4th detector LoI group

4th Expression of Interest: 18 institutions from 9 countries in 4 regions

John Hauptman
ECFA'08 Warsaw 9-12 June 2008

Additional 4th talks at ECFA '08 Warsaw

- Corrado Gatto: Tues., 10 Jun, 10:00, Detector Performance and Software Tools.
  "4th Concept Detector Performance" (20')
- Corrado Gatto: Weds., 11 Jun, 9:45, Detector Optimization Studies.
  "4th Concept" (30')
- Franco Grancagnolo: Weds., 11 Jun, 15:10, Tracking/VTX
  "Update on Cluster Counting for the 4th Concept" (20')
- Alexander Mikhailichenko/JH: Tues., 10 Jun, 9:20, MDI Session
  "4th MDI issues and IP design"
- John Hauptman: Tues, 10 Jun, 14:00, MDI Session
  "Recent results and plans in dual-readout calorimetry"

The 4th group has introduced three major innovations in large detectors and some innovations in MDI, all of which are published or tested. They are

i. An ultra-low mass tracking system The KLOE chamber has operated trouble-free for 10 years, and cluster-counting cosmic track tests are in progress at INFN, Lecce. [Grancagnolo: 2 NIM papers, 4 conf. papers, PhD thesis, one major Review (Beijing), several talks]

ii. Dual-readout calorimeters Thoroughly tested at CERN by DREAM collaboration, simulated by 4th for physics performance and particle identification. [Wigmans: 12 NIM papers, one major Review (DESY), dozens of talks]

iii. An iron-free magnetic field configuration The tracking magnetic flux is returned by a second solenoid. [Mikhailichenko/Hauptman: LNS notes, several talks, Fermilab/Cornell engineering study]

iv. Flexible and robust MDI (Machine Detector Interface) Based on experience at FFTB *Phys. Rev. Lett. 74* (1995) 2479. [Mikhailichenko: PRL, internal notes]

Full detector simulation, calibration and physics analysis by root-based ILCroot (C++ and English languages) fully supported by CERN and used world-wide by almost all physics groups. [Gatto: dozens of talks]

Each of these in more words:

i. An ultra-low mass tracking system with of a He-based gas, single-electron cluster counting and composite wires; we anticipate 50 micron point resolution, 100 vector points, transparency to IP debris, and 2.5% dE/dx resolution.

ii. Dual-readout calorimeters with fine-segmentation crystals in front and a DREAM-like fiber calorimeter behind; we expect excellent hadronic and electromagnetic energy resolutions, 10-interaction-length depth, and novel particle identification capabilities. Successful beam tests of all aspects has been performed at CERN by the DREAM, including simulations for 4th by the Lecce group;

iii. A novel no-iron magnetic field configuration with flux return by a second solenoid allowing better muon measurement, open-detector survey and alignment, quick push-pull and (re)installations; and,

iv. Flexible MDI with Final Focus (FF) controls incorporated into detector for precision FF and suppression of ground motion, easy laser optical system for gamma-gamma collisions, easy push-pull, no fringe field, and capability to control magnetic field everywhere.

Powerful flexible ILCroot can swap in different physics and detector simulators at run-time, one platform for all work, compatible with the world, and has simulated SiD-ILD-4th tracking systems, SiD vertex, and all of the 4th concept detector.

Expression of Interest by the Fourth Concept Detector Group ("4th") at the International Linear Collider

Collaborating Institutions (18), Countries (9), Regions (4)

DAPNIA/SPP, F-91191 GIF sur Yvette, **France**

INFN, Sezione di Lecce, Dipartimento di Fisica,
via Lecce-Arnesano, 73100, Lecce, **Italy**

INFN, Sezione di Messina,
via Tommaso Cannizzaro, I-98100 Messina, **Italy**

INFN, Sezione di Pavia, Via Bassi, 6 - 27100, Pavia, **Italy**

INFN, Sezione di Pisa, Polo Fibonacci Largo B. Pontecorvo, 3 - 56127 Pisa, **Italy**

INFN, Trieste, Padriciano 99; I-34012 Padriciano, Trieste, **Italy**

Univ. of Udine and INFN Ts. - G.C. Udine, Via delle Scienze, I-33100 Udine, **Italy**

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

Korea Detector Laboratory, Department of Physics, Korea University,
Seoul 136-701, **Korea**

Budker Institute of Nuclear Physics, 11 Prospect Lavrentyeva, Novosibirsk, 630090, **Russia**

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

Institute of Experimental Physics, Watsonova 47, Kosice 043 53, **Slovakia**

Physics Department, Middle East Technical University, Ankara, **Turkey**

Institute for Low temperature Physics and Engineering, Kharkov, **Ukraine**

Laboratory of Nuclear Science, Cornell University, Ithaca, NY 14853-5001 **USA**

Fermi National Accelerator Laboratory, Batavia, IL 60510 **USA**

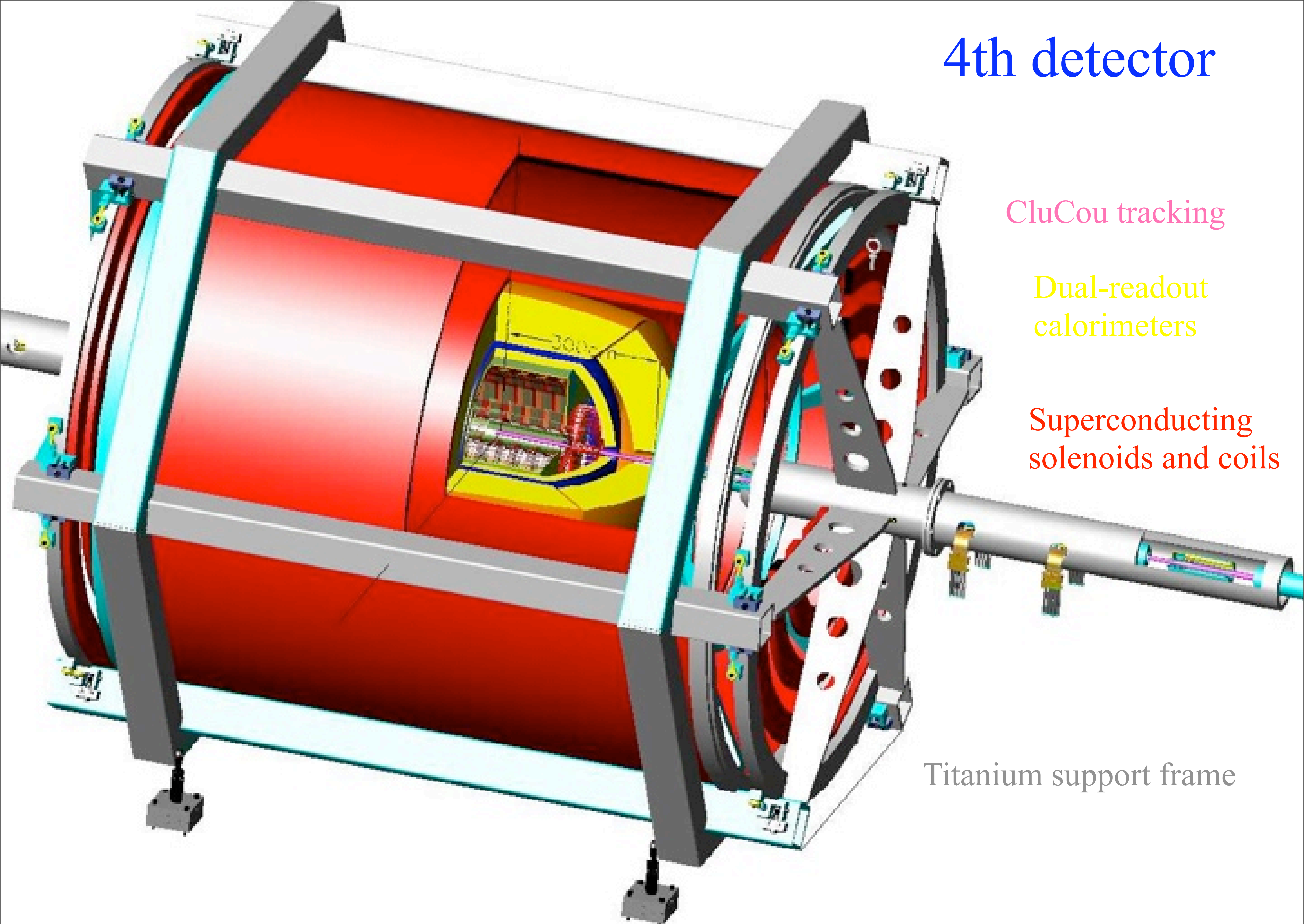
Departments of Physics and Astronomy, Materials Science and Engineering,
Iowa State University, Ames, IA 50011 **USA**

Department of Physics, Texas Tech University,
Lubbock, TX 79409-3783 **USA**

University of Ghana and Ghana Atomic Energy Commission, Legon-Accra, **Ghana**

9 June 2008

4th detector



CluCou tracking

Dual-readout
calorimeters

Superconducting
solenoids and coils

Titanium support frame

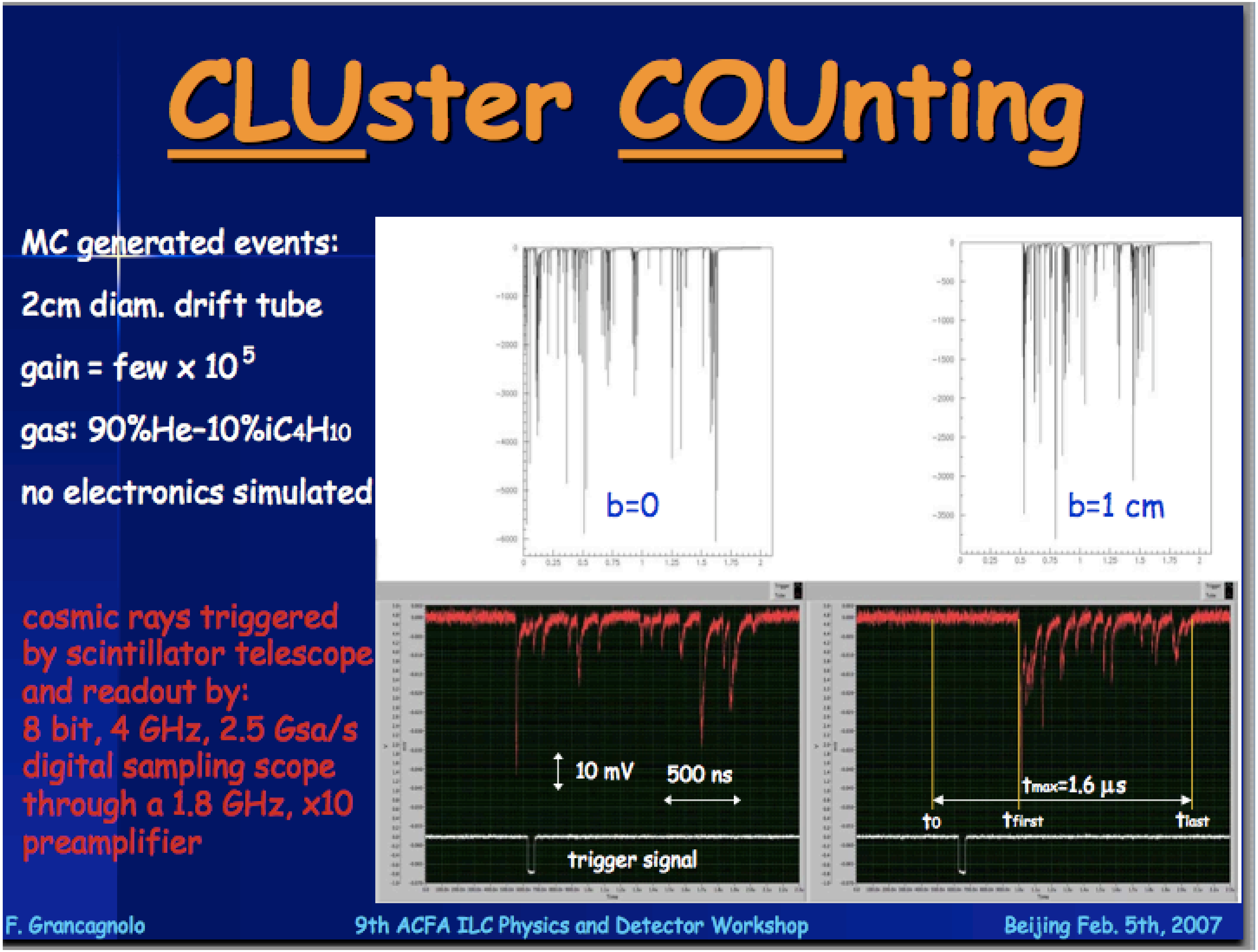
It looks different because it is different.

Tracking: "CluCou" cluster counting KLOE chamber

- KLOE is already the lowest mass (and the largest volume) chamber ever built, with 10 years of trouble-free running
- He gas is a critical feature:
  (a) reduces multiple scattering material;
  (b) lowers the drift velocity to allow cluster counting;
  (c) reduces the Lorentz angle; and,
  (d) reduces the keV-MeV electromagnetic conversions in the tracking volume by a factor of 10.
- New low-mass composite wires being studied.
- Read out within one beam crossing
- z-coordinate information
- Good *dE/dx* measurement, maybe 2.5%

See Franco Grancagnolo talk

Nearly "massless" chamber; count individual electron clusters.



CLUster COUnting

MC generated events:

2cm diam. drift tube

gain = few x 10^5

gas: 90%He-10%iC_4H_{10}

no electronics simulated

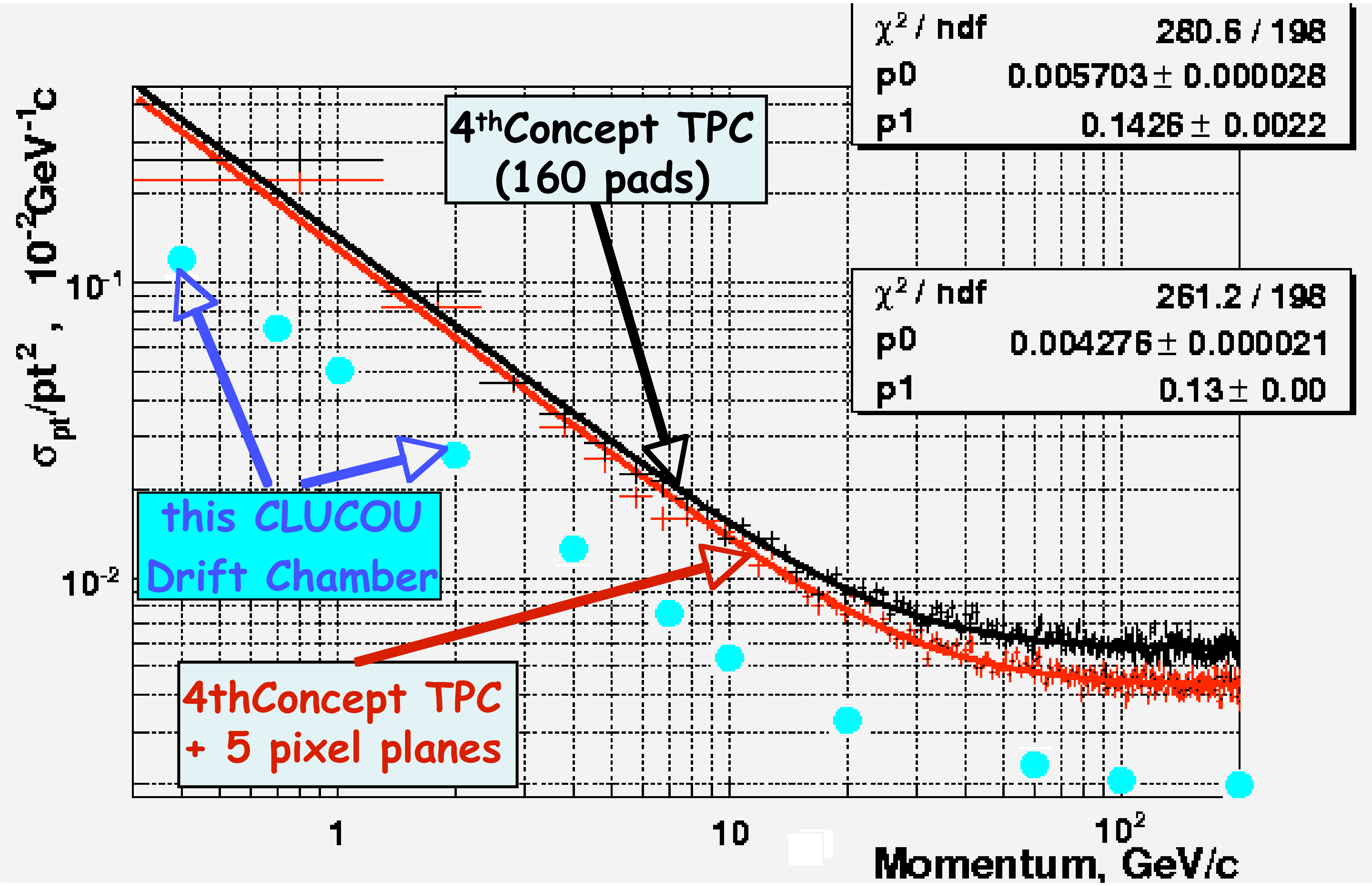
cosmic rays triggered by scintillator telescope and readout by:
8 bit, 4 GHz, 2.5 Gsa/s digital sampling scope through a 1.8 GHz, x10 preamplifier

F. Grancagnolo 9th ACFA ILC Physics and Detector Workshop Beijing Feb. 5th, 2007

Momentum Resolution

$$2\times10^{-5} \oplus \frac{5\times10^{-4}}{p_{\perp}\sin\theta}$$

Helium is transparent to beam debris photons by a factor of 10 compared to Ar or Si. And, Carbon fiber Ni/Au coated wires.



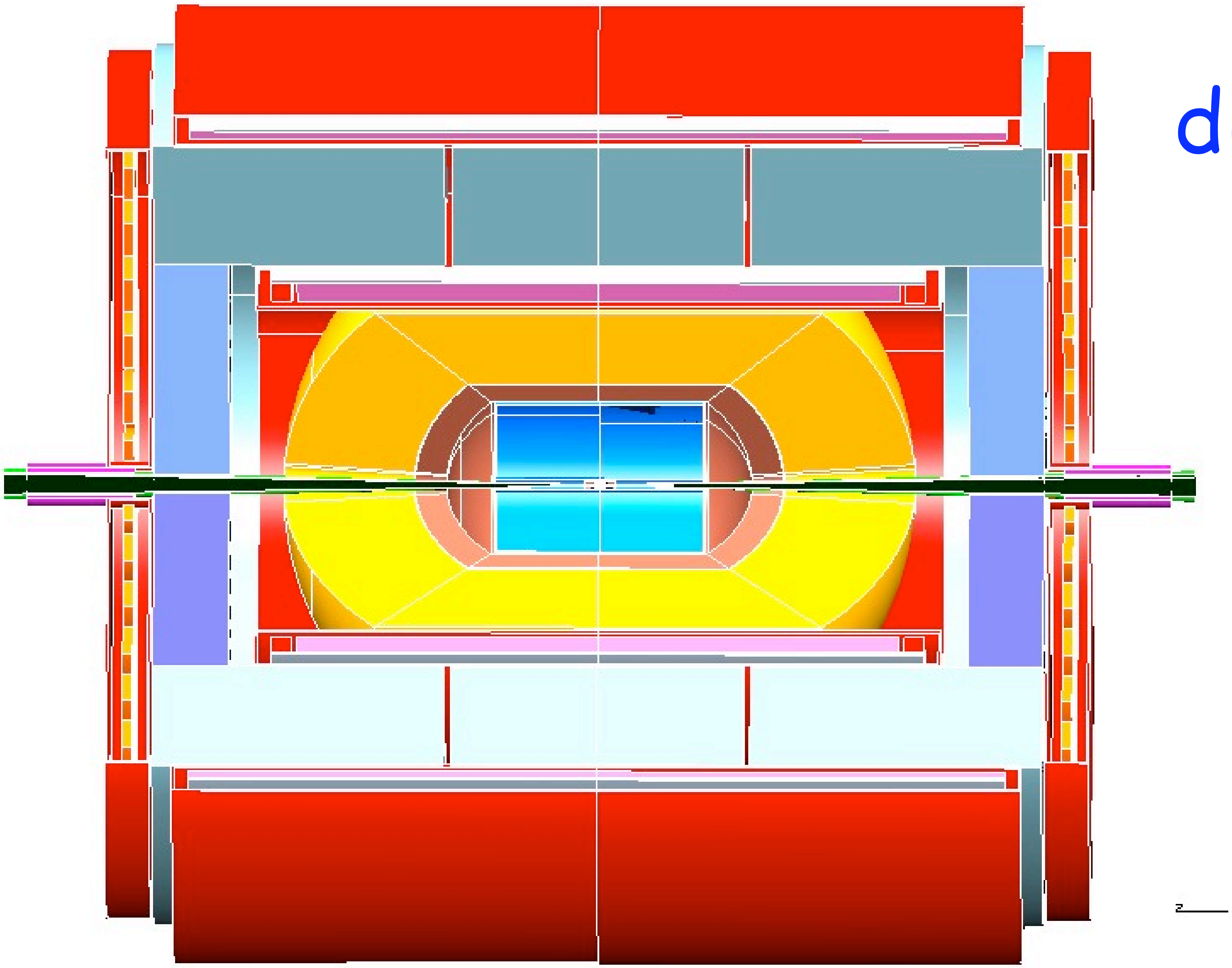
A drift chamber à la KLOE with cluster counting (≥ 1GHz, ≥ 2Gsa/s, 8bit)

- 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 σ_b = 50 μm (σ_z = 300 μm)
- 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:

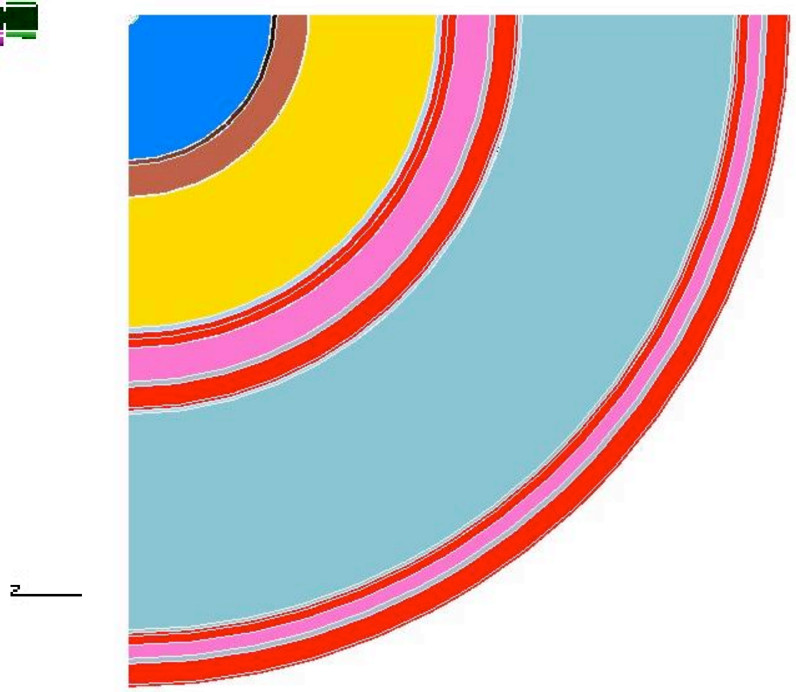
- cluster counting techique is at reach (front end VLSI chip)
- fast and efficient counting of single electrons to form clusters is possible
- 50 μm spatial resolution has been demonstrated

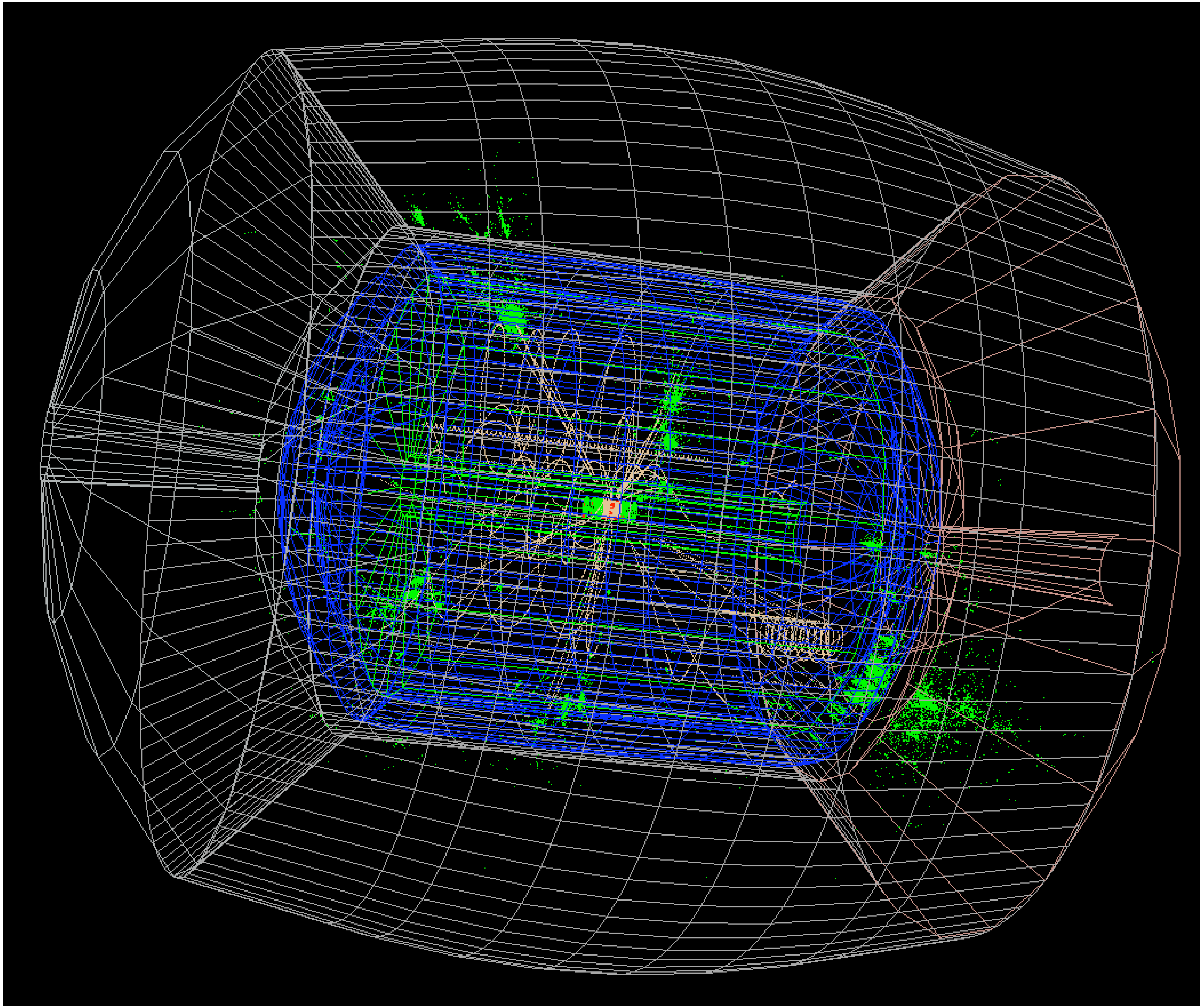
4thConcept CluCou layout



diameter x length

12.8 m x 15.4 m





Calorimetry: based on successful dual readout tests of the DREAM collaboration

- Deep fiber calorimeter like DREAM, but optimized;

- Crystal dual-readout in front with fine lateral segmentation for pi-zero reconstruction and precision EM measurement;

- Time-history of scintillating fibers for neutron measurement, particle ID, and sub-ns time-of-flight; and,

- Time-history of Cerenkov fibers for baseline and inter-bunch monitor, and for sub-ns time-of-flight.

- Modest: about 20K fiber and 80K crystal channels.

Hadron calorimetry is “as easy as 1, 2, 3 … “

“LESSON 6: To improve energy resolution, measure every fluctuation event-by-event”

- Spatial fluctuations are huge, λ_{Int}, with local high density EM deposits.

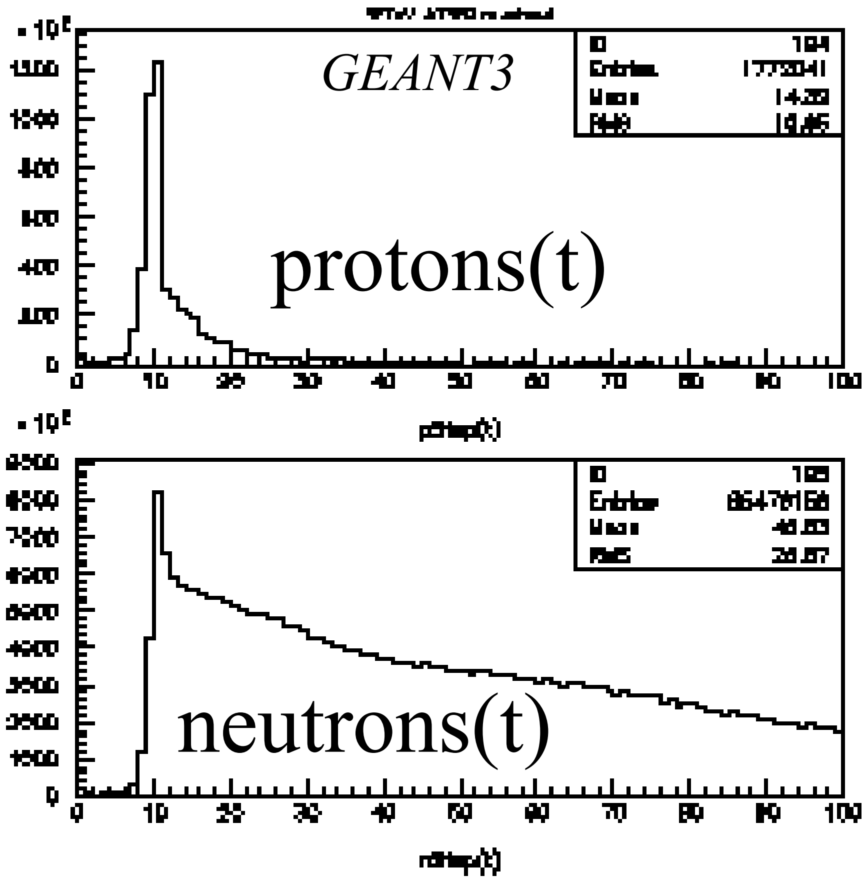
  → fine spatial sampling with scintillation fibers every 2-3 mm.

- EM fraction fluctuations are huge, 10% - 90%, of total shower energy.

