4th Concept Detector

G P Yeh

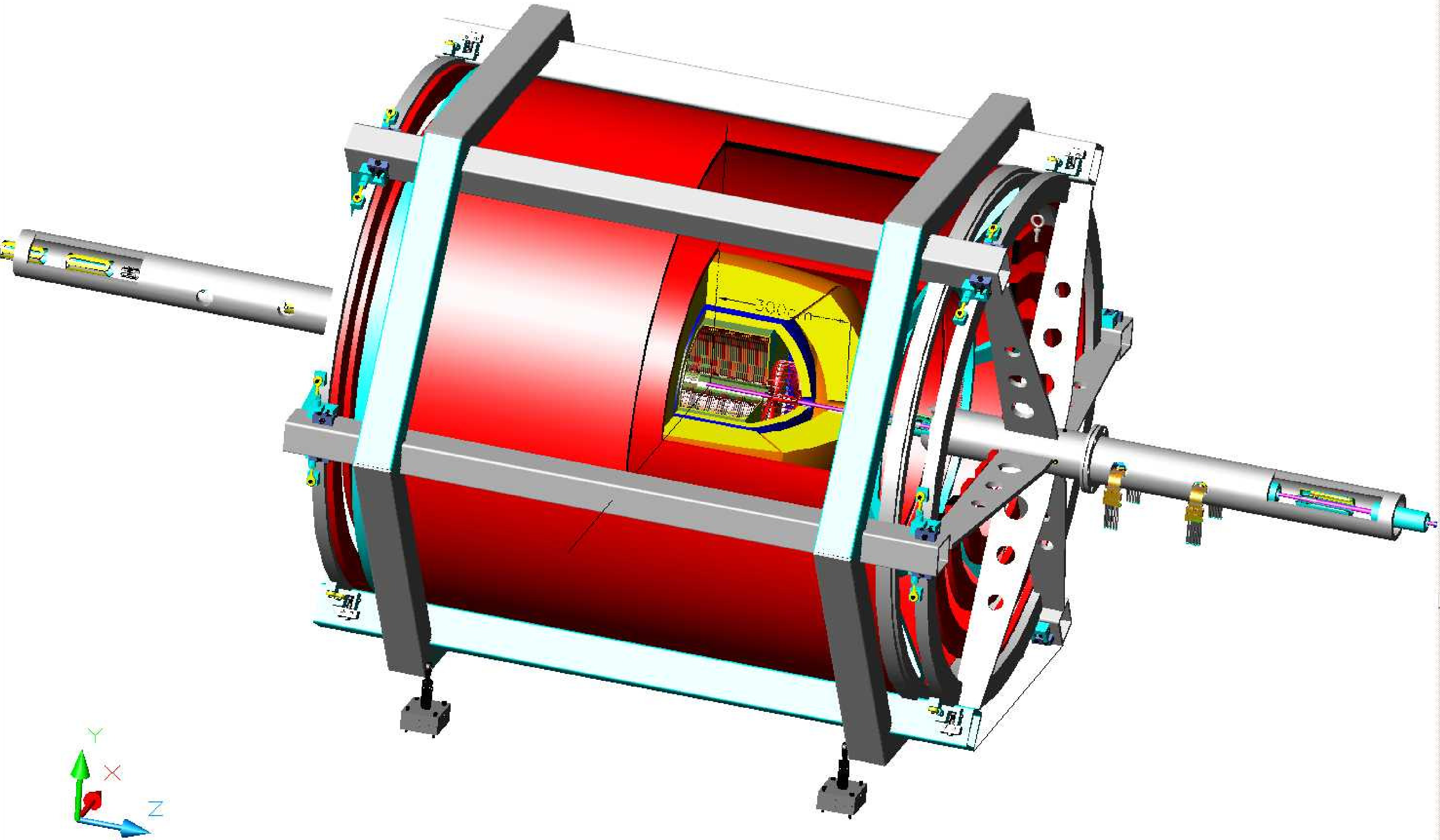
TILC08, Sendai, Japan

Mar. 3-6, 2008

4 Concepts → 3 LoI

• GLD	SiLC	TPC	PFA	ILD
• LDC	SiLC	TPC	PFA	
• SiD	Si		PFA	SiD
• 4th	SiLC	CluCou	Dual Readout	4th

4th Concept Detector



4th Concept Detector

Started @ Snowmass
8 / 2005

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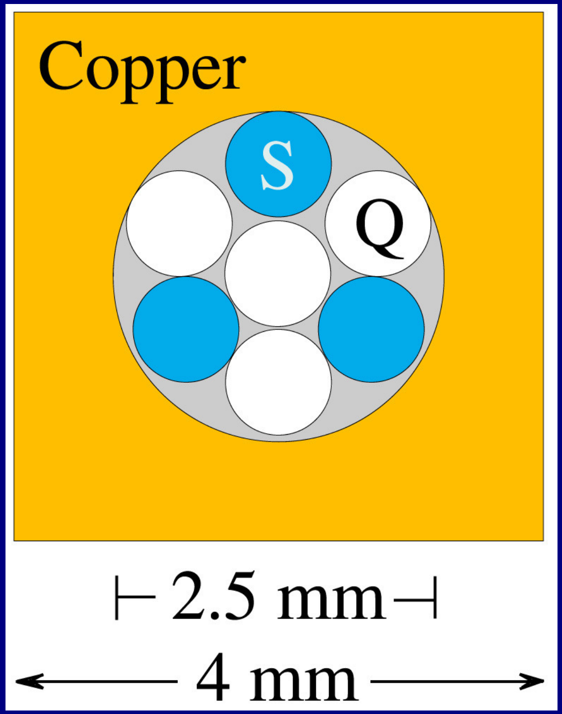
www.4thconcept.org

4th Concept Detector for **ILC**

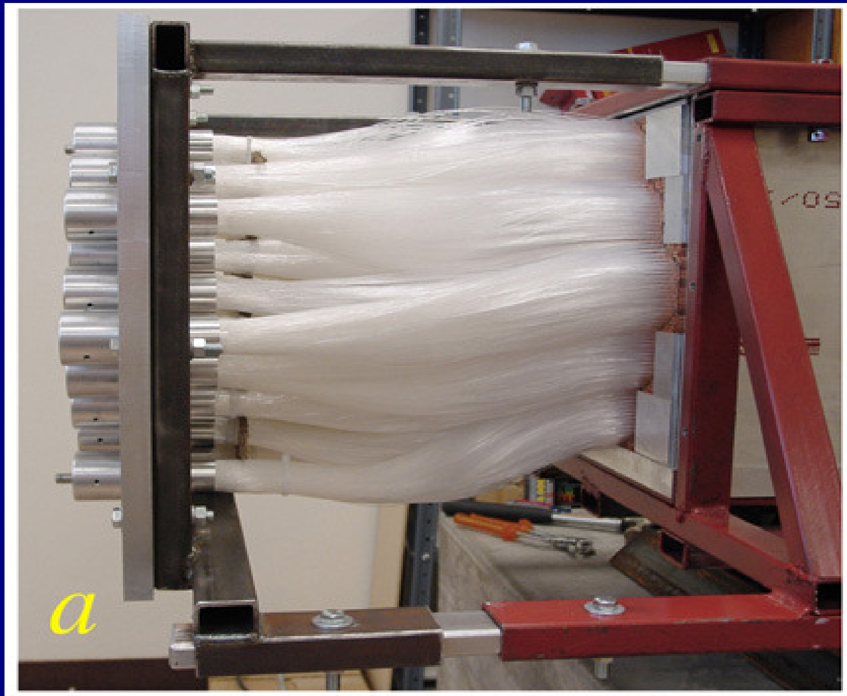
- **Pixel Vertex Detector**
- **Central & Forward Tracking**
  - **SiLC + CluCou SiT TPC ?**
  - **Picosecond TOF flavor tagging ?**
- ✓ **Dual Readout calorimeter** (with Test_Beam **data**)
  - **Scintillation + Cerenkov crystal ECAL**
  - **Scintillation + Cerenkov fiber HCAL**
  - **neutron**
- **Dual Solenoid iron-free Muon system**
- ✓ **ILCroot software**

Dual Readout fiber calorimeter

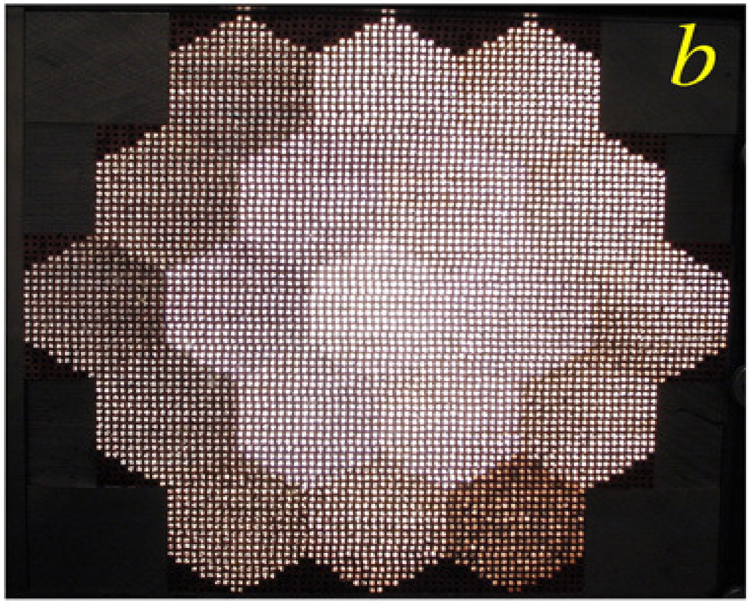
first developed by R. Wigmans



Unit cell



Back end of 2-meter deep module

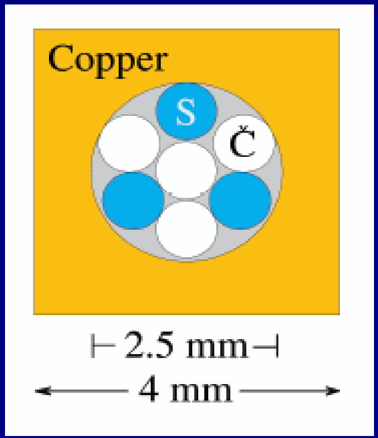


Physical channel structure

http://www.phys.ttu.edu/dream

DREAM module

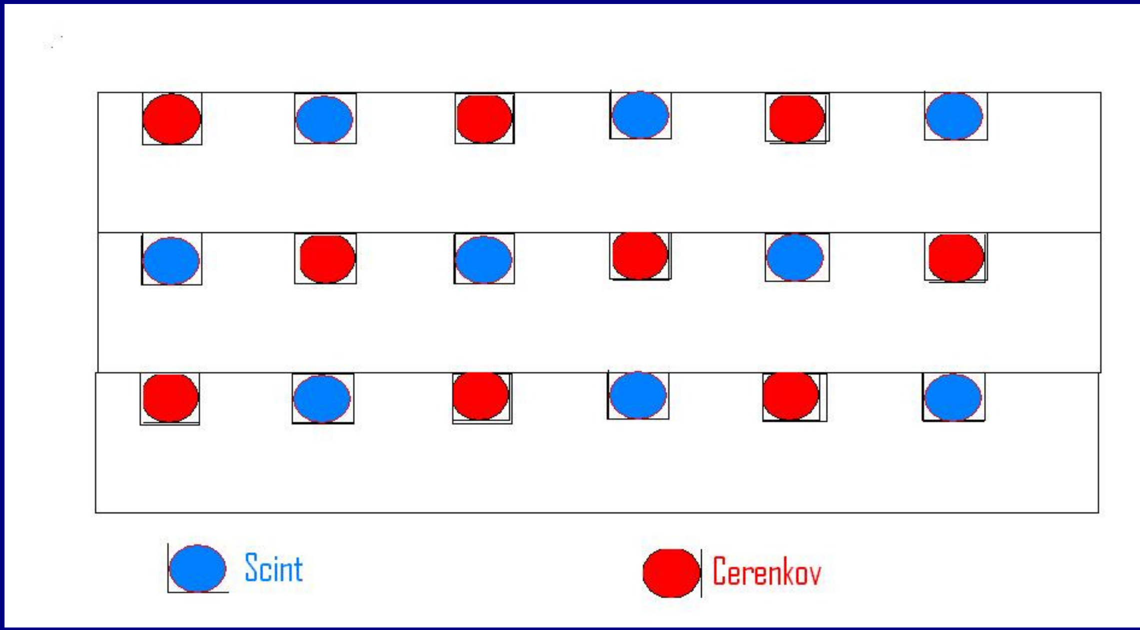
3 scintillating fibers
4 Cerenkov fibers



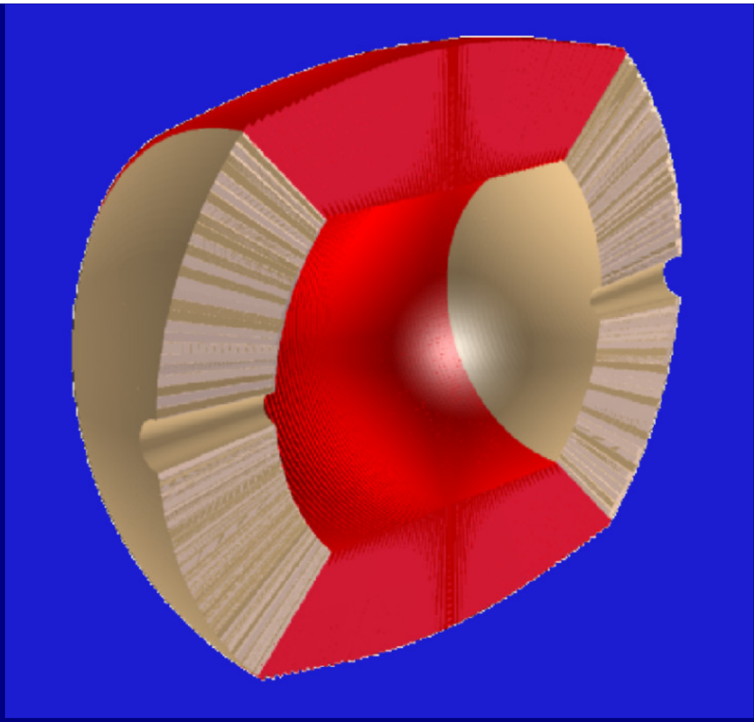
"Unit cell"

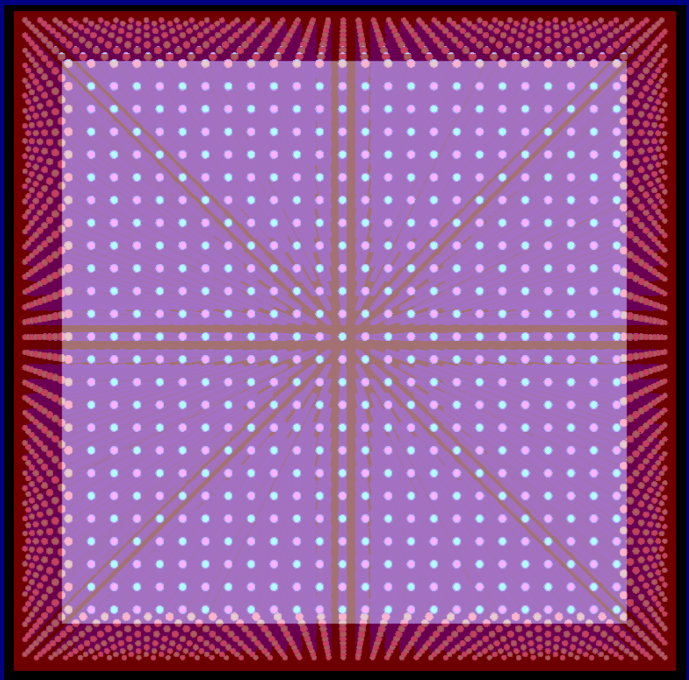
ILC module

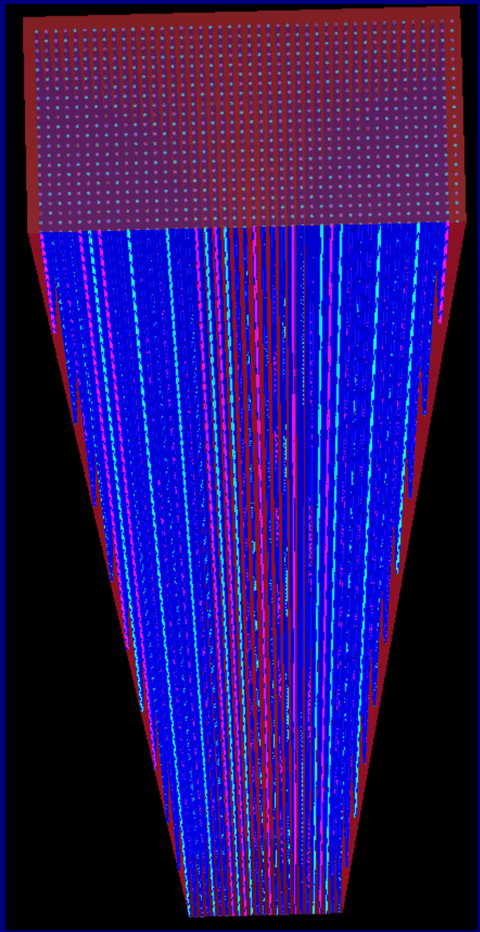
2mm Pb or brass plates
fibers every 2 mm



