Some Ideas & Brainstorming

(mainly driven by complementary approaches to the calorimetry,

but the concept which may be a winner is a tracking one …)

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Some history

- Detectors I’ve been particularly involved in:
  - Omega PLUG scintillating fiber ECAL
  - OPAL Time-of-flight
  - D∅ scintillating fiber tracker trigger

Ideas

- Concept #3: frankyaug05
  - Radially distinct calorimeter sections with fine granularity
- Hermetic timing layer in ECAL
  - For eg. reactions like $e^+e^- \rightarrow \nu\ \nu\ \gamma$ this is very useful
- Scintillating fiber tracking layers for track matching to ECAL and time-of-flight.

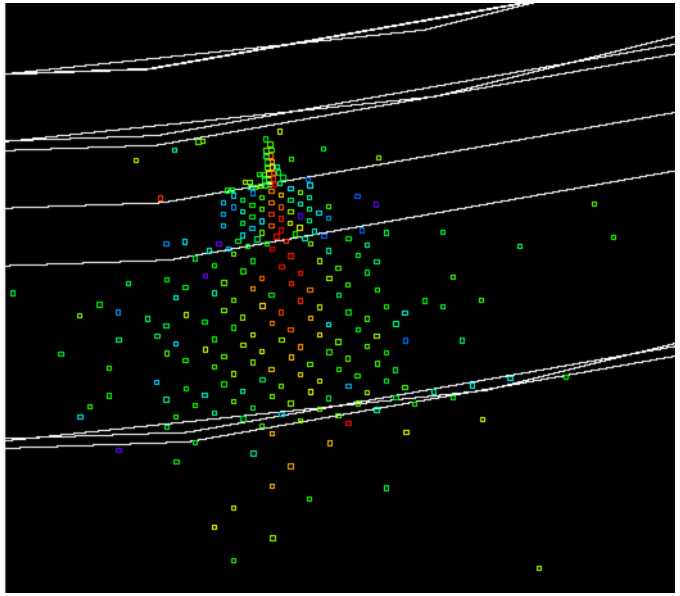
frankyaug05

A radially staggered buildable analog calorimeter with exquisite granularity, with no cost optimization using Tungsten. B = 3T.

With M. Thomson.
Acknowledgements to N. Graf

	R(m)	Nlayers	X0	Active	Cell-size (mm)
EM Barrel 1:	2.10	10	0.5	Si	2.5 × 2.5 × 0.32
EM Barrel 2:	2.13	10	0.5	Si	10 × 10 × 0.32
EM Barrel 3:	2.16	20	0.5	Sc	20 × 20 × 2
HCAL:	2.255	50	2.0	Sc	40 × 40 × 2

(W was cheaper in 05..)



50 GeV photon

Choices made based on current R&D work, driven by making sensible, robust design with aggressive performance and minimizing Silicon area in a GLD-scale detector.

Expect: $\sigma_E/E = 11\%/\sqrt{E}$ at low energy

Scintillating fiber tracking layers

With the advent of SiPM's with $1mm^2$ area, the challenges of the above detector are avoided. Allows direct coupling of Sc. fiber to high gain photo-detector in B-field at room temperature.

D∅: average light yield of 8 photo-electrons per MIP, using system with 1.5% light collection efficiency (including trapping, reflector, transitions, attenuation in scintillator, attenuation in > 8m wave-guide, VLPC quantum efficiency).

With same fibers and 1.6m length expect 50 photo-electrons (L+R) with 65% PDE MPPC-100. Standard fibers $\lambda > 3.5$m

SiPM’s

- Noise not a major issue with coincidences.
- Dynamic range (100 pixels) and PDE of 65% of MPPC-100 is well adapted to 1mm fibers.