  → measure EM content with Cerenkov fibers, Eth ~ 0.25 MeV, mostly electrons from $\pi^0 \rightarrow \gamma\gamma$

- Binding energy (BE) loss fluctuations from nuclear breakup

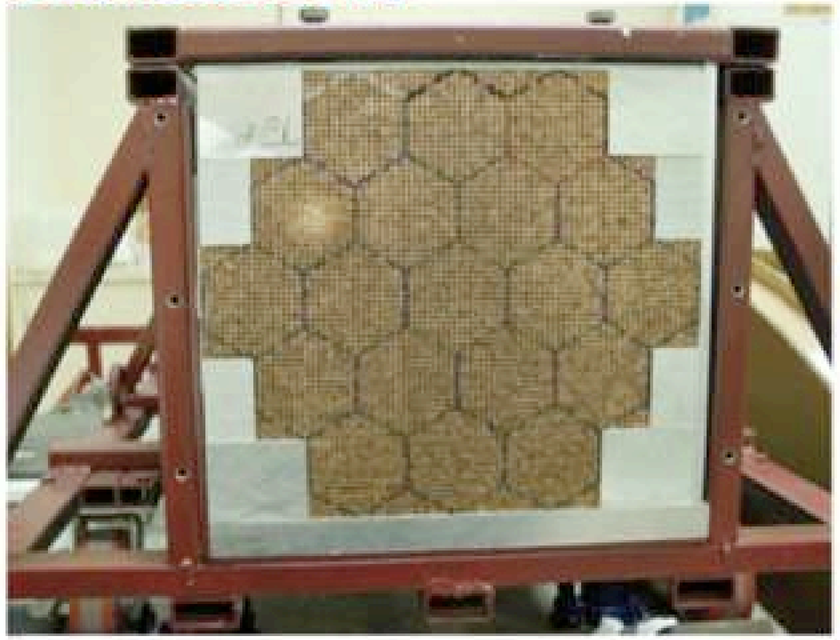
  → measure MeV neutron content of showers

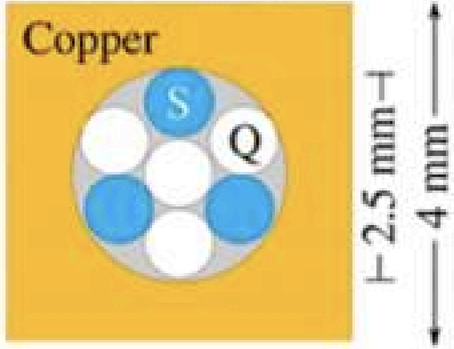


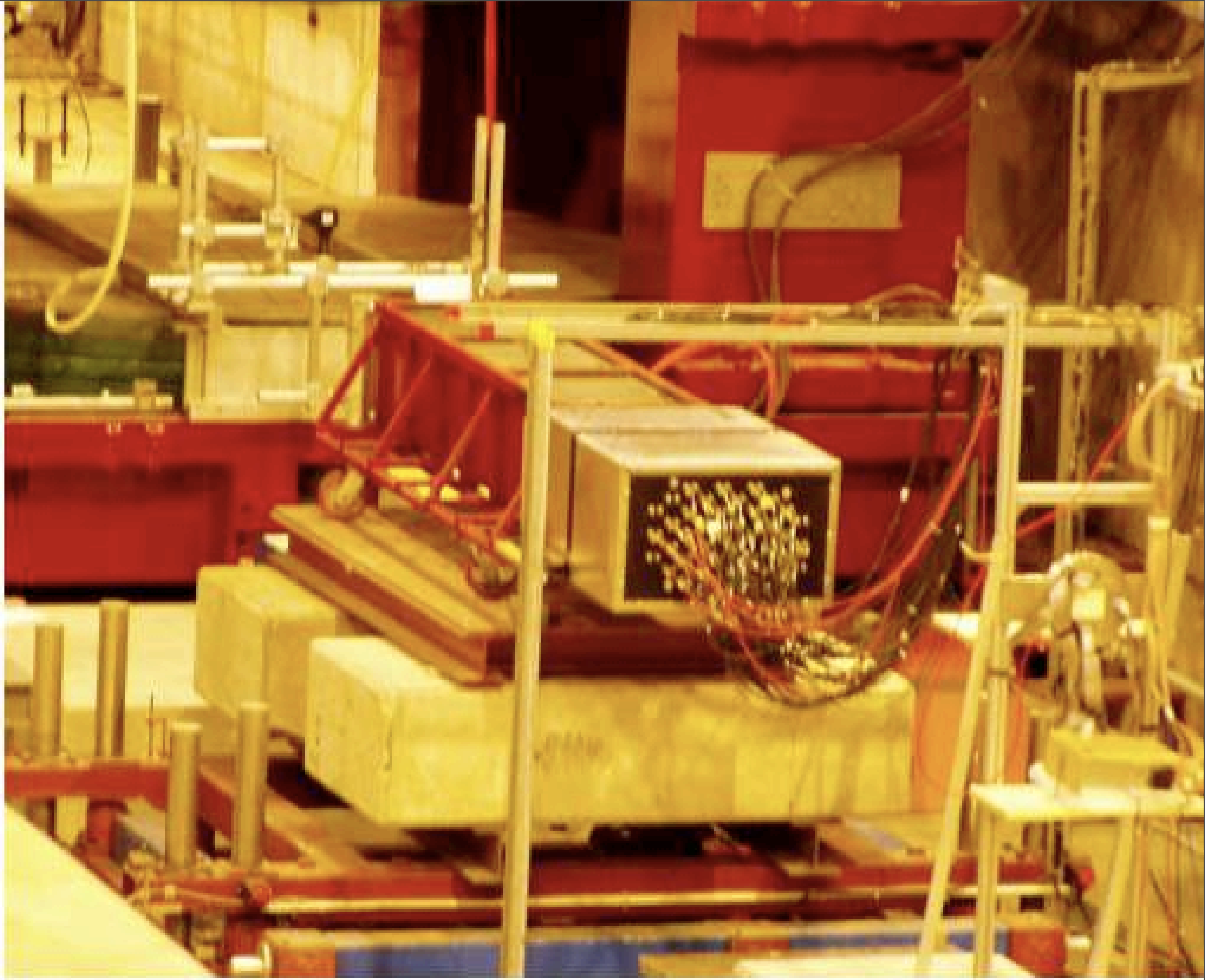
The theoretical limit (Wigmans) for hadronic energy resolution is

$$\frac{\sigma_E}{E} \approx \frac{13\%}{\sqrt{E}}$$

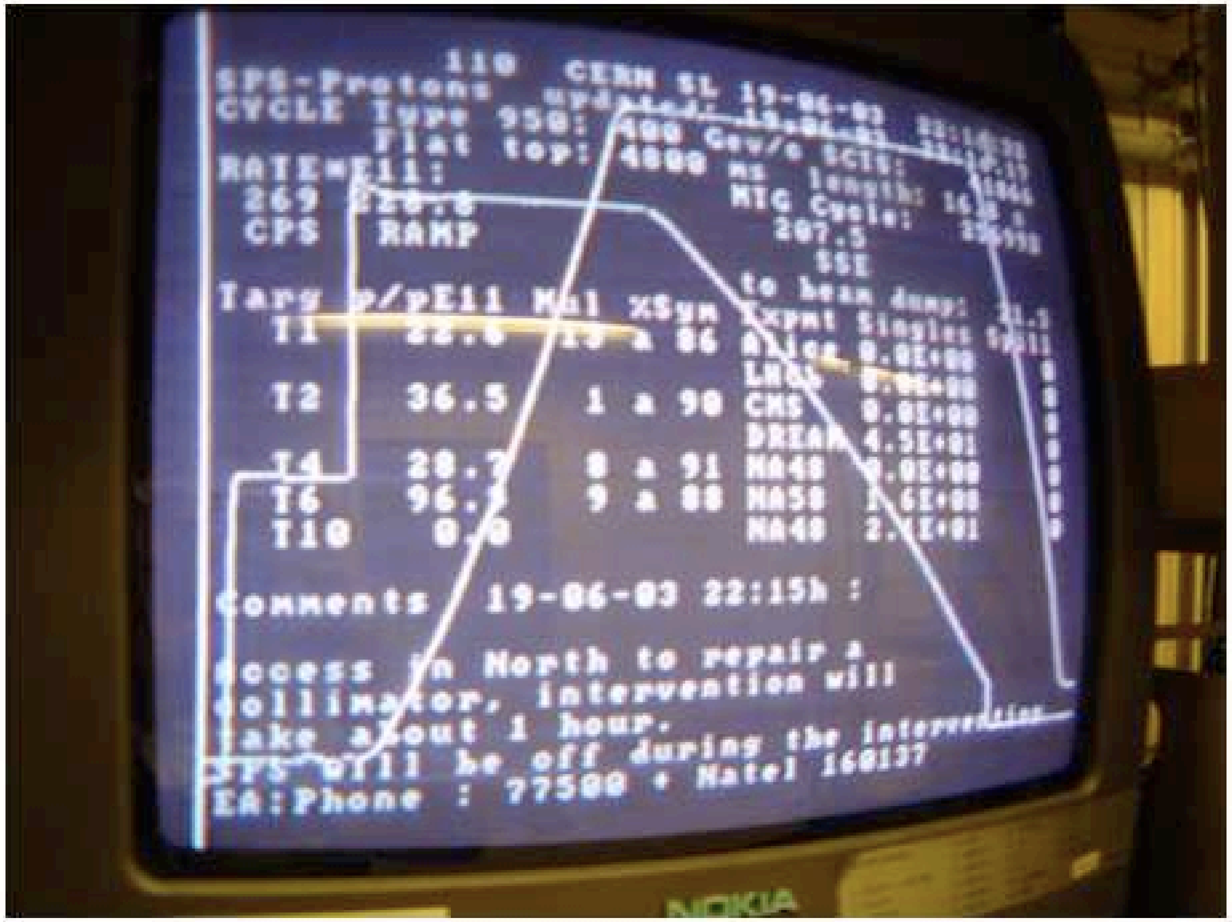
Dual-readout DREAM: Structure







- *Some characteristics of the DREAM detector*
  - Depth 200 cm (10.0 $\lambda_{\rm int}$)
  - Effective radius 16.2 cm (0.81 $\lambda_{\rm int}$, 8.0 ρ_M)
  - Mass instrumented volume 1030 kg
  - Number of fibers 35910, diameter 0.8 mm, total length ≈ 90 km
  - Hexagonal towers (19), each read out by 2 PMTs



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          110     CERN SL 19-06-03 22:1[illegible]
SPS-Protons   updated: 19-06-03 22:1[illegible]
CYCLE Type 950: 400 GeV/c SC1S: [illegible]
       Flat top: 4800 ms length: 16.8 s
RATE*E11:             MIG Cycle: [illegible]
 269  [illegible]          207.5
 CPS  RAMP                  SSE
                      to beam dump: 21.[illegible]
Targ p/pE11 Mul XSym  Expmt Singles [illegible]
  T1   22.6   13 a 86 Alice 0.0E+00
                      LHCb  0.0E+00
  T2   36.5    1 a 90 CMS   0.0E+00
                      DREAM 4.5E+01
  T4   28.7    8 a 91 NA48  0.0E+00
  T6   96.[illegible]    9 a 88 NA58  1.6E+00
  T10   0.0           NA48  2.[illegible]E+01

Comments   19-06-03 22:15h :

Access in North to repair a
collimator, intervention will
take about 1 hour.
SPS will be off during the intervention
EA:Phone  :  77500 + Natel 160137
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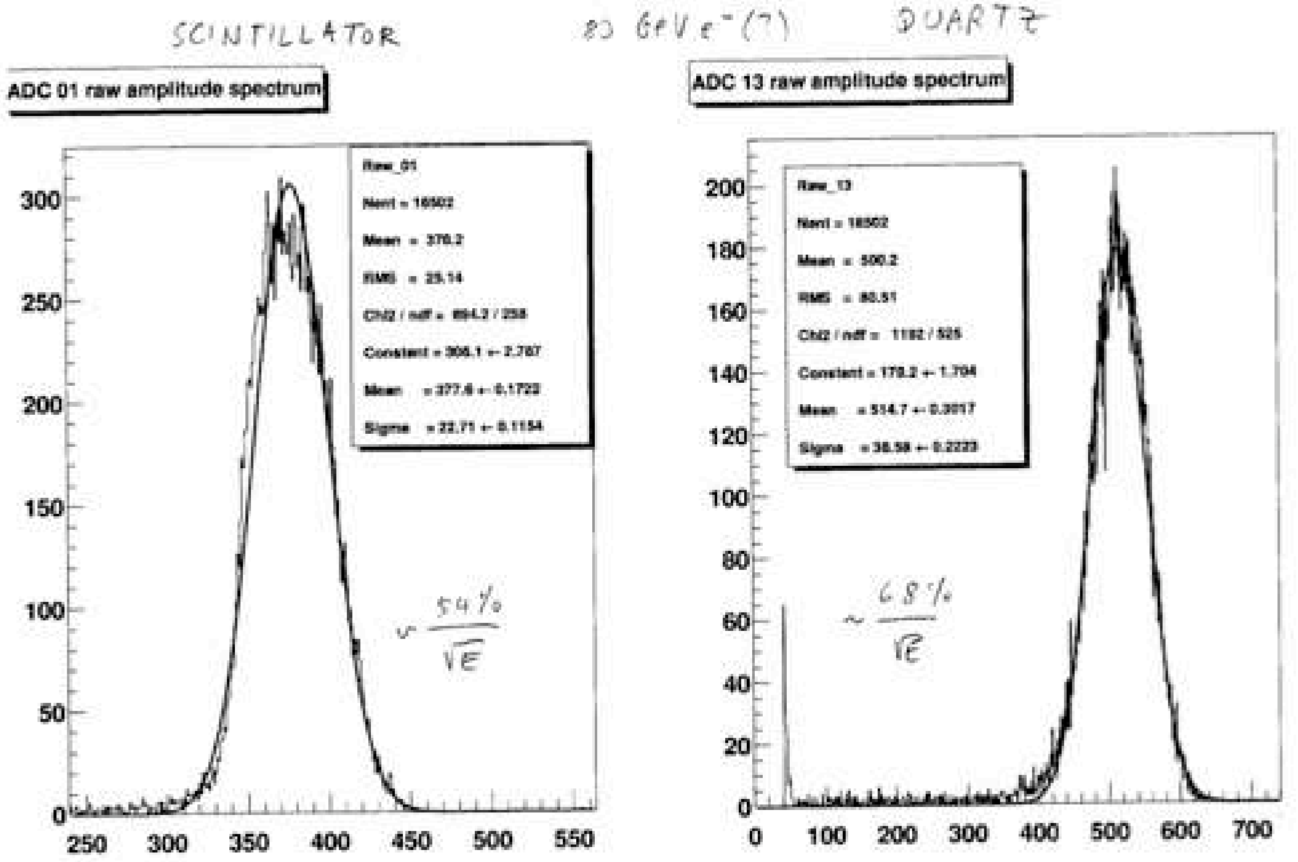
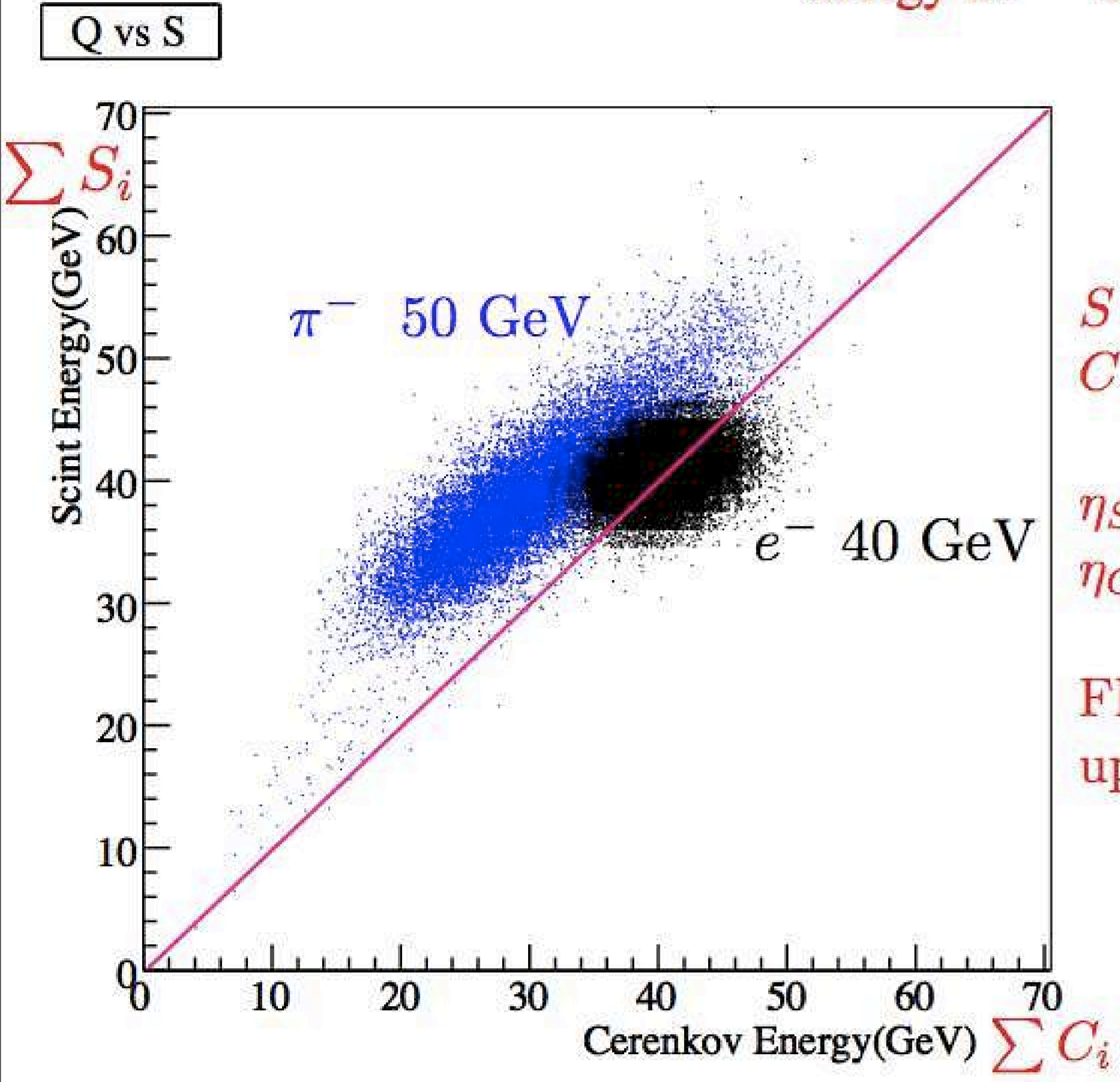


Dual-REAdout Method

- Calibrate both S and C to 40 GeV electrons;
- Therefore, energy units are electromagnetic GeV;
- Take single pion or "interaction jet" data at beam energy E. S and C response functions are



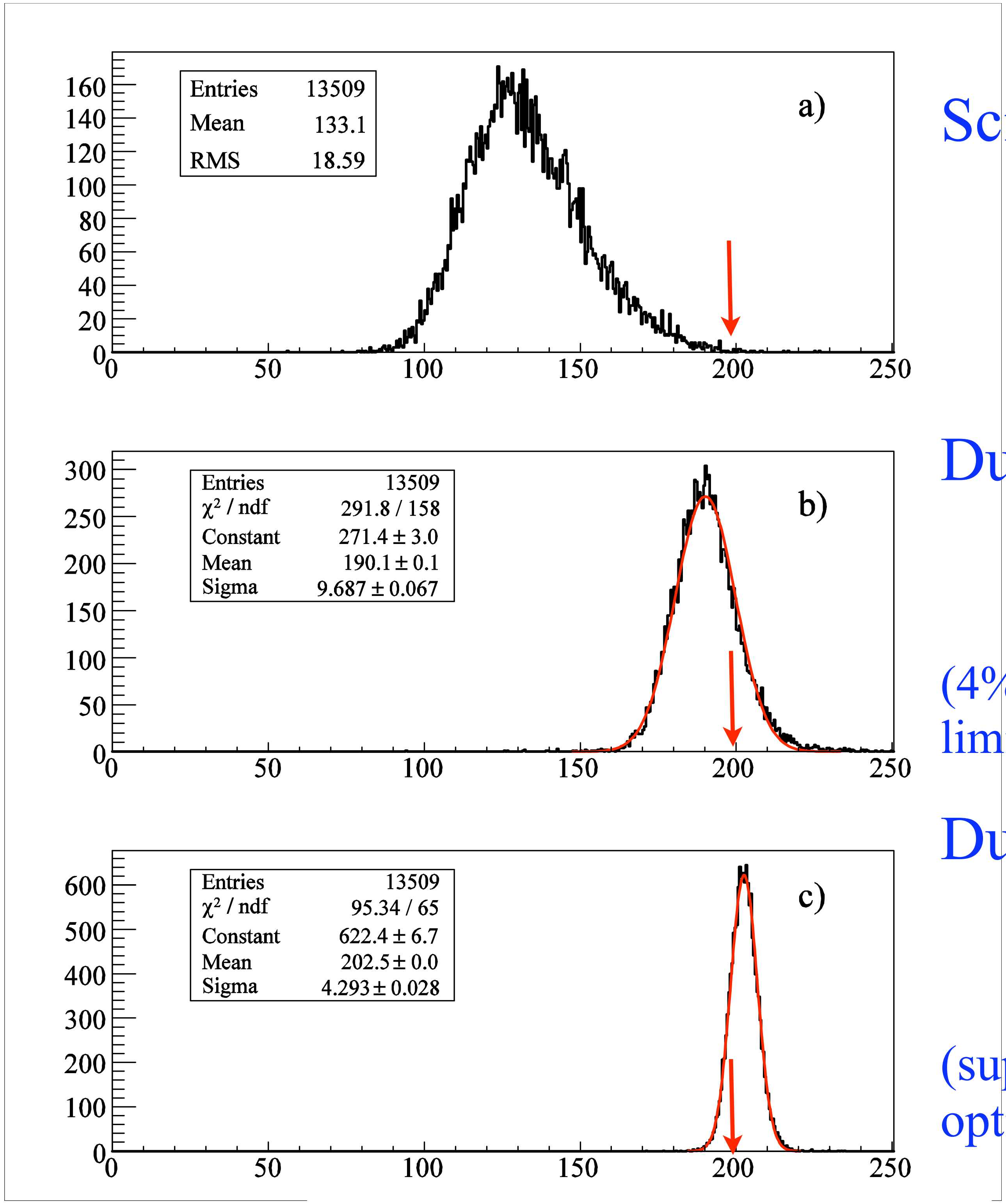
$$S = [f_{EM} + (1 - f_{EM})/\eta_S]E$$
$$C = [f_{EM} + (1 - f_{EM})/\eta_C]E$$

$\eta_S = (e/h)_S \sim 1.4$ (like Sc sampling calor)

$\eta_C = (e/h)_C \sim 5.0$ (like HF of CMS)

Fluctuations in f_{EM} drive S and C up and down, but differently.

DREAM data: 200 GeV π^- energy response



Scintillating (S) fibers only

Dual-readout of S and Cerenkov (C)

$$f_{EM} \propto (C/E_{shower} - 1/\eta_C)$$

(4% leakage + neutron BE loss fluctuations, and limited by photoelectron statistics in C)

Dual-readout of S and C:

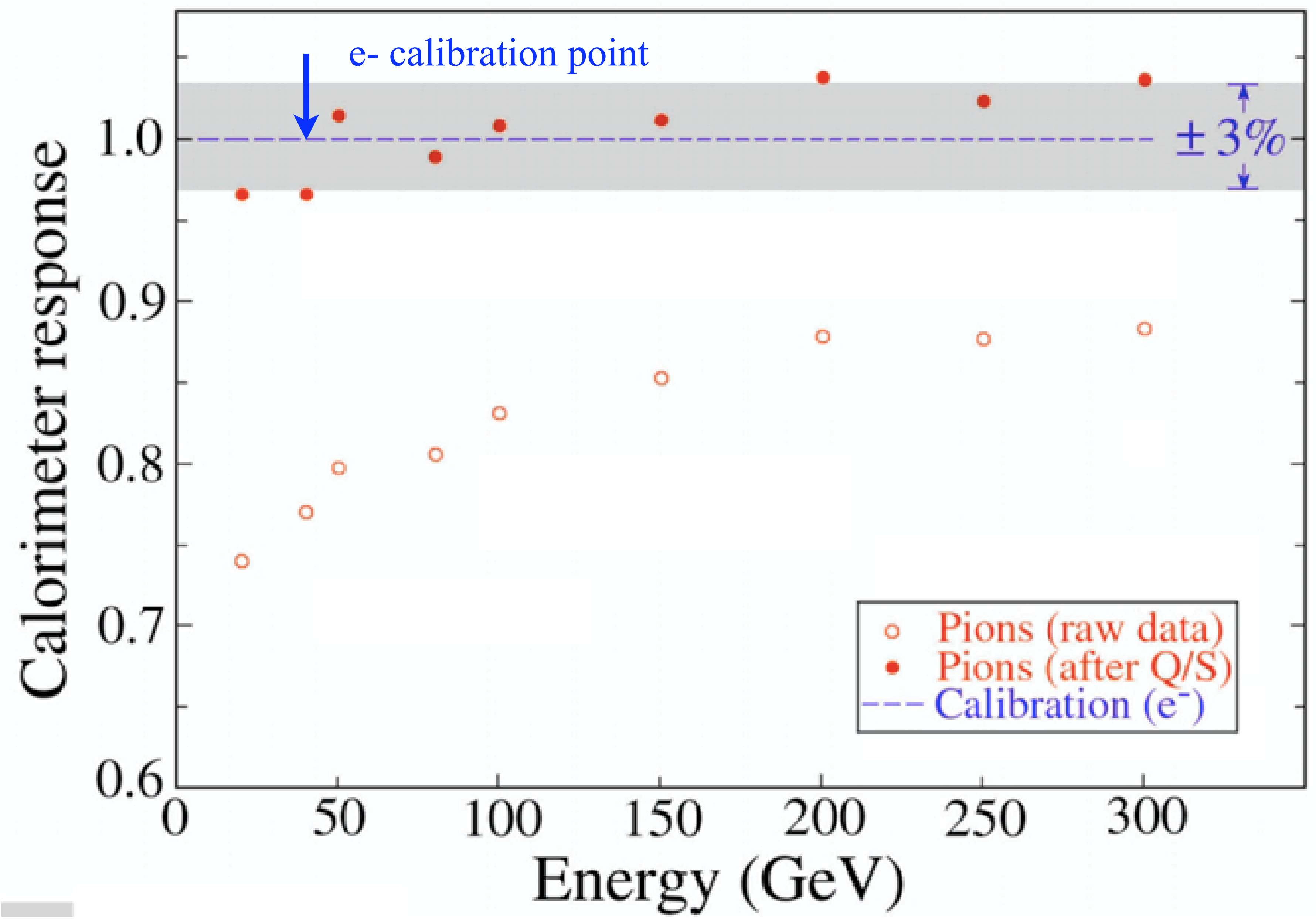
$$f_{EM} \propto (C/E_{beam} - 1/\eta_C)$$

(suppresses leakage and BE fluctuations; too optimistic)

Data NIM A537 (2005) 537.

Hadronic energy linearity over the whole SPS range, 20-300 GeV/c.

(500 GeV not too far away ⟶)



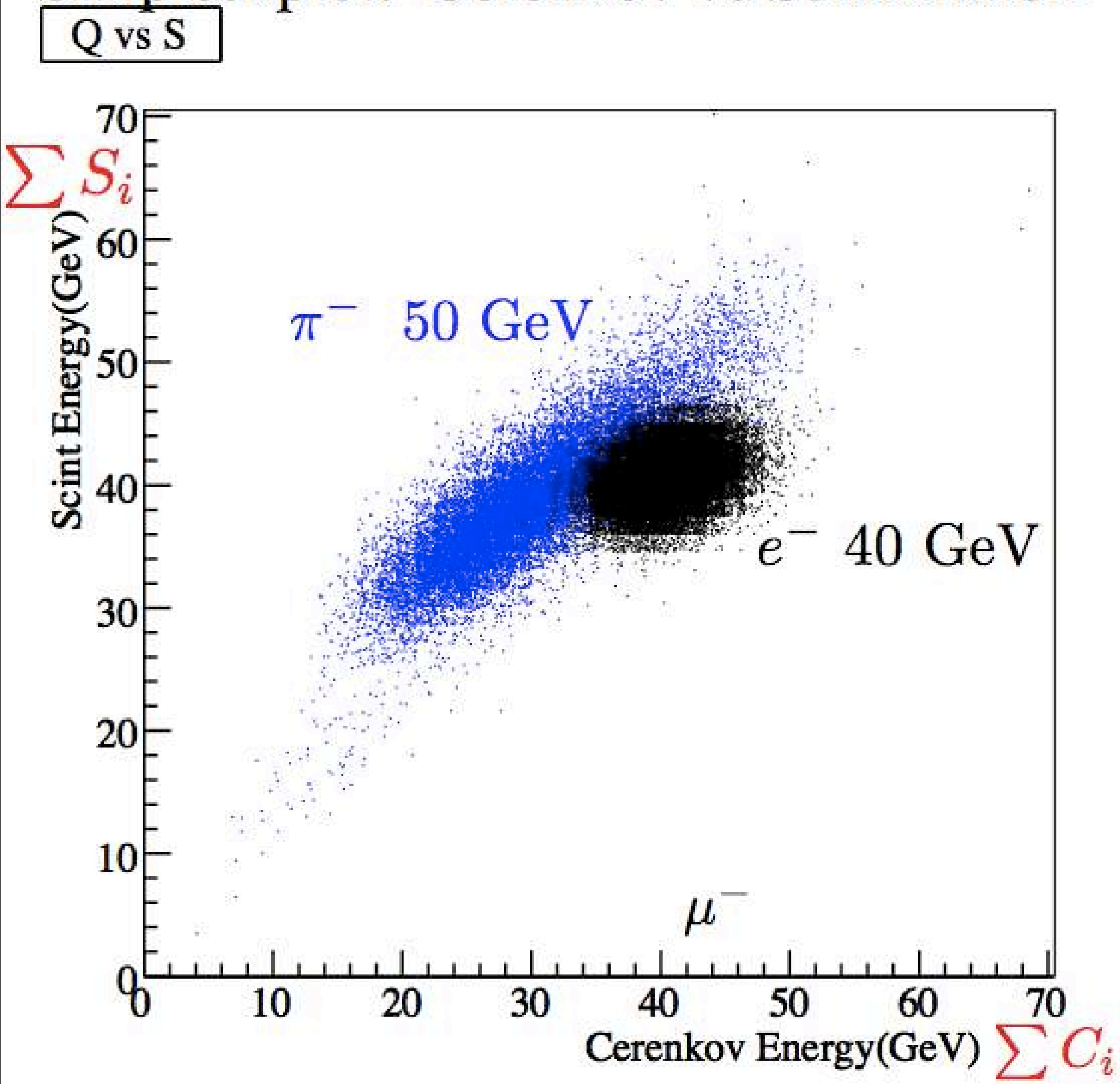
Hadronic linearity may be the most important achievement of dual-readout calorimetry.