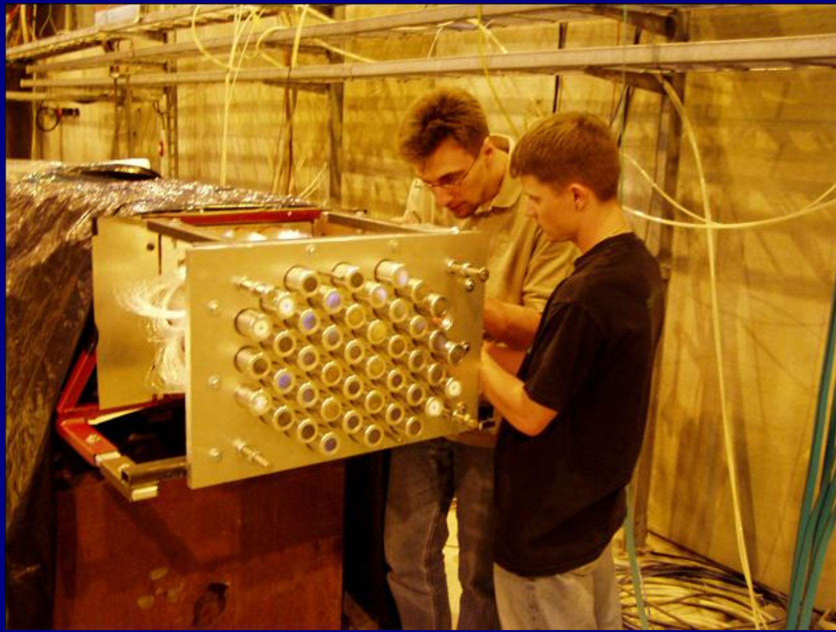
Dual Readout
calorimeter



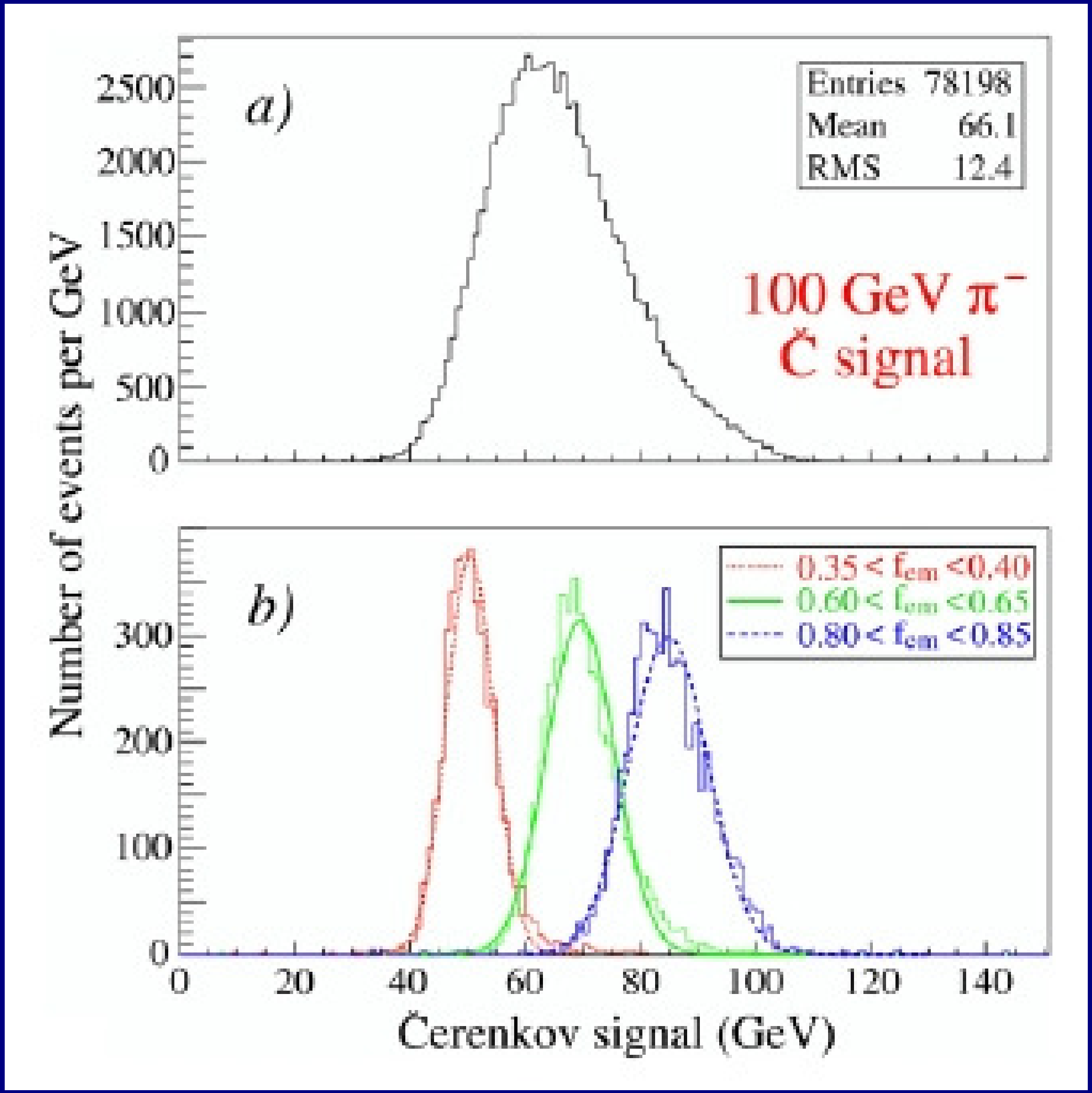




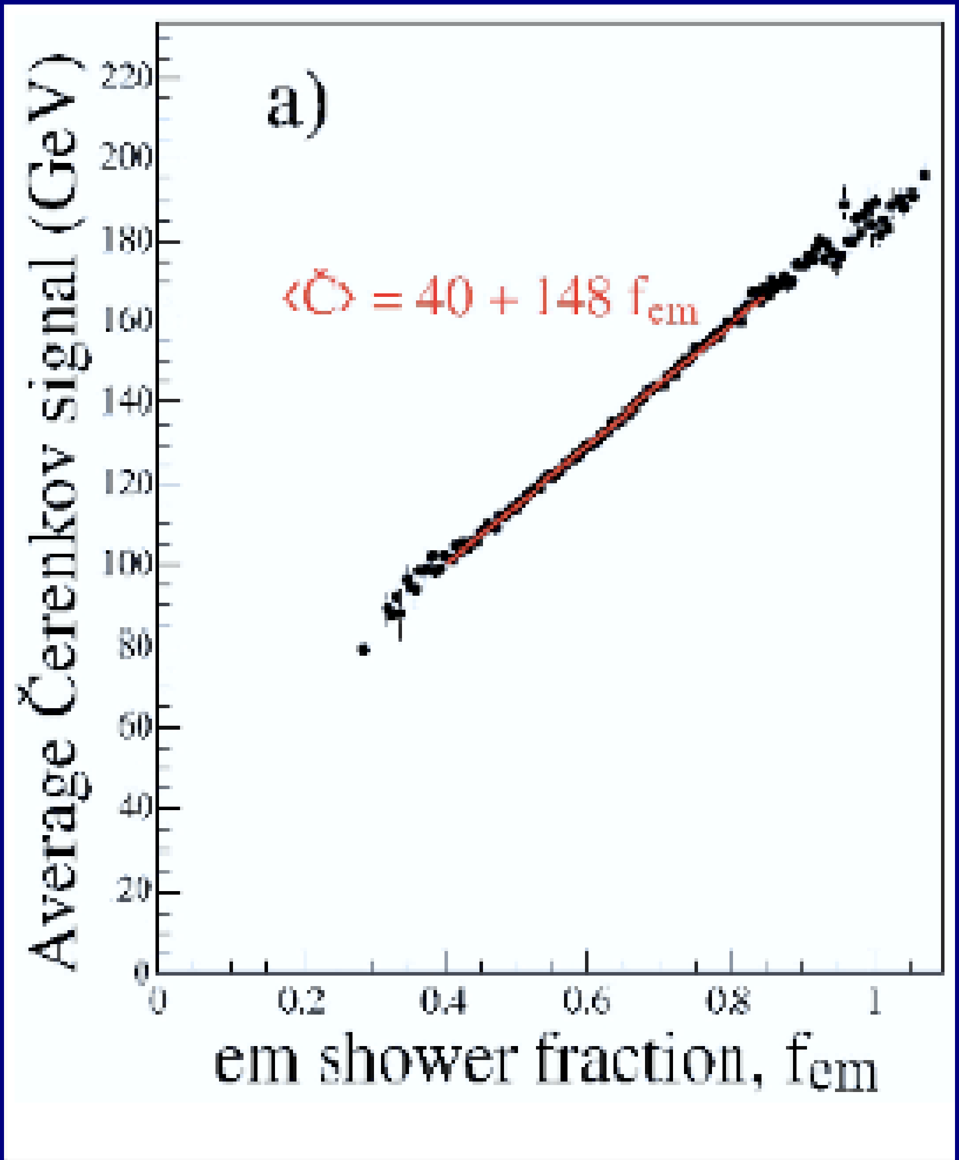
DREAM calorimeter

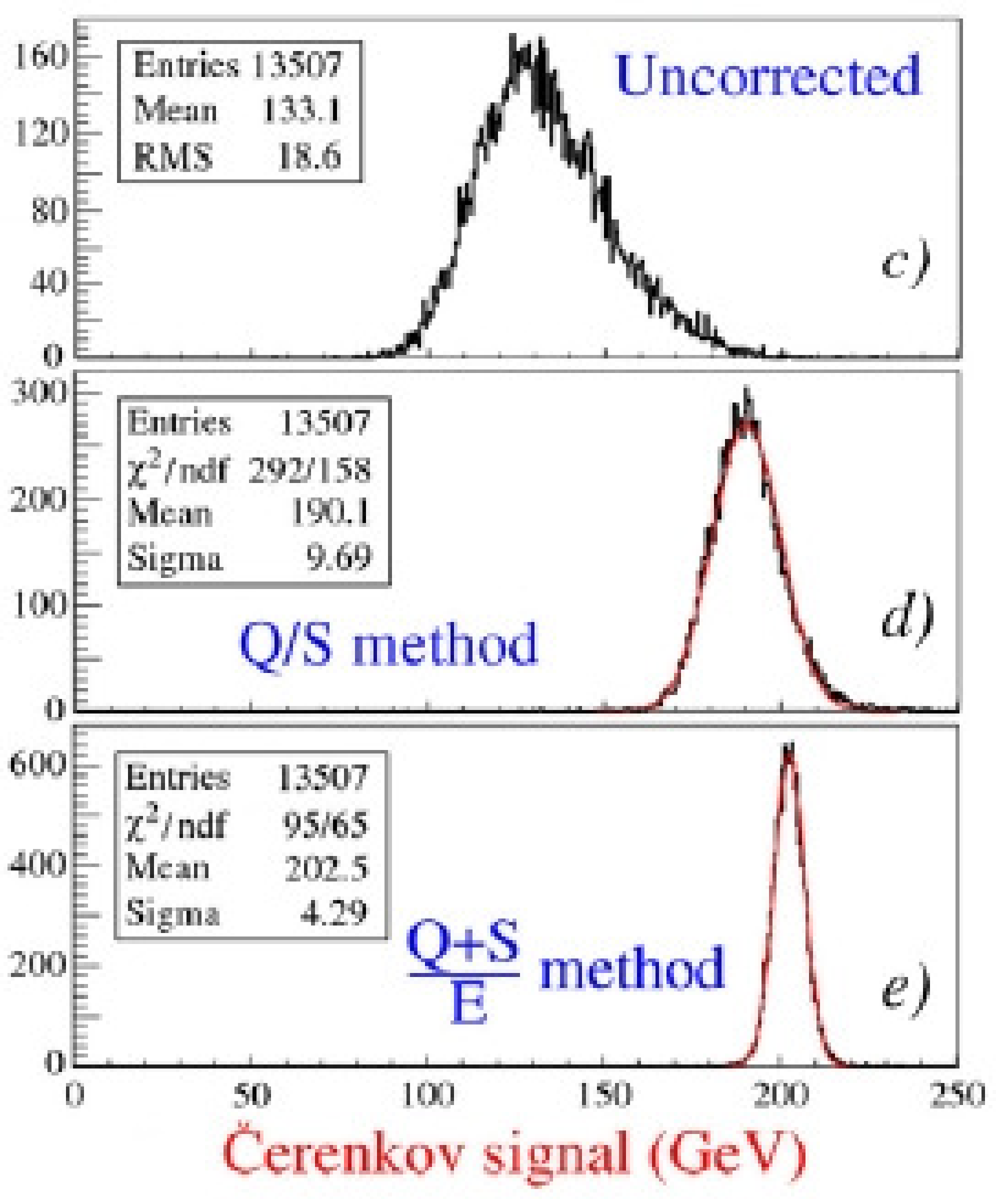


Hadron Energy Resolution & fluctuation of EM fraction in hadron showers



DREAM data 200 GeV π^- Energy response

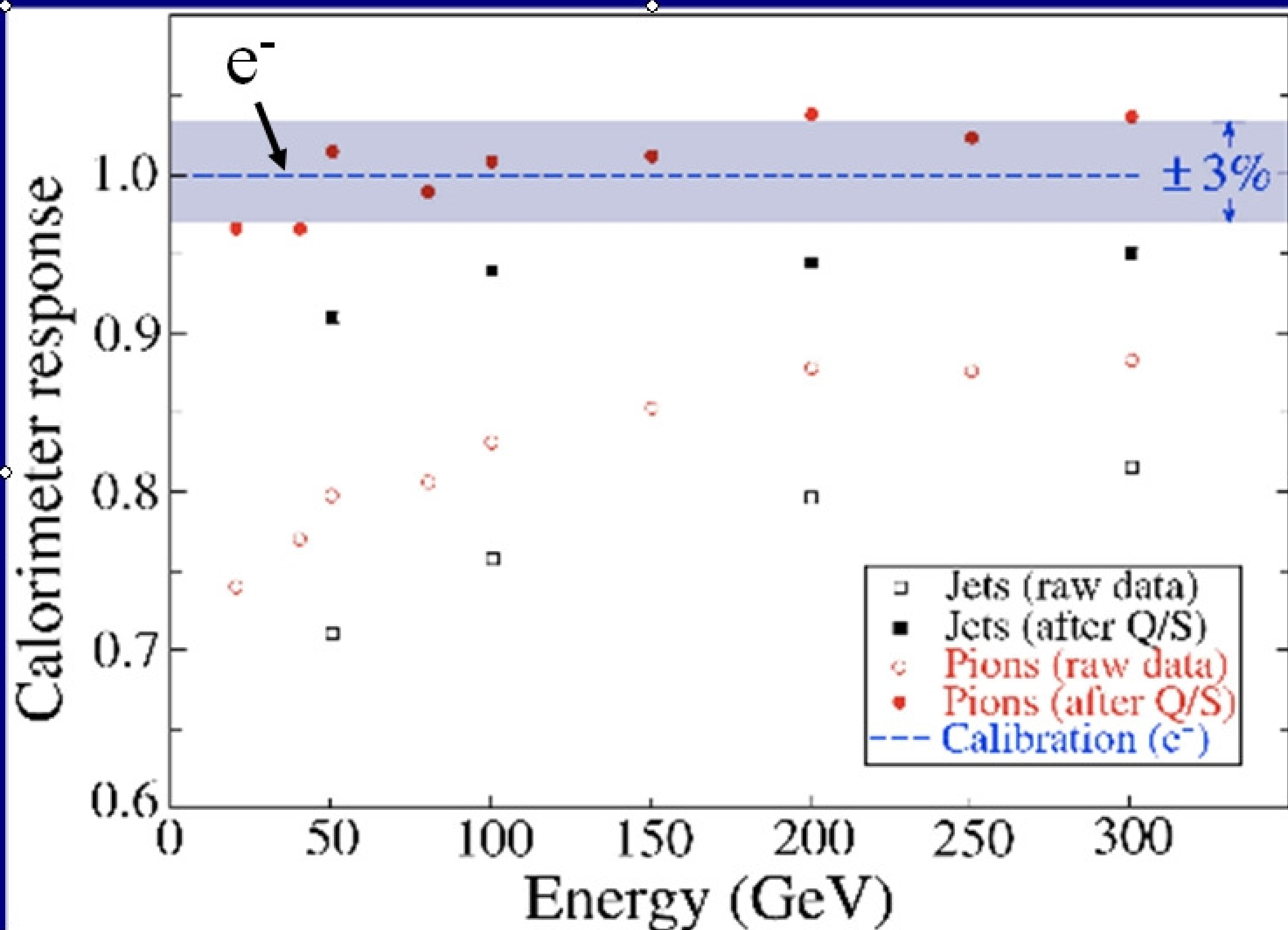




Data NIM A537 (2005) 537.

More important than good Gaussian response:

DREAM module calibrated with 40 GeV e^- responds linearly to π^- and "jets" from 20 to 300 GeV.



Data NIM A537 (2005) 537

Software

✓ **ILCroot** **Easy to use**

- based on ALICE ALIroot
- Single Framework

generation, simulation, reconstruction, analysis