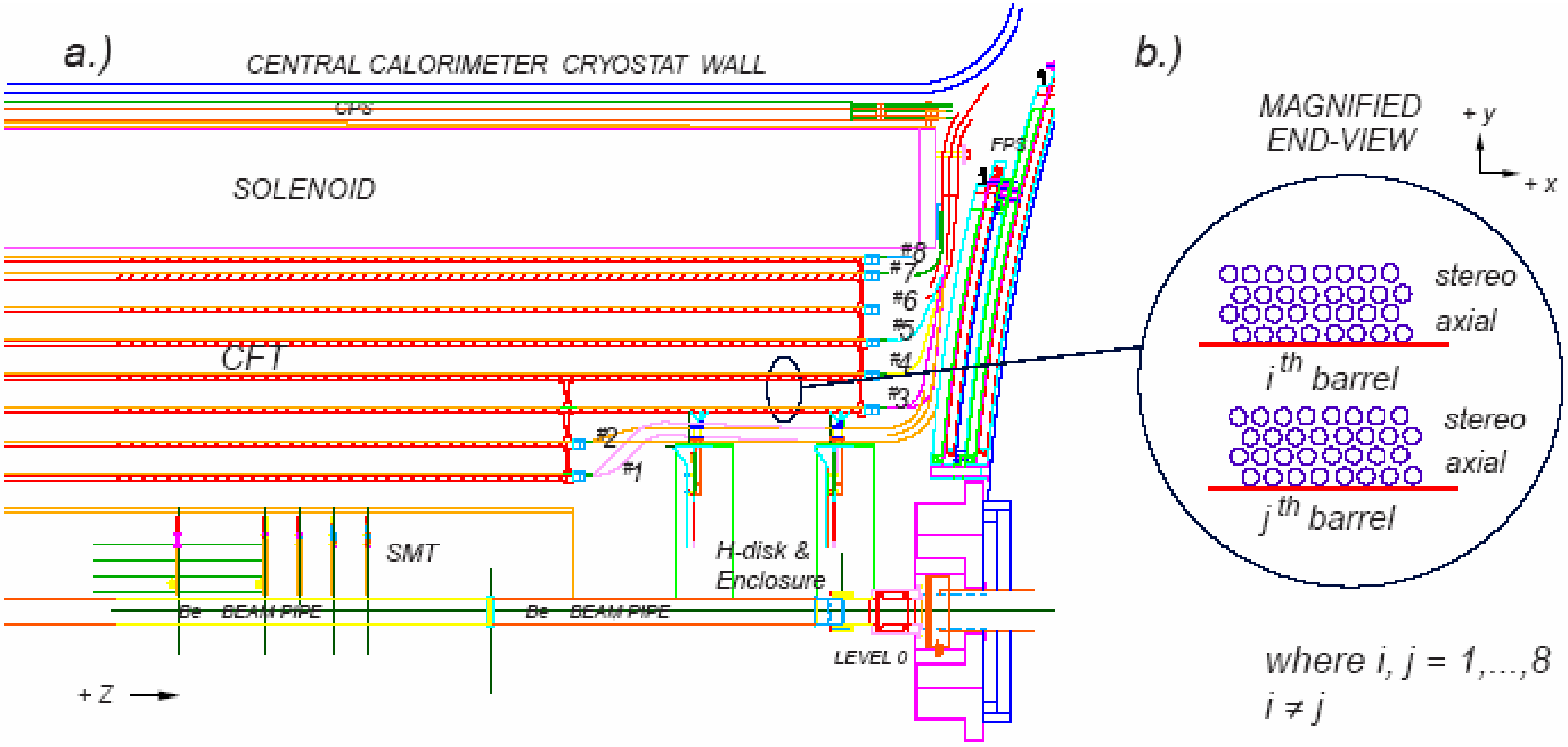