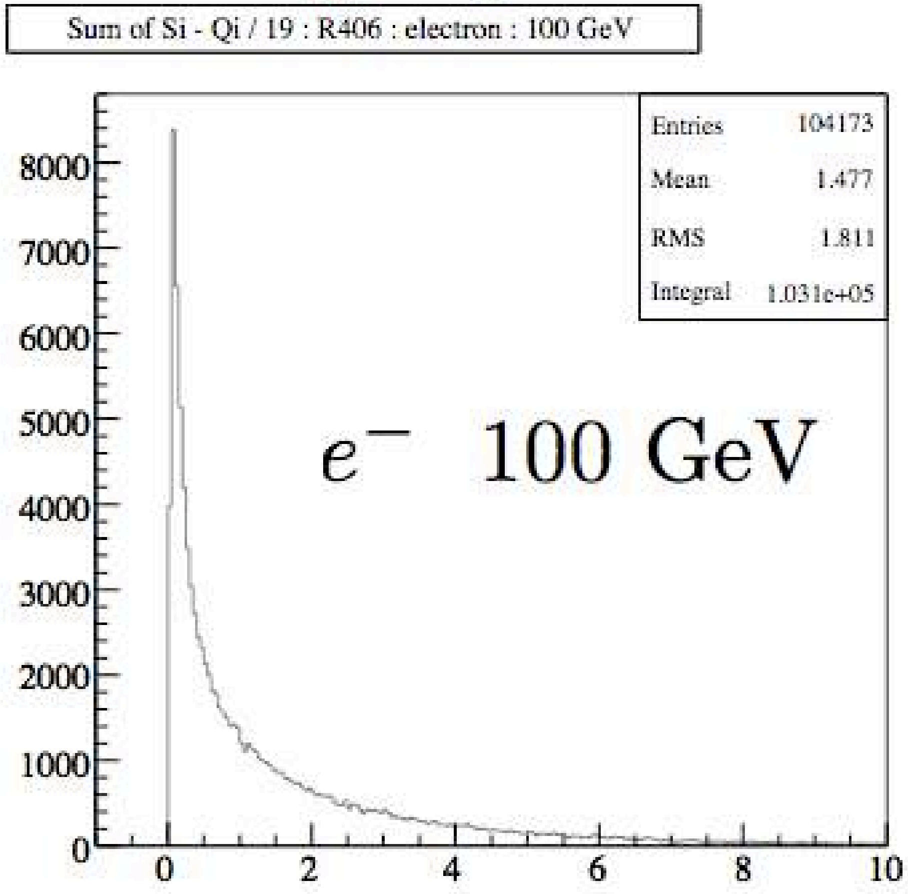
Data NIM A537 (2005) 537.

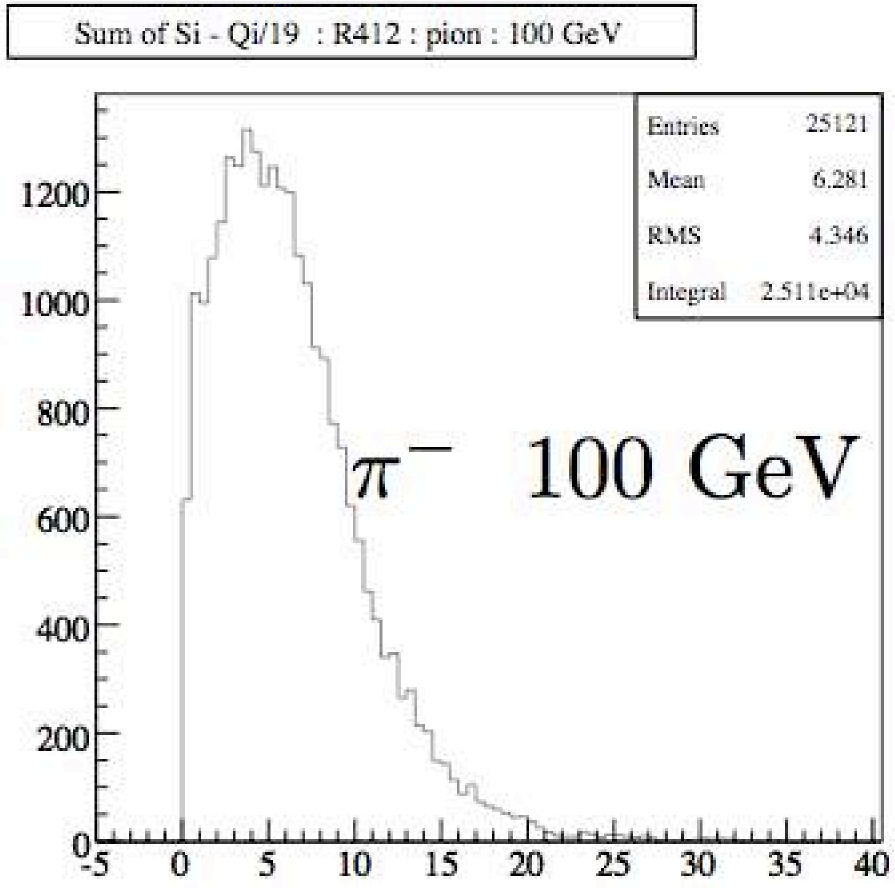
Pion and electron ID

$$\chi^2 \sim \frac{1}{n}\sum_i^n [C_i - S_i]^2$$

Simplest plot: Cerenkov vs Scintillation


Q vs S

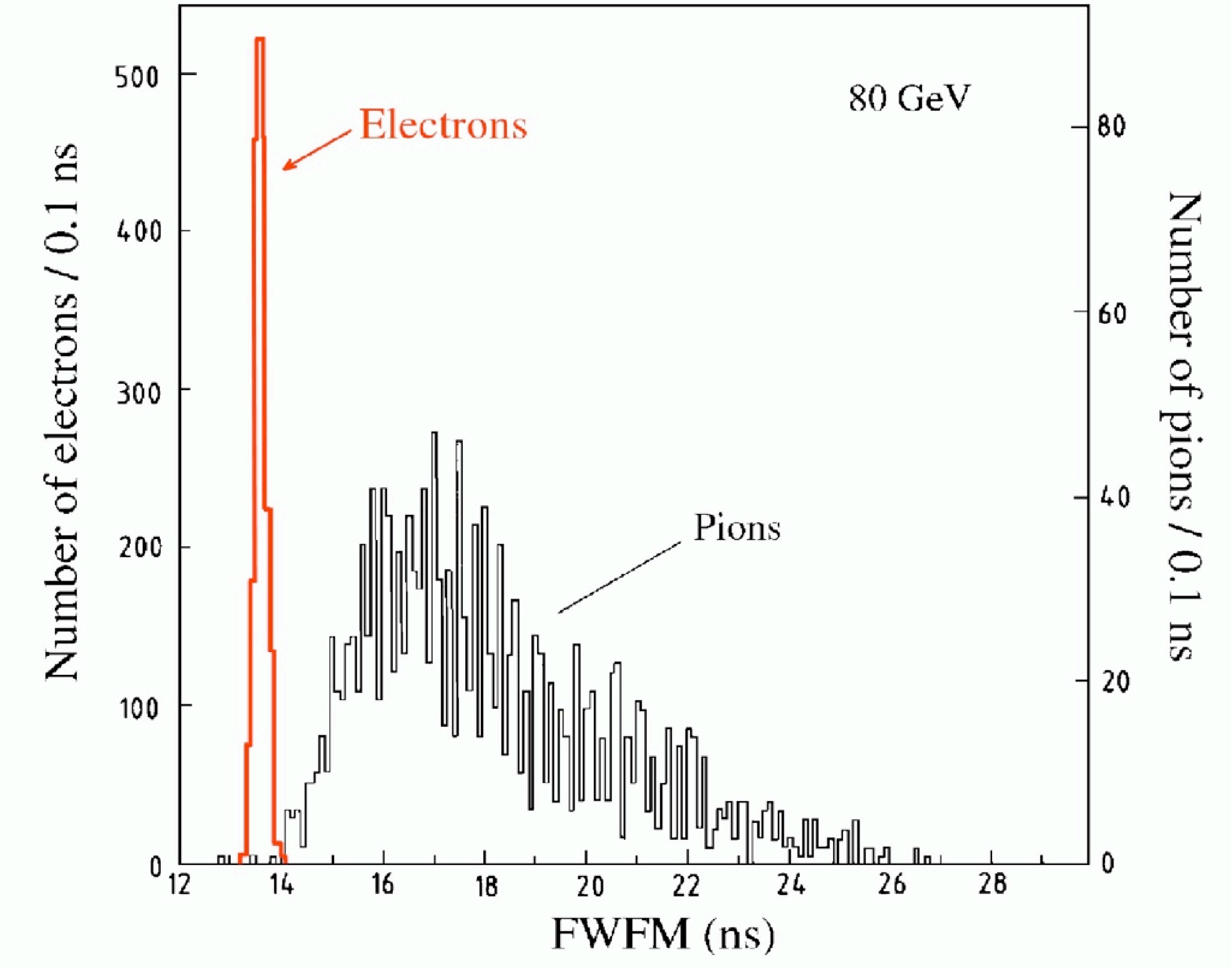

Sum of Si - Qi / 19 : R406 : electron : 100 GeV


Sum of Si - Qi/19 : R412 : pion : 100 GeV

Pion and electron ID: time-history of scintillating fibers, S(t):

A S(t) measurement yields dramatic separation of EM and hadronic showers by watching the time history of the arrival of light at the photoconverter.

Note bene: this statistic is independent of the chi-squared statistic.

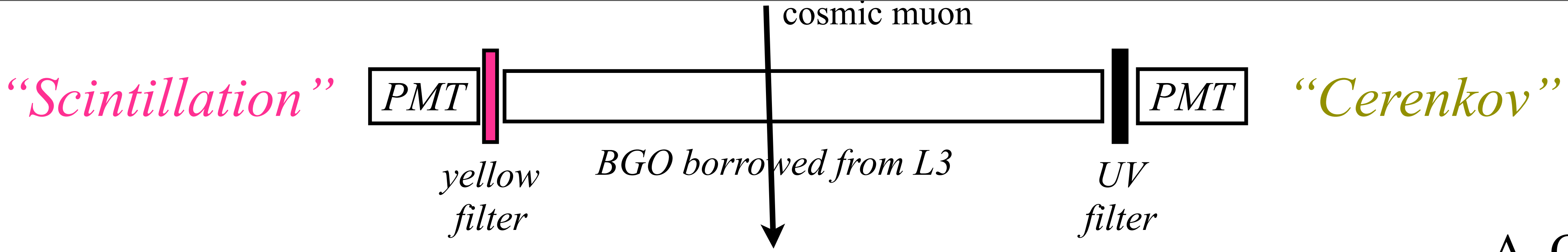


Full-width at 1/5 maximum of Spe(t) pulse.
SPACAL data, Acosta, et al., NIM 1991.

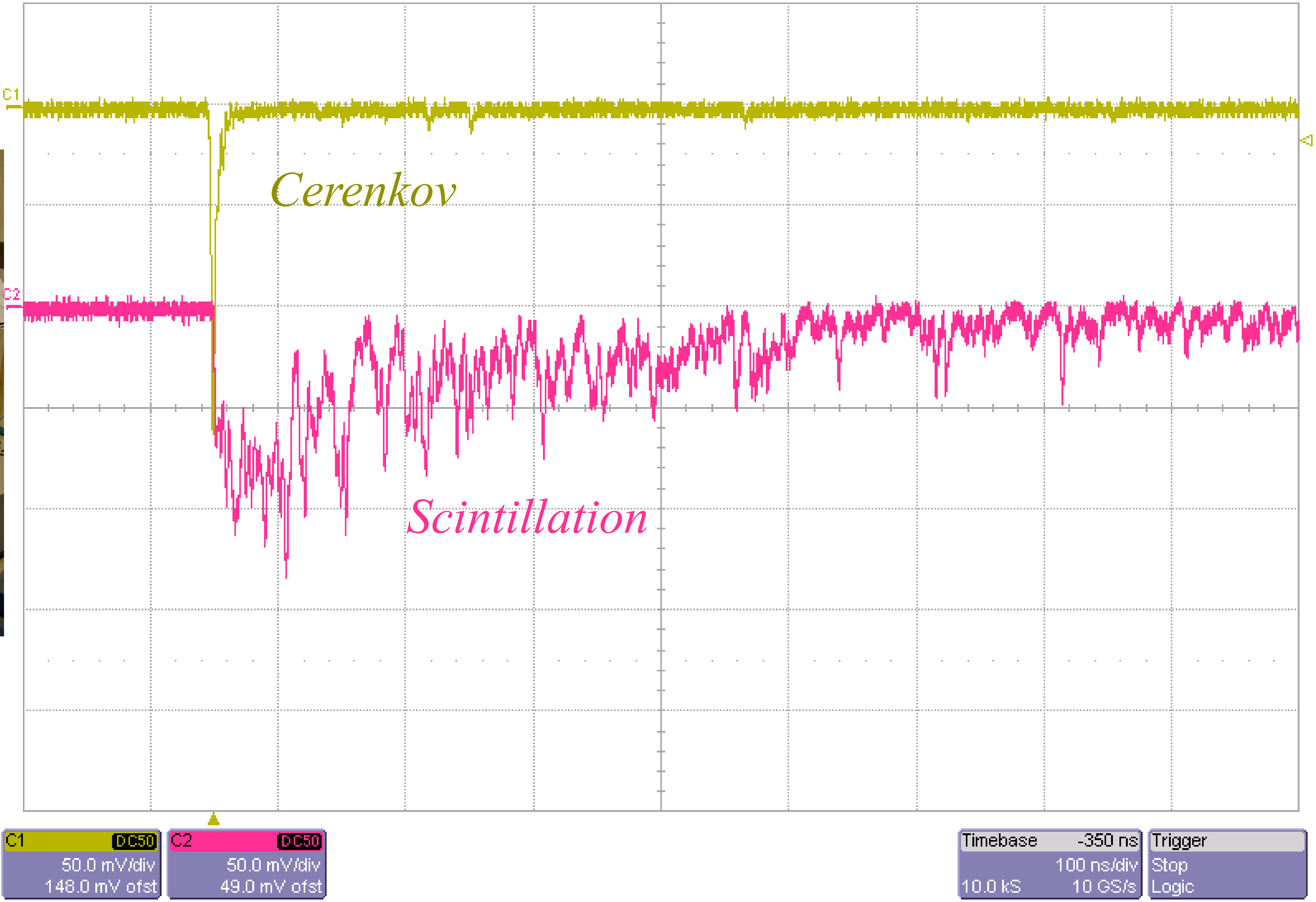
DREAM collaboration papers:

TTU, UCSD,
ISU, Pavia,
Rome I, Cosenza,
Cagliari, Pisa

1. **“Hadron and Jet Detection with a Dual-Readout Calorimeter”**, N. Akchurin, K. Carrell, J. Hauptman, H. Kim, H.P. Paar, A. Penzo, R. Thomas, R. Wigmans, *Nucl. Instrs. Meths.* **A537** (2005) 537-561.
2. **“Electron Detection with a Dual-Readout Calorimeter”**, *Nucl. Instrs. Meths.* **A536** (2005) 29-51.
3. **“Muon Detection with a Dual-Readout Calorimeter”**, *Nucl. Instrs. Meths.* **A533** (2004) 305-321.
4. **“Comparison of High-Energy Electromagnetic Shower Profiles Measured with Scintillation and Cerenkov Light”**, *Nucl. Instrs. Meths.* **A548** (2005) 336-354.
5. **“Separation of Scintillation and Cerenkov Light in an Optical Calorimeter”**, *Nucl. Instrs. Meths.* **A550** (2005) 185-200.
6. **“Comparison of High-Energy Hadronic Shower Profiles Measured with Scintillation and Cerenkov Light”**, *Nucl. Instrs. Meths.* **A584** (2007) 304-318.
7. **“Measurement of the Contribution of Neutrons to Hadron Calorimeter Signals,”** N. Akchurin, L. Berntzon, A. Cardini, G. Ciapetti, R. Ferrari, S. Franchino, G. Gaudio, J. Hauptman, H. Kim, F. Lacava, L. La Rotonda, M. Livan, E. Meoni, H. Paar, A. Penzo, D. Pinci, A. Policicchio, S. Popescu, G. Susinno, Y. Roh, W. Vandelli, and R. Wigmans, *Nucl. Instrs. Meths.* **A581** (2007) 643-650
8. **“Dual-Readout Calorimetry with Lead Tungstate Crystals,”** *Nucl. Instrs. Meths.* **A584** (2007) 273-284
9. **“Contributions of Cerenkov Light to the Signals from Lead Tungstate Crystals,”** *Nucl. Instrs. Meths.* **A582** (2007) 474-483.
10. **“Effects of the Temperature Dependence of the Signals from lead Tungstate Crystals”**, in draft.
11. **“Separation of Crystal Signals into Scintillation and Cerenkov Components”,** in progress.
12. **“Dual-Readout Calorimetry with Crystal Calorimeters”**, in progress.
13. **“Neutron Signals for Dual-Readout Calorimetry”**, in progress.



A. Cardini



C1 DC50
50.0 mV/div
148.0 mV ofst

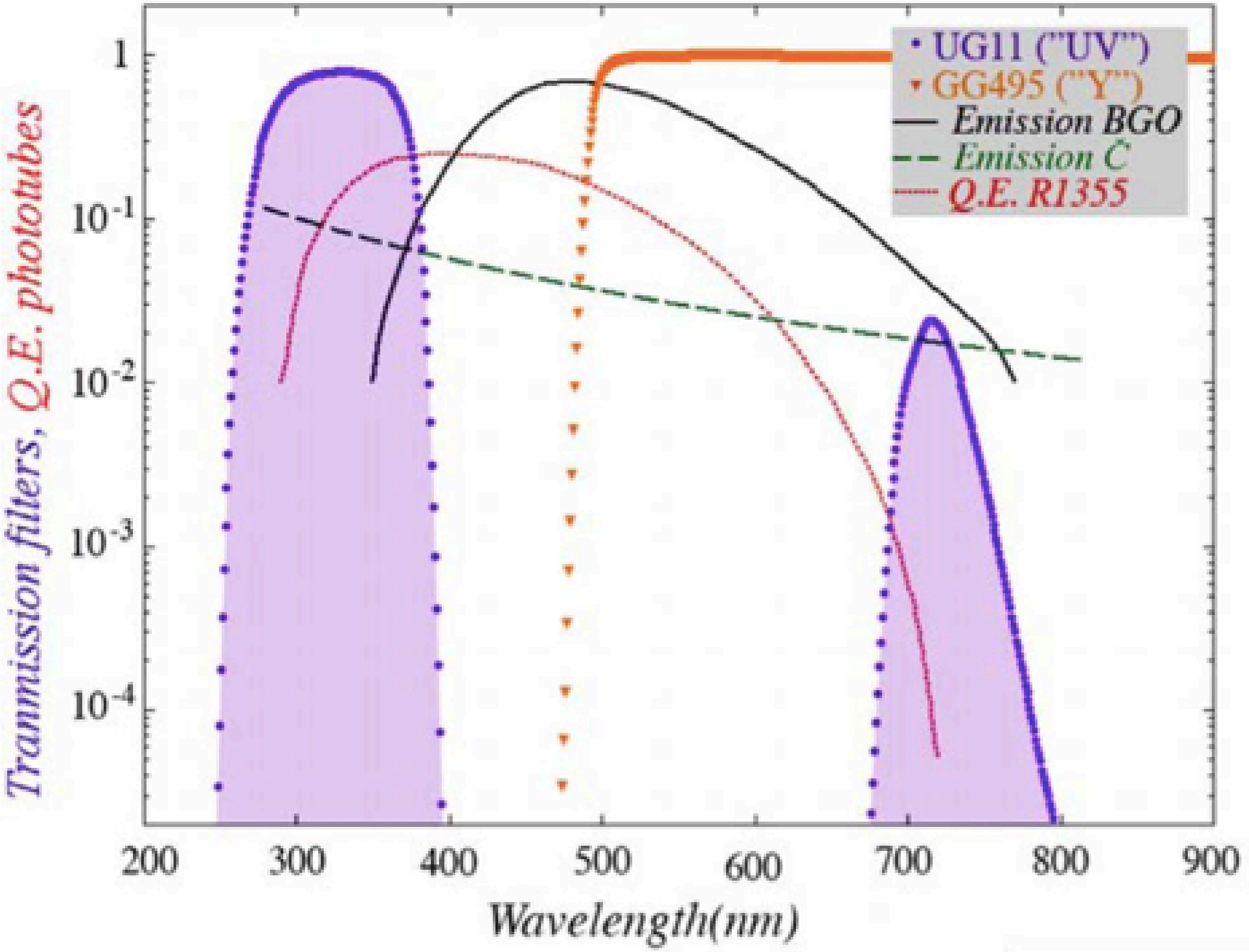
C2 DC50
50.0 mV/div
49.0 mV ofst

Timebase -350 ns
100 ns/div
10.0 kS 10 GS/s

Trigger
Stop
Logic

We can now do dual-readout in a single crystal ==> EM precision

Enanchment of Čerenkov component using spectral difference between Čerenkov and scintillation light => use Y and UV filters

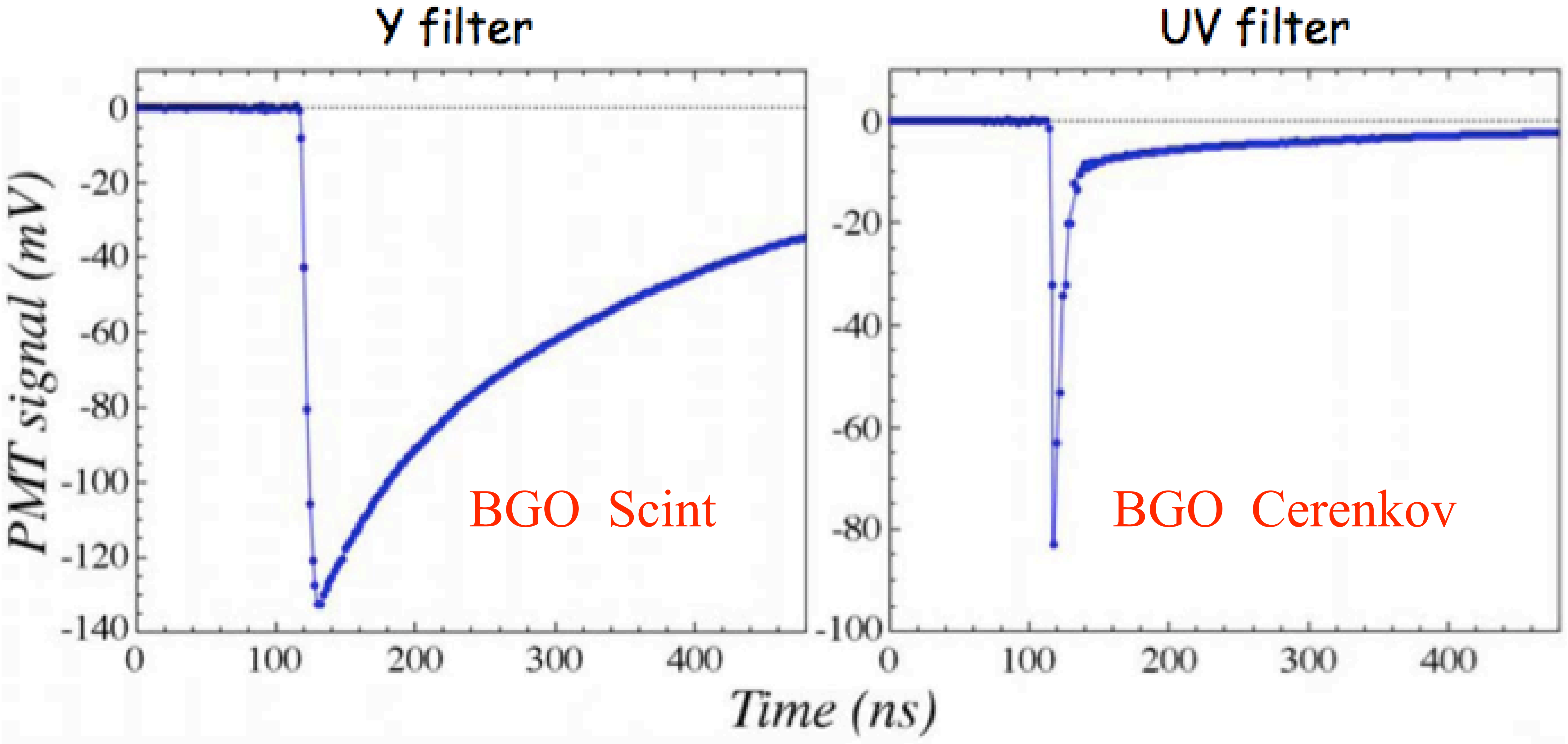


Y filter: highly transparent for BGO scintillation light (centered at 480 nm)

UV filter: highly transparent for Č light in the range 320-400 ns.
Less than 0.1% of the scintillation light penetrates this filter

Even though the Č light is a small fraction of the light produced, the UV signal is mostly Č light.

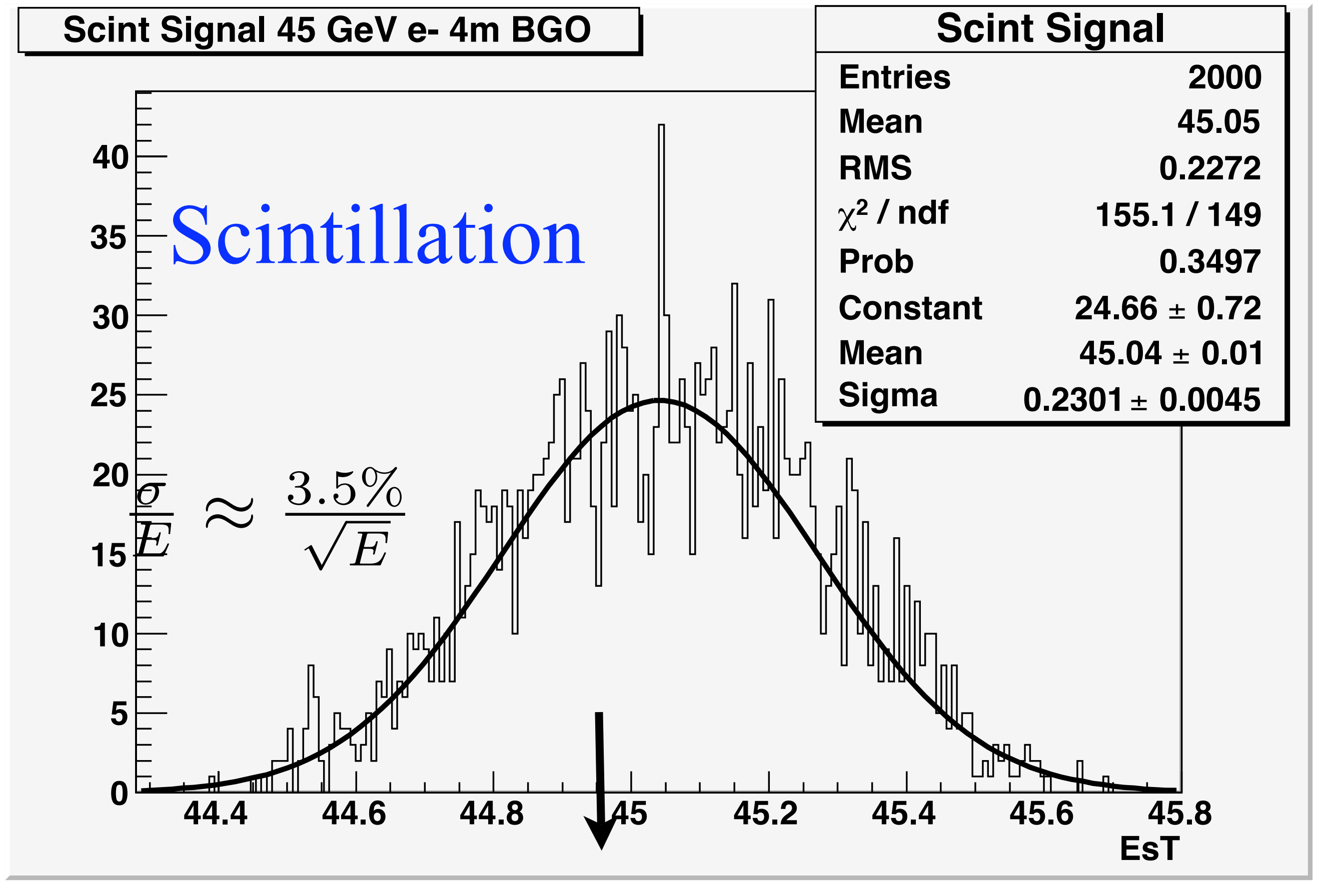
Average time structure for 50 GeV electrons