www.fisica.unile.it/~danieleb/ilcRoot

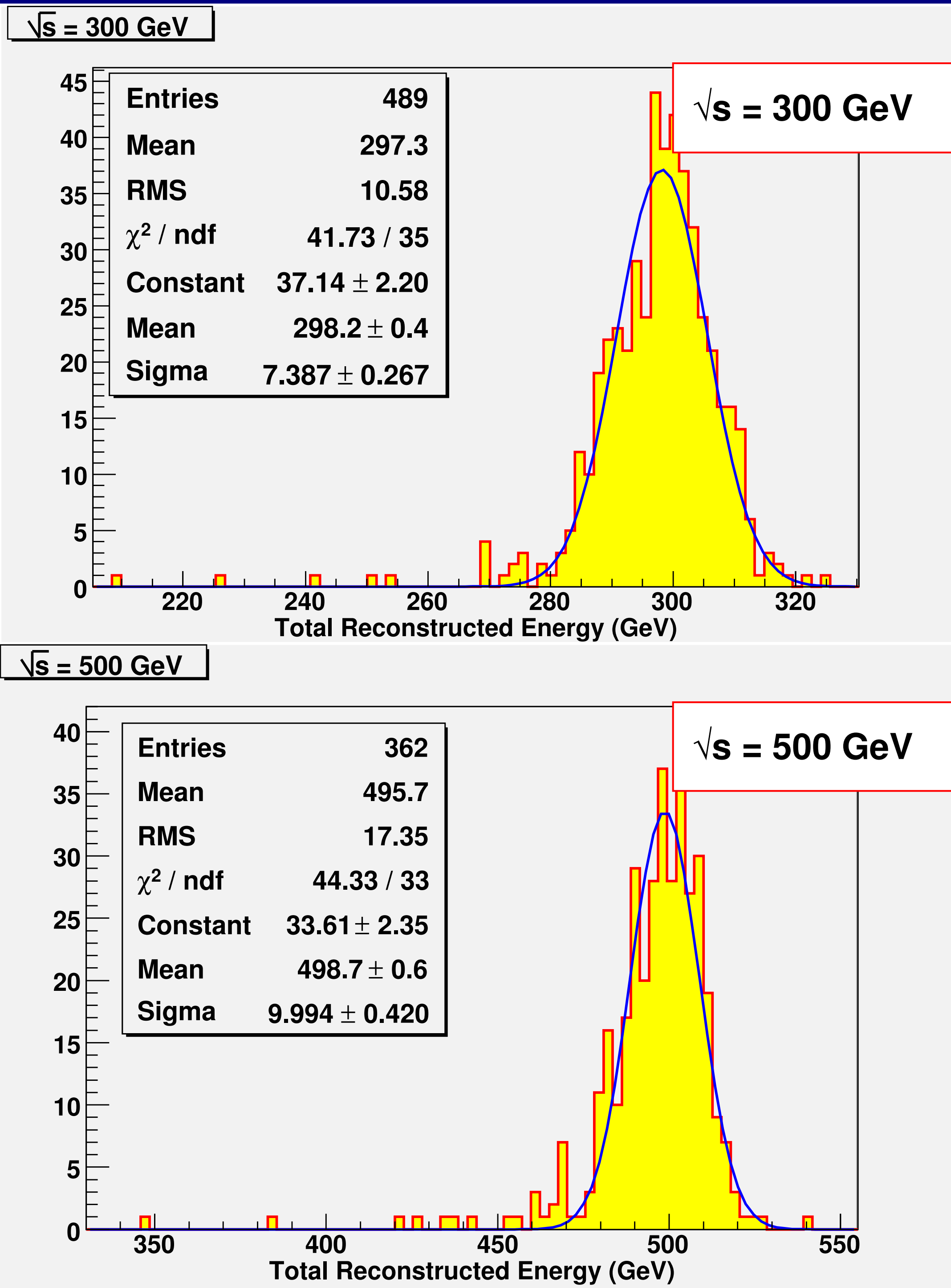
ilc.fnal.gov/detector/rd/physics/detsim/**ilcroot**.shtml

cd-amr.fnal.gov/ilc/ilcsim/**ilcsim-grid**.shtml

Large scale Grid Computing at Fermilab

Please see Corrado Gatto's presentation in this SiLC Workshop,
and Corrado's and Anna Mazzacane's presentations in
ilc.fnal.gov/conf/alcpg07/

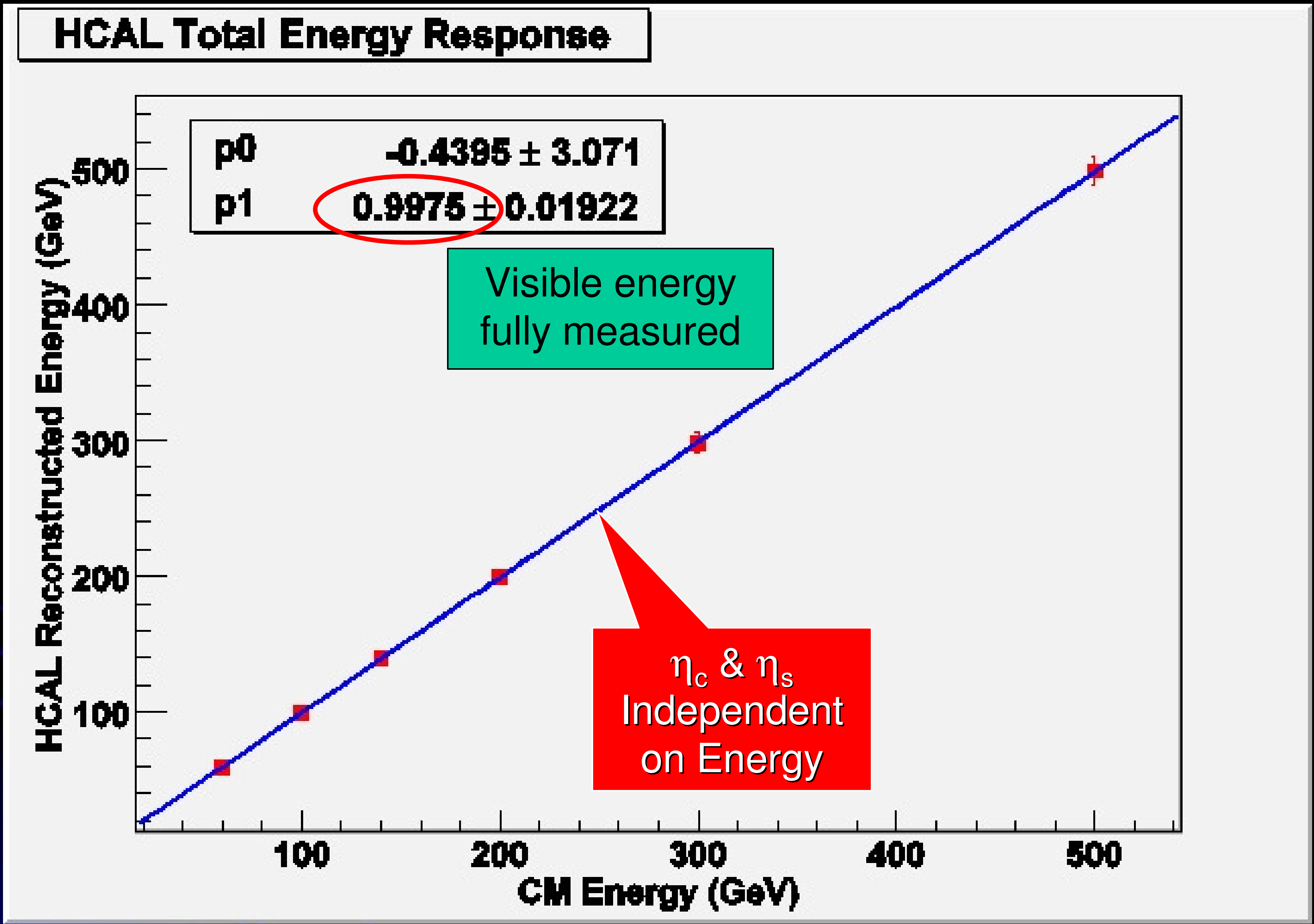
Total Energy Reconstructed



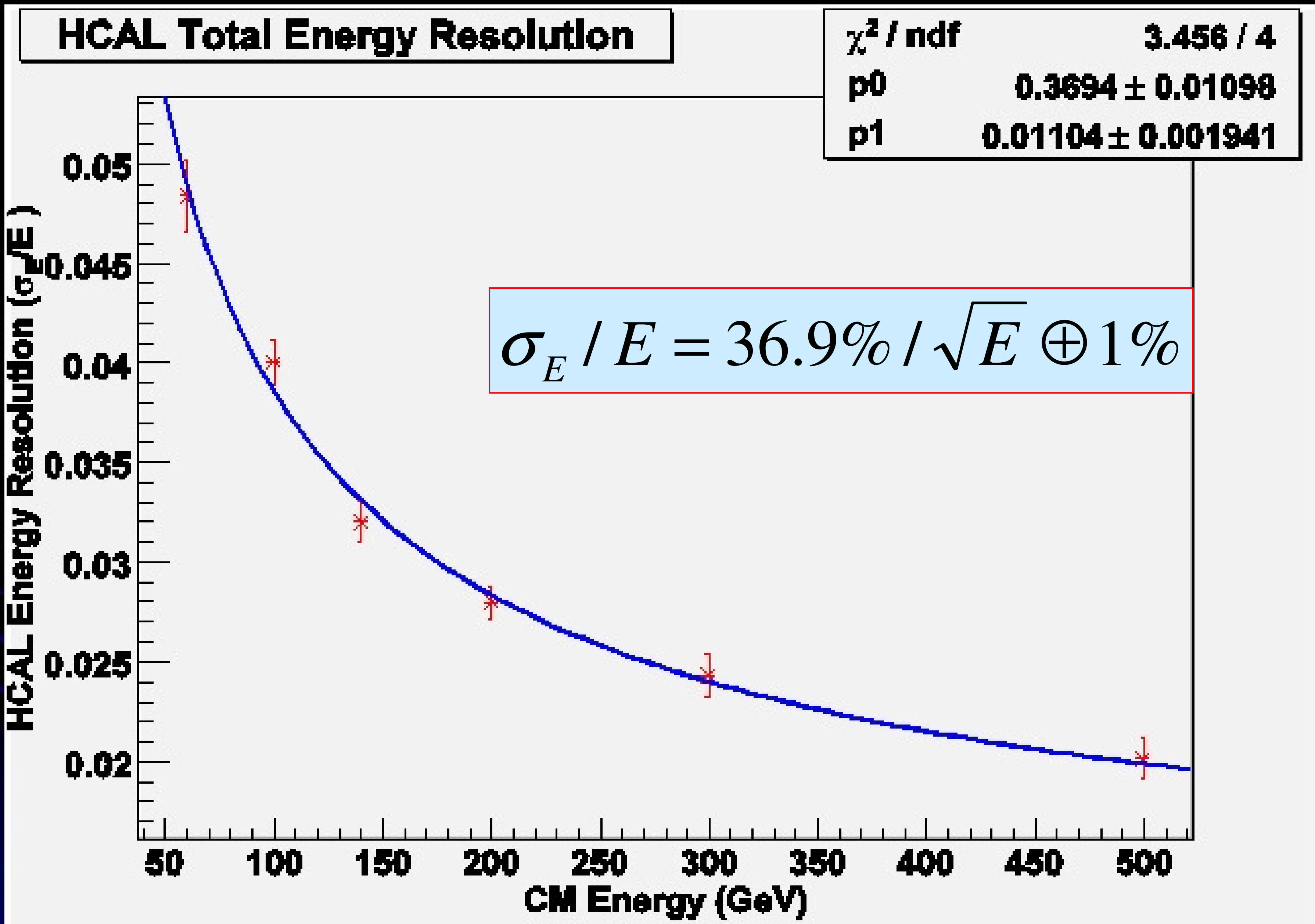
(**rms90** : rms of central 90% of events)

E_{CM}(GeV)	σ: $\sigma/E = \alpha/\sqrt{E}$	rms_{90}: $\sigma/E = \alpha/\sqrt{E}$
60	37.5	32.1
100	40.1	34.0
140	37.9	32.7
200	39.6	34.9
300	42.1	36.7
500	45.0	40.6