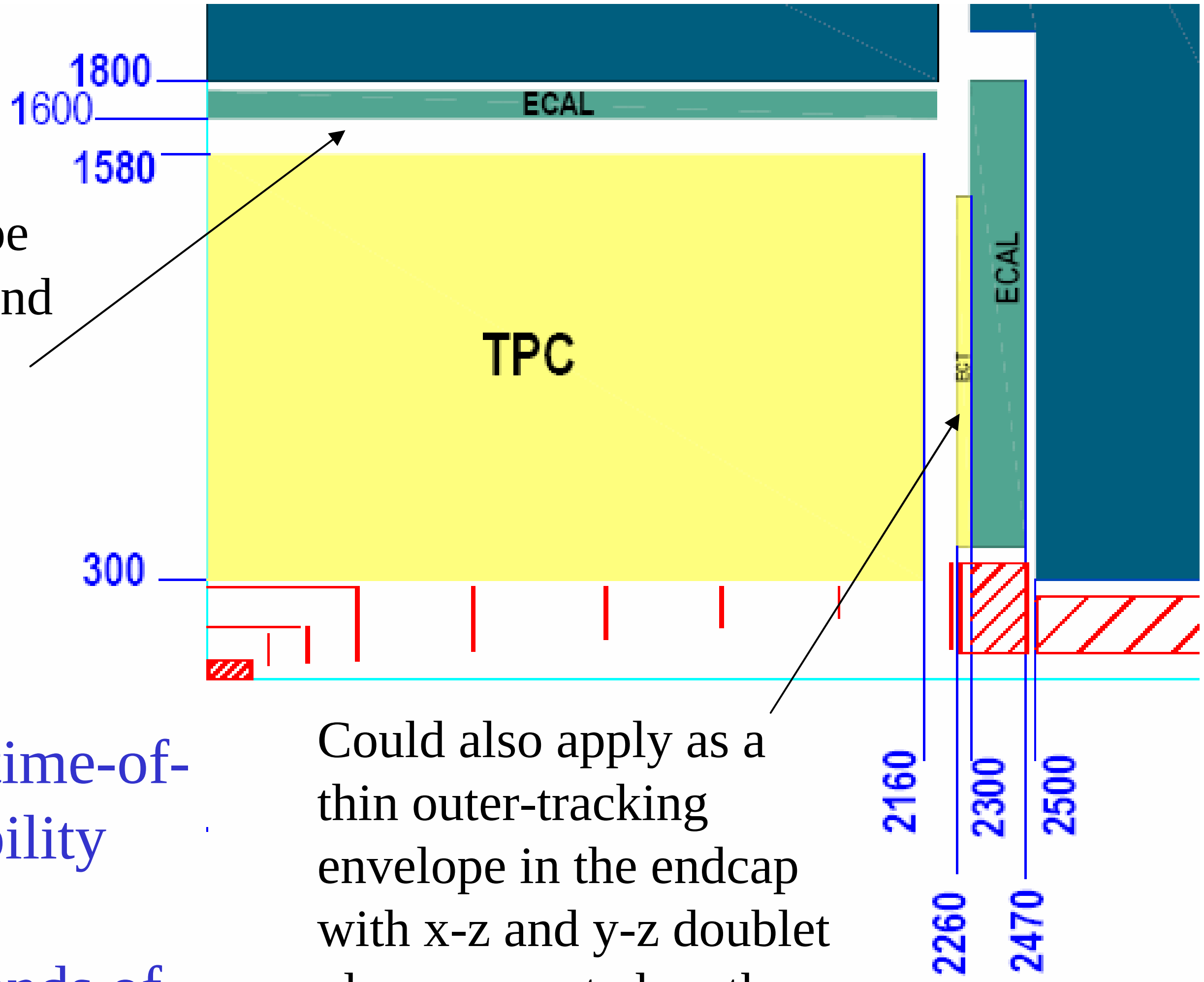