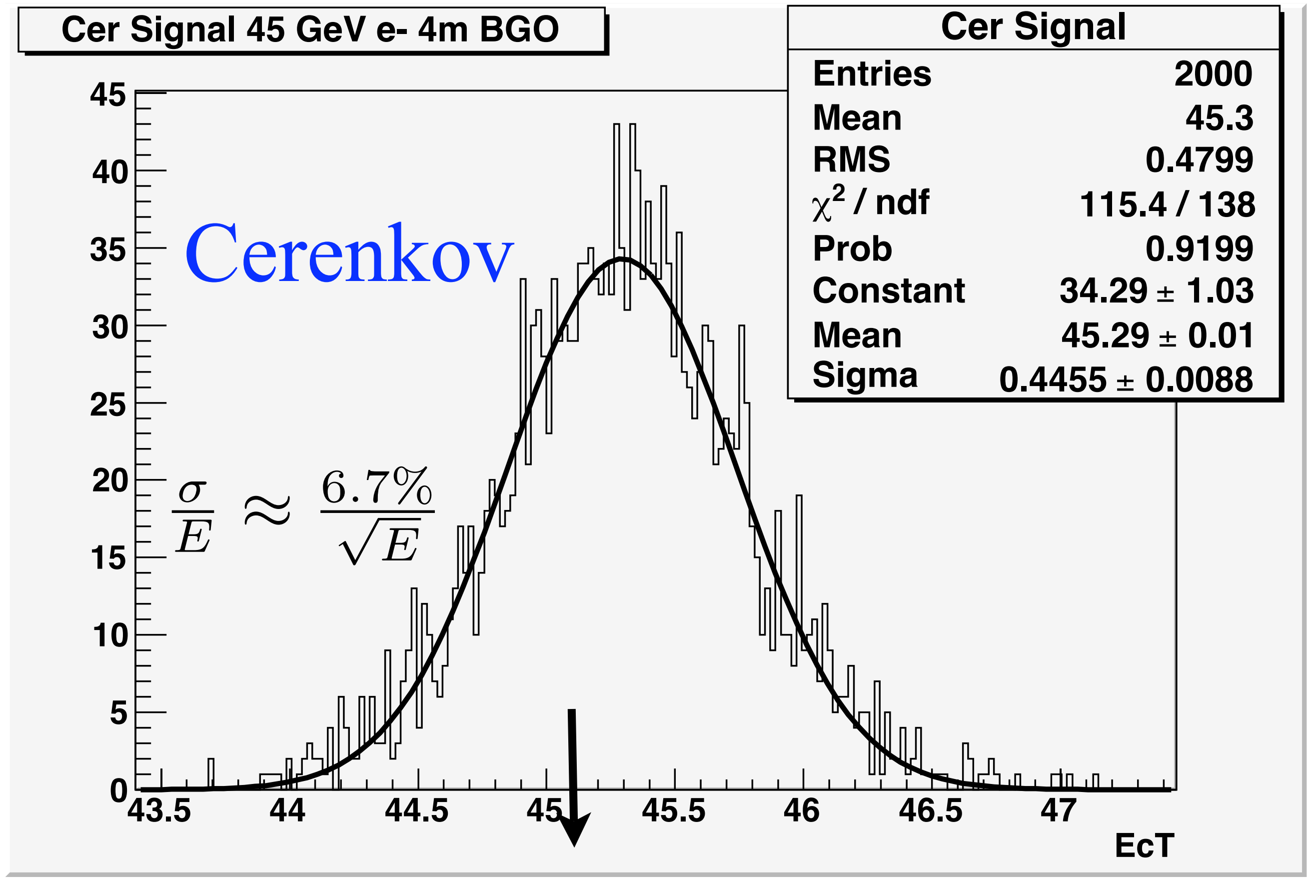


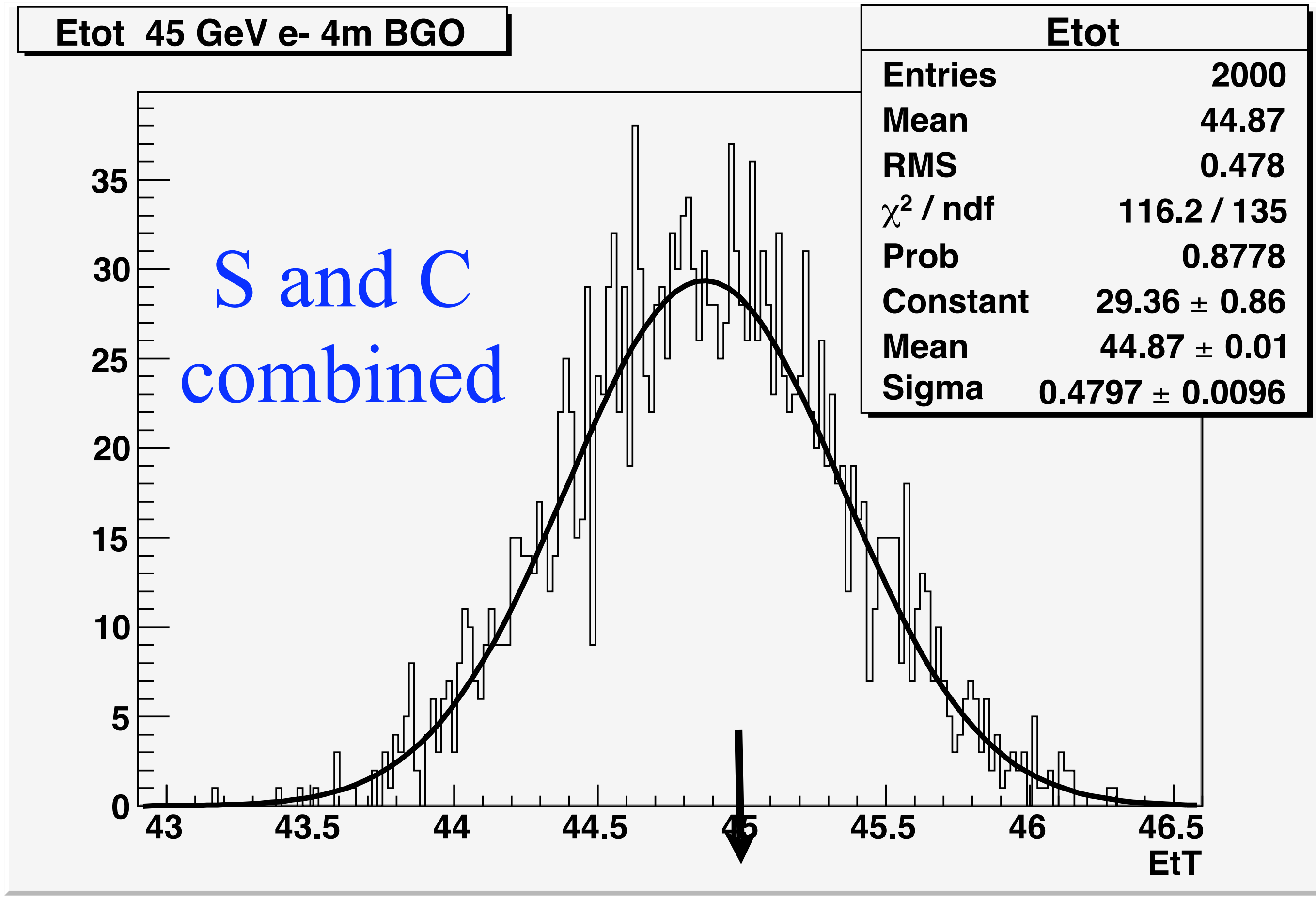
C. Voena, Pavia, CALOR08 26-30 May 2008

DREAM data

"BGO calorimeter" 45 GeV electrons





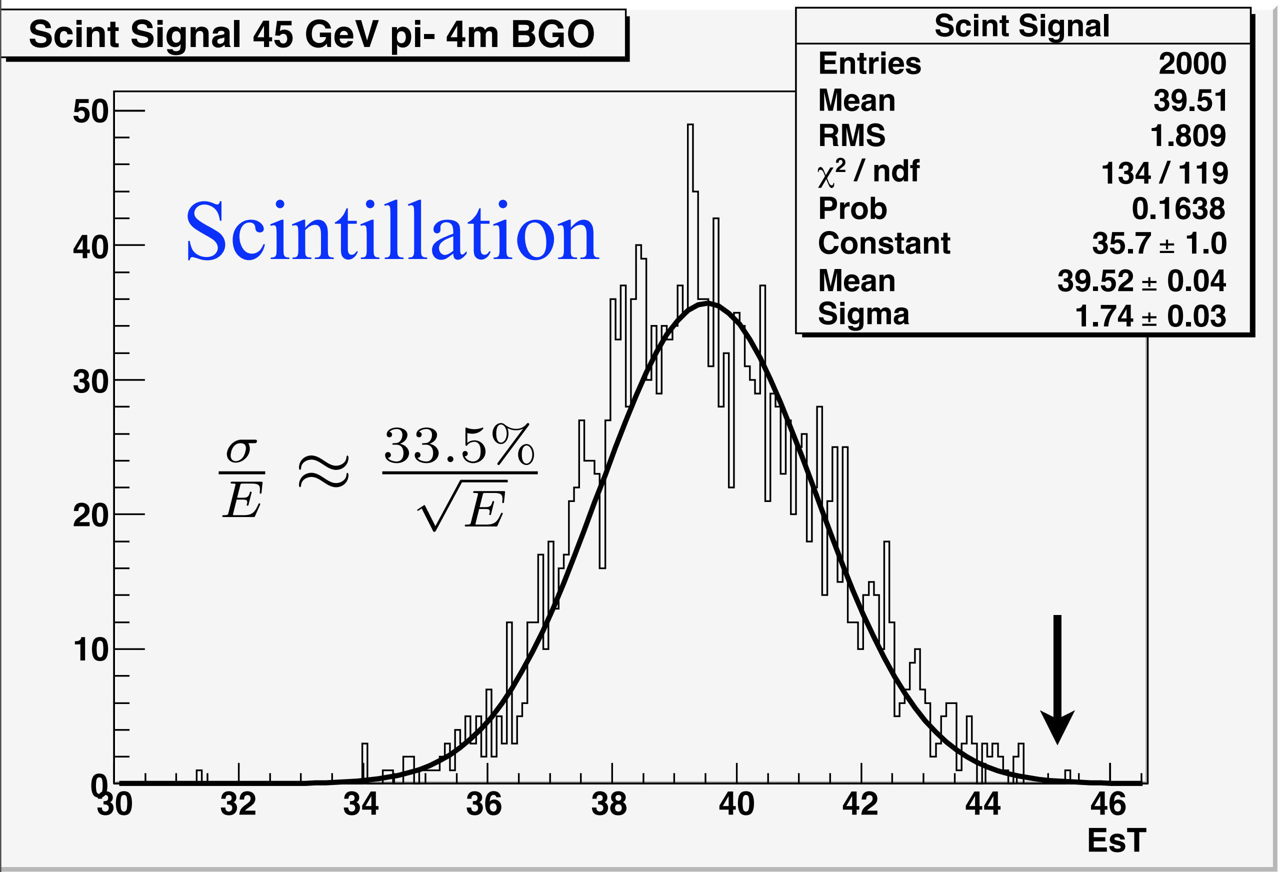


Vito Di Benedetto, INFN, Lecce

(4th calorimetry)

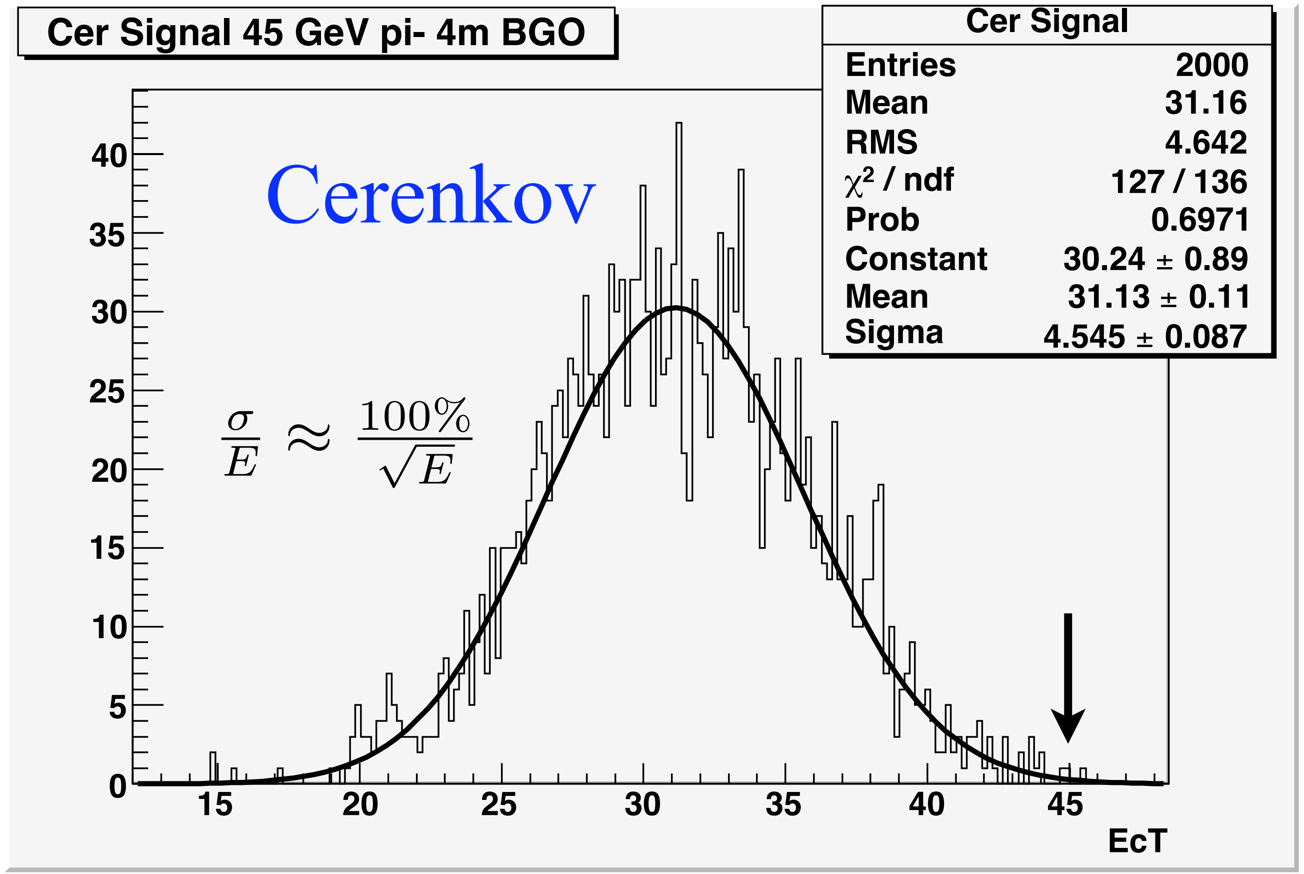
"BGO calorimeter" 45 GeV pions

Vito Di Benedetto



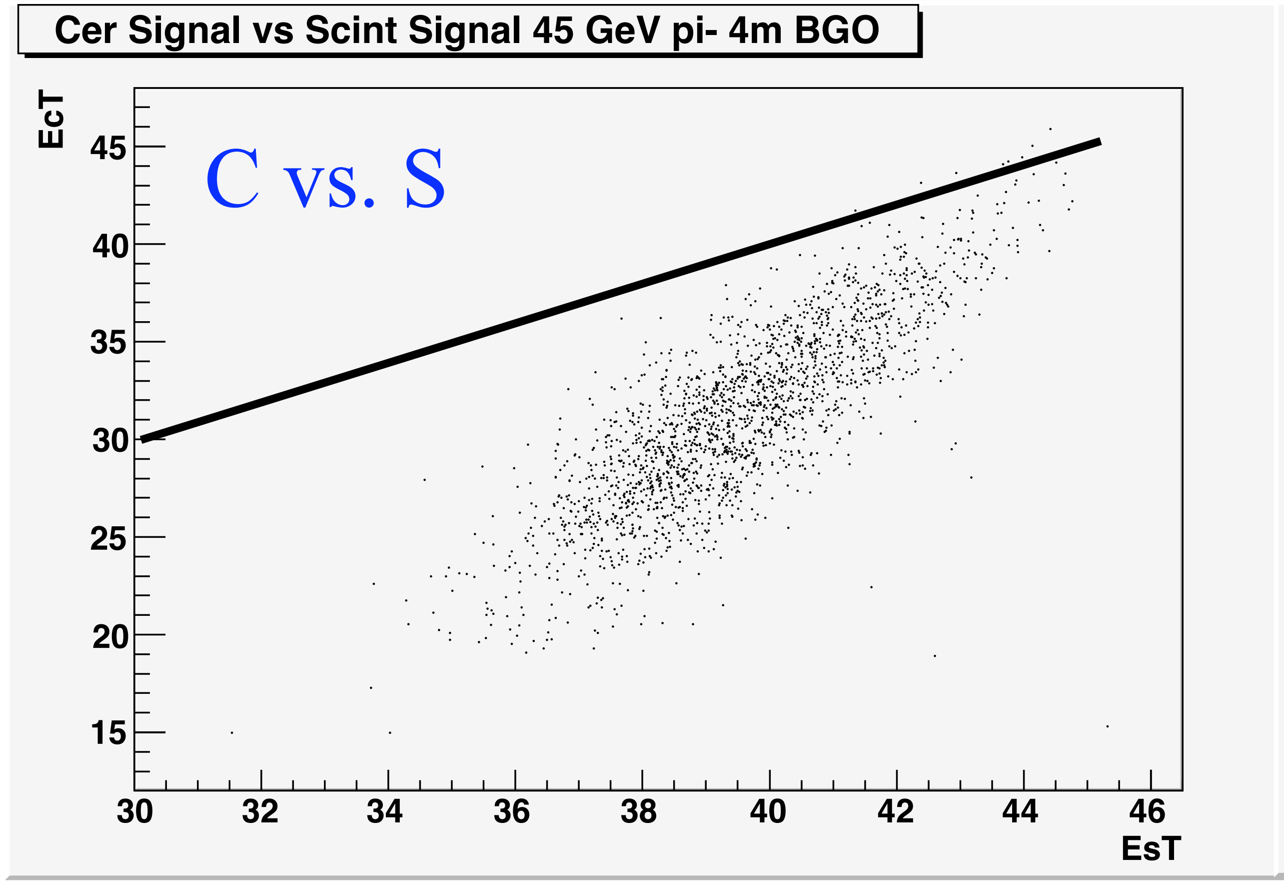
Scintillation

$$\frac{\sigma}{E} \approx \frac{33.5\%}{\sqrt{E}}$$

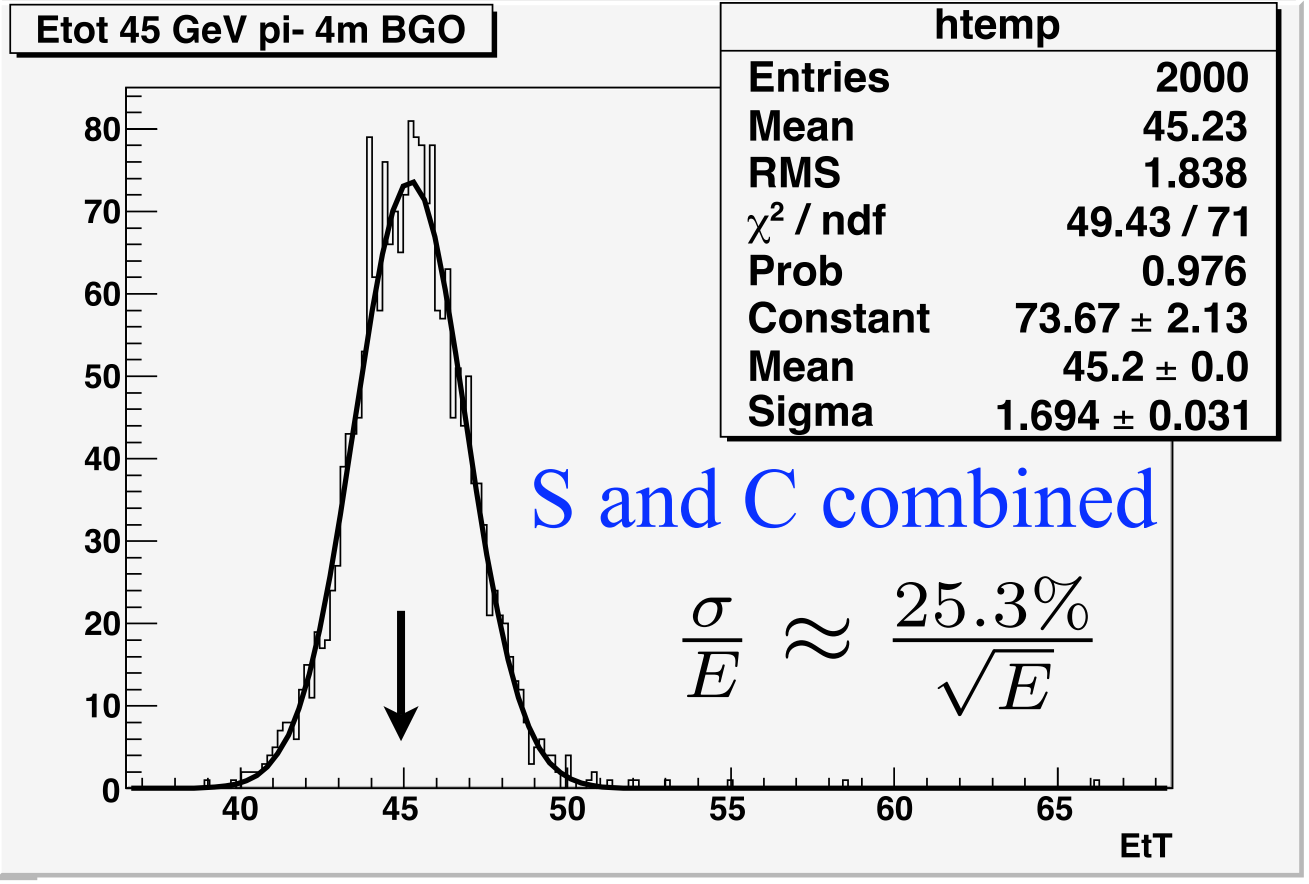


Cerenkov

$$\frac{\sigma}{E} \approx \frac{100\%}{\sqrt{E}}$$



C vs. S



S and C combined

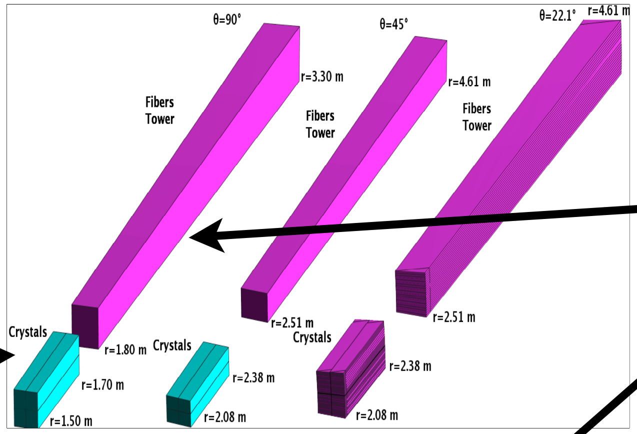
$$\frac{\sigma}{E} \approx \frac{25.3\%}{\sqrt{E}}$$

Therefore, we expect to be able to combine a BGO dual-readout front-end to a DREAM-like back end, both with time-history readout at ~ 1 GHz, and

- maintain excellent hadronic energy resolution;
- achieve excellent electromagnetic energy resolution;
- achieve $\pi\rightarrow\gamma\gamma$ reconstruction for $\tau\rightarrow\rho\nu$;
- achieve a sub-nanosecond time-of-flight capability for odd, heavy objects (SUSY, e.g.) that may decay in the tracking volume; and,
- enable a continuous inter-bunch monitor of all energetic activity.

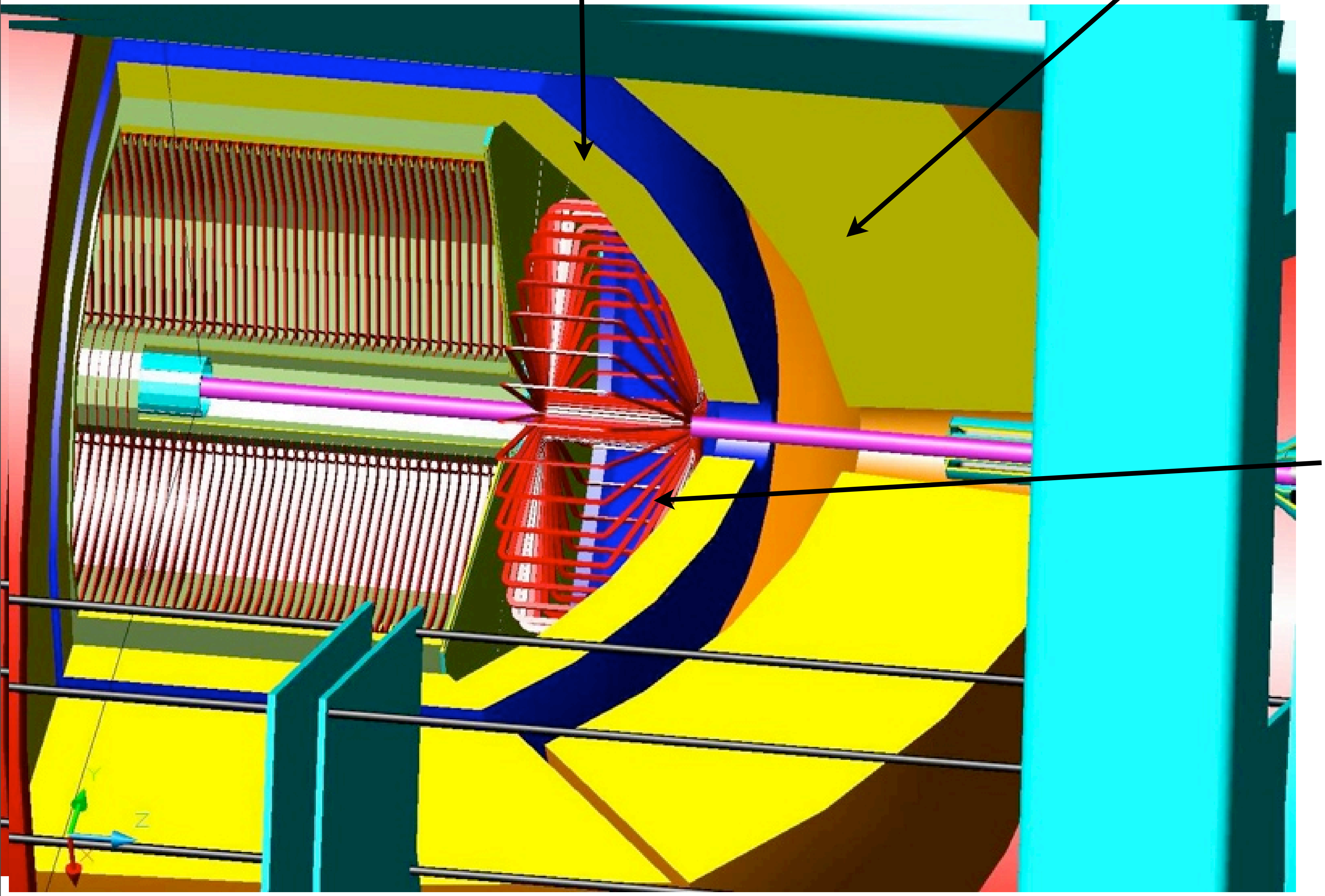
(CERN DREAM beam test July-August '08)

Fiber and crystal configuration



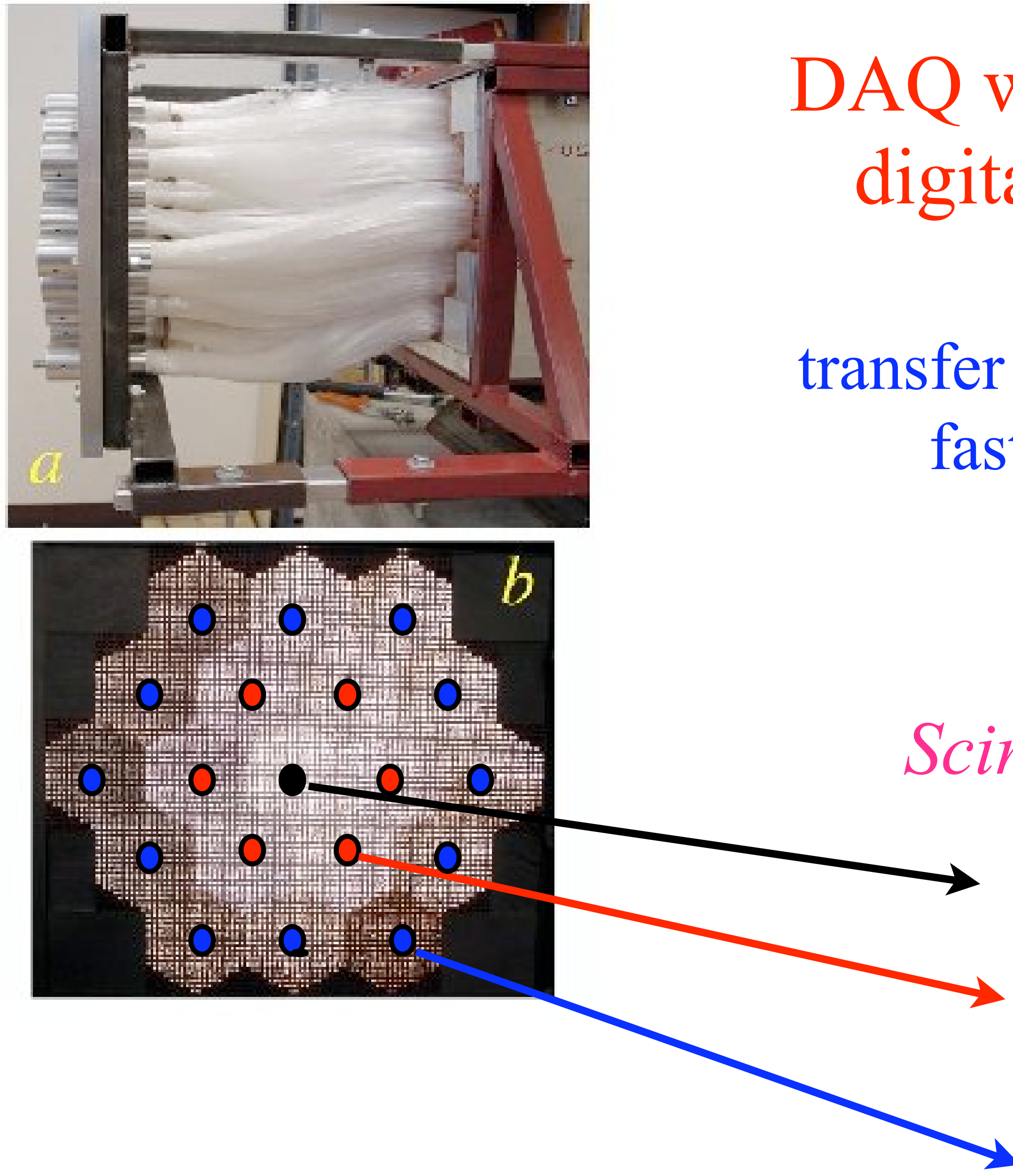
fiber dual-readout

BGO dual-readout



Forward toroid (not yet under study)

Next: BE losses ~ MeV neutrons. 100-300 GeV pi+ data



DAQ was 1 GHz 4-chan digital storage scope

transfer to counting house in fast air-core cables

Scintillating fibers

“Fast 1”

“Fast 2”

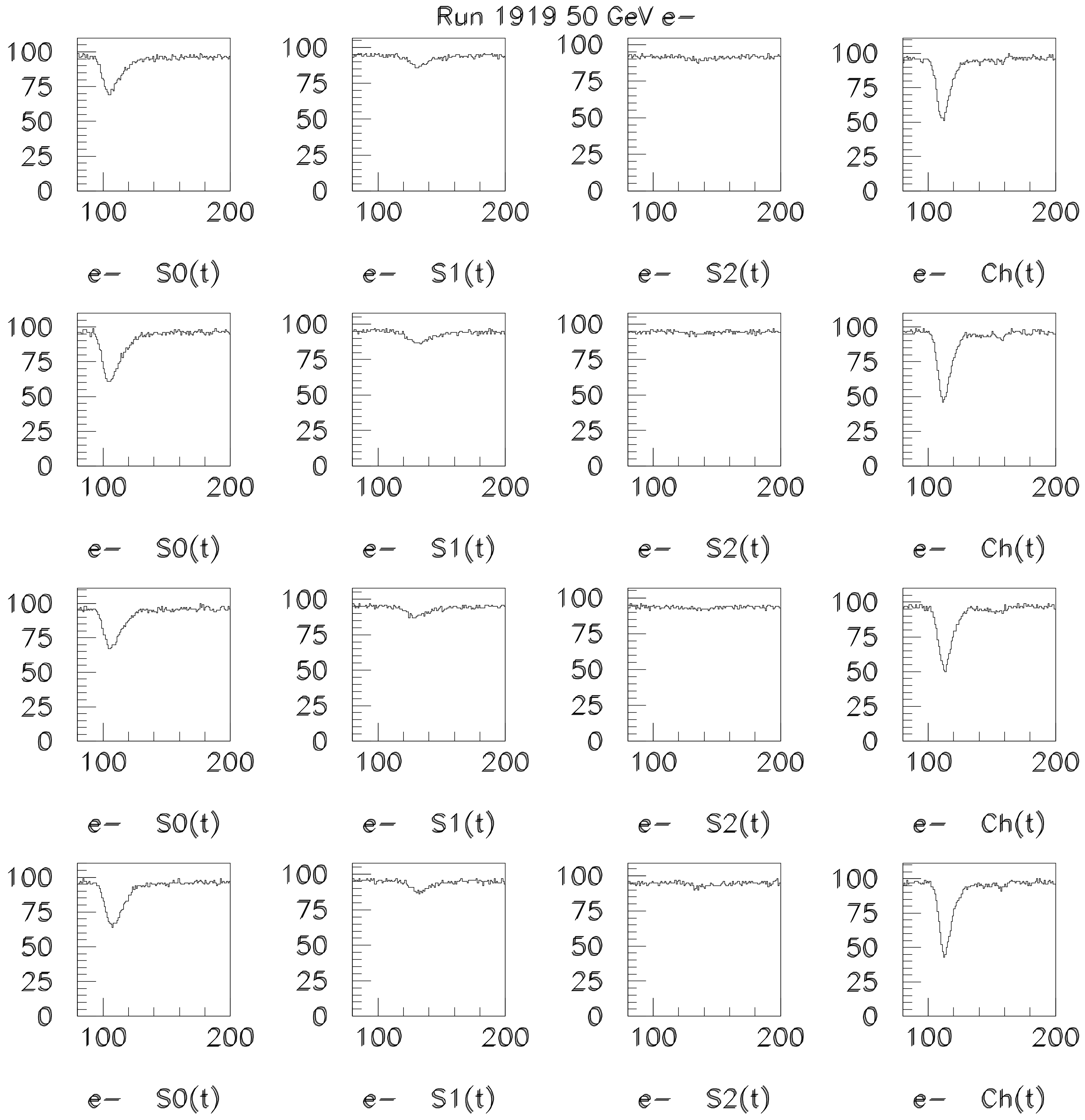
“Fast 3”

Cerenkov fibers

1● + 6● + 9● → “Fast 4”

Complete volume interrogation of DREAM: see delayed neutrons event-by-event. Analysis of data in progress.