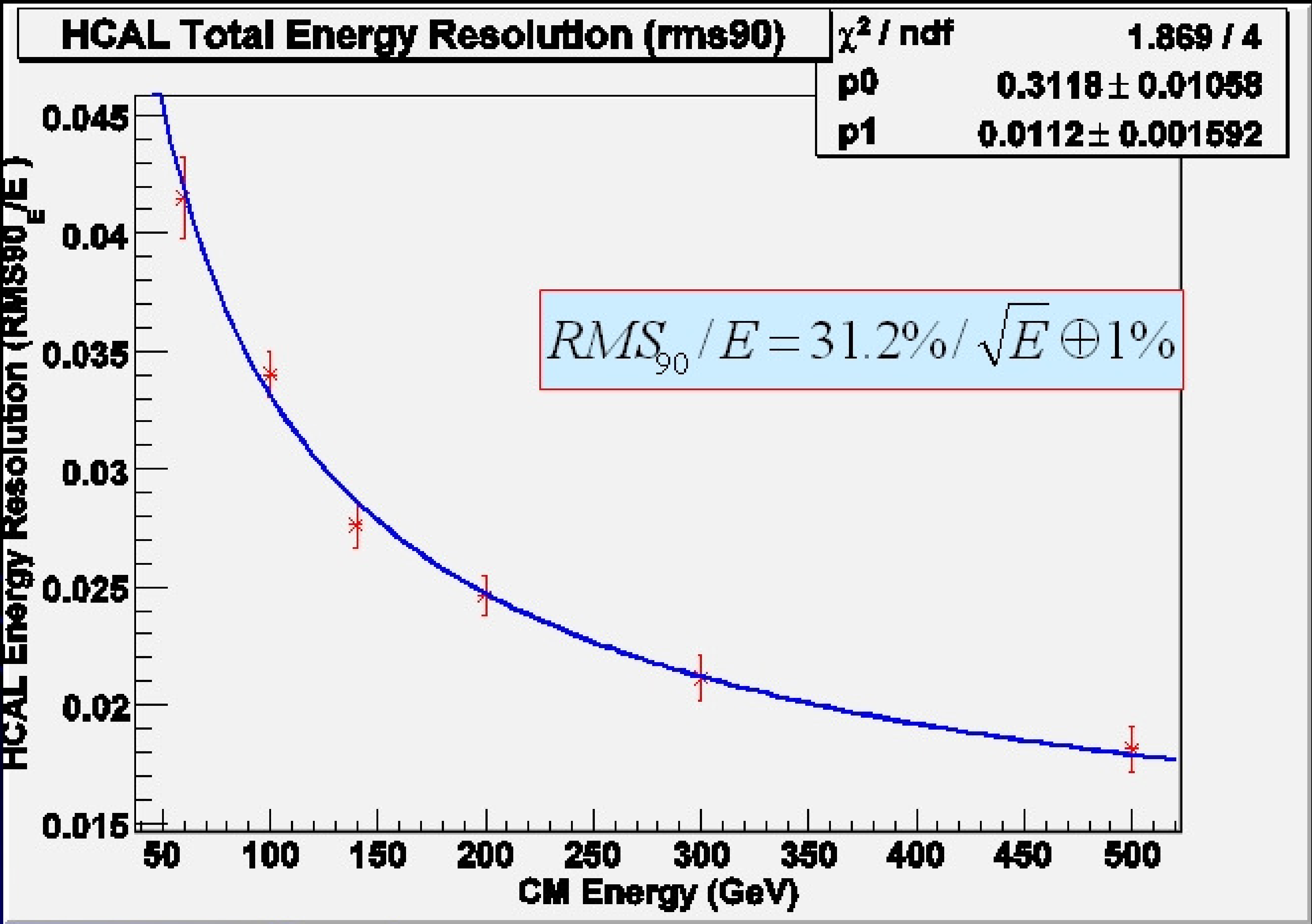
HCAL Energy Response with single π



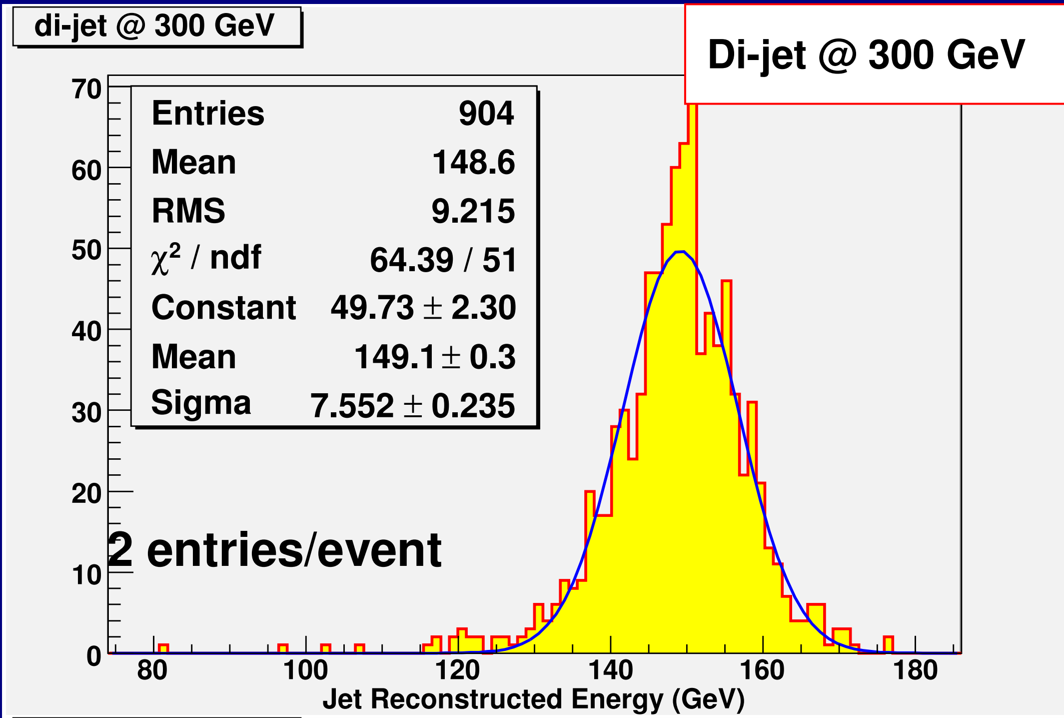
Total Energy Resolution (Gaussian fit)

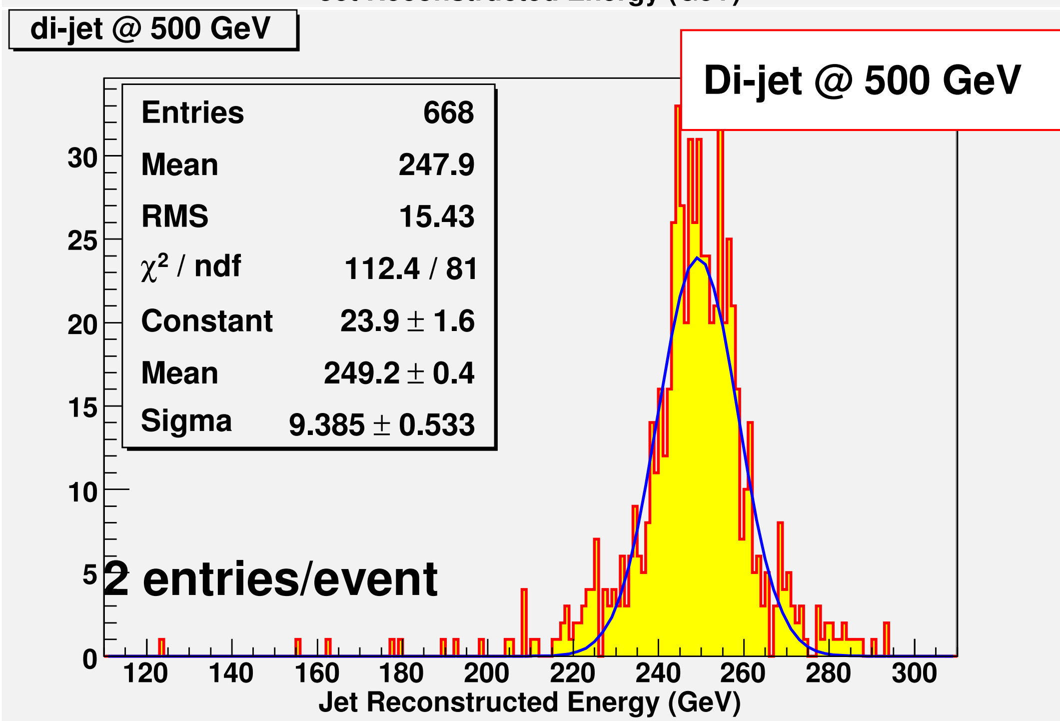


Total Energy Resolution (rms$_{90}$)



Jet Energy Reconstructed

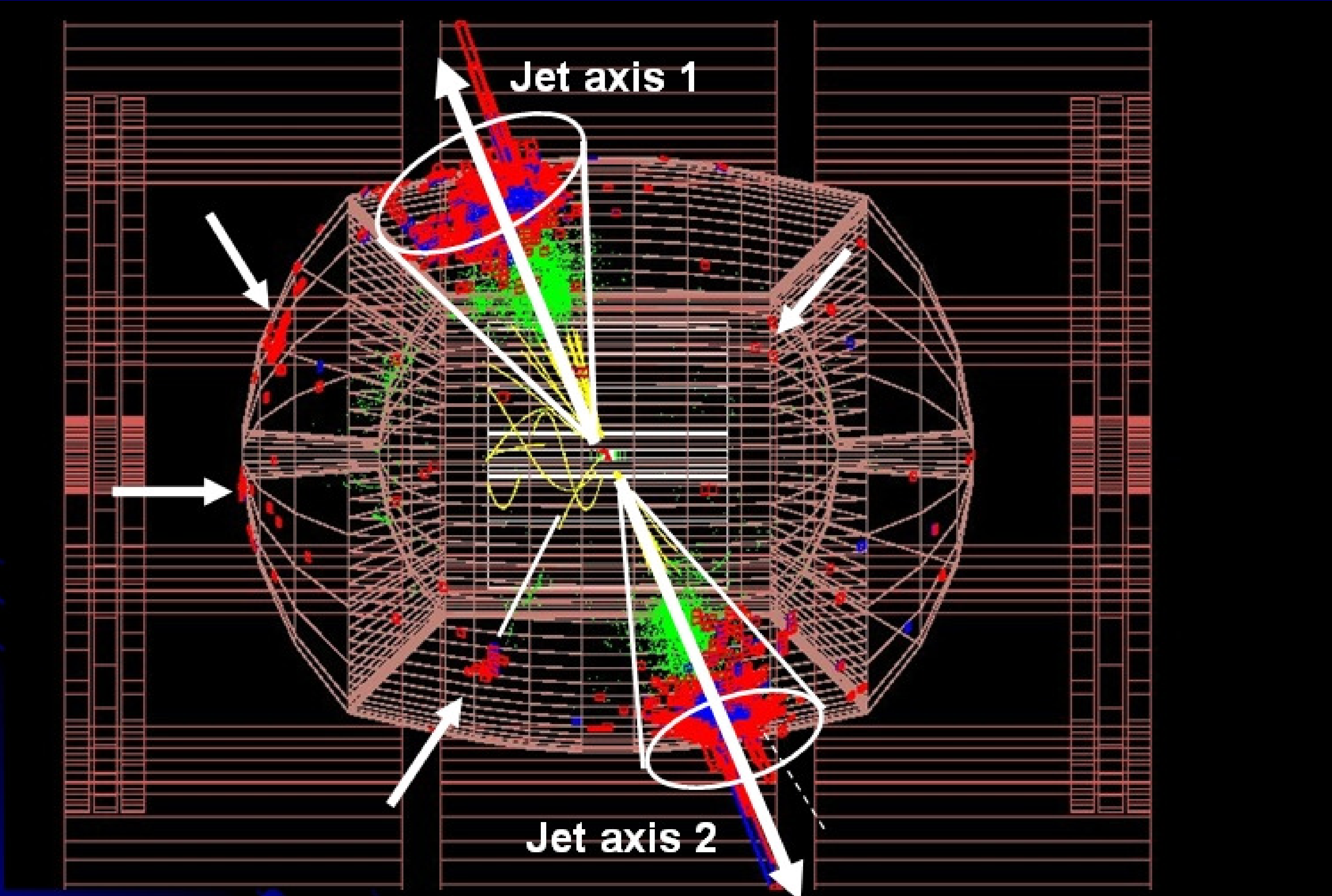




(rms90 : rms of central 90% of events)

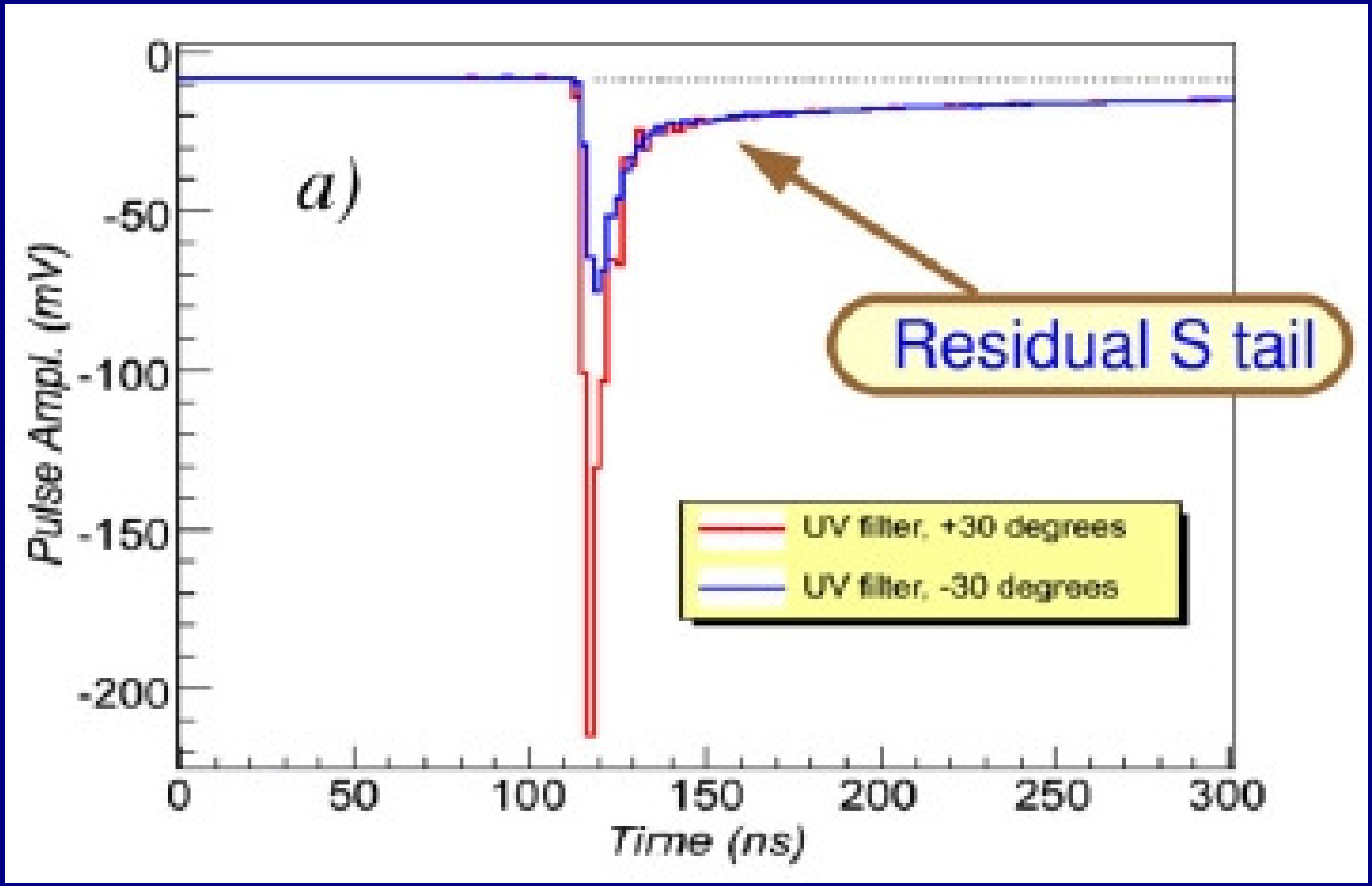
E_{jet}(GeV)	σ: $\sigma/E = \alpha/\sqrt{E}$	rms_{90}: $\sigma/E = \alpha/\sqrt{E}$
30	43.0	39.9
50	45.0	39.8
70	42.3	38.0
100	42.6	37.1
150	49.4	41.3
250	45.2	41.0