Figure 1: Schematic $r - z$ view of one quarter of the CFT: a) nested eight barrel configuration and b) magnified $r - \phi$ end view of the two doublet layers per barrel [1].

32 layers of fibers arranged on 8 support-cylinders. Within each super-layer, 2 layers for axial, 2 for stereo.

Material budget total approx 9% X_0. One super-layer = 1.1%X_0

Applying to LDC ?



Could apply as a thin outer-tracking envelope in the barrel with r-ϕ and r-z doublet planes mounted either on the ECAL barrel or the TPC field cage.

Could also apply as a thin outer-tracking envelope in the endcap with x-z and y-z doublet planes mounted on the ECAL endcap

In both locations, time-of-flight (TOF) capability appears feasible, especially if both ends of the fibers are read-out.

Measure r-ϕ

Measure r-z

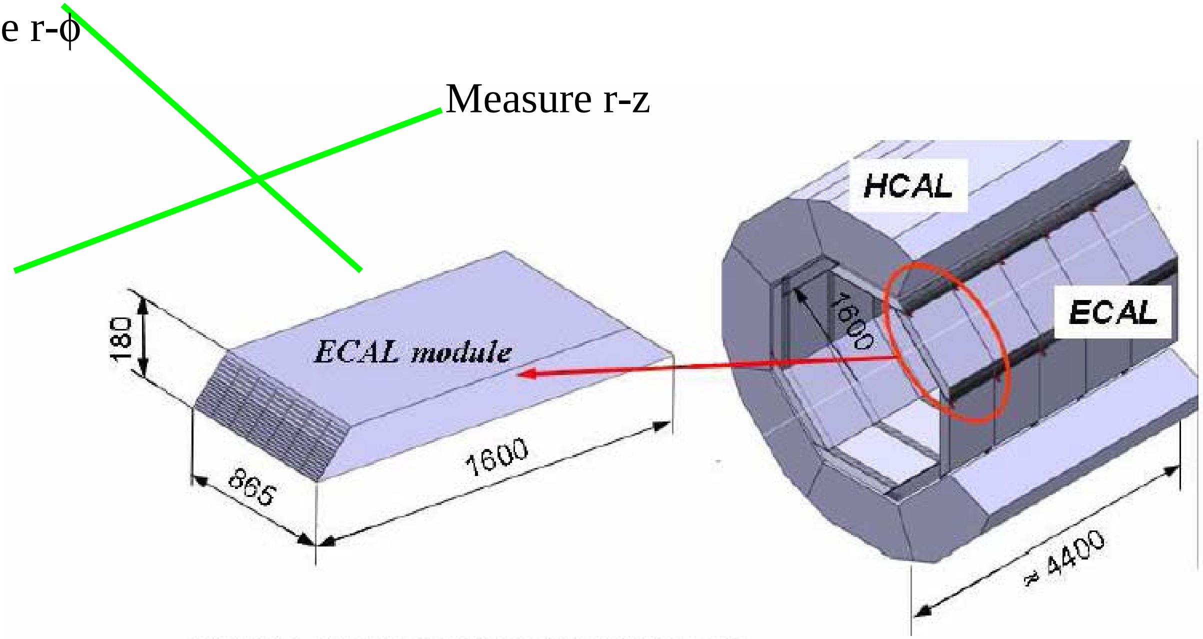


Figure 31. Struture of modules of the ECAL barrel.

Would prefer 3 modules in z.

For timing performance probably best to split in 3.