Fast-1 Fast-2 Fast-3 Fast-4



50 GeV e-
data events

event #1

event #2

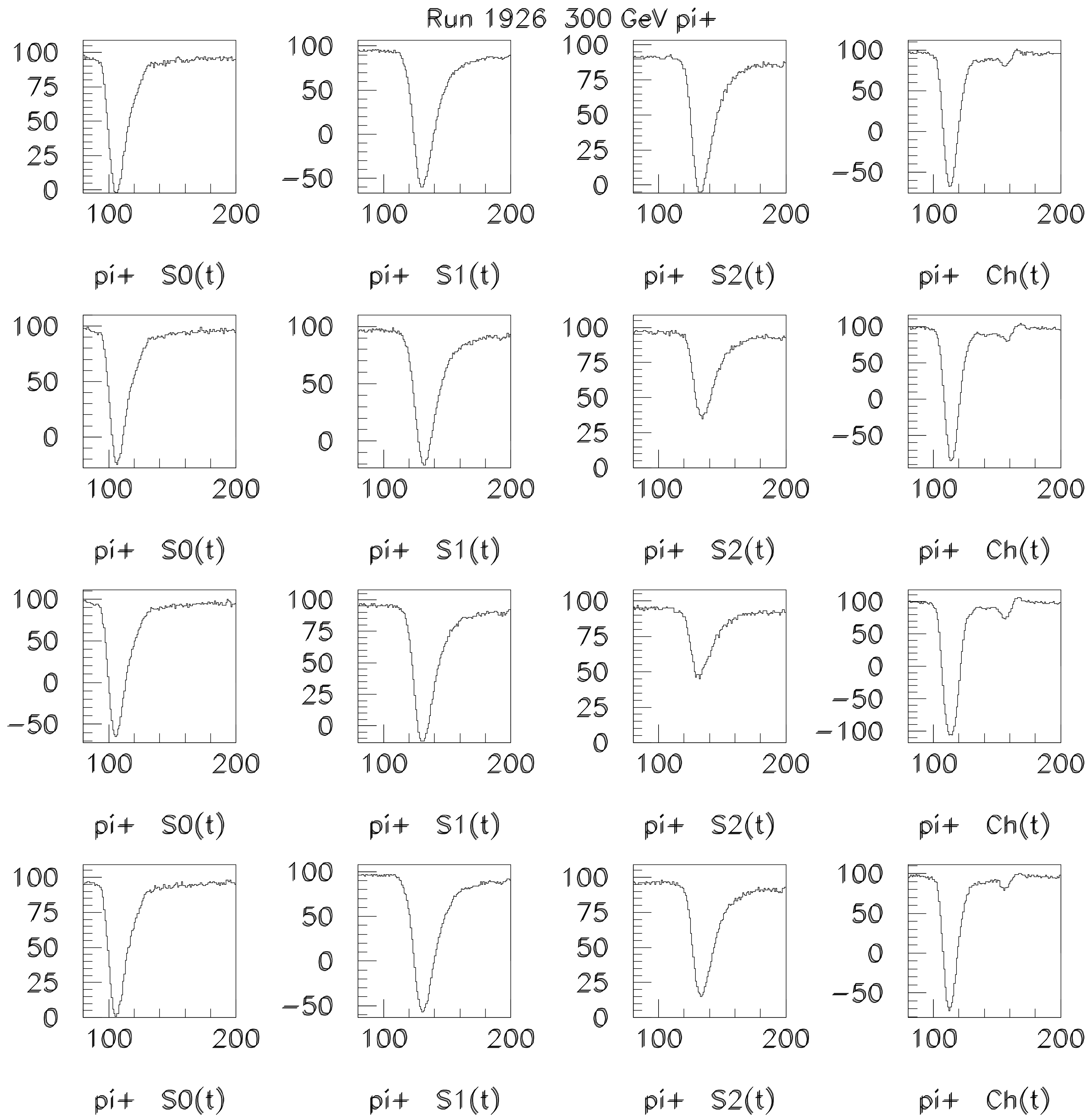
event #3

event #4

(clearly electrons)

300 GeV pi- data events

Fast-1 Fast-2 Fast-3 Fast-4



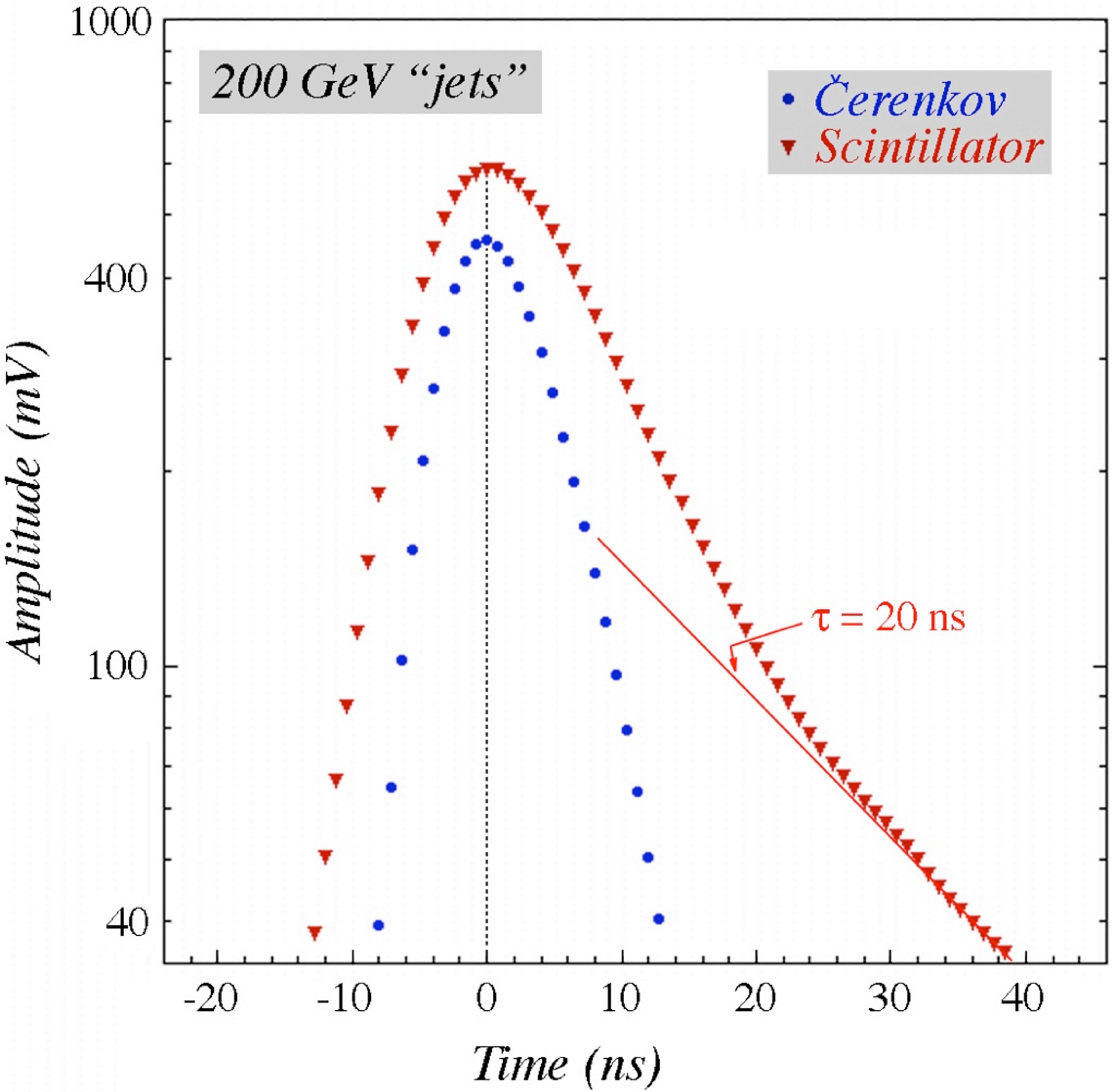
event #1

event #2

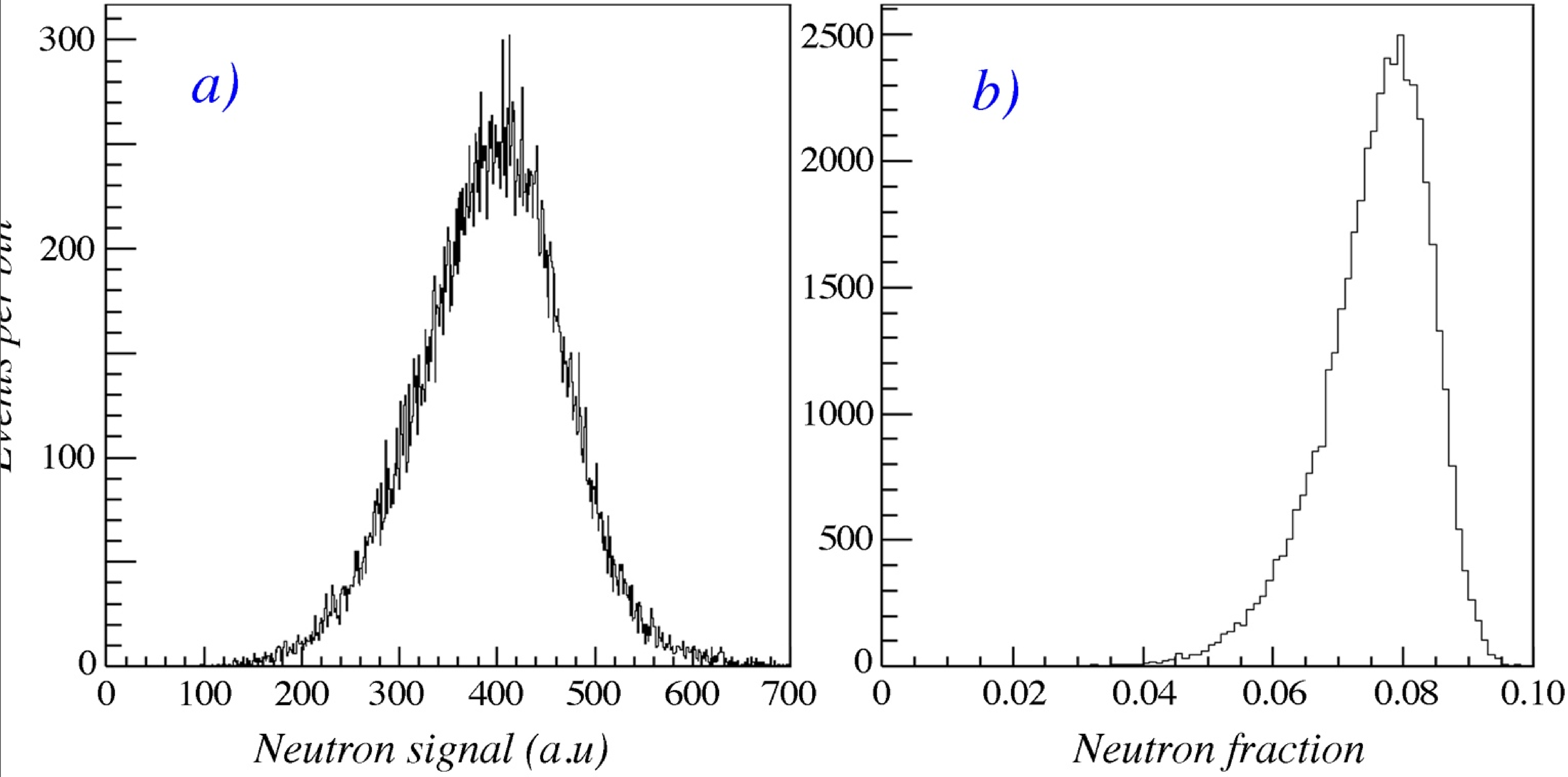
event #3

event #4

(clearly pions)



“neutron signal” defined simply as the integral of the Scintillation pulse over 20-40 ns

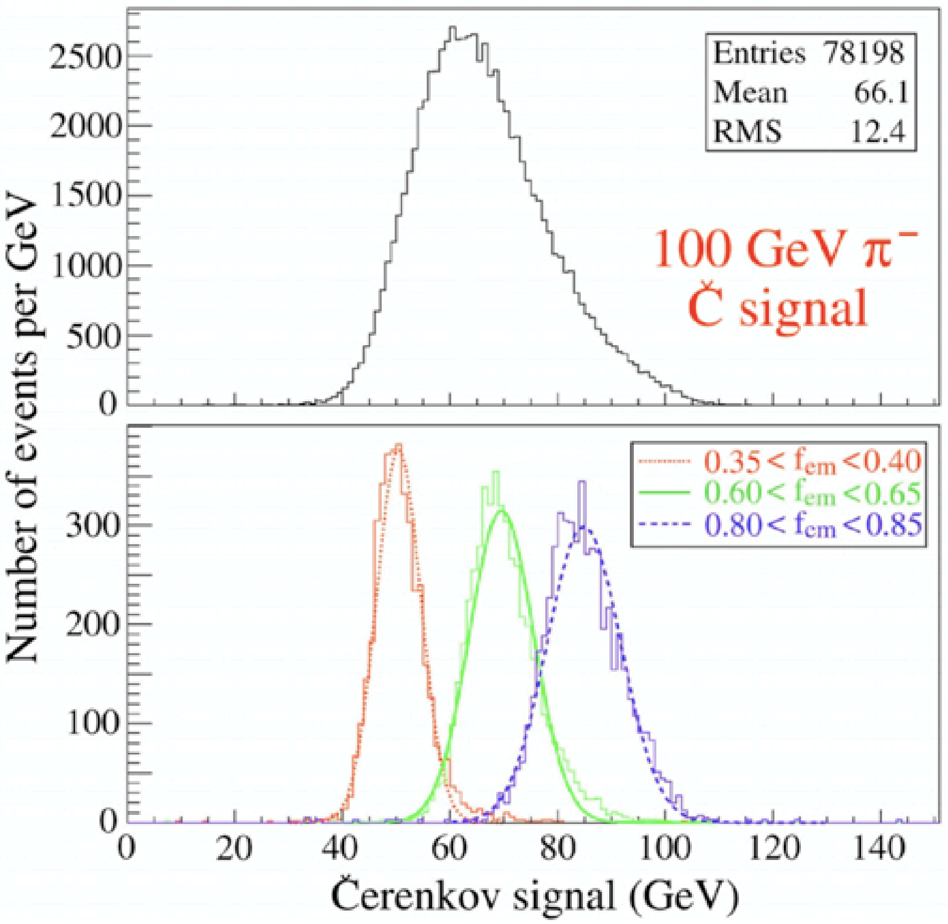


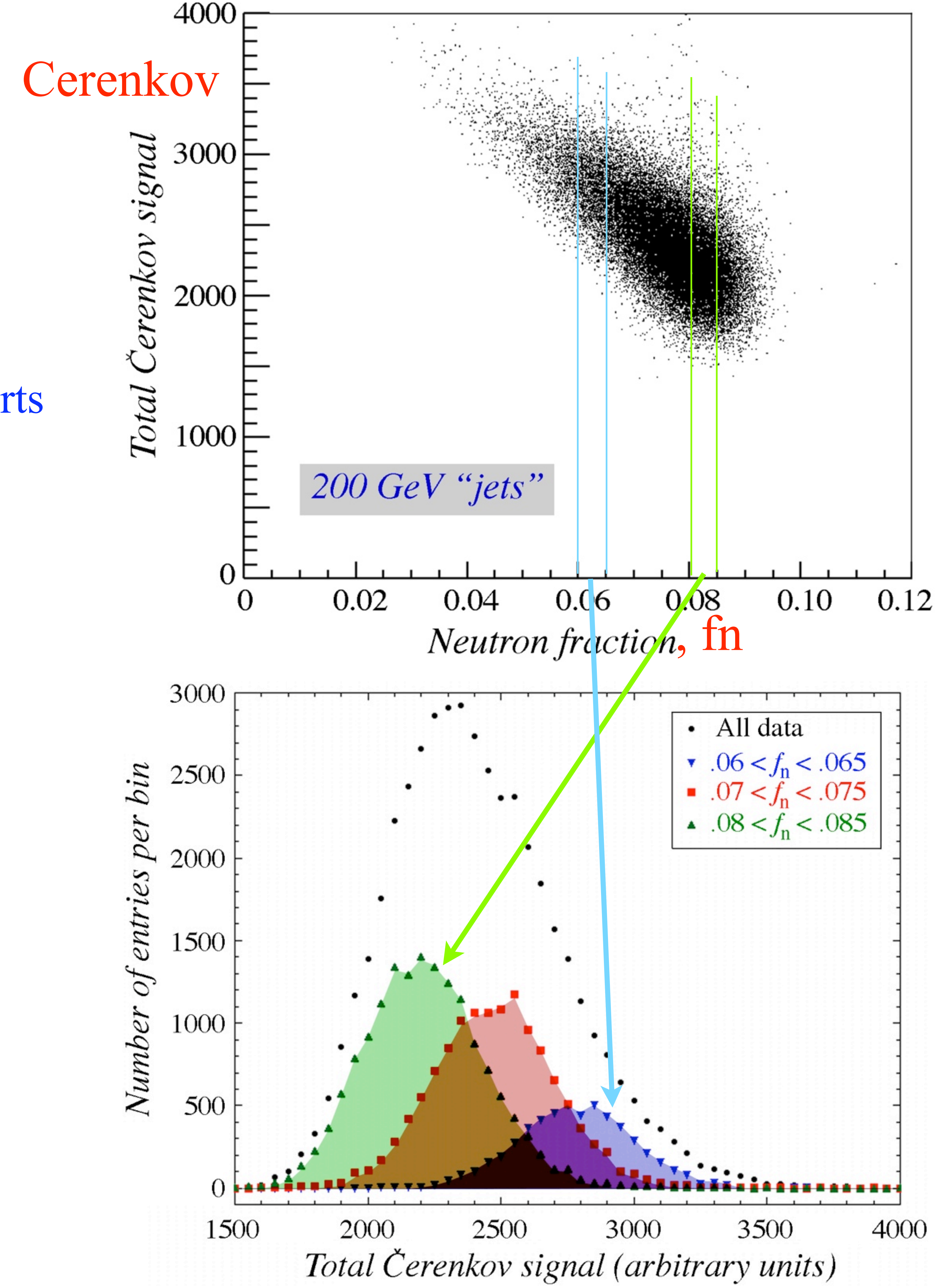
fn = En (EM energy units) / 200 GeV

The neutron fraction is anti-correlated with the Cerenkov signal (as expected)

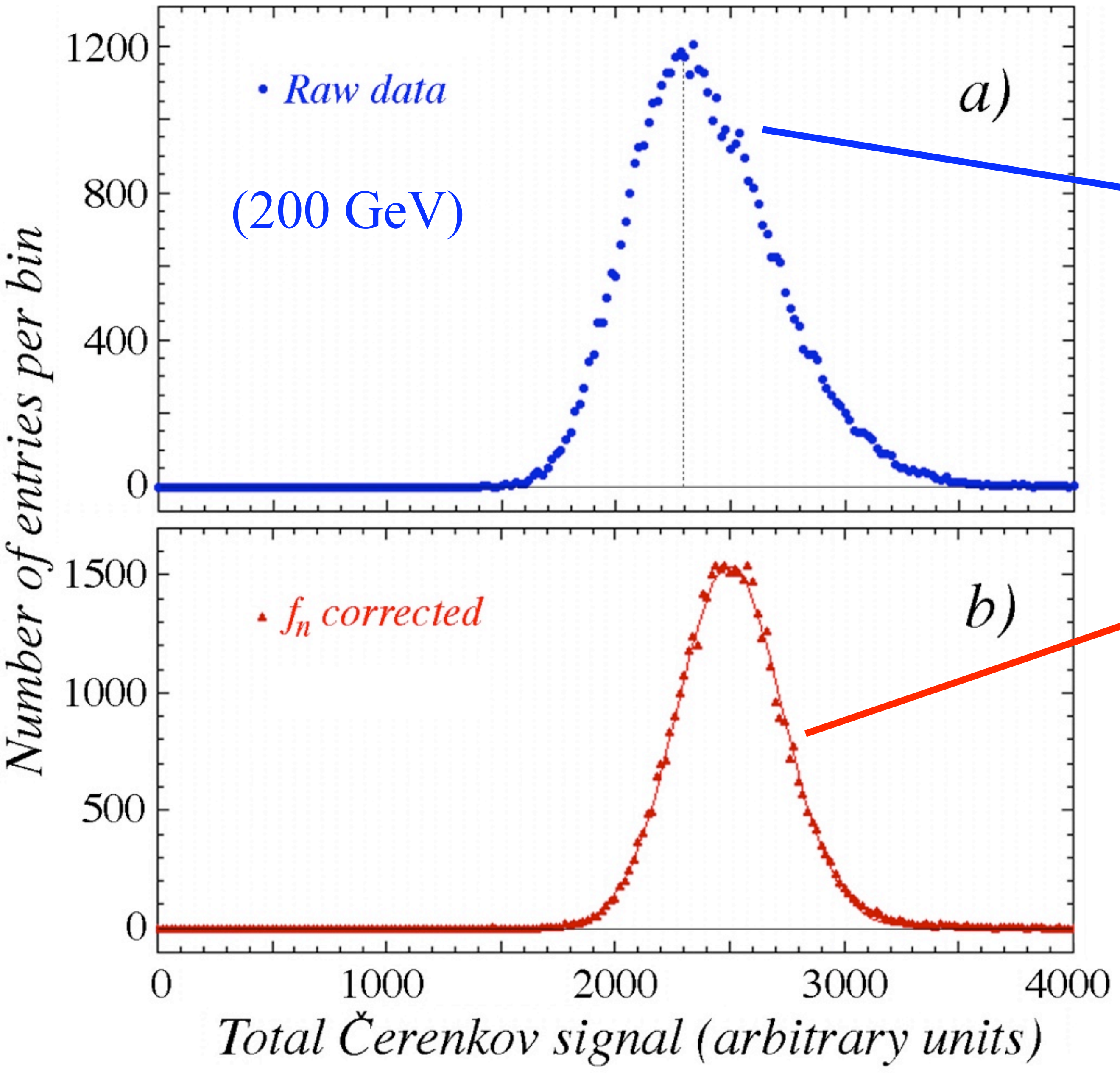
More interestingly, the total Cerenkov distribution can be decomposed into its constituent parts as a function of fn.

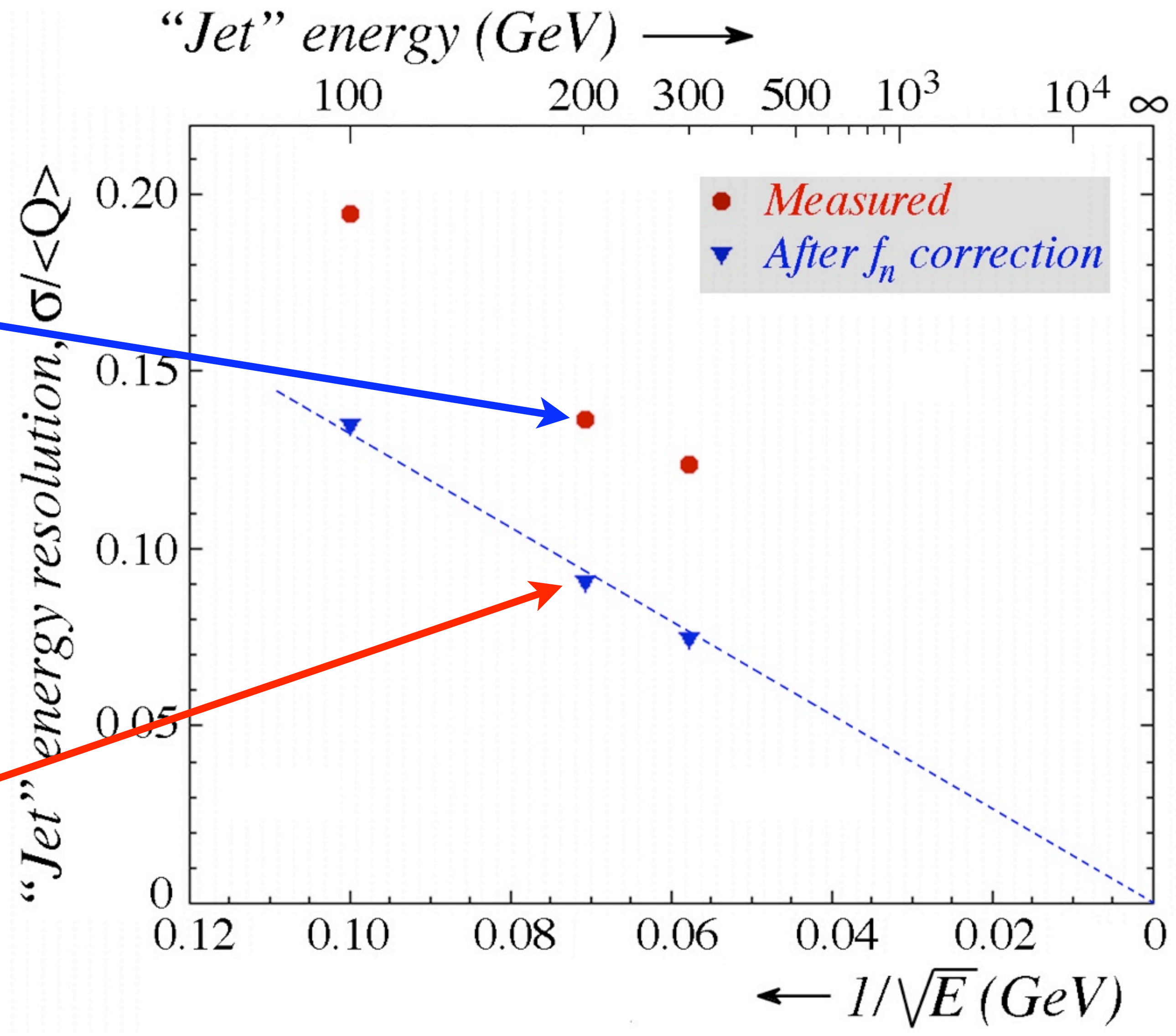
Analogous to the fEM plot below.





Linearly correcting each Cerenkov distribution
in an fn bin to fn=0.07 (arbitrary, middle value)
results in the "fn corrected" distribution

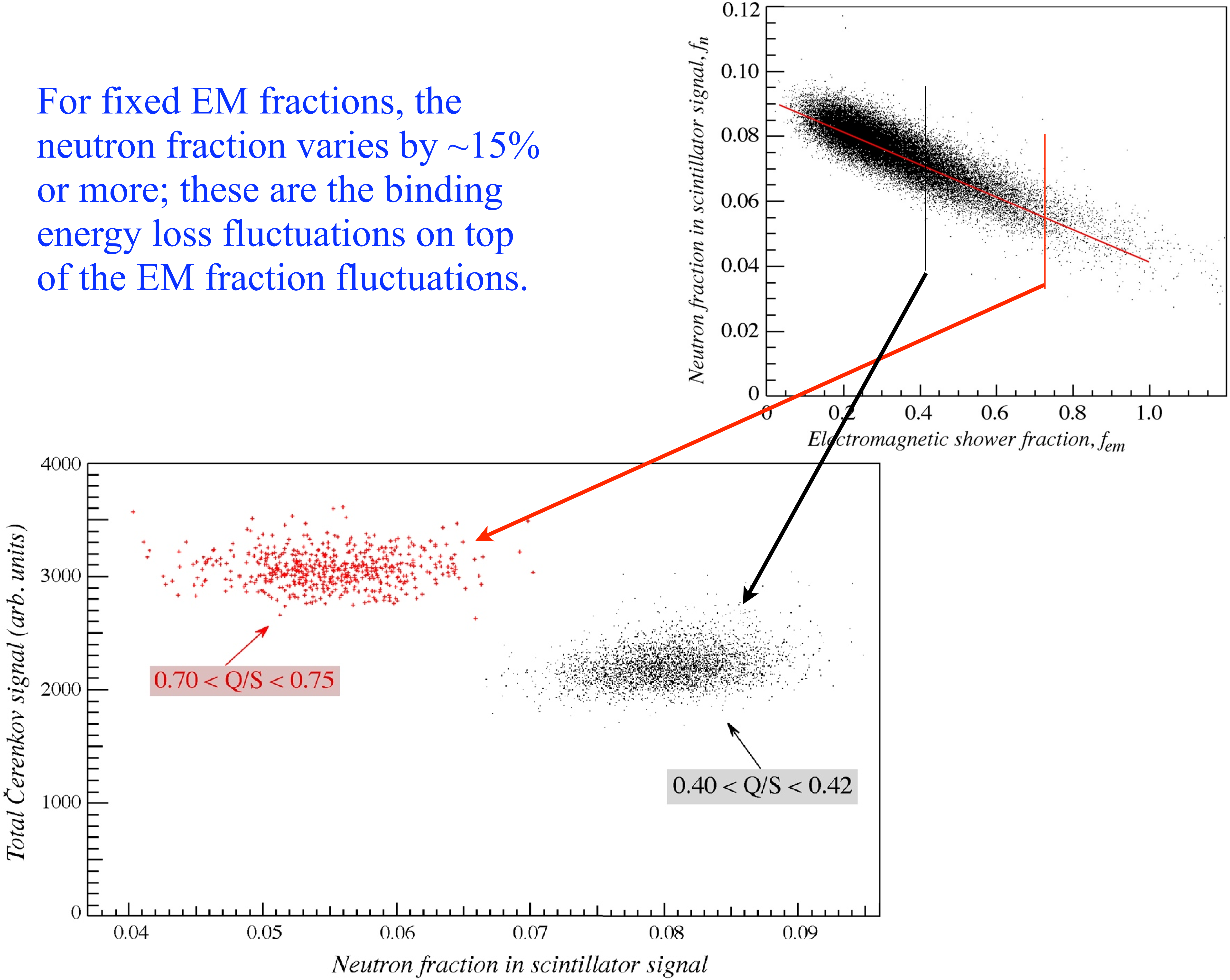




(1) fn-corrected Cerenkov resolution
improves with shower energy ... AND ...