500 GeV dijets corrections possible



Time Structure

Average signal produced by 50 GeV electrons traversing BGO crystal



Richard Wigmans & DREAM Team

Dual Readout calorimeter

- Resolution with Hadronic Calorimeter only

  Total Energy reconstructed :

  $\sigma_E/E = 36.9\%/\sqrt{E}$ (σ) 31.2 $\%/\sqrt{E}$ (rms_{90})

  Jet Energy reconstructed (clustering based on Calorimeter alone)

  $\sigma_E/E = 42.2\%/\sqrt{E}$ 38.5$\%/\sqrt{E}$ (rms_{90})

- Improving Resolution :

  * low transverse momenta tracks, decaying tracks (kinks, V0s), γs

  * Leftover muons leaving the calorimeter

Optimize Performance of the Calorimeter

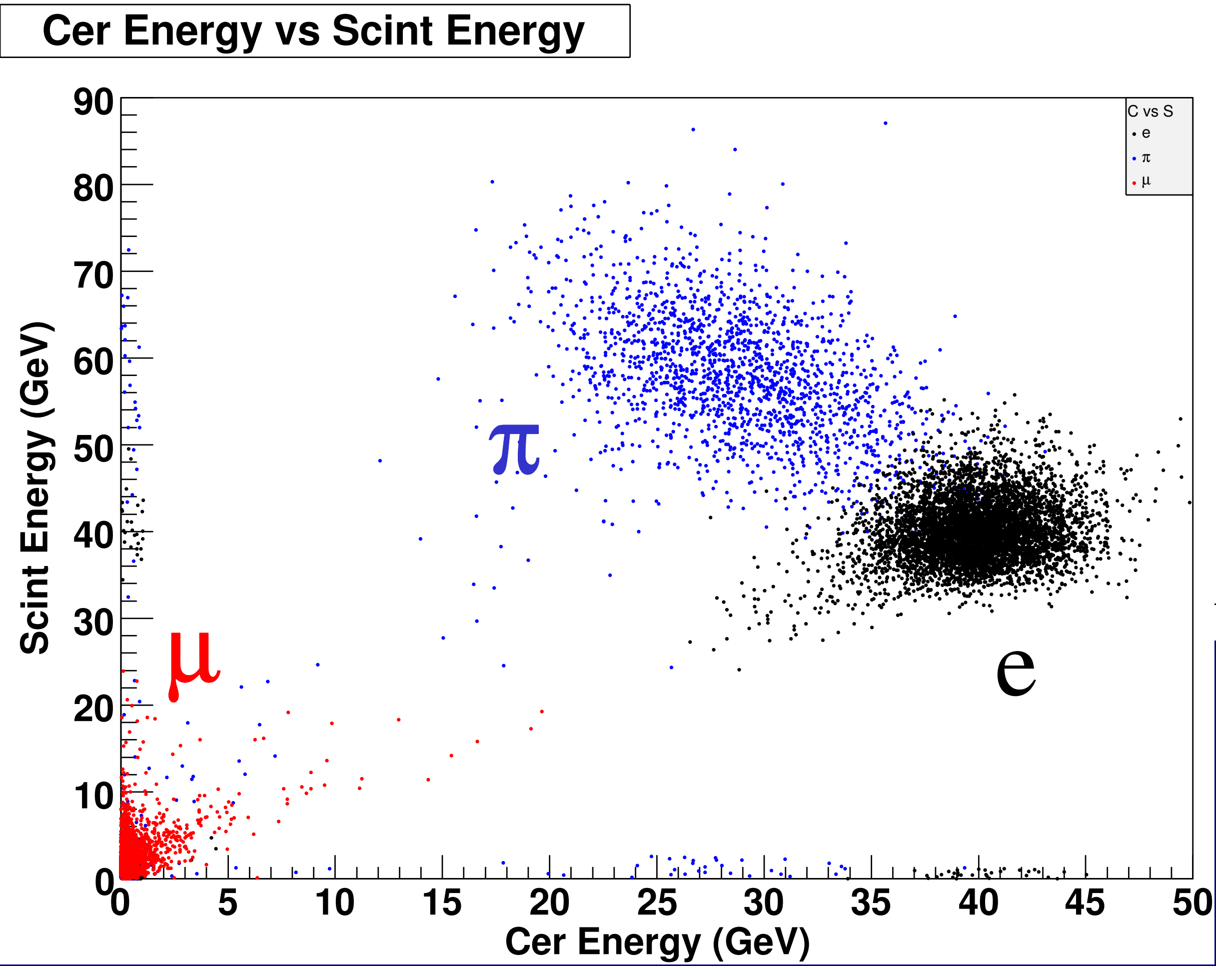
e.g. measure neutrons to correct visible energy

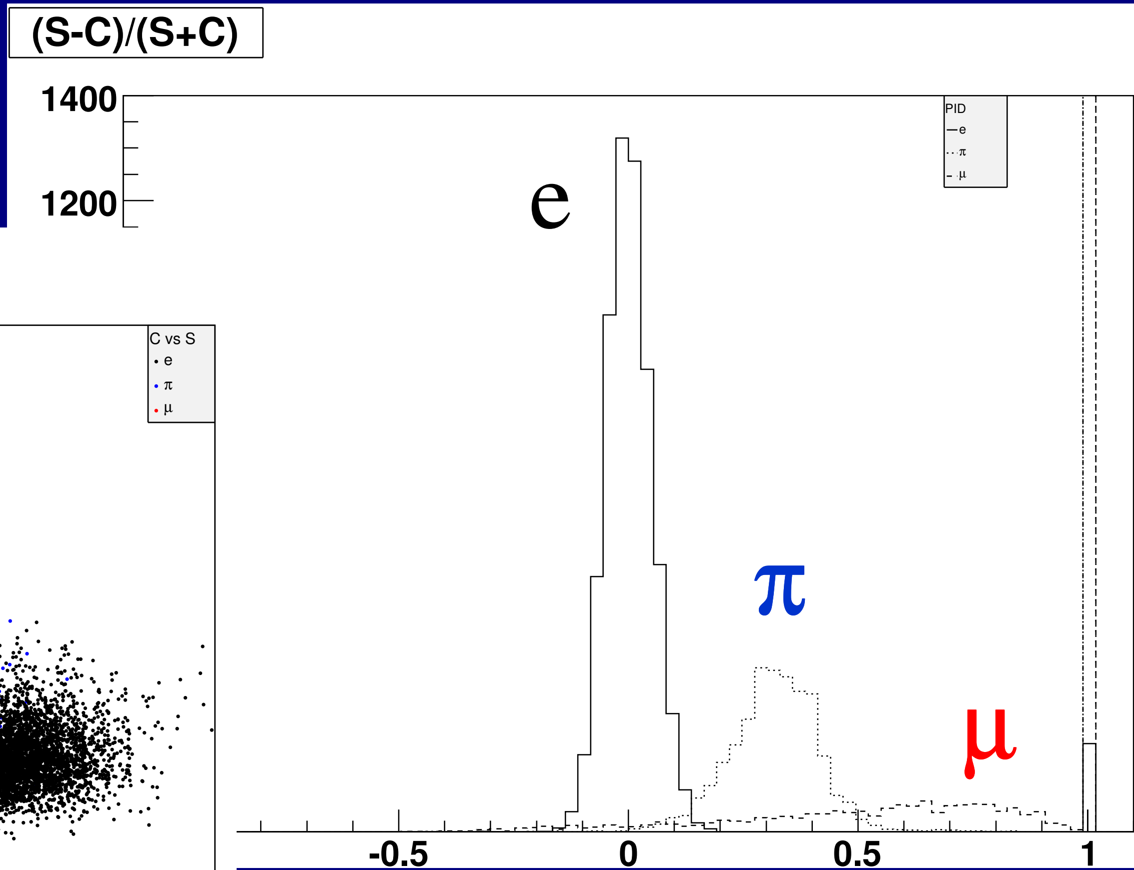
(nuclear binding energy losses)

Use information from Tracking and Calorimetry

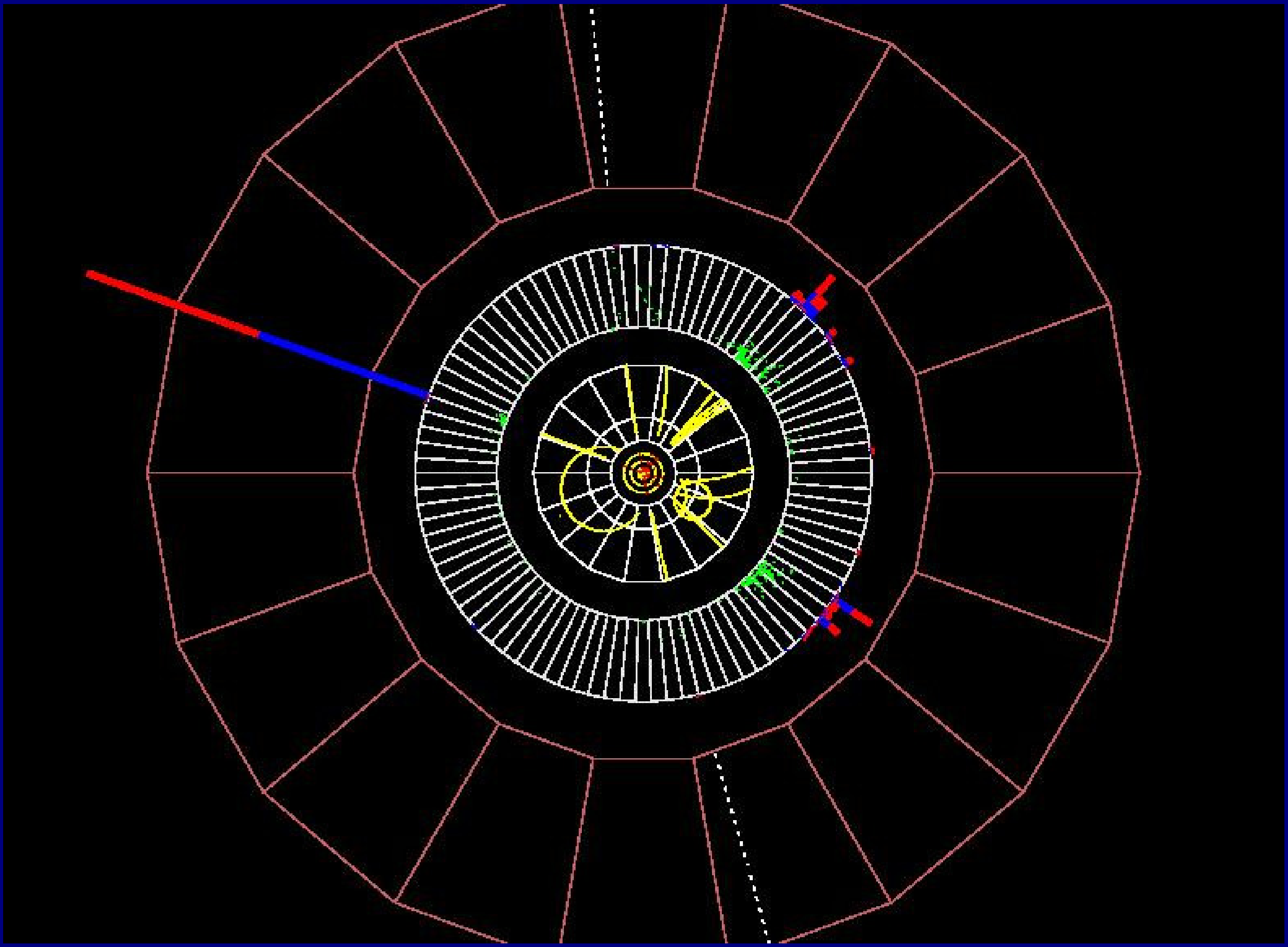
PID from Hcal

40 GeV particles





$$e^+e^- \rightarrow H^0Z^0 \rightarrow W^+W^-\mu^+\mu^- \rightarrow jj\ \ e^-\nu\ \ \mu^+\mu^-$$



Illustrates the detectors of **4th** Concept … **particle ID** "obvious"

Review of the R&D for Calorimetry

W. Lohmann
DESY

On behalf of the ILC Detector R&D Panel
(a Panel of the World-Wide Study Organising Committee)

(Jean-Claude Brient, Chris Damerell, Ray Frey, Dean Karlen,
Wolfgang Lohmann, Hwanbae Park, Yasuhiro Sugimoto,
Tohru Takeshita, Harry Weerts)

ALCPG07 Oct. 24, 2007 Fermilab

Comments and Recommendations

DREAM

4th Concept

- The novel technology of the DREAM calorimeter is extremely interesting
- The promising results from both test beam measurements and simulations are appreciated
- The ongoing test beam activities are fully supported
- The transition from the current test beam module to a larger scale module needs a list of concerns to be clarified. This list contains e.g.
  - The influence of inert upstream material on the performance of the calorimeter
  - The performance for benchmark physics processes including processes with tau lepton decays
  - Optimisation of the granularity for benchmark processes
  - , Identification for key parameters to control a large scale calorimeter.
  - Calibration and monitoring. Methods currently used in the test beam will not be applicable.
  - Long-term stability of fibres and photo-sensors

- The committee is concerned about the limited recources of the DREAM collaboration and strongly supports a significant strenghtening, in particular to perform the simulation studies to clarify the concerns mentioned above.

Outcome of the tracking review

- Our responsibility is to work with the R&D collaborations to ensure that the feasibility of their critical goals can be demonstrated by 2010-2012
- This means (for tracking) that the community can be confident that the option they choose will satisfy the challenging physics needs
- We reviewed the **LCTPC, CLUCOU, SiLC, SiD tracking** R&D collaborations
- We were extremely impressed by the great progress made by all these groups, in some cases with very limited resources
- **However, we concluded that we are currently far from the goals, for all tracking options**

Main technical recommendations

- Building a tracking system with excellent performance for θ_p >7 degrees will be challenging. *Feasibility is not yet demonstrated*

- Why not simply move on to the 'engineering designs' of these tracking systems and study their performance with Geant 4?