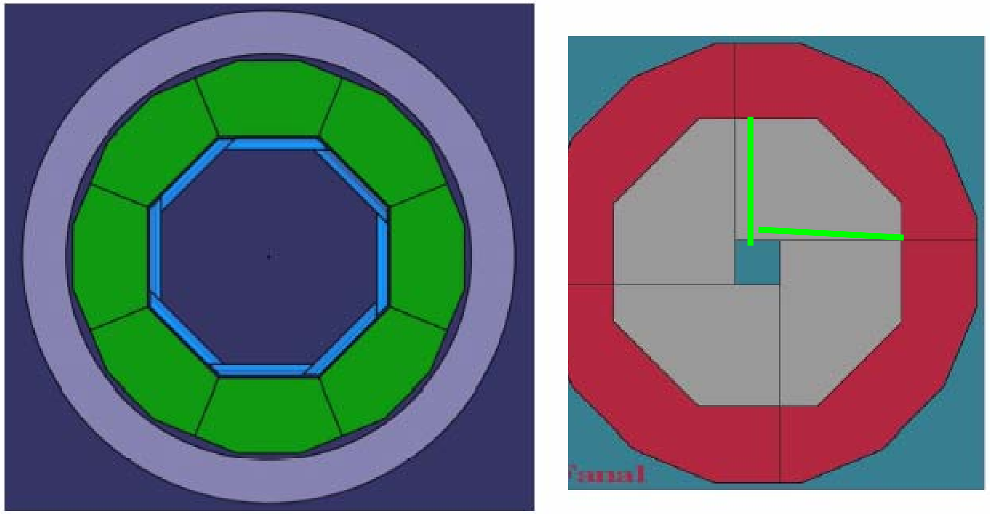
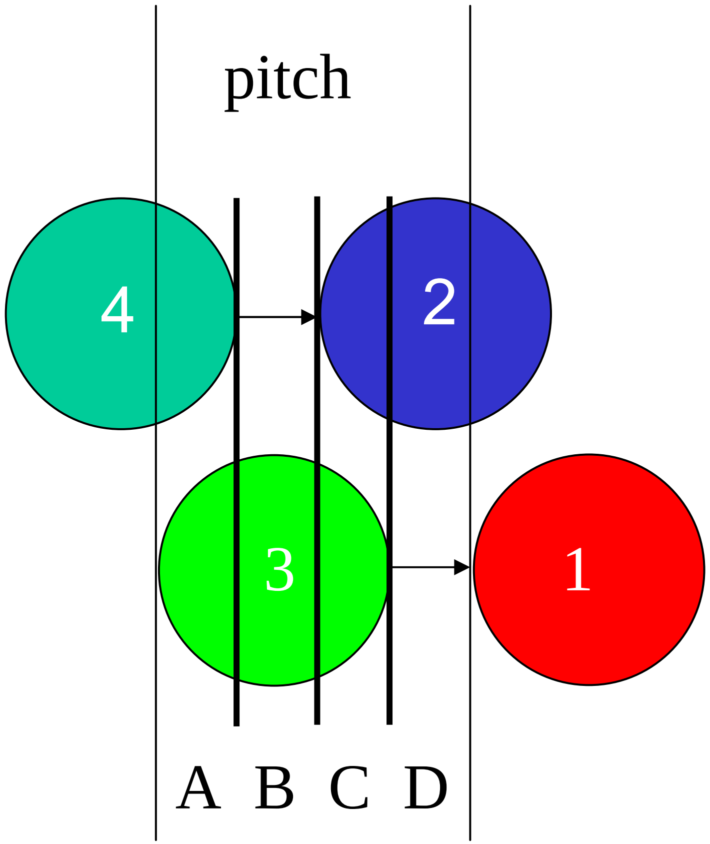


Figure 32. Possible endcap design of the electromagnetic calorimeter.

Could also imagine a x-u plane with 45 degree angle

Doublets 101



The D∅ scheme:
pitch=960µm, leading to
$\sigma_{r-\phi}$ = 90 µm (test-beam)

With sufficient light budget, doublet layer leads to 4 ≈ well defined regions per pitch unit (A, B, C, D) with approximately the same width. So intrinsic resolution is about (pitch/4)/√12 assuming no cross-talk and high efficiency.

With only a few layers, need redundancy in case of single dead channels.

So prefer to read-out both ends of the fiber IF it can be done easily.

This lends itself to a classic TOF-like application too.

Achievable Performance ?

- Assuming doublet arrangement for each plane with redundant readout, expect 100% efficiency per coordinate, and high efficiency for precise pitch/4 effective cell size.
- Geometries with vernier-style readout can be considered using the measured light output per layer.

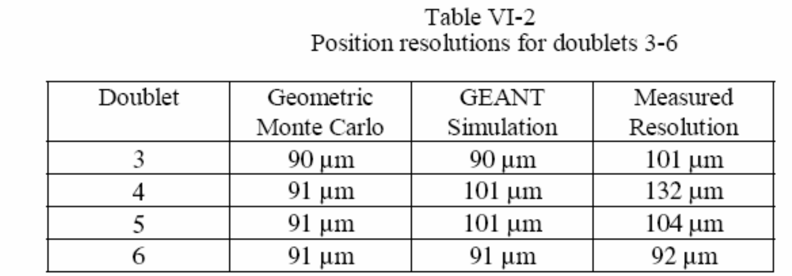
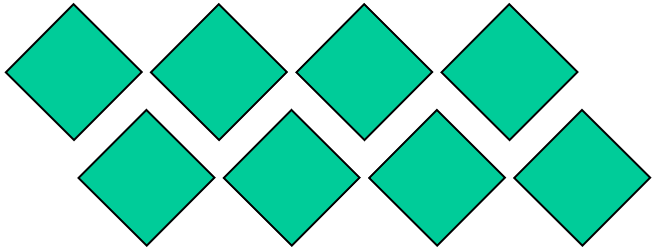