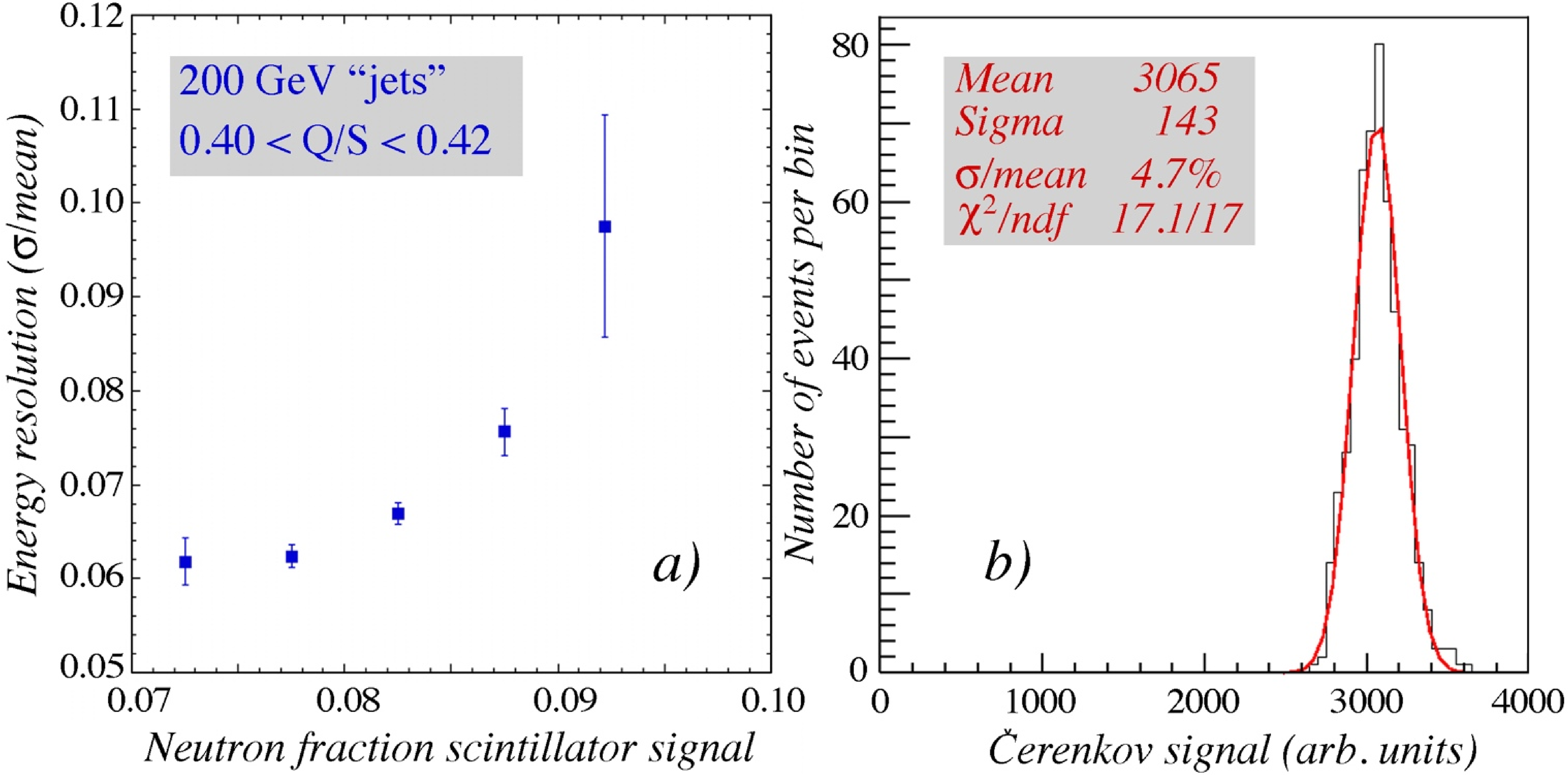
(2) Its dependence leaves no "constant term"

For fixed EM fractions, the neutron fraction varies by ~15% or more; these are the binding energy loss fluctuations on top of the EM fraction fluctuations.

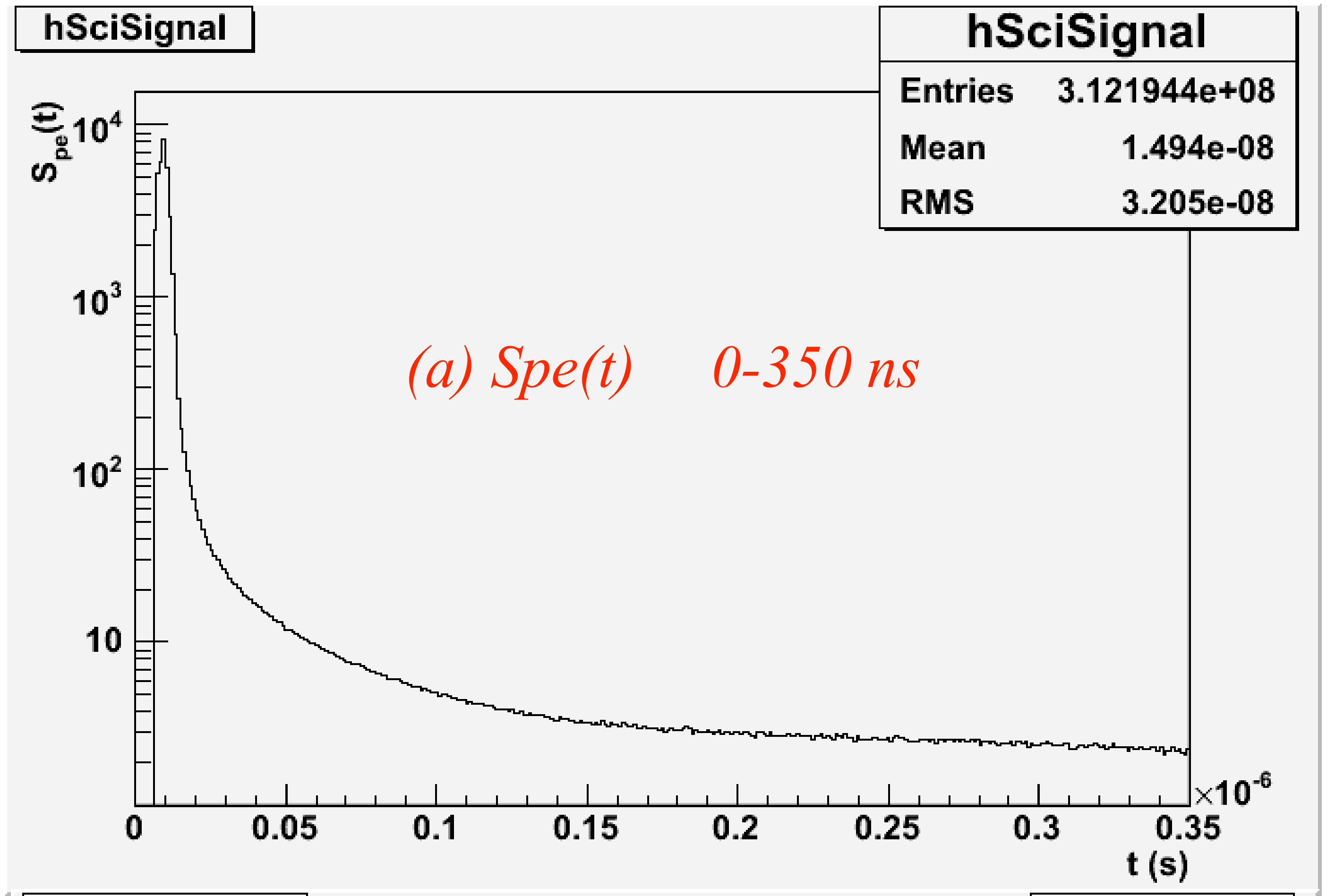


For fixed EM fraction, the resolution in the Cerenkov signal worsens as the neutron fraction grows larger, and its fluctuations grow larger.

Fix both EM fraction (~0.55) and neutron fraction (0.045<fn<0.065). The resolution in C signal is 4.7%. Neutron fraction (0.050<fn<0.055) tighter, the resolution is 4.4%.

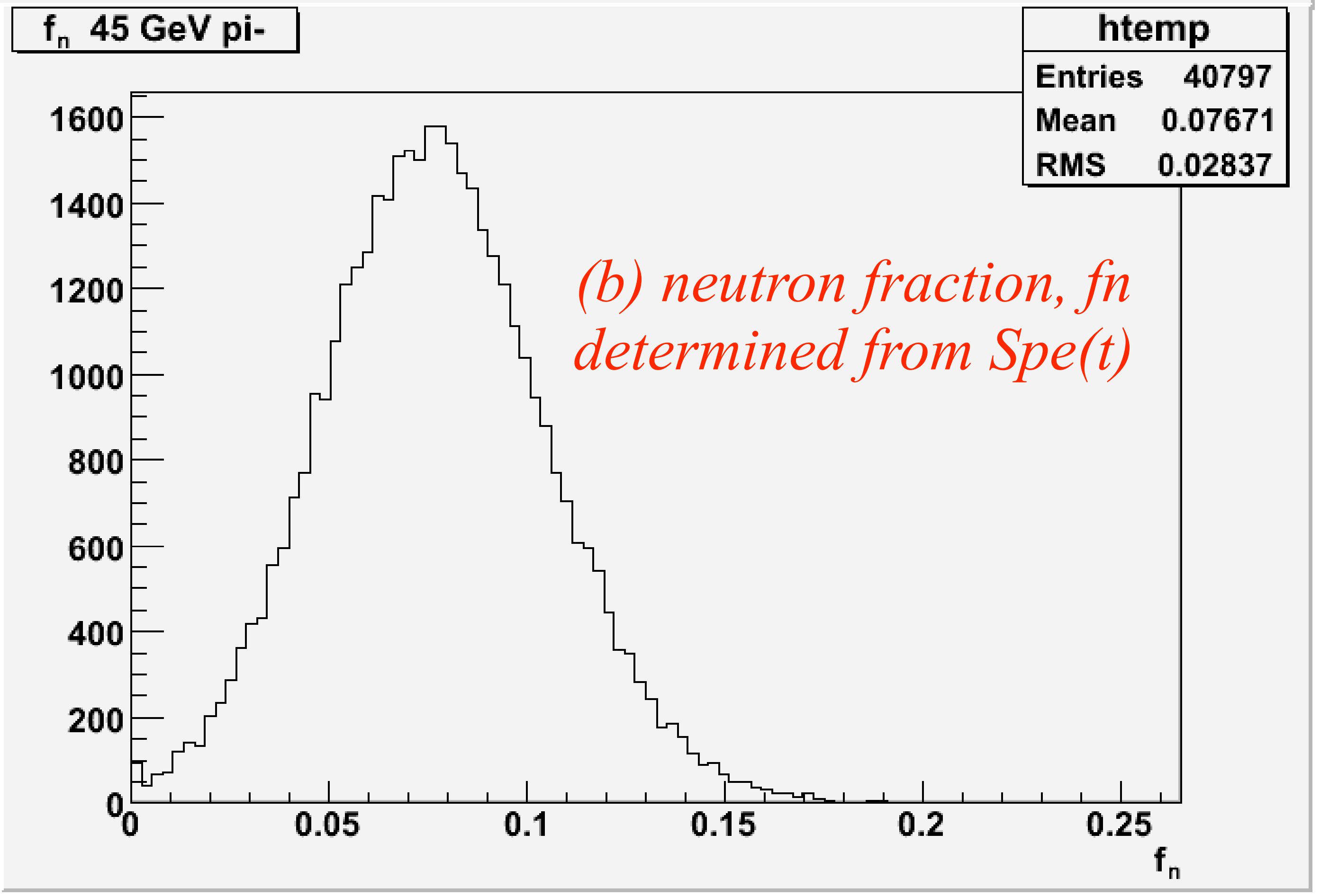


Note bene: leakage fluctuations in DREAM are ~4%.

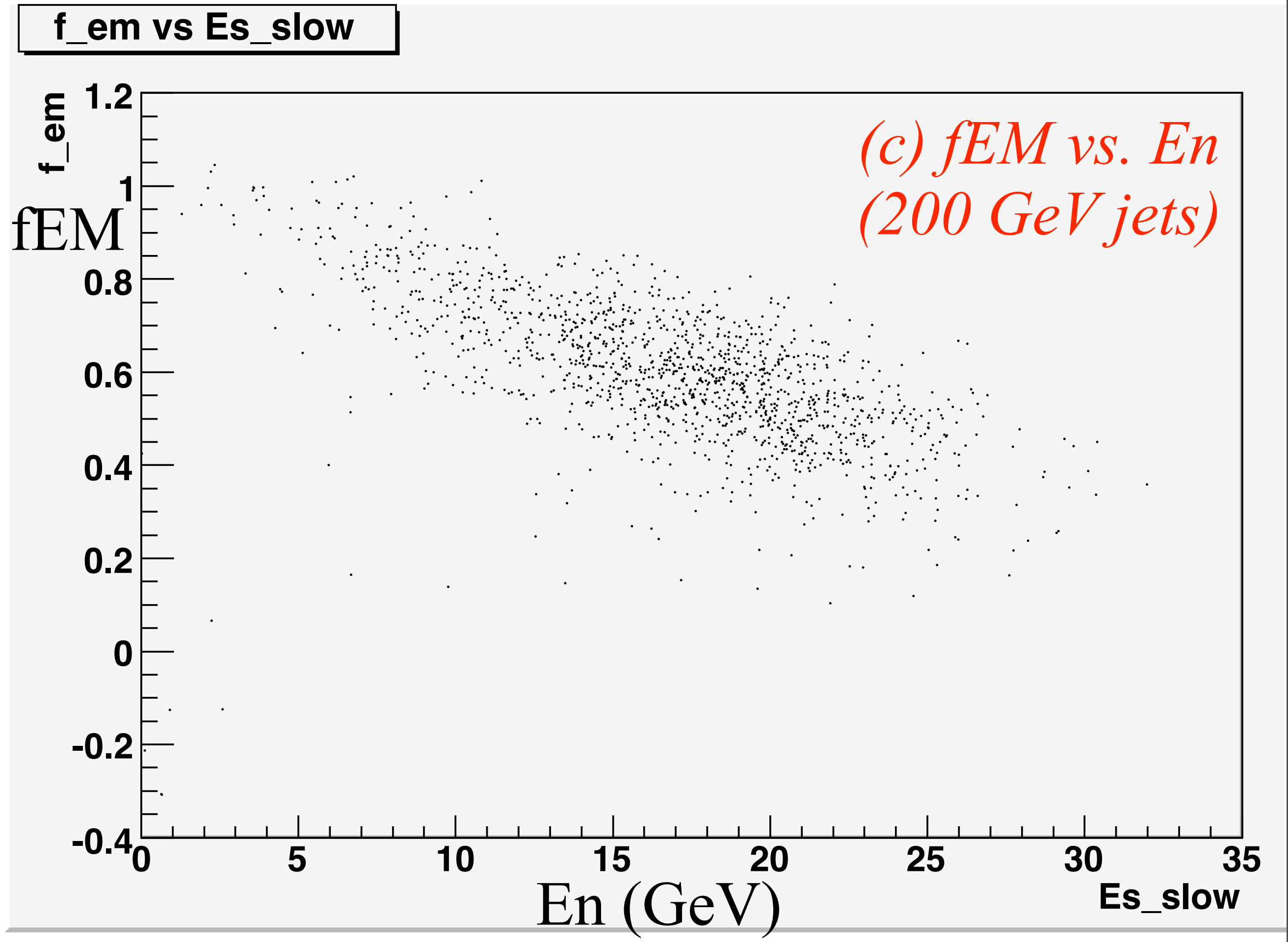


(a) Spe(t) 0-350 ns

We have a fair understanding of neutrons in both DREAM data and in the 4th detector.

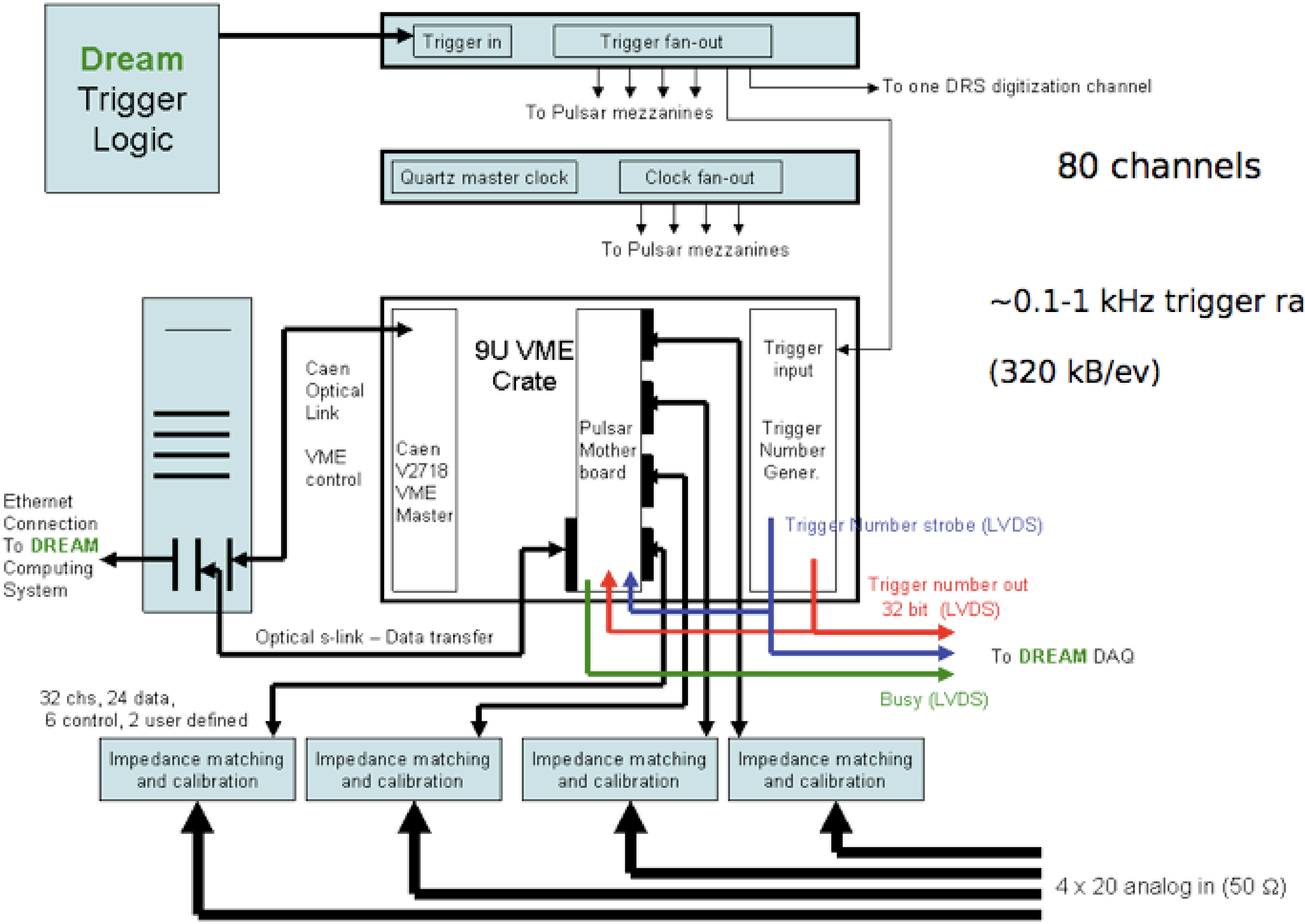


(b) neutron fraction, fn determined from Spe(t)



(c) fEM vs. En (200 GeV jets)

Setup for the DREAM test beam 2008



80 channels

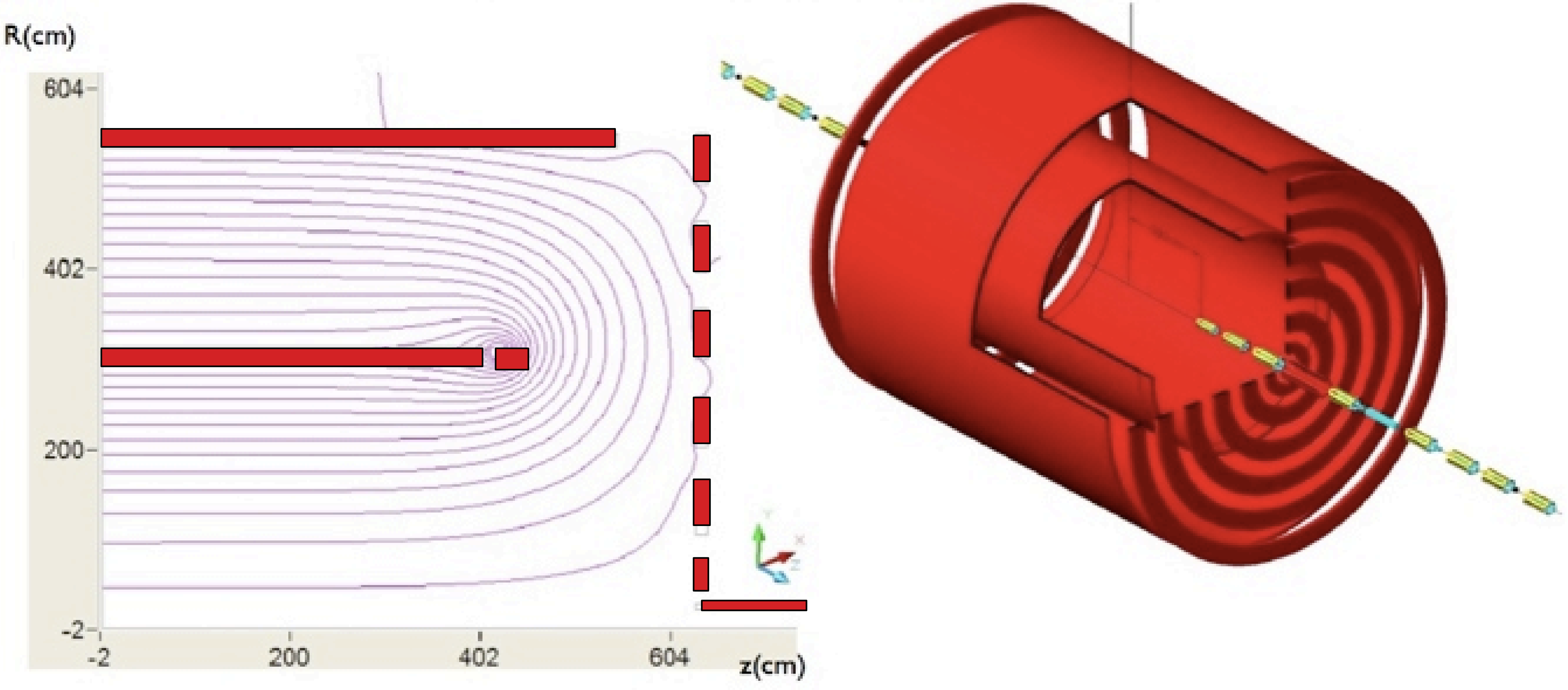
~0.1-1 kHz trigger rate

(320 kB/ev)

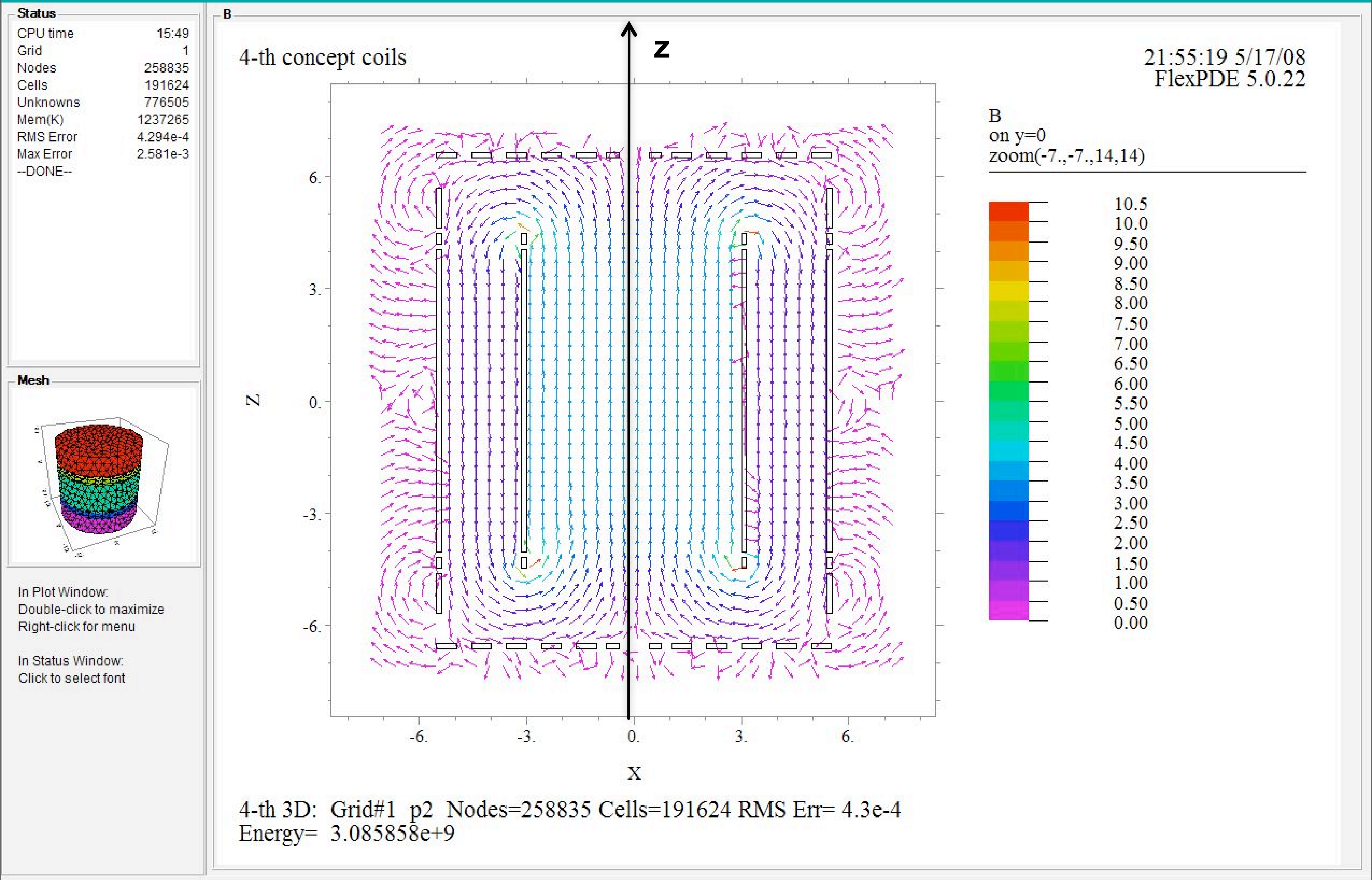
Magnetic field:

- New magnetic field, new “wall of coils”, iron-free
- Many benefits to muon detection, physics and MDI
- A. Mikhailichenko design

Magnetic field of dual solenoid and wall of coils



MAGNETIC FIELD VECTORS, 3D CALCULATION



Status

CPU time	15:49
Grid	1
Nodes	258835
Cells	191624
Unknowns	776505
Mem(K)	1237265
RMS Error	4.294e-4
Max Error	2.581e-3

--DONE--

Mesh

In Plot Window:
Double-click to maximize
Right-click for menu

In Status Window:
Click to select font

B

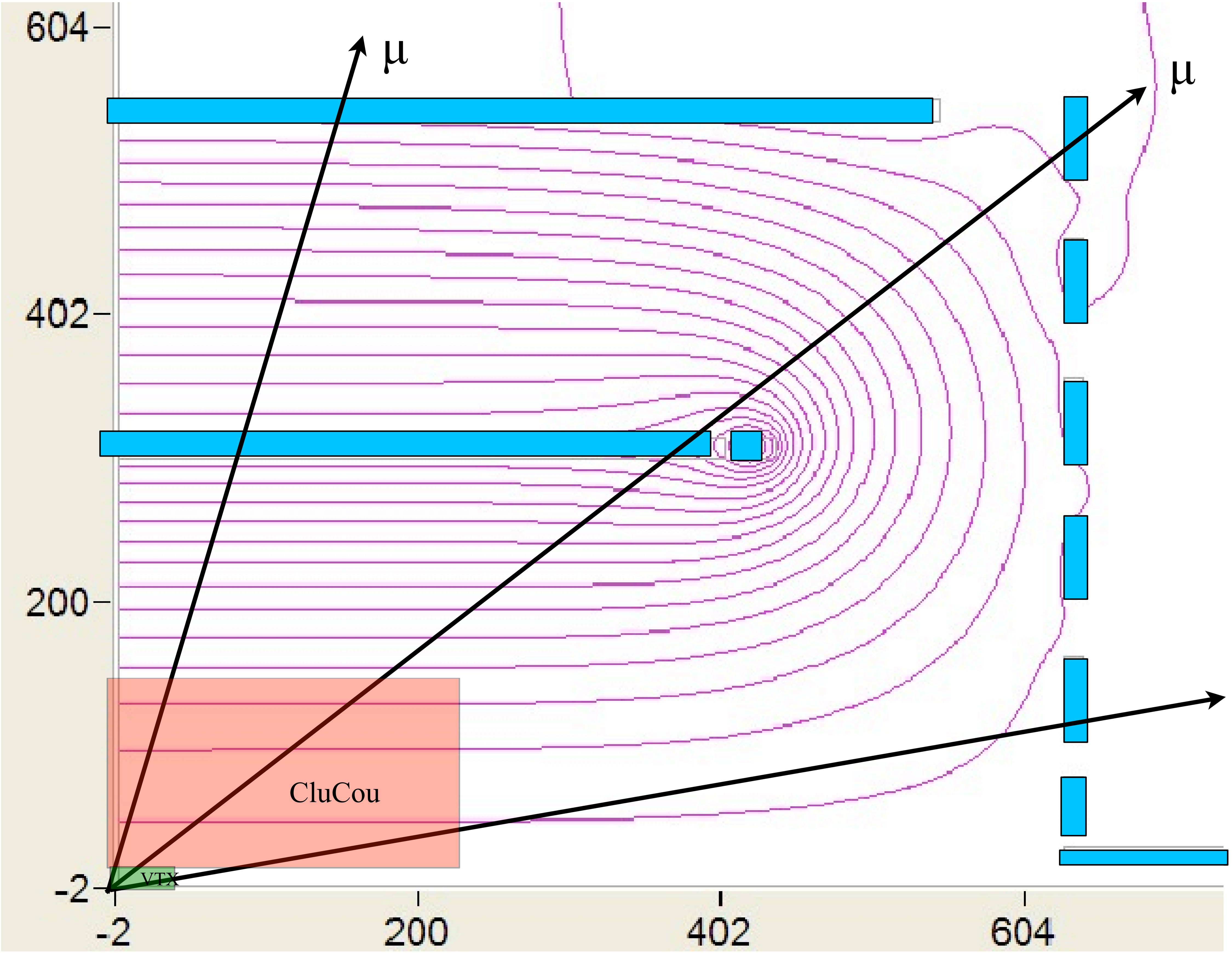
4-th concept coils

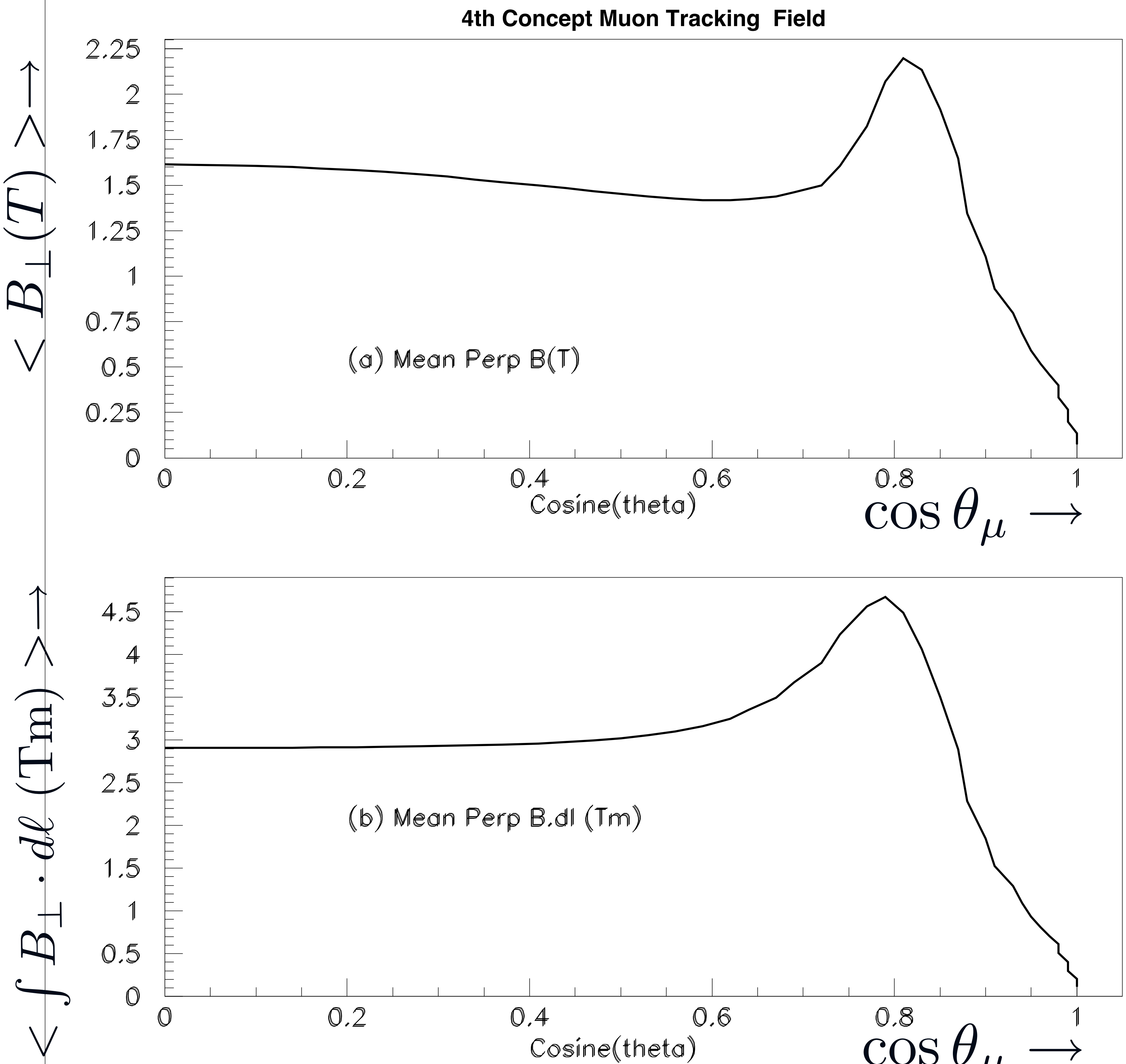
21:55:19 5/17/08
FlexPDE 5.0.22

B
on y=0
zoom(-7.,-7.,14,14)