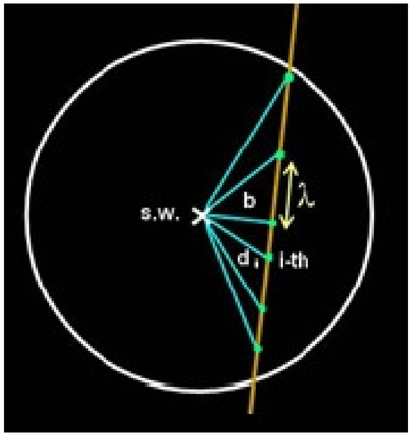
- There is a risk that such designs would be too optimistic. Forward tracking has generally performed badly. We all know the solution (drastic reduction in material budget) but *can this be achieved in practice?* The committee concluded that this crucial question, on which a great deal of ILC physics depends, could not be answered only by adventurous designs

- We became convinced of the need to construct large prototypes (~1 m diameter), and operate them under ILC-like beam conditions in a 3-5 T field, to establish what performance will be achievable at ILC, both for central and forward tracking

- Until such tests are completed successfully, we do not consider that any of the three options proposed (all-silicon, TPC-plus-silicon, or drift-chamber-plus-silicon) could be considered ready for selection as an ILC tracking system [a unanimous recommendation of the committee, but not every collaboration agrees with this; maybe we are wrong]

All-pixel ? 30 Gpixels

CLUster COUnting



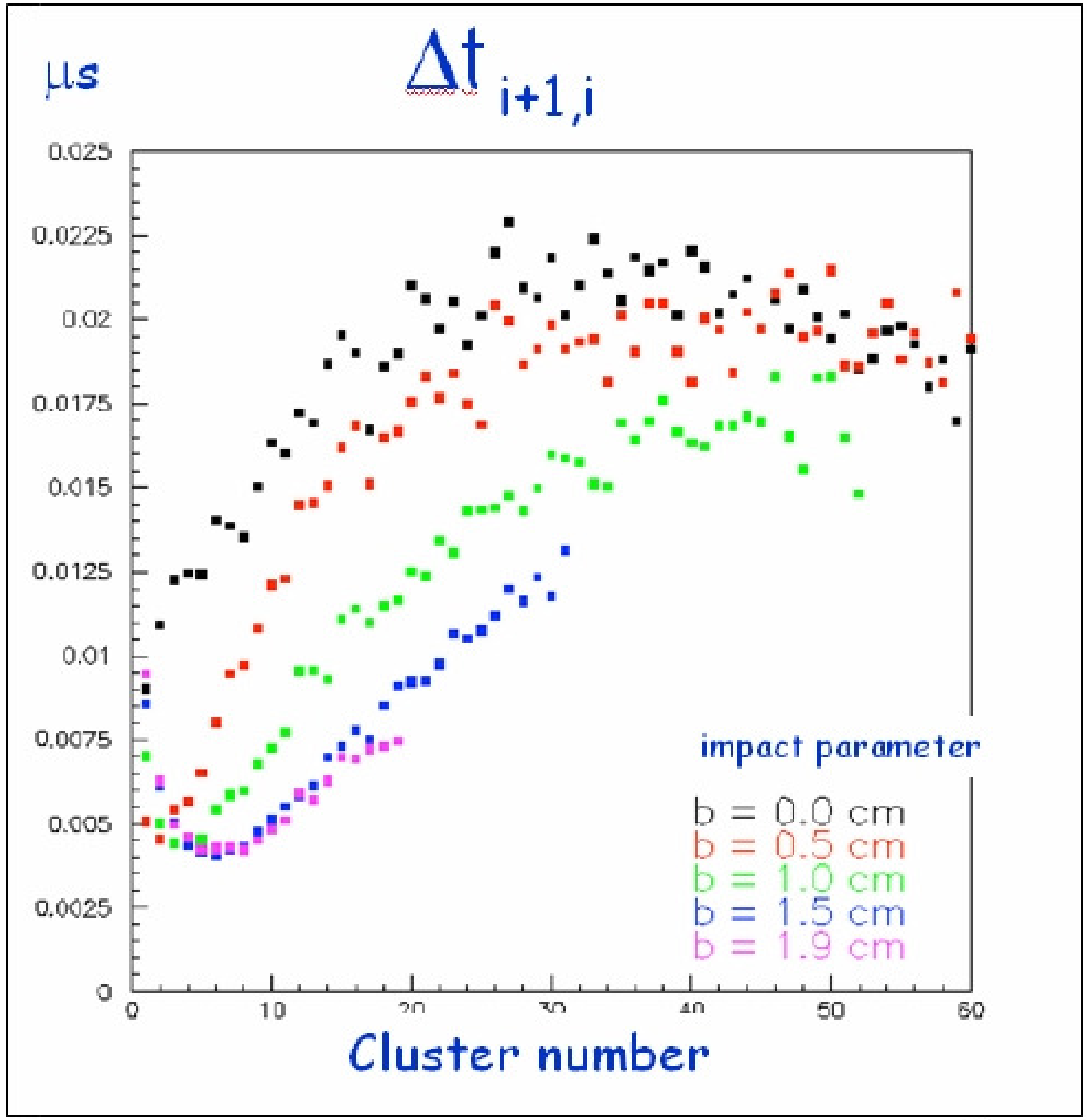
2 cm drift tube

90%He-10%iC_4H_{10}

few x 10^5 gain

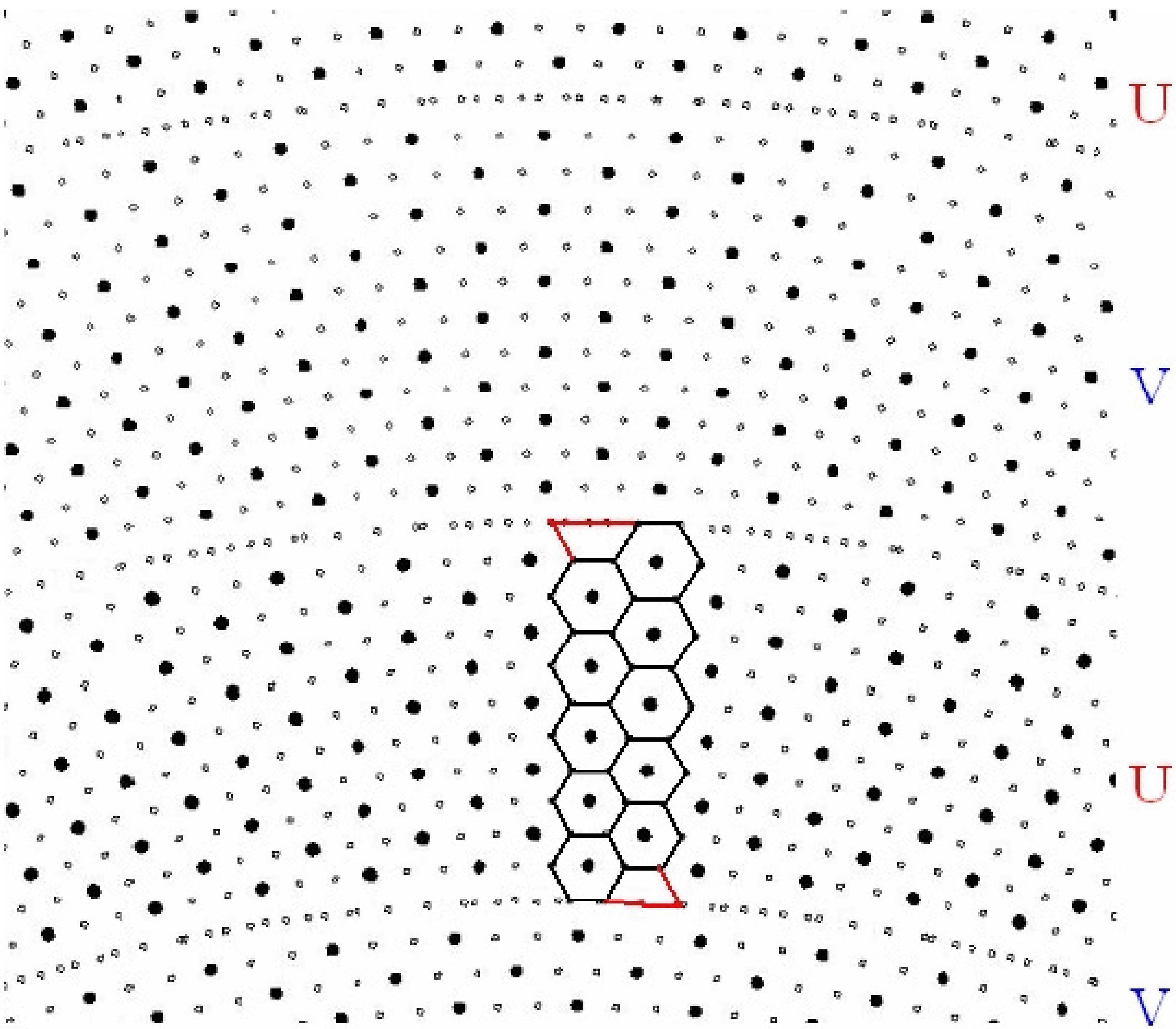
$\Delta t_{i+1,i}$: time separation between consecutive ionization clusters, as a function of their ordered arrival time, for different impact parameters. (caveat: electrons!)

In this He mixture , **provided that:**
sampling frequency of signals > 2 Gsa/s and rise (and fall) time of single electron signals < 1ns
single electron counting is possible.



4thConcept ILC Drift Chamber

Layout



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

cell height: 1.00 ÷ 1.20 cm
cell width: 6.00 ÷ 7.00 mm

(max. drift time < 300 ns !)

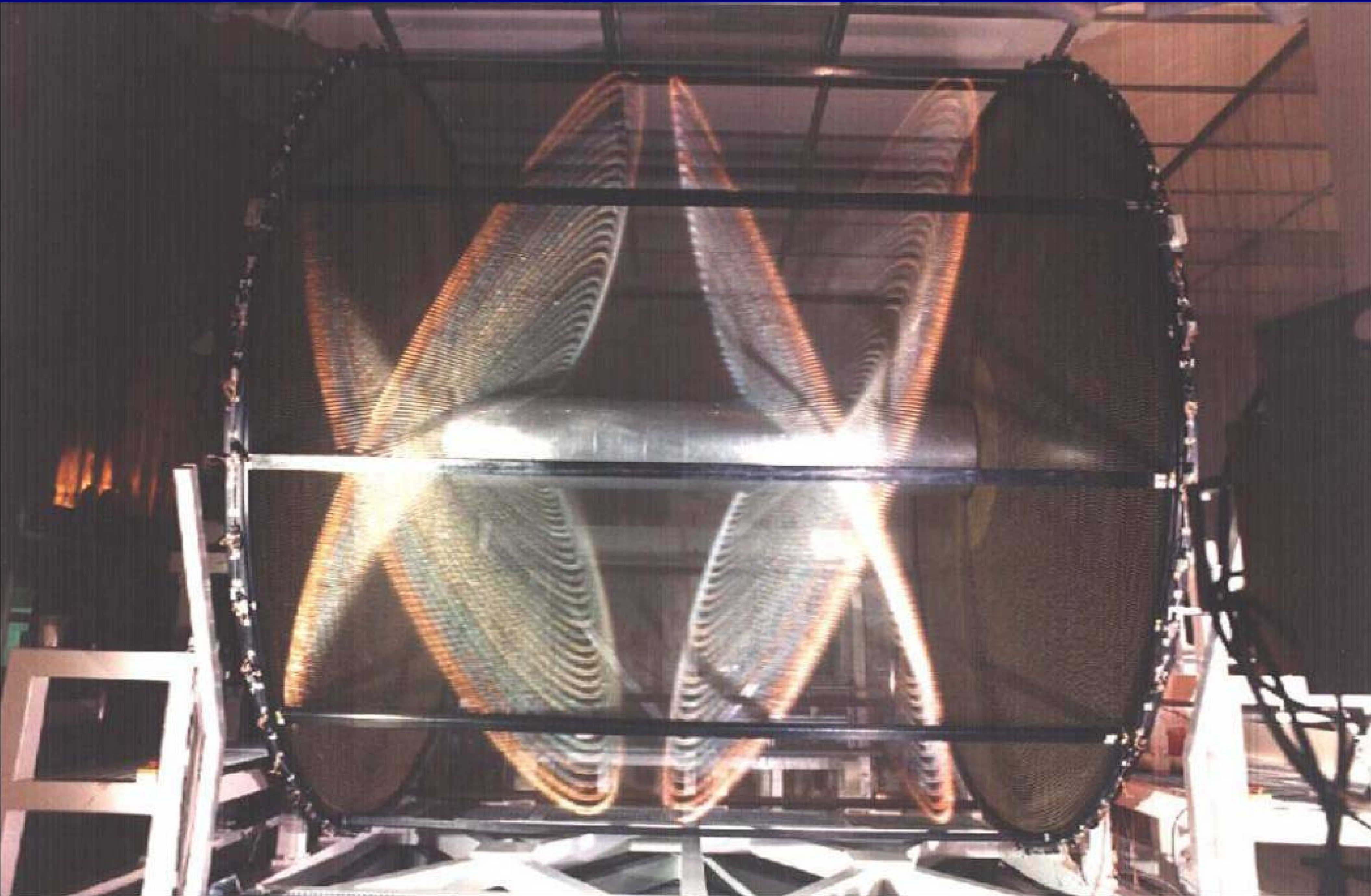
20 superlayers, in 200 rings
10 cells each (7.5 in average)
at alternating stereo angles
±72 ÷ ±180 mrad
(constant stereo drop = 2 cm)

60000 sense w. 20 μm W
120000 field w. 80 μm Al

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

>90% sampled volume

KLOE Drift Chmaber



CluCou Summary for ILC

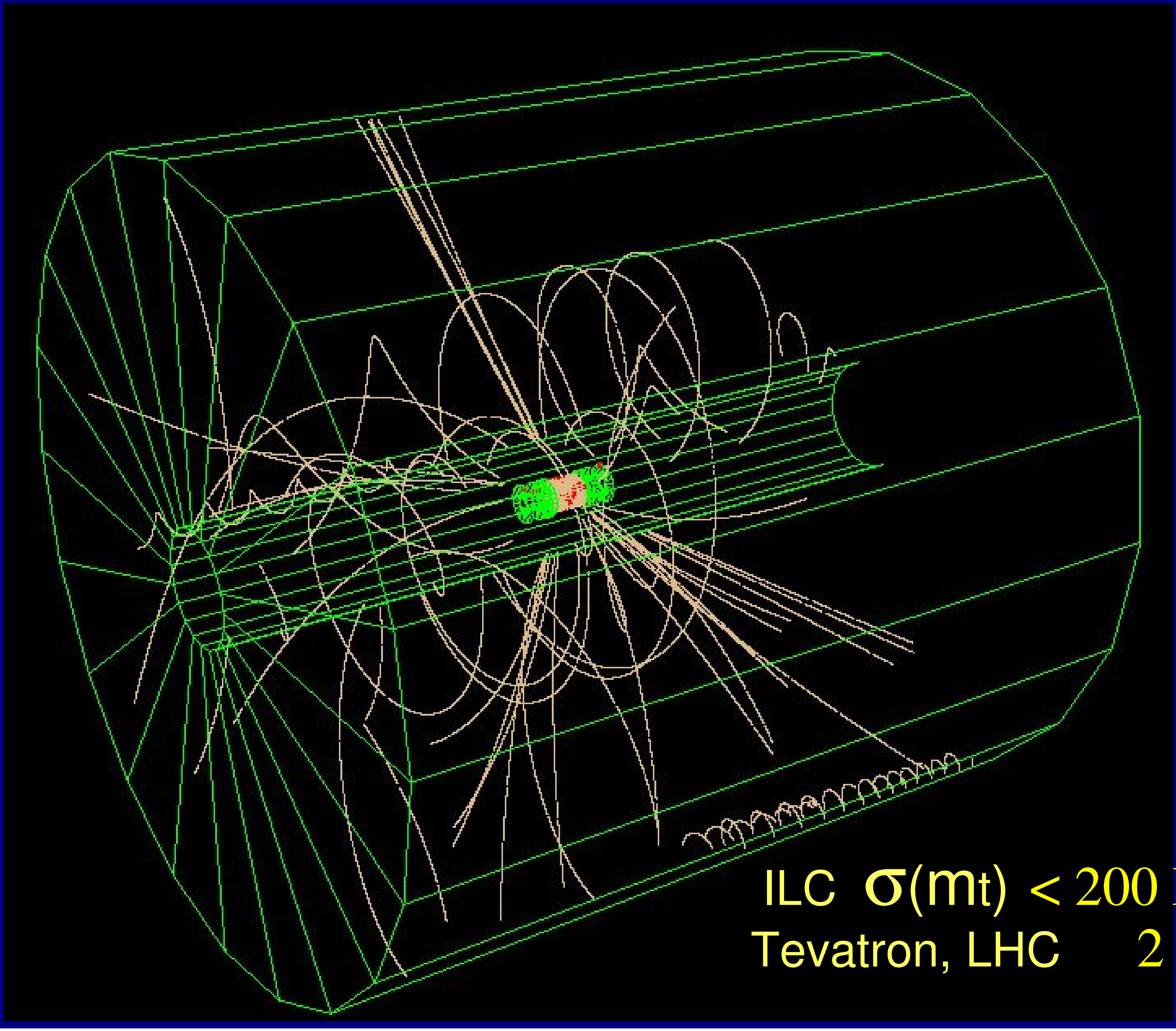
A drift chamber à la KLOE with cluster counting (≥ 1GHz, ≥ 2Gsa/s, 8bit)

