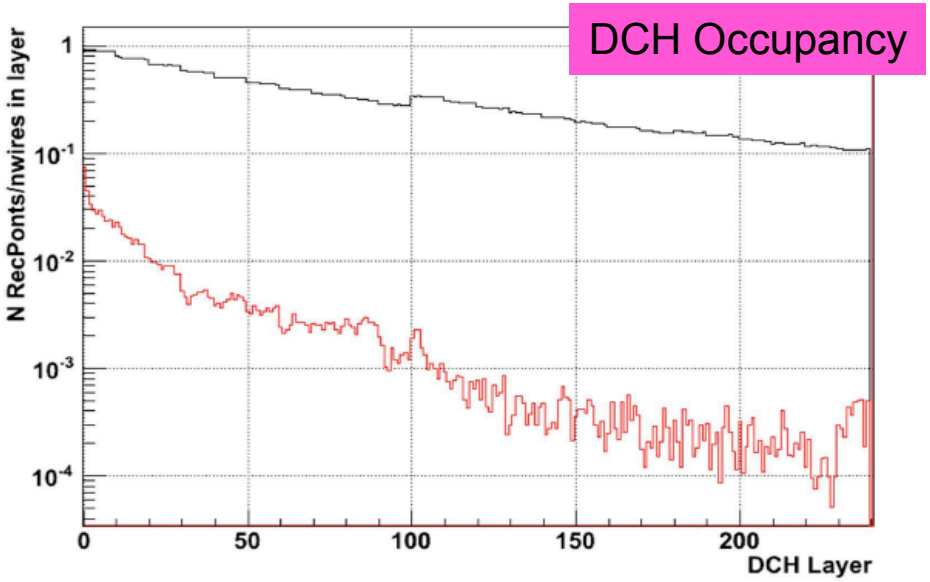
Occupancy with Beam Background

120 MeV



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

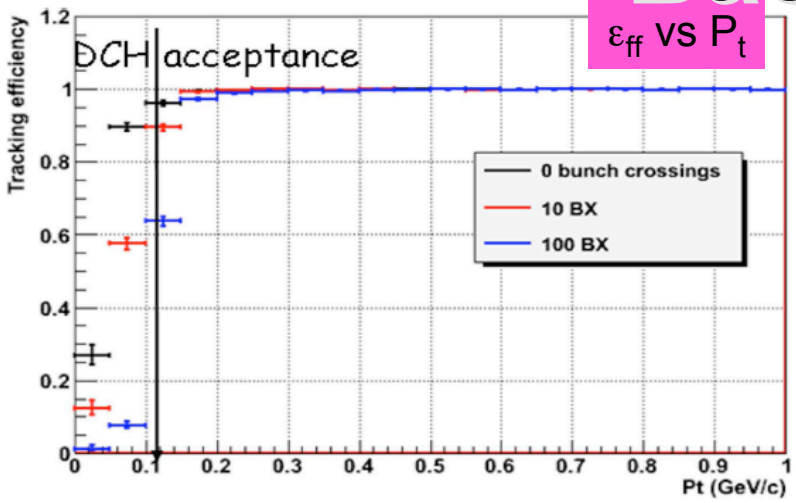




ttbar –> 6 jets
10-100 BX beam bkg

Tracking Efficiency with Beam Background

ε_{ff} vs P_t



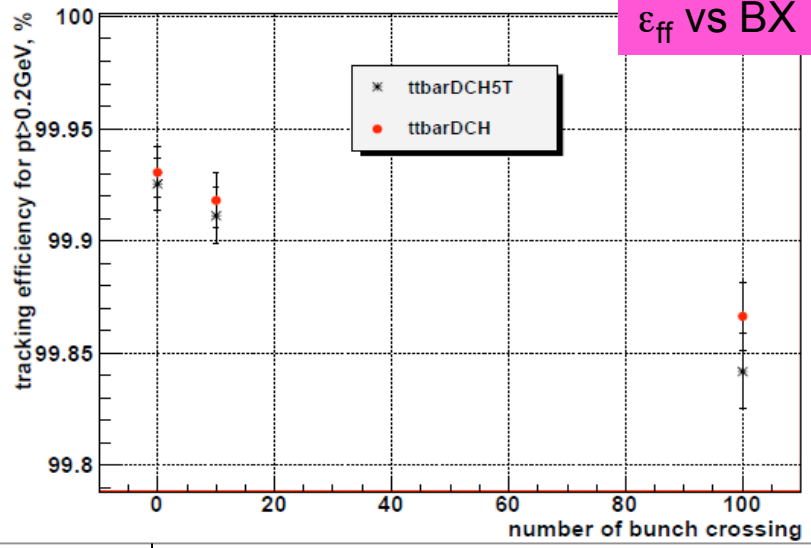
Fake track definition

1 misassigned cluster in VTX
10% misassigned clusters in DCH