4-th 3D: Grid#1 p2 Nodes=258835 Cells=191624 RMS Err= 4.3e-4
Energy= 3.085858e+9

Muon trajectories from the interaction point





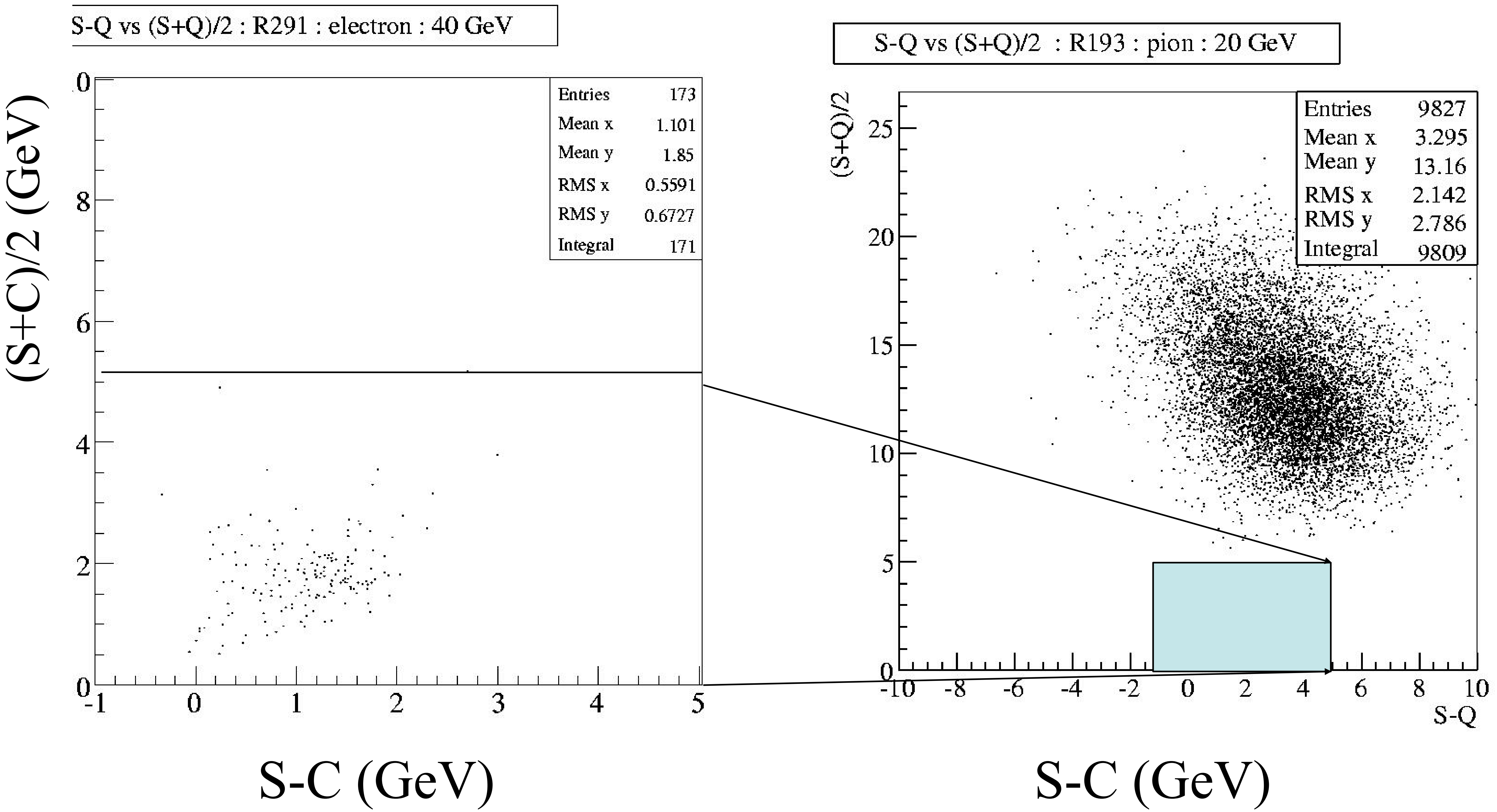
Dual solenoid

Tracking along muon trajectories in the annulus between solenoids.

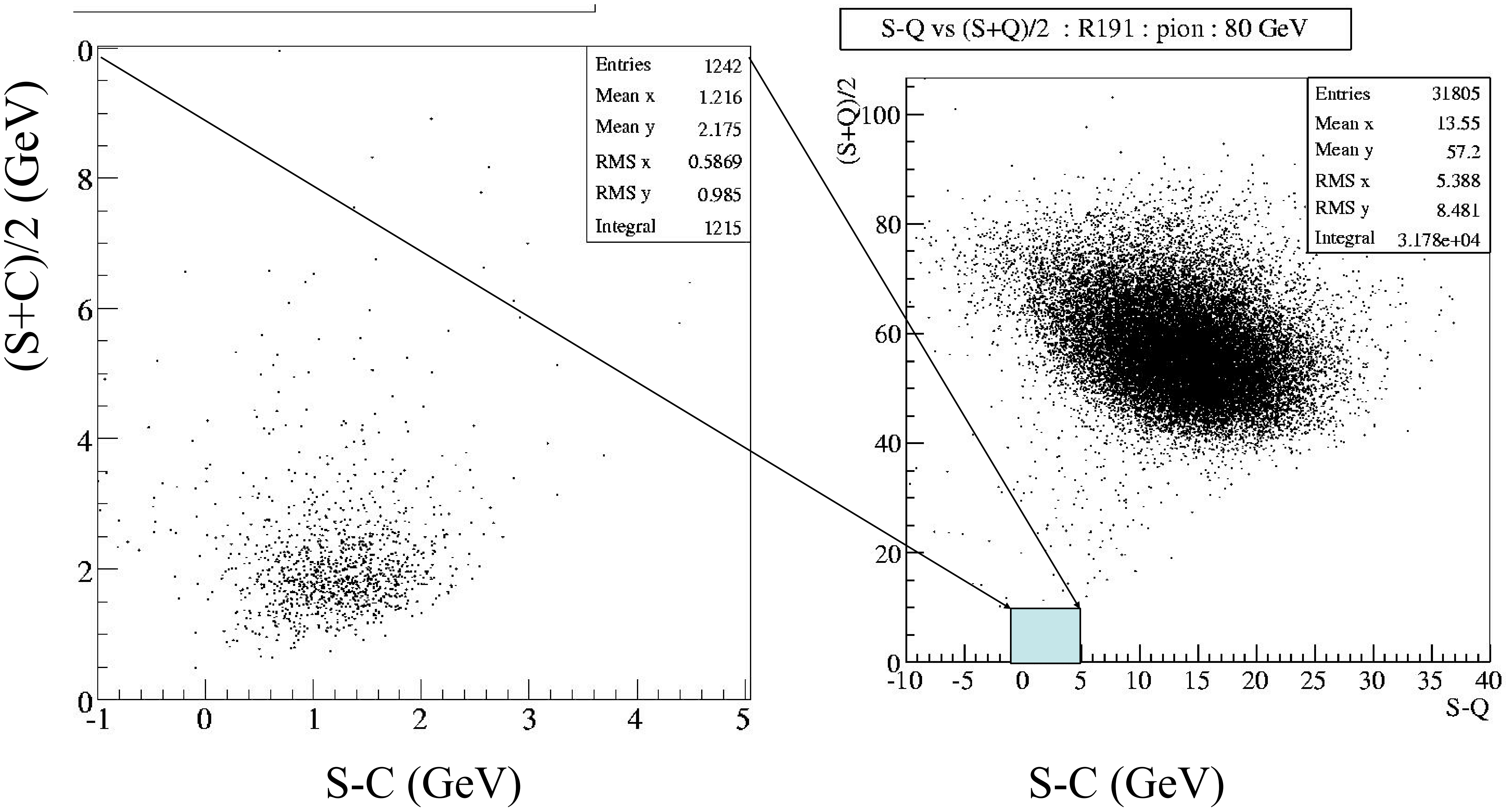
Cluster counting drift tubes for muon tracking.

Unique muon identification: S-C ~ *dE/dx* ~ constant for muons

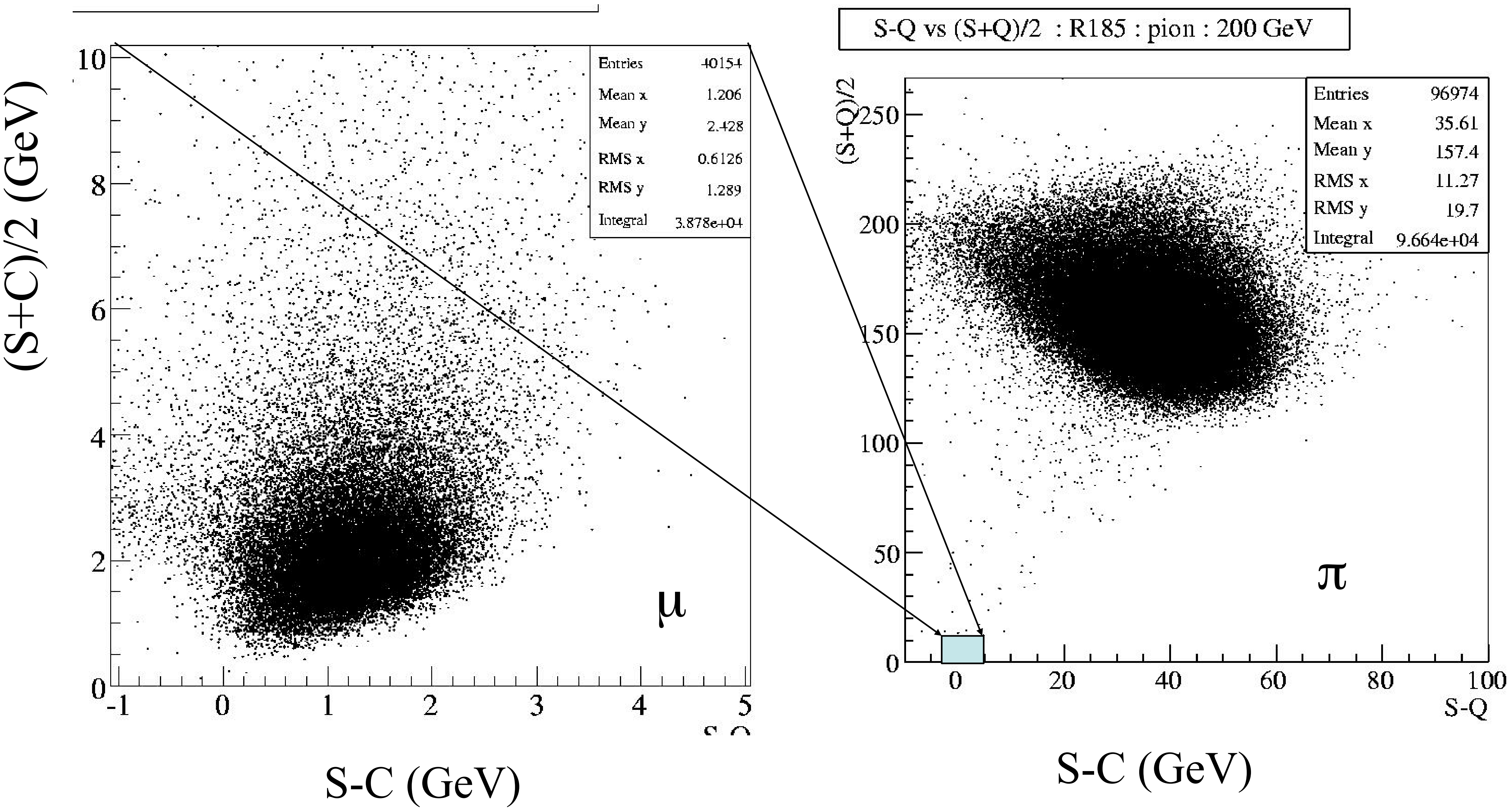
Muons and Pions (20 GeV)



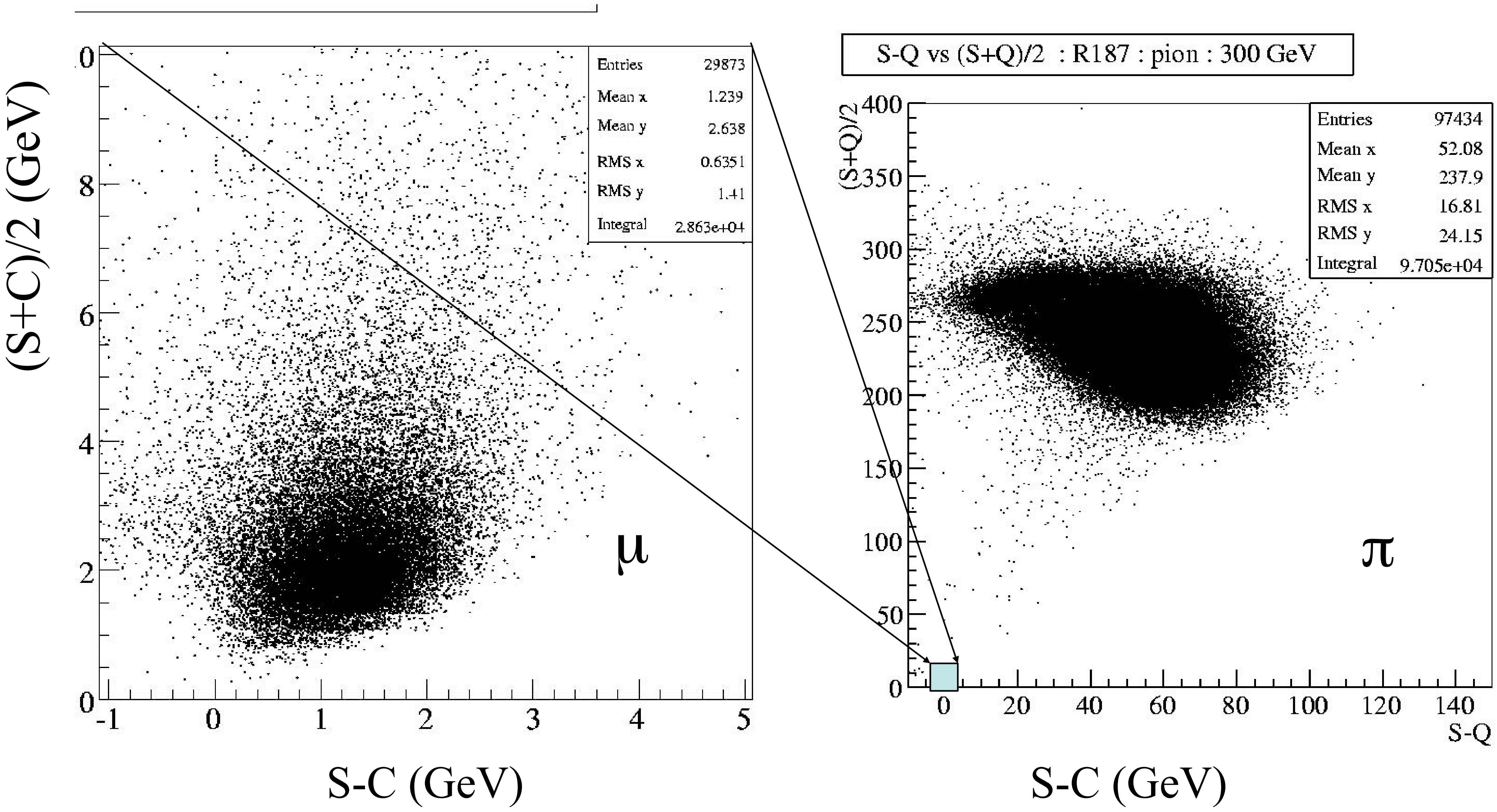
Muons and Pions (80 GeV)



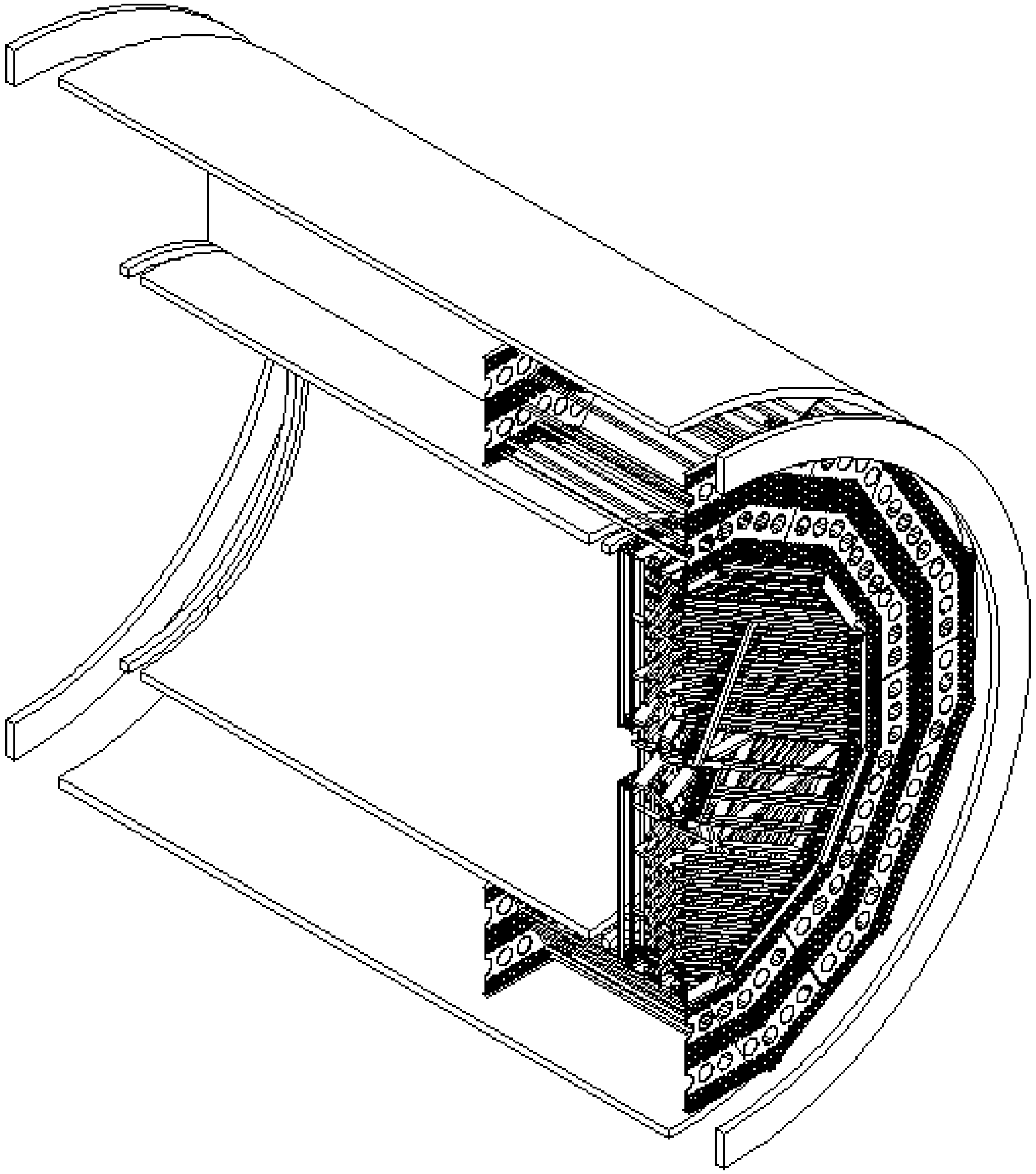
Muons and Pions (200 GeV)



Muons and Pions (300 GeV)



Full muon system: same He-based, low mass, high resolution CluCou, filling the volume between the solenoids, but wires are inside tubes (like ATLAS).

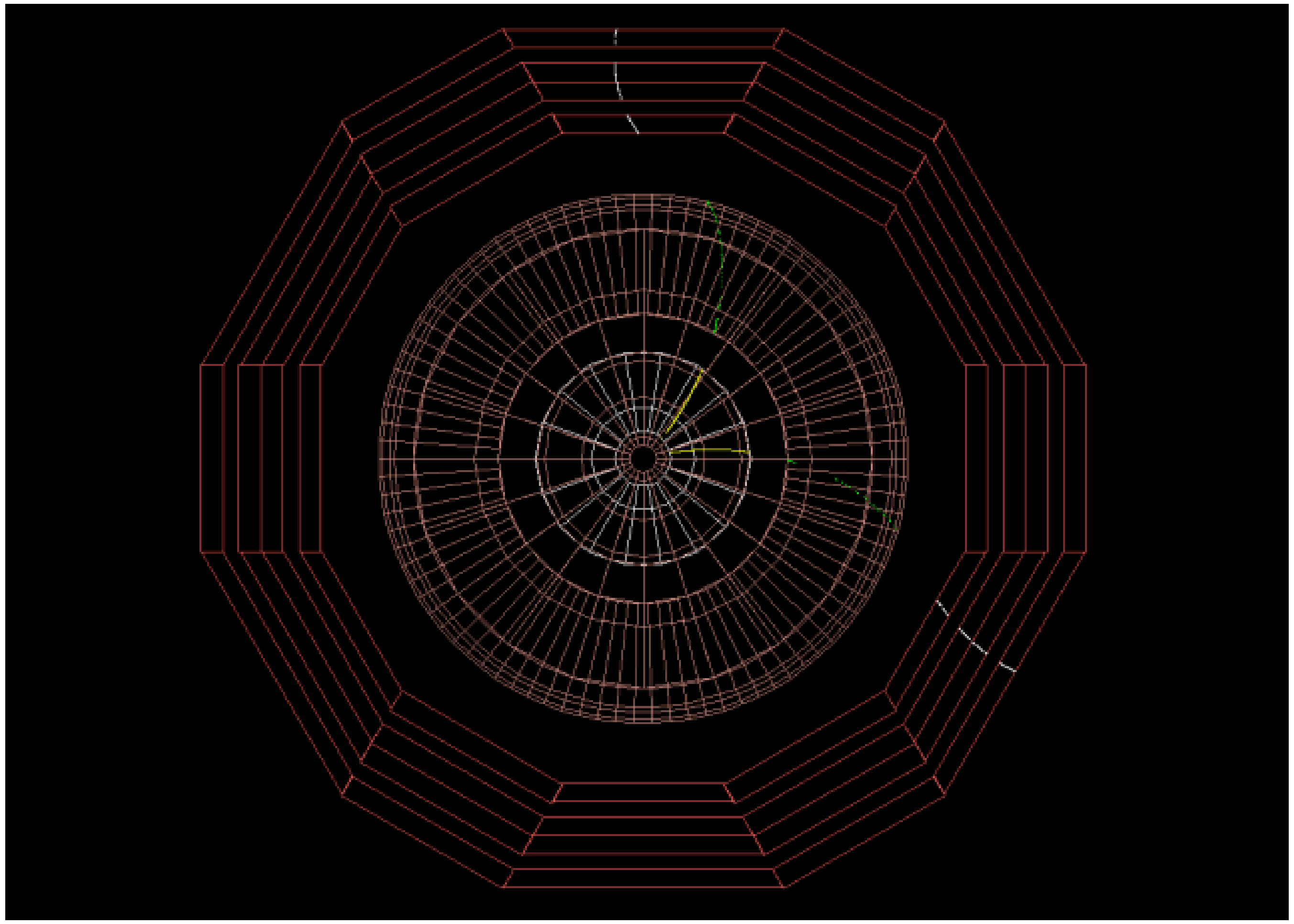


Barrel:
31500 tubes
21000 channels
840 cards

End caps:
8640 tubes
9792 channels
456 cards

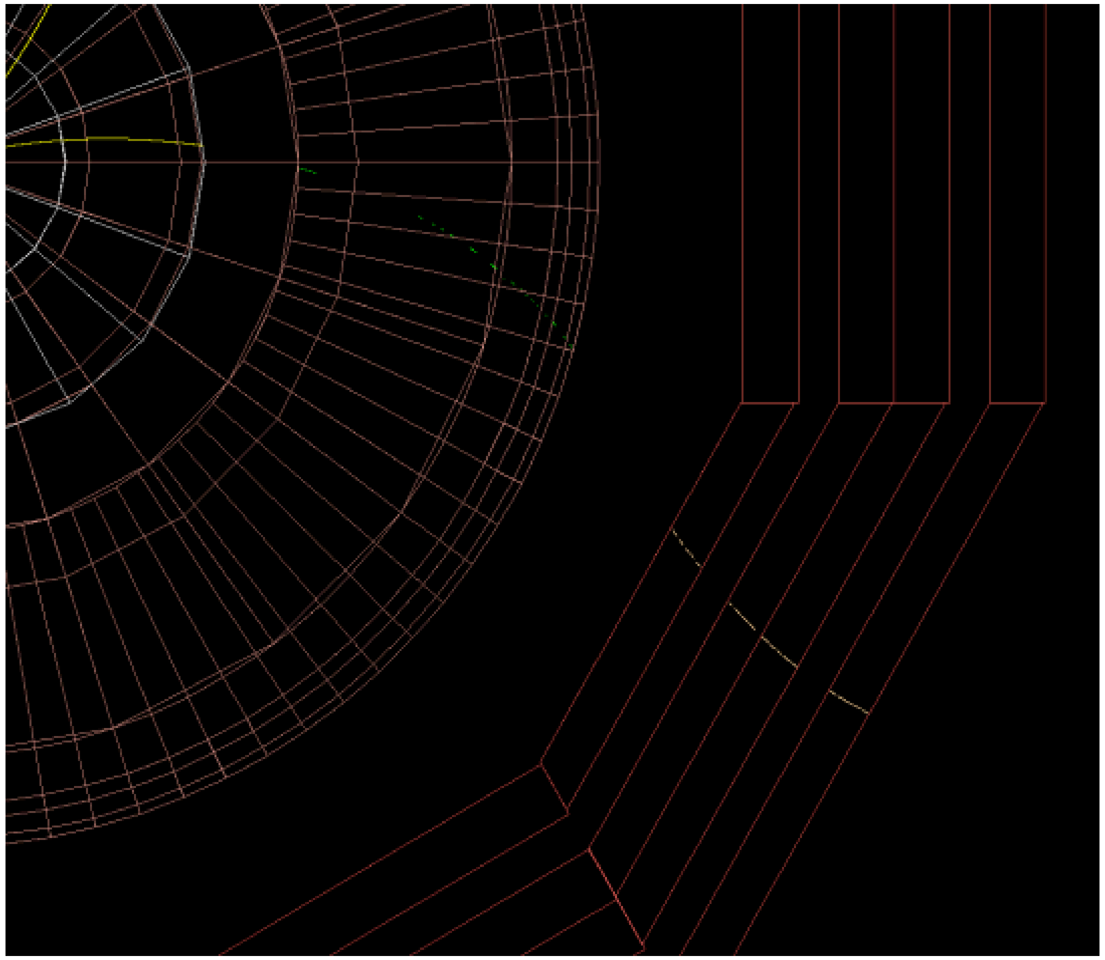
Total:
40140 tubes
30792 channels
1296 cards

μ^+ and μ^- at 3.5 GeV/c



Muons are easy and obvious at 3.5 GeV/c.

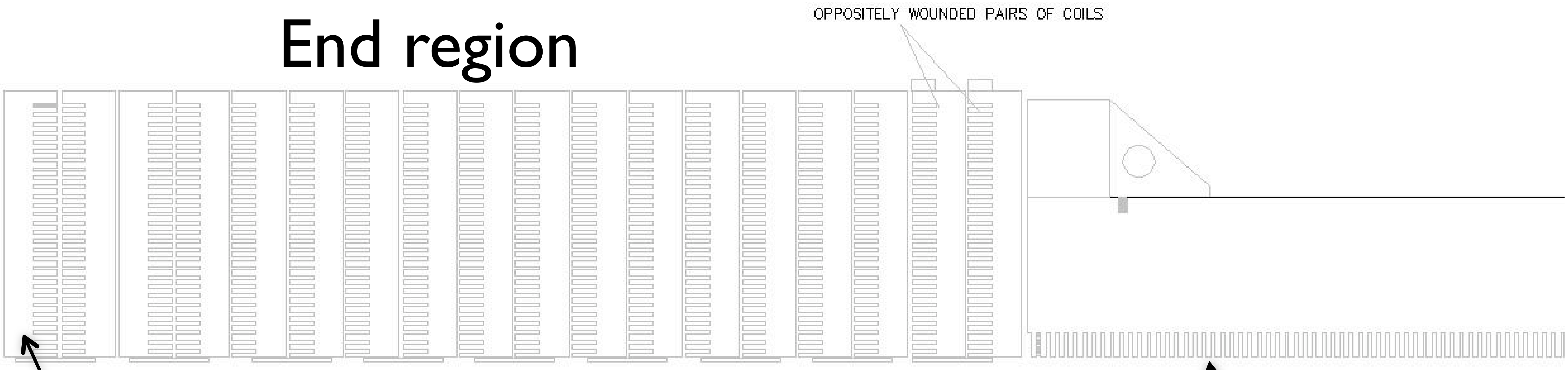
We intend to push the acceptance for muons down to 1 GeV/c. This will require fine coordination of CluCou and the dual-readout BGO and fiber calorimeters.