- uniform sampling throughout >90% of the active volume
- 60000 hexagonal drift cells in 20 stereo superlayers (72 to 180 mrad)
- cell width 0.6 ÷ 0.7 cm (max drift time < 300 ns)
- 60000 sense wires (20 µm W), 120000 field wires (80 µm Al)
- high efficiency for kinks and vees
- spatial resolution on impact parameter $\sigma_b = 50\ \mu m$ ($\sigma_z = 300\ \mu m$)
- particle identification $\sigma(dN_{cl}/dx)/(dN_{cl}/dx) = 2.0\%$
- transverse momentum resolution $\Delta p_\perp / p_\perp = 2 \cdot 10^{-5}\, p_\perp \oplus 5 \cdot 10^{-4}$
- gas contribution to m.s. 0.15% X_0, wires contribution 0.40% X_0
- high transparency (barrel 2.8% X_0, end plates 5.4%/cosθ X_0+electronics)
- easy to construct and very low cost

is realistic, provided:

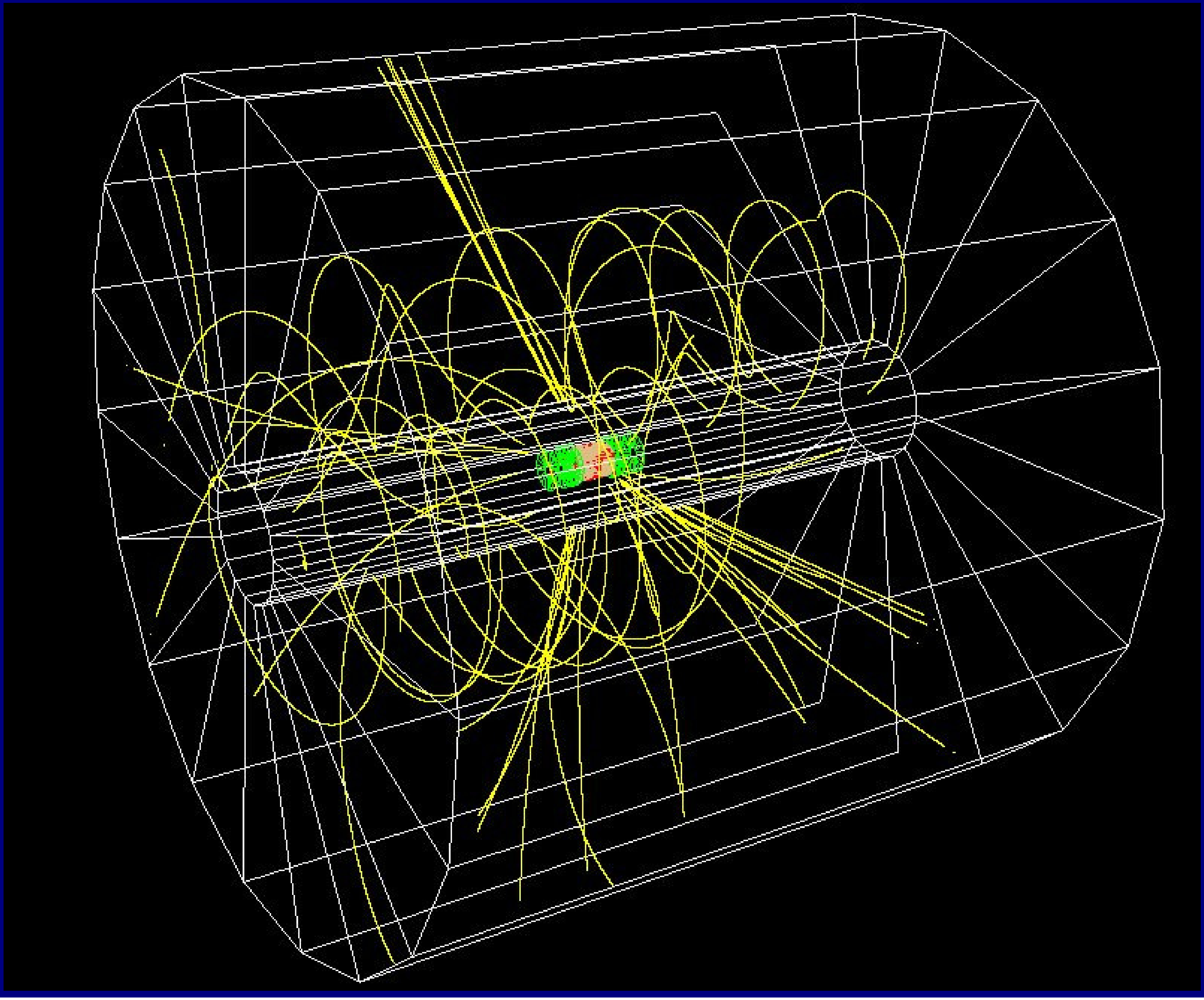
- cluster counting techique is at reach (front end VLSI chip)
- fast and efficient counting of single electrons to form clusters is possible
- 50 µm spatial resolution has been demonstrated

CluCou in ILCroot $e^+ e^- \rightarrow t^+ t^-$

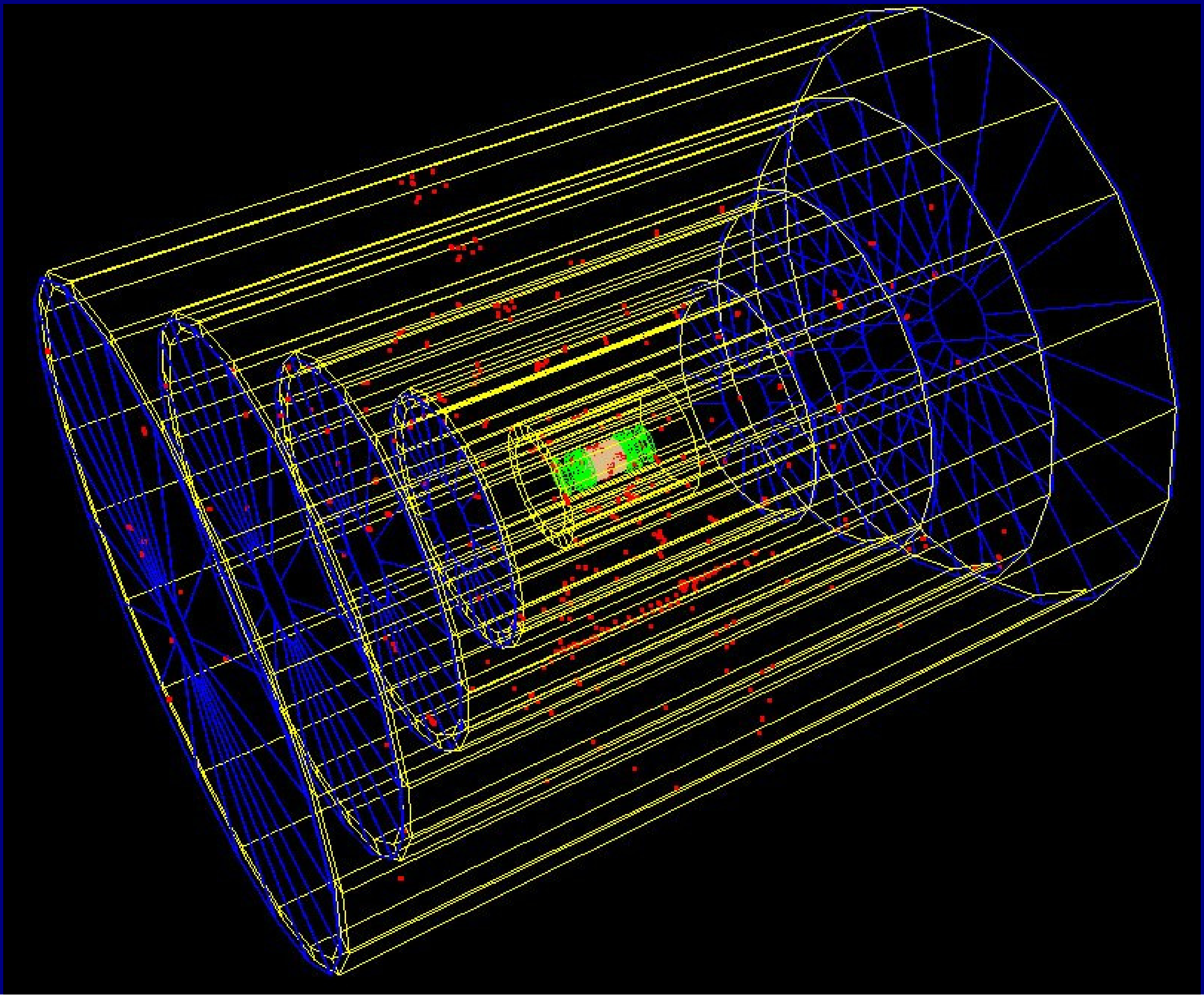


ILC $\sigma(m_t)$ < 200 MeV
Tevatron, LHC 2 GeV

TPC in ILCroot $e^+ e^- \rightarrow t^+ t^-$

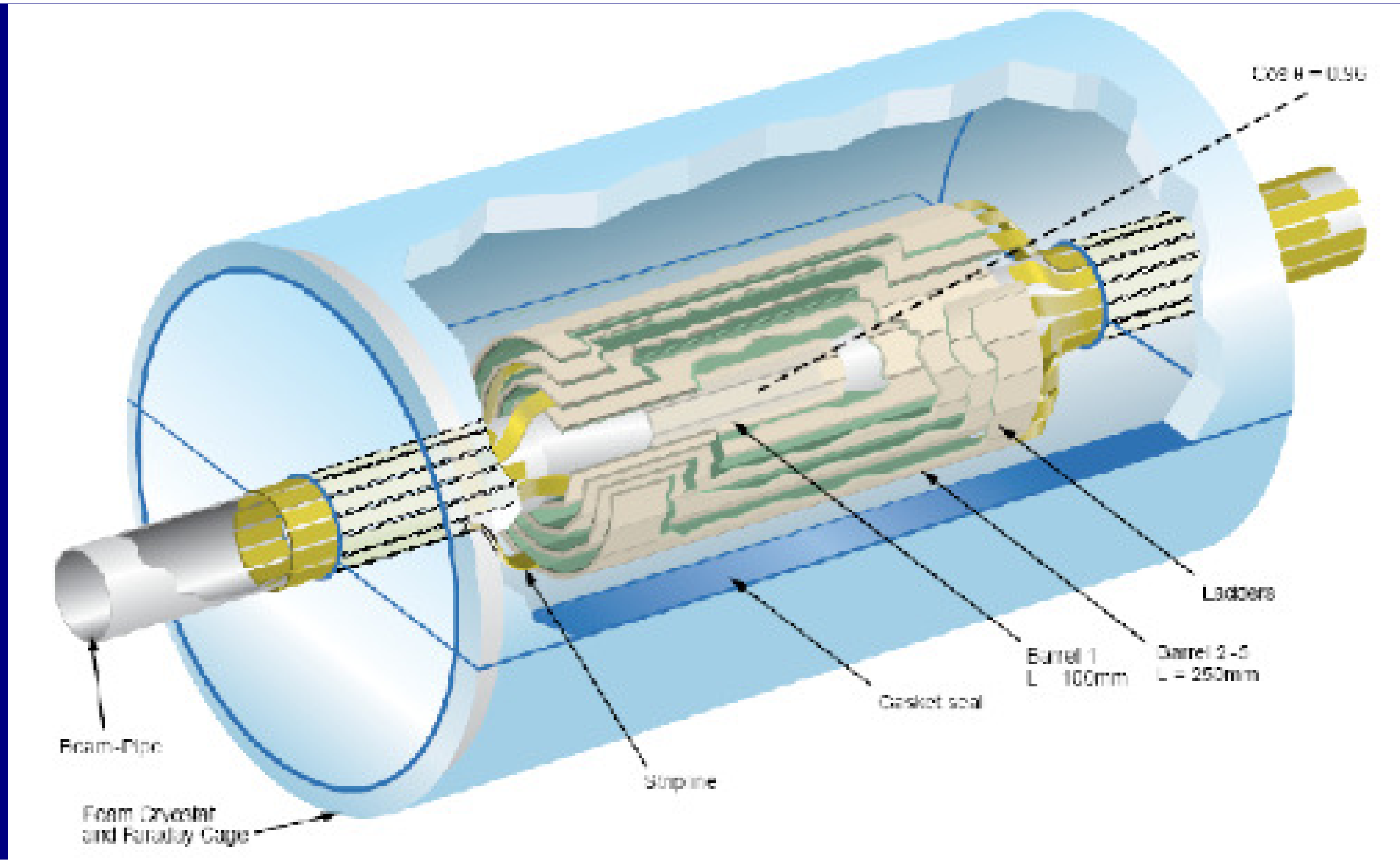


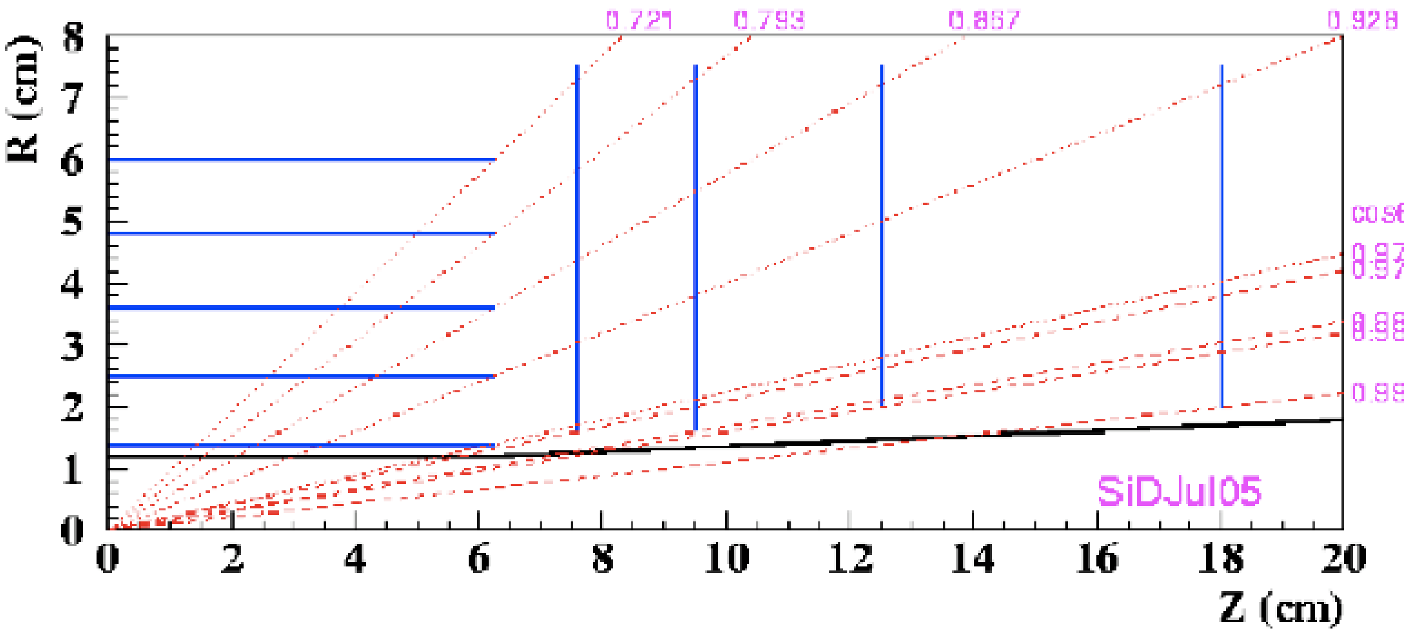
SiD in ILCroot $e^+ e^- \rightarrow t^+ t^-$