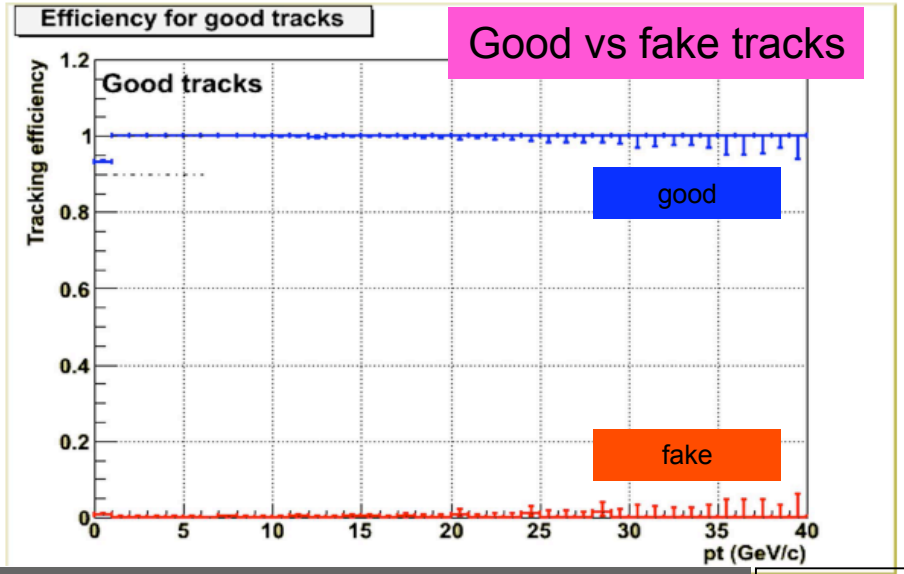
Sources of inefficiencies

seeding for low Pt & Kalman filter with fake clusters

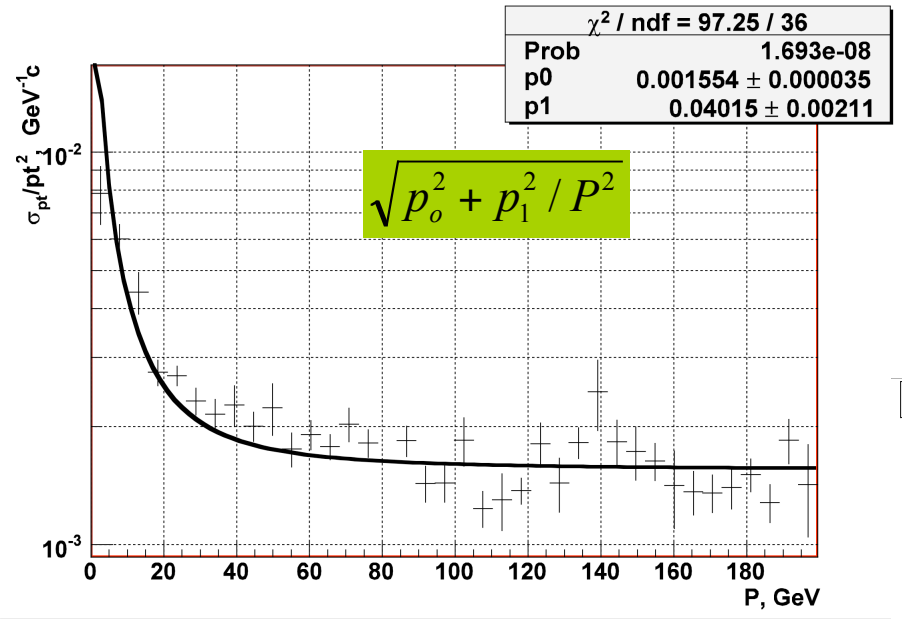
ε_{ff} vs BX



Good vs fake tracks

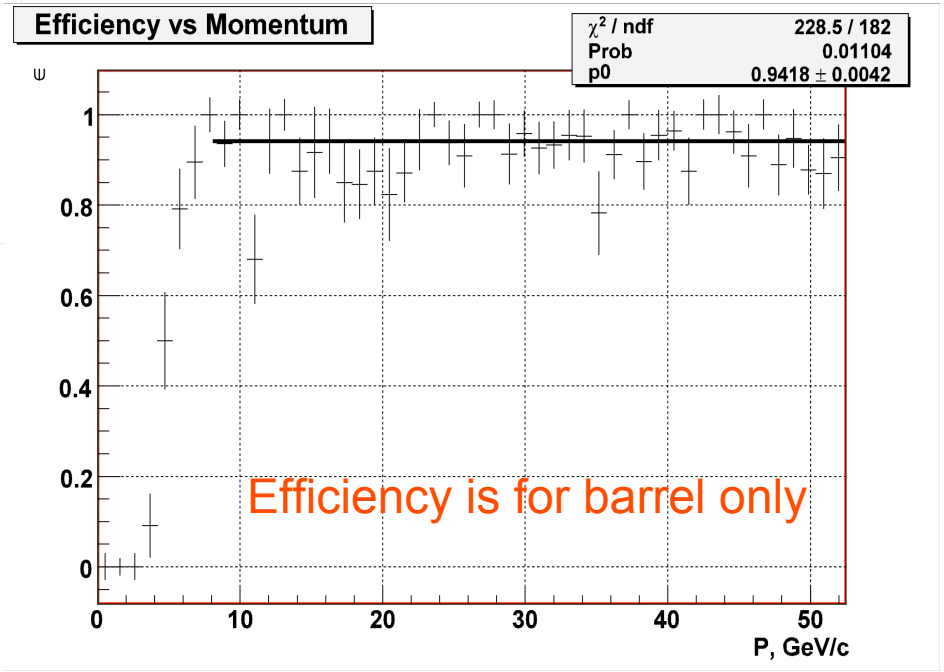


Muon Spectrometer Performance



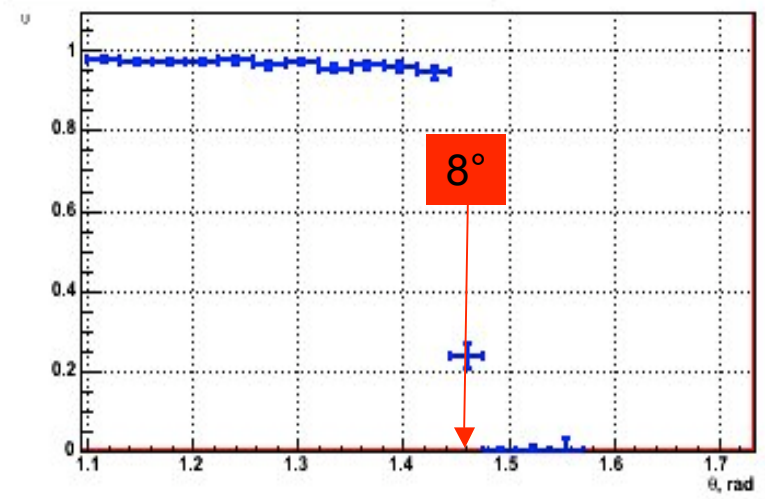
Cracks excluded

Requires tracks already reconstructed in DCH

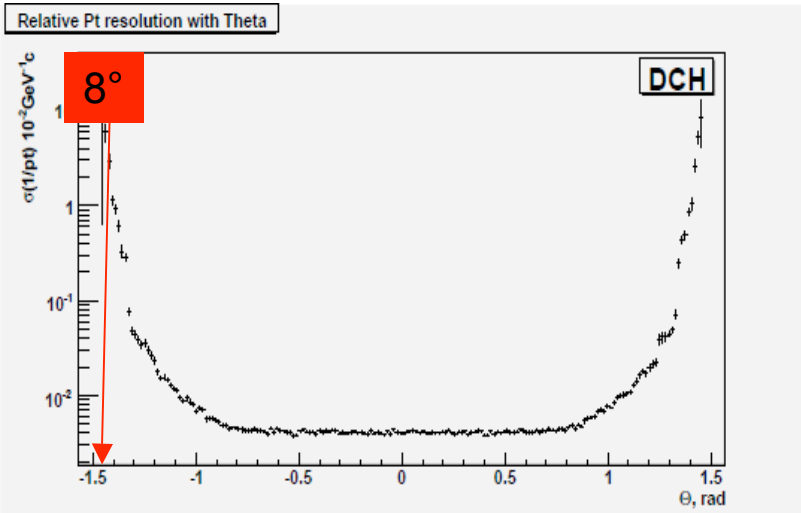


$$\sigma(P_t^{-1}) = 0.04/P \oplus 1.5 \times 10^{-3} GeV^{-1}c$$

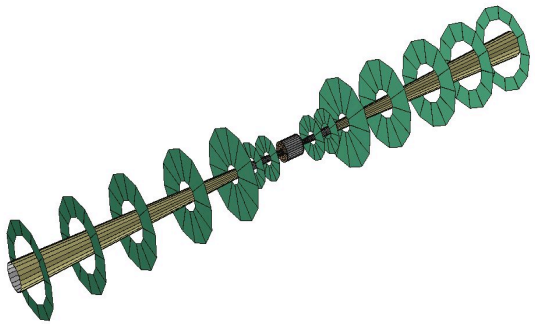
Alternative technological Options



Drift chamber efficiency vs theta



Momentum resolution vs theta



Synergy with collaborators from SILC: introduce a set of silicon detectors inside inner cylindrical wall of drift chamber, eventually, increase inner radius of chamber