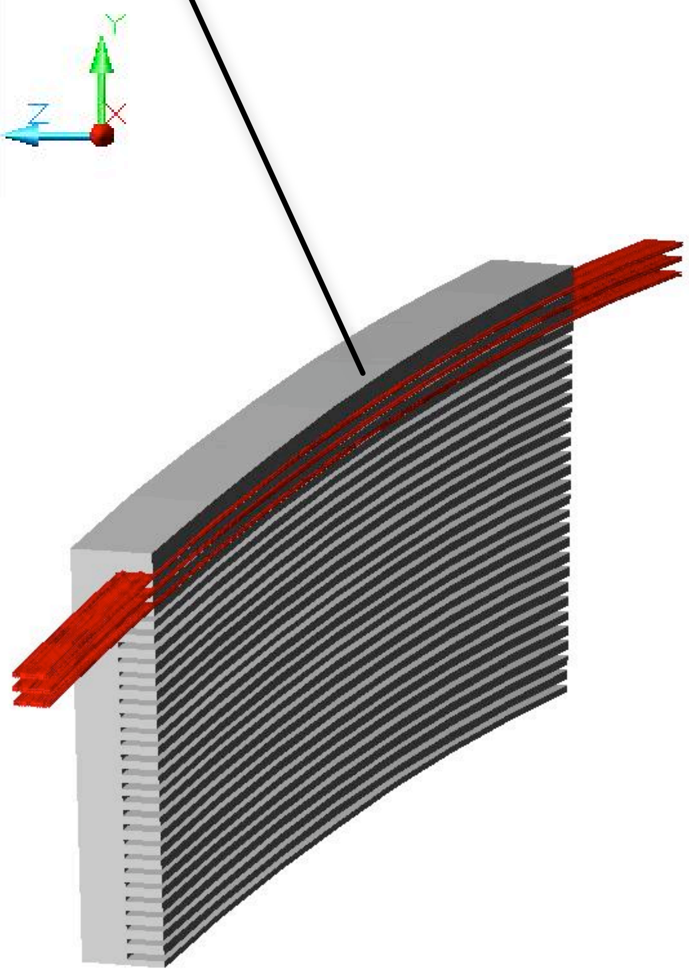


MAIN SC COIL SCHEMATICS

(A. Mikhailichenko)

End region



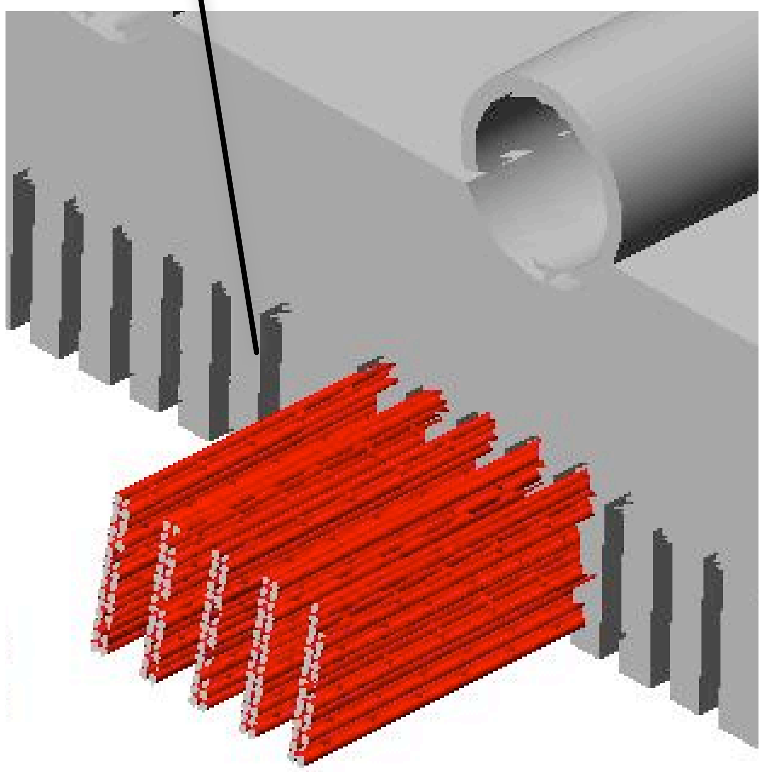


Use indirect cooling

SC cable embedded into grooves made in Al cylinders (discs)

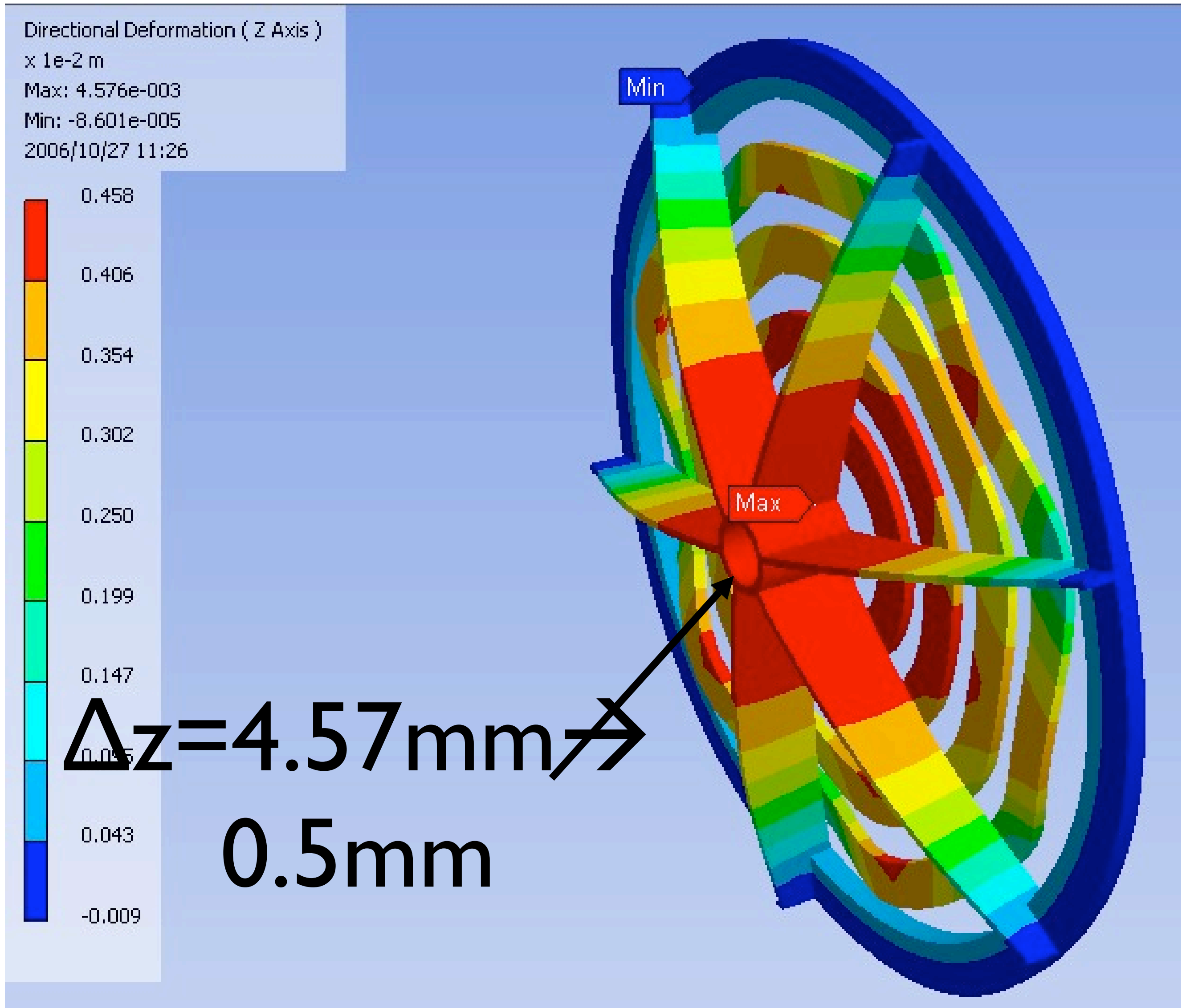
Coil is sectioned

Cable 20x2 - Ø1mm NbTi wires



Maximal deformation is in the middle of holder. It is below 5mm (V.Medjidzade, B.Wands).

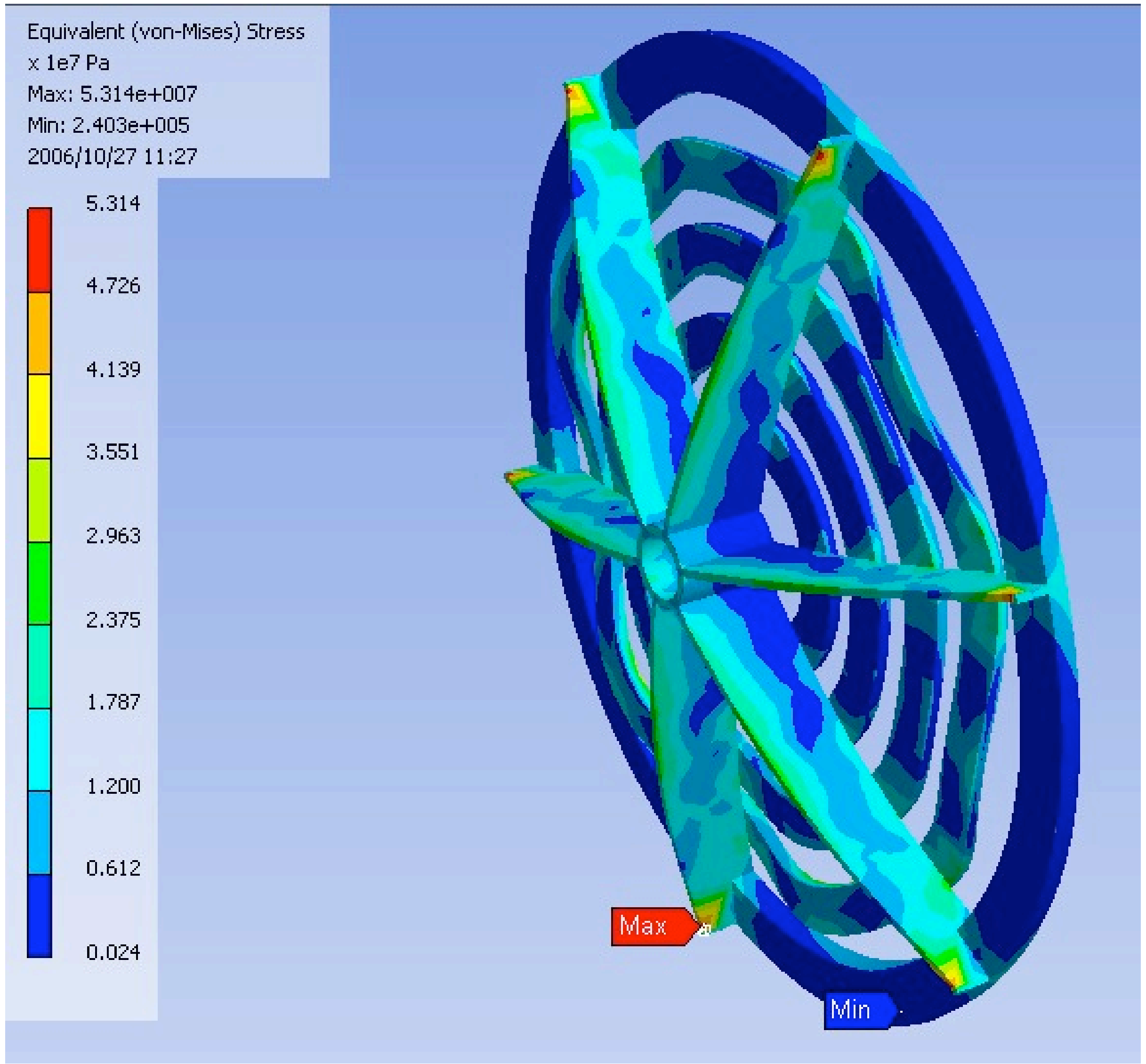
Active movers of FF lenses will compensate this effect easily.



Directional Deformation (Z Axis)
x 1e-2 m
Max: 4.576e-003
Min: -8.601e-005
2006/10/27 11:26

Δz=4.57mm → 0.5mm

Deformation of FF holder is in z-direction.



Equivalent (von-Mises) Stress
x 1e7 Pa
Max: 5.314e+007
Min: 2.403e+005
2006/10/27 11:27

Reinforcement can be done as well.

LATEST OPTIMIZATIONS REDUCED THIS DEFORMATION ~TEN TIMES

MDI (Machine Detector Interface)

- A. Mikhailichenko, 4th contact

Getting rid of more than 10,000 tonnes of iron is a very big deal, opening up many new possibilities for detectors.

i. Integrate FF and machine into detector;

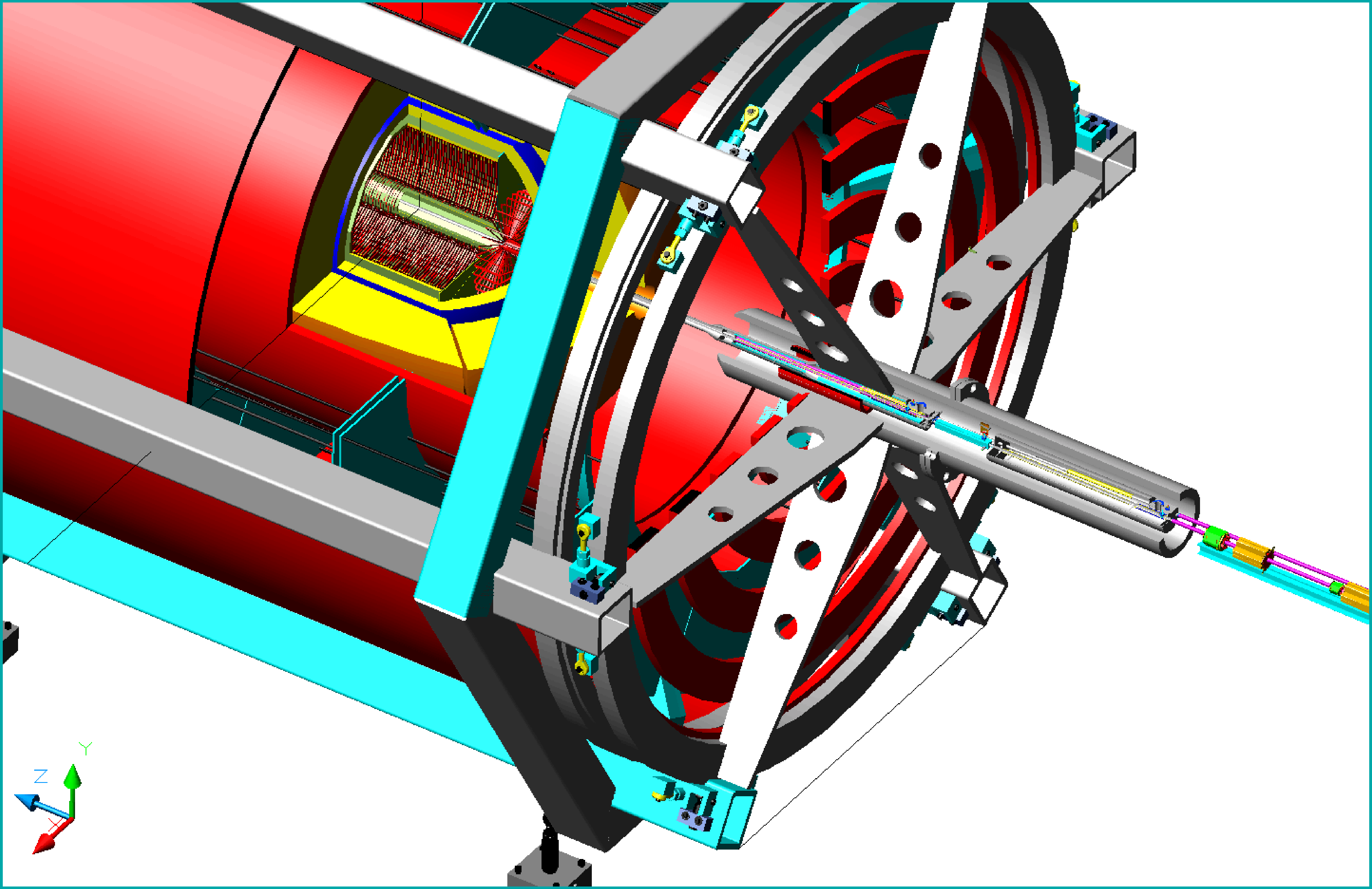
ii. Any crossing angle OK, but lobby for zero-degree crossing with a double kicker BDS and two IRs;

iii. Easy installation and reinstallations (push-pull no problem);

iv. Reverse B to cancel detector asymmetries, especially important for polarized beams;

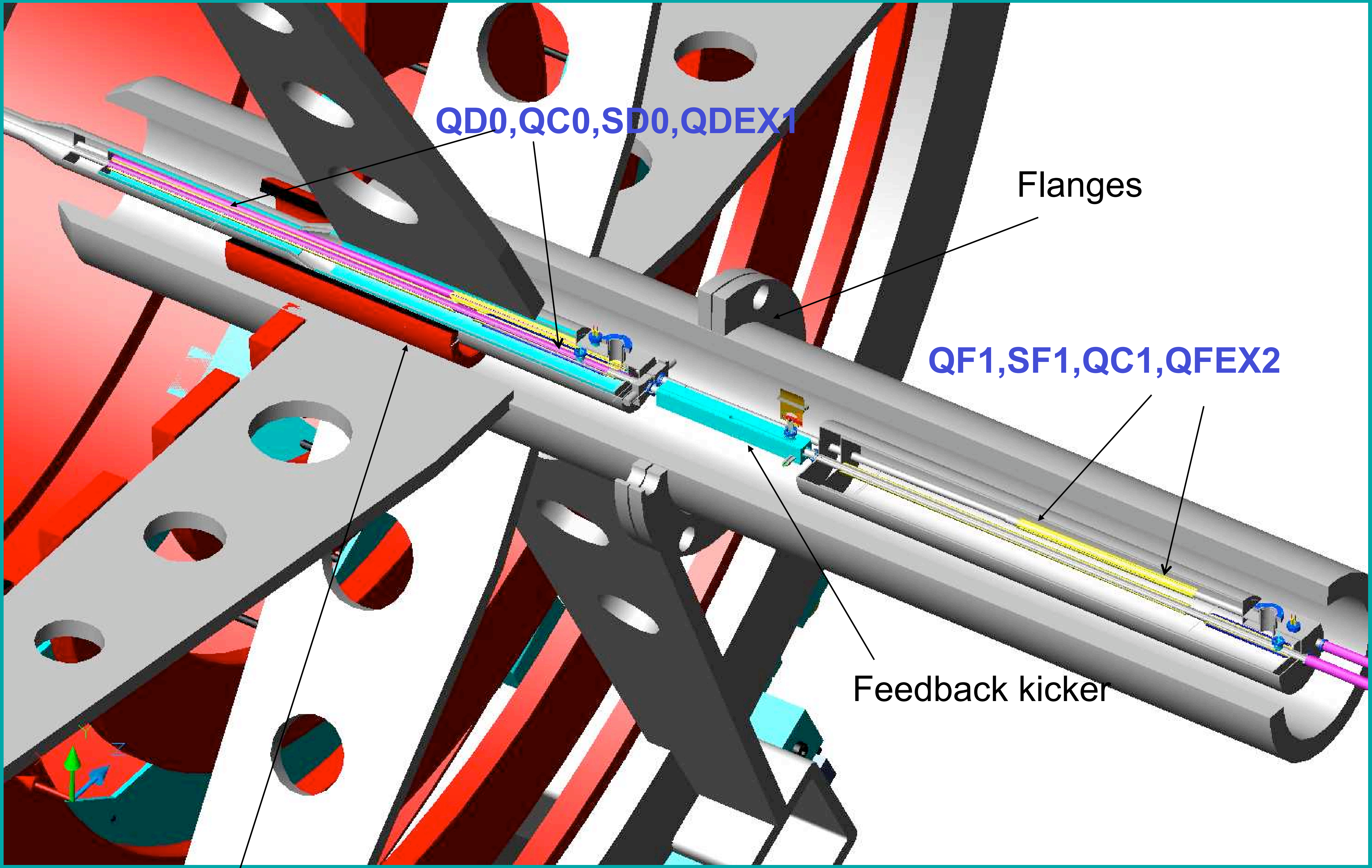
v. Numerous experimental conveniences, e.g., surveying, new add-ons or replacements in later years, etc.

14 mrad CROSSING ANGLE (BASELINE)



Open space allows easy modifications for gamma-gamma option

14 mrad crossing angle optics fragment



QD0,QC0,SD0,QDEX1

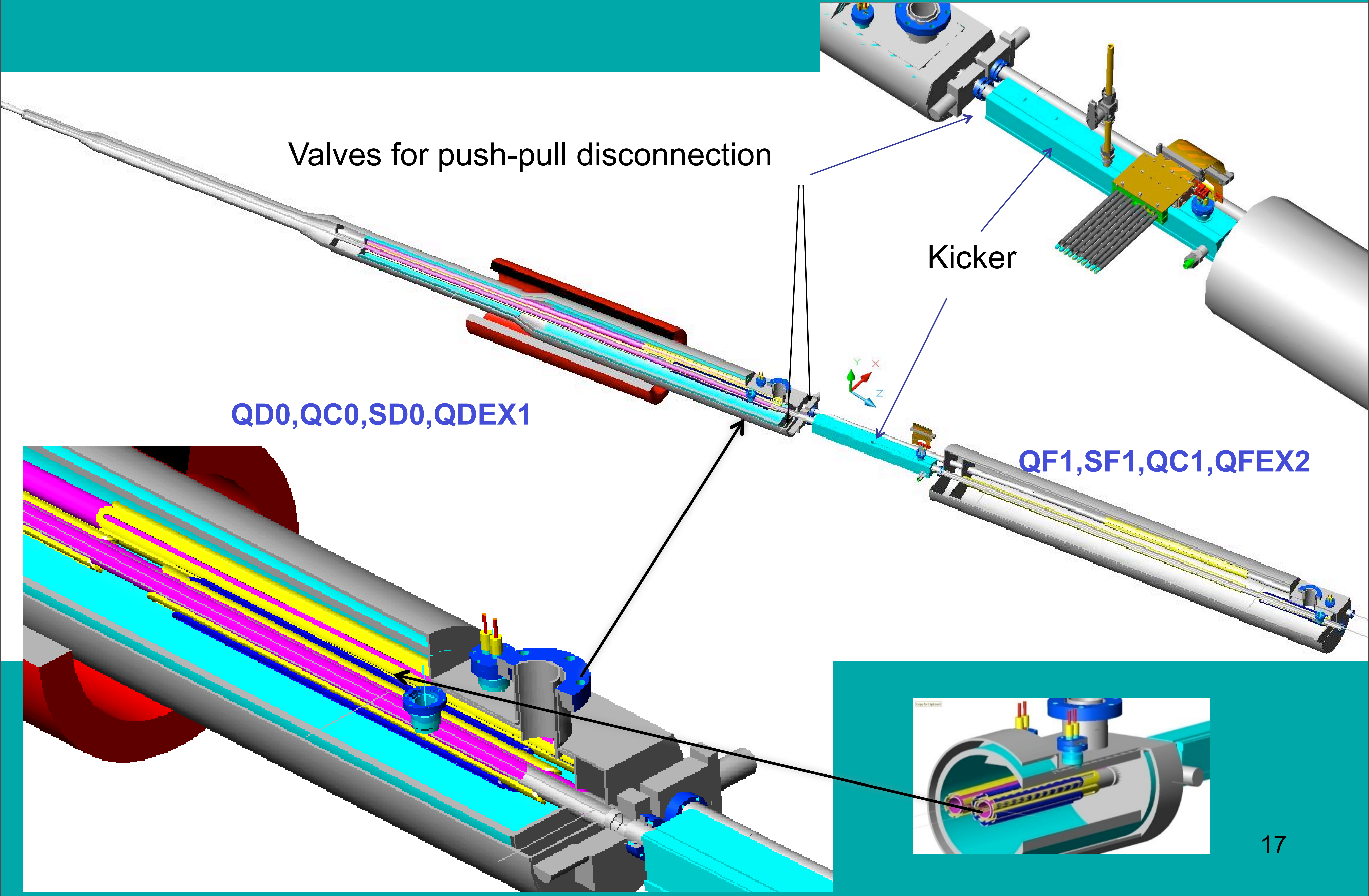
Flanges

QF1,SF1,QC1,QFEX2

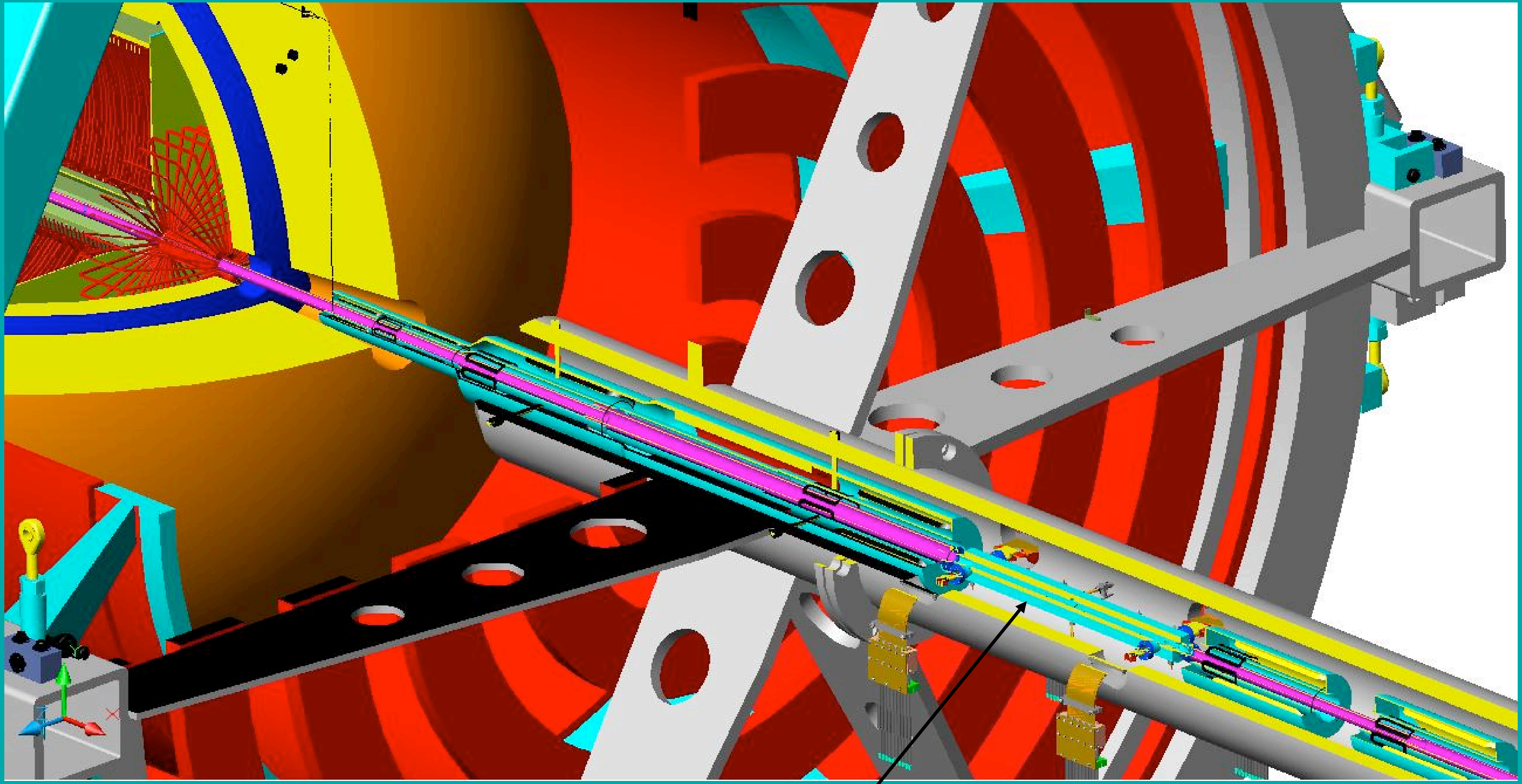
Feedback kicker

Anti-solenoid

FINAL DOUBLET (IN/OUT), SEXTUPOLES



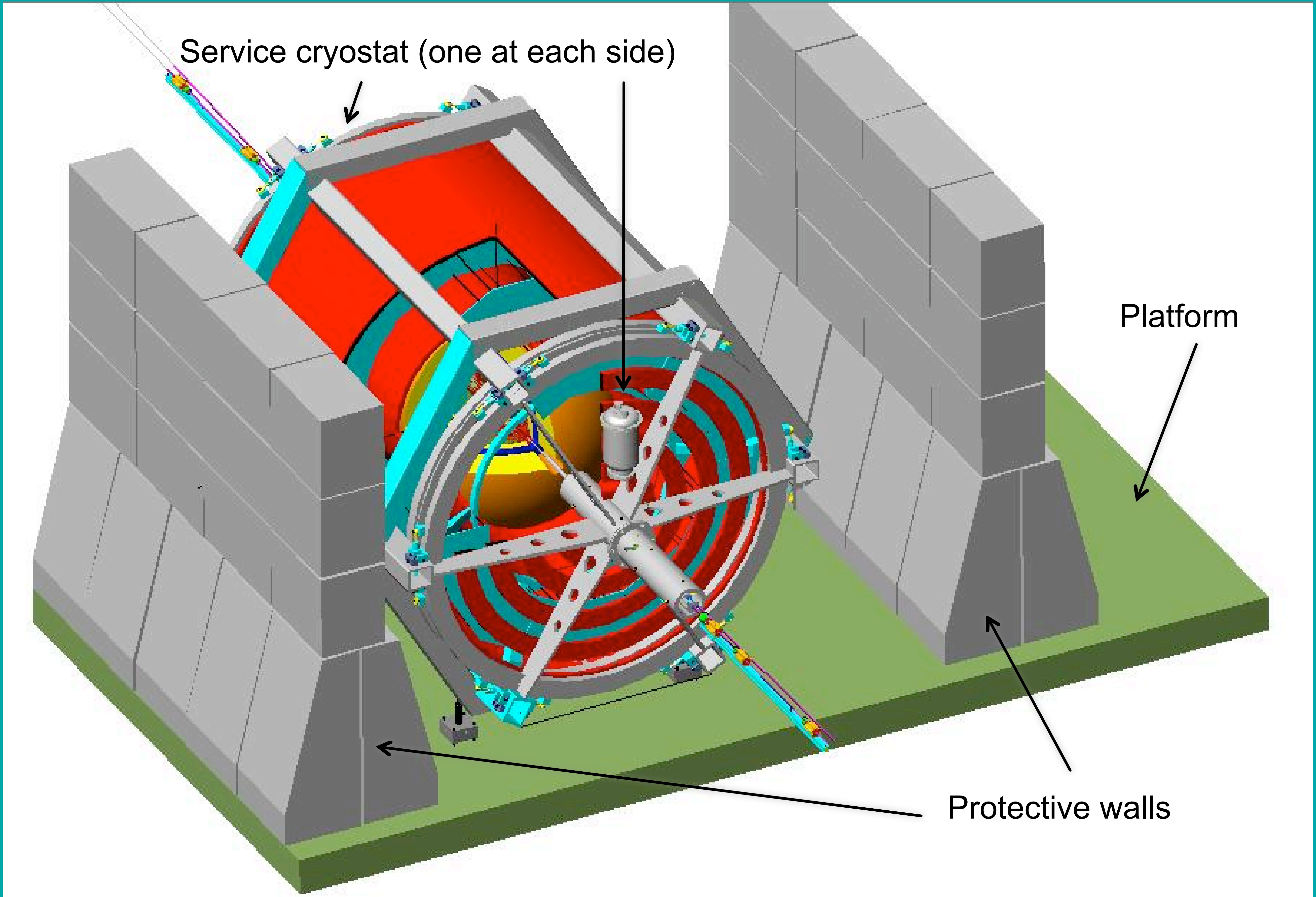
OPTICS WITH ZERO CROSSING ANGLE