Table VI-2
Position resolutions for doublets 3-6

Doublet	Geometric Monte Carlo	GEANT Simulation	Measured Resolution
3	90 μm	90 μm	101 μm
4	91 μm	101 μm	132 μm
5	91 μm	101 μm	104 μm
6	91 μm	91 μm	92 μm

D∅ basically achieves pitch/10 = 100 μm for these 775 μm active diameter fibers with only 8 photo-electrons per MIP.

Ultimate performance limited by fiber placement errors in the ribbon at the ≈ 20 μm level



Square is probably best for this.

For LDC, shorter fibers, flat planes, no light-guides => estimate 80 μm resolution for both r-ϕ and r-z (barrel)

or for z-x and z-y (endcap).

Timing Performance

- Standard D∅ radiation hard scintillator t_{decay} = 7ns. BCF-20 has t_{decay} = 2.7ns at 492 nm.
- For each track could have on average about 6 time measurements each with about 20 photo-electrons.
  - Time resolution will depend on method and electronics. With the large spread in effective propagation speeds due to photon emission angles and the 1600:1 aspect ratio of the fibers, I suspect a timing based on the arrival time of the earliest photo-electron may be appropriate.
  - Another technique, would be to mirror one-end, and use a multi-hit TDC to time both the direct and reflected light.
  - Having several measurements with precision input fromTPC will help control time systematics vs propagation distance.
  - Guess something like 250 ps easily achievable, probably more like 100 ps.

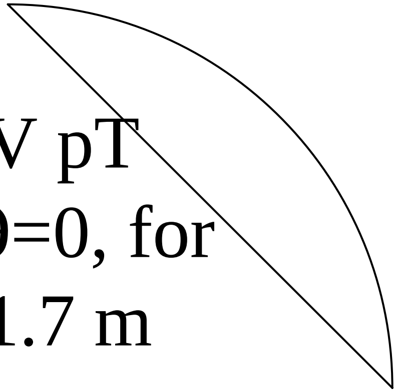
Channel Count

- Barrel (r-ϕ). 1600 doublets per octagon.
  - => 50 k fiber ends * n_modules = 150k (for n=3)
- Barrel (r-z). 4400 doublets per octagon.

  => 140 k fiber ends
- Endcap (x-z). 1200 doublets per quadrant
  - y-z. 1200 doublets per quadrant
  - => Total of 38k fiber ends.
- In total 333k fiber ends. (only 3.3% of GLD ECAL!)
- So, may need to decide what level of redundancy, position precision and time resolution we can afford and need
  - But given developments in SiPM's it is probably not a show-stopper.

Temporal calorimetry for energy flow ?

Idea: Use time difference between $\beta=1$ straight line (photon) and $\beta<1$ curved track (charged pi, K, p)



- ΔT for 1.5 GeV pT tracks at $\cos\theta=0$, for B=4.0 T, R=1.7 m
  - pi : 0.59 ns
  - K : 0.89 ns
  - p : 1.68 ns

ΔT for 3.0 GeV pT tracks at $\cos\theta=0$, for B=4.0 T, R=1.7 m

  - pi : 0.12 ns
  - K : 0.19 ns
  - p : 0.39 ns

Loopers have pT = 1.02 GeV here.