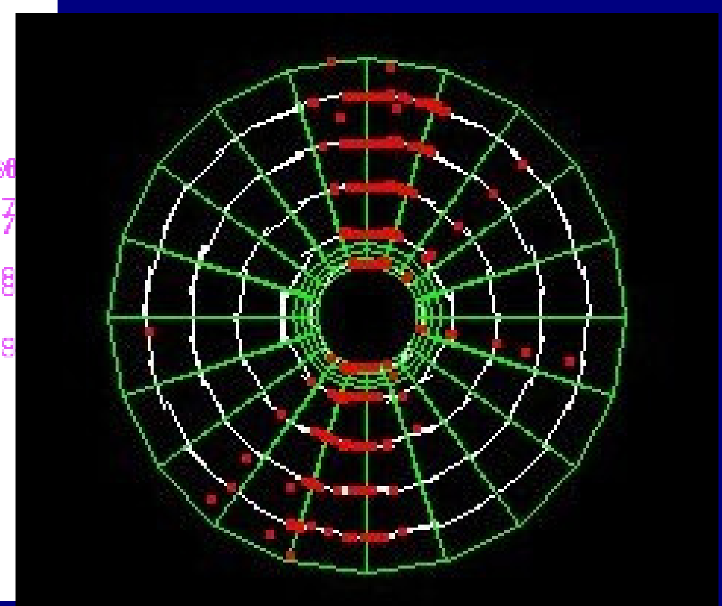


Pixel vertex detector

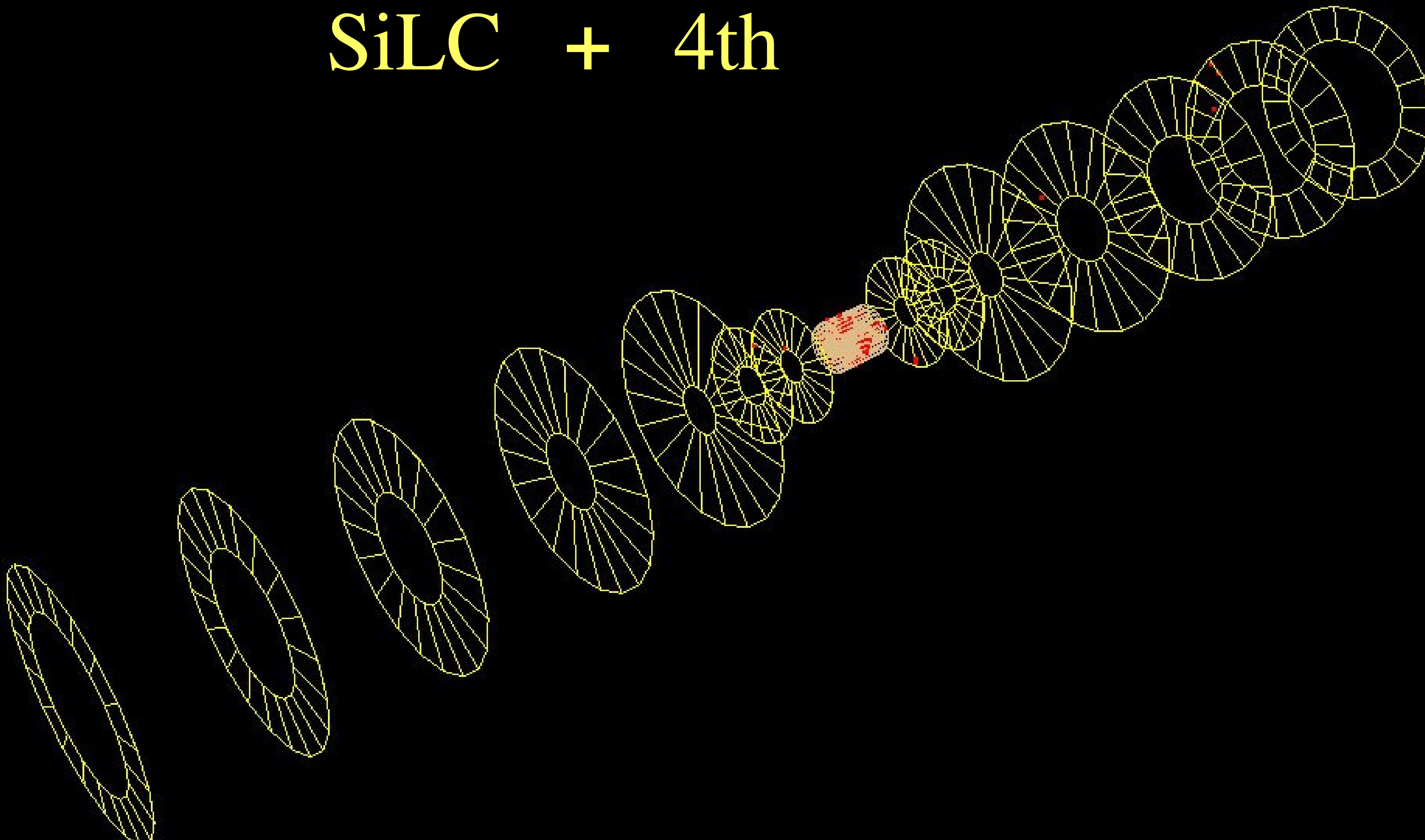
Fermilab + SiD/4th



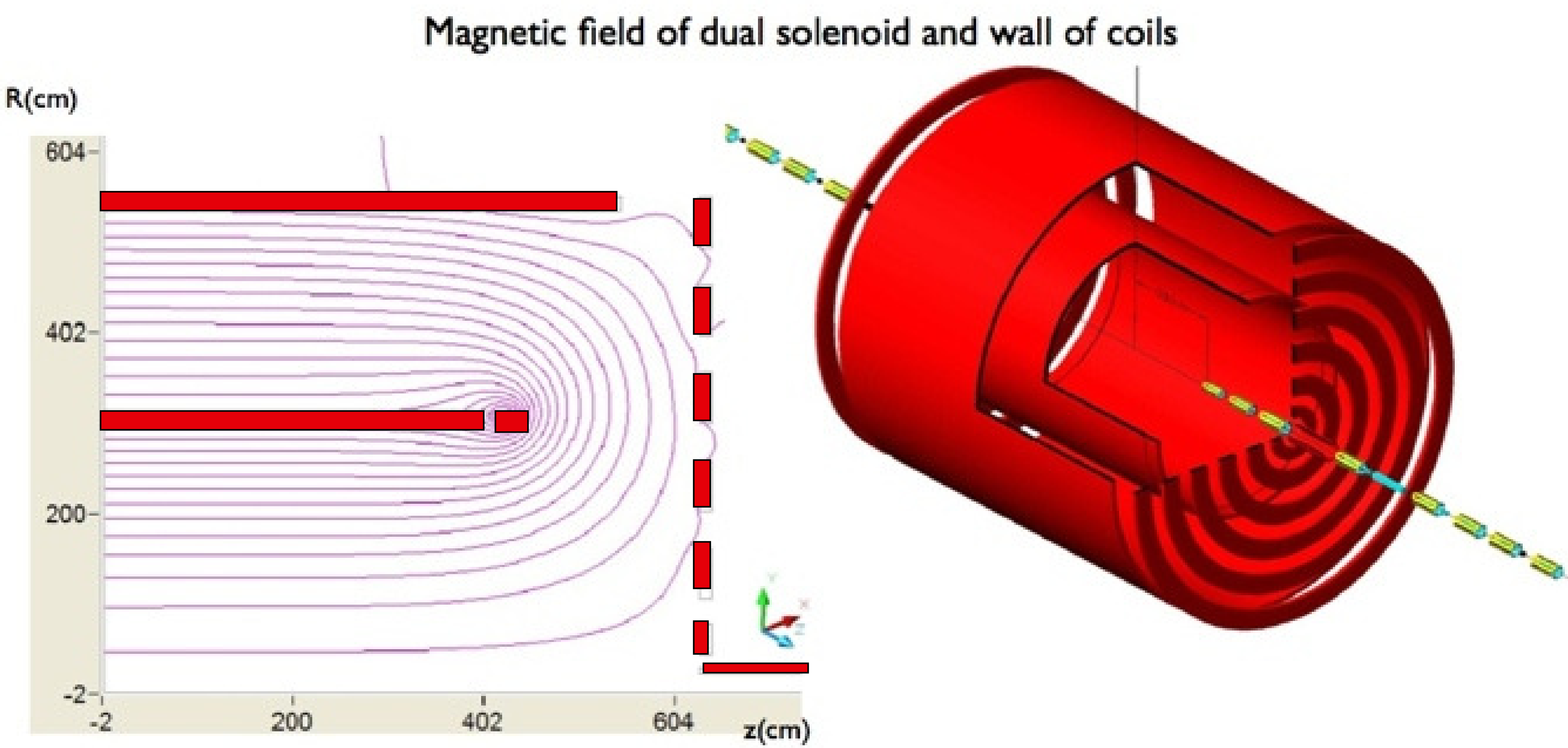




SiLC + 4th



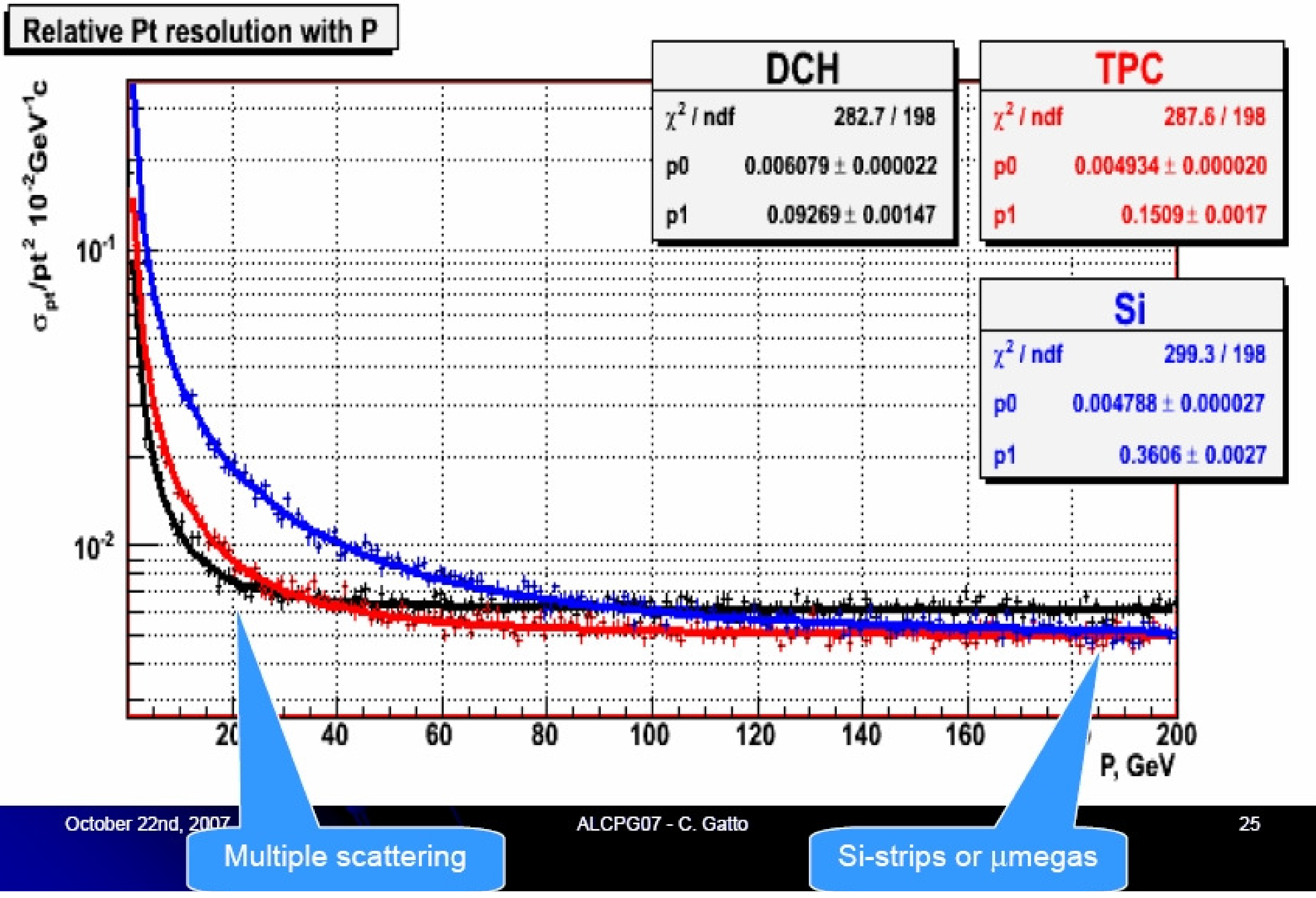
New magnetic field, new ``wall of coils'', iron-free: many benefits to muon detection and MDI, Alexander Mikhailichenko design



$\sqrt{p_o^2 + p_1^2 / P^2}$

Momentum Resolution vs P

10 muons



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

DCH

$$\sigma(P_t^{-1}) = 9.3/P \oplus 0.61\times10^{-4}\,GeV^{-1}c$$
$$\sigma(\vartheta) = 0.79/P^{0.81} \oplus 0.034\ mrad$$
$$\sigma(\varphi) = 1.39/P \oplus 0.037\ mrad$$
$$\sigma(D_o) = 15.3/P^{0.62} \oplus 2.4\ \mu m$$
$$\sigma(Z_o) = 19.2/P^{0.64} \oplus 3.4\ \mu m$$

TPC

$$\sigma(P_t^{-1}) = 15.1/P \oplus 0.49\times10^{-4}\,GeV^{-1}c$$
$$\sigma(\vartheta) = 0.74/P^{0.78} \oplus 0.032\,mrad$$
$$\sigma(\varphi) = 1.27/P \oplus 0.030\,mrad$$
$$\sigma(D_o) = 16.0/P^{0.63} \oplus 2.2\ \mu m$$
$$\sigma(Z_o) = 17.1/P^{0.74} \oplus 3.3\ \mu m$$

SiT

$$\sigma(P_t^{-1}) = 36.1/P \oplus 0.48\times10^{-4}\,GeV^{-1}c$$
$$\sigma(\vartheta) = 0.6/P^{0.77} \oplus 0.10\,mrad$$
$$\sigma(\varphi) = 1.5/P \oplus 0.029\,mrad$$
$$\sigma(D_o) = 15.3/P^{0.57} \oplus 2.2\ \mu m$$
$$\sigma(Z_o) = 15.8/P^{0.64} \oplus 6.3\ \mu m$$

MS effect

Single sensor effect

LCIO Version 2?

LCIO is constantly evolving: your input is needed

(see also Romans talk on the needs of the online community)

How shall we evolve LCIO: ?

- root as IO package?
- home grown solutions?
- other solutions?

Added functionality for analysis:

- trajectory discussion here at this workshop
- we need a similar discussion on clusters
- maybe other objects

Still part of LCIO or beyond the scope?

* LDC, GLD, 4th, CMS, Atlas, Alice, CDF, D0, … all use C++
* Geant4 is also in C++

In discussions with many HEP colleagues, all agree :

the common language C++ & ROOT enable / facilitate

* Tevatron/LHC ILC comparisons & collaborations
* Tevatron/LHC colleagues to join ILC more easily

LoI

LDC + GLD = ILD is expected to use C++ .

C++ (and English) should be the common language in the ILC detectors,
would strengthen worldwide ILC collaborations & HEP.

Other languages could be additional / optional for colleagues who prefer them.

Roadmap

LoI

ILD SiD 4th

use a common set of Monte Carlo events.
same events/particles at the generation level.
stored in StdHep format
http://cepa.fnal.gov/psm/stdhep/
at Fermilab, KEK, SLAC, DESY, CERN . . .

Each LoI can do its detector simulation, analyses.

Summary

4th Concept Detector

- **Pixel Vertex Detector**

o **Central & Forward Tracking**

SiLC + CluCou SiT TPC ?

Picosecond TOF flavor tagging ?

✓ **Dual Readout calorimeter** (with Test_Beam **data**)

Scintillation + Cerenkov crystal ECAL
Scintillation + Cerenkov fiber HCAL
neutron

▪ **Dual Solenoid iron-free Muon system**

✓ **ILCroot software**