Conclusion: of order 100 ps resolution needed for time differences of the primary particle to be useful => looks impractical

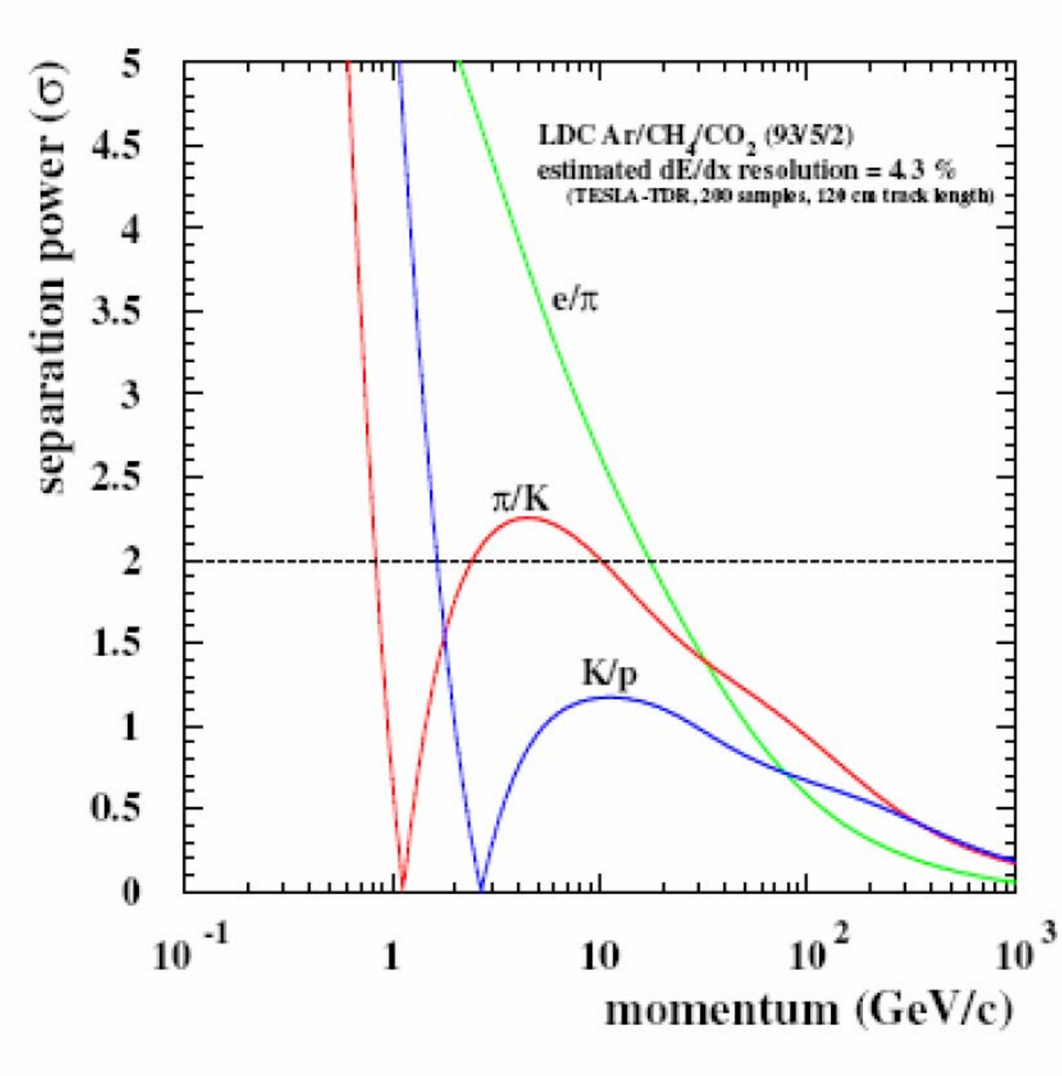
Particle ID

$\beta=1$, flight time for 2m is 7 ns.

So expect resolution on $1/\beta$ for $\sigma_t=100$ ps of about 1.5%.

1.5 GeV gives pion/kaon ΔT of 300 ps.

So expect 3σ separation pi/K separation at 1.5 GeV which complements dE/dx nicely.



Summary

- For about 1% X_0, can envisage space points with resolution of 100 μm, time resolution of 100 ps, and minimized distance to ECAL.
- Smaller fibers are feasible to 250 μm, but need multi-anode SiPM designed for smaller area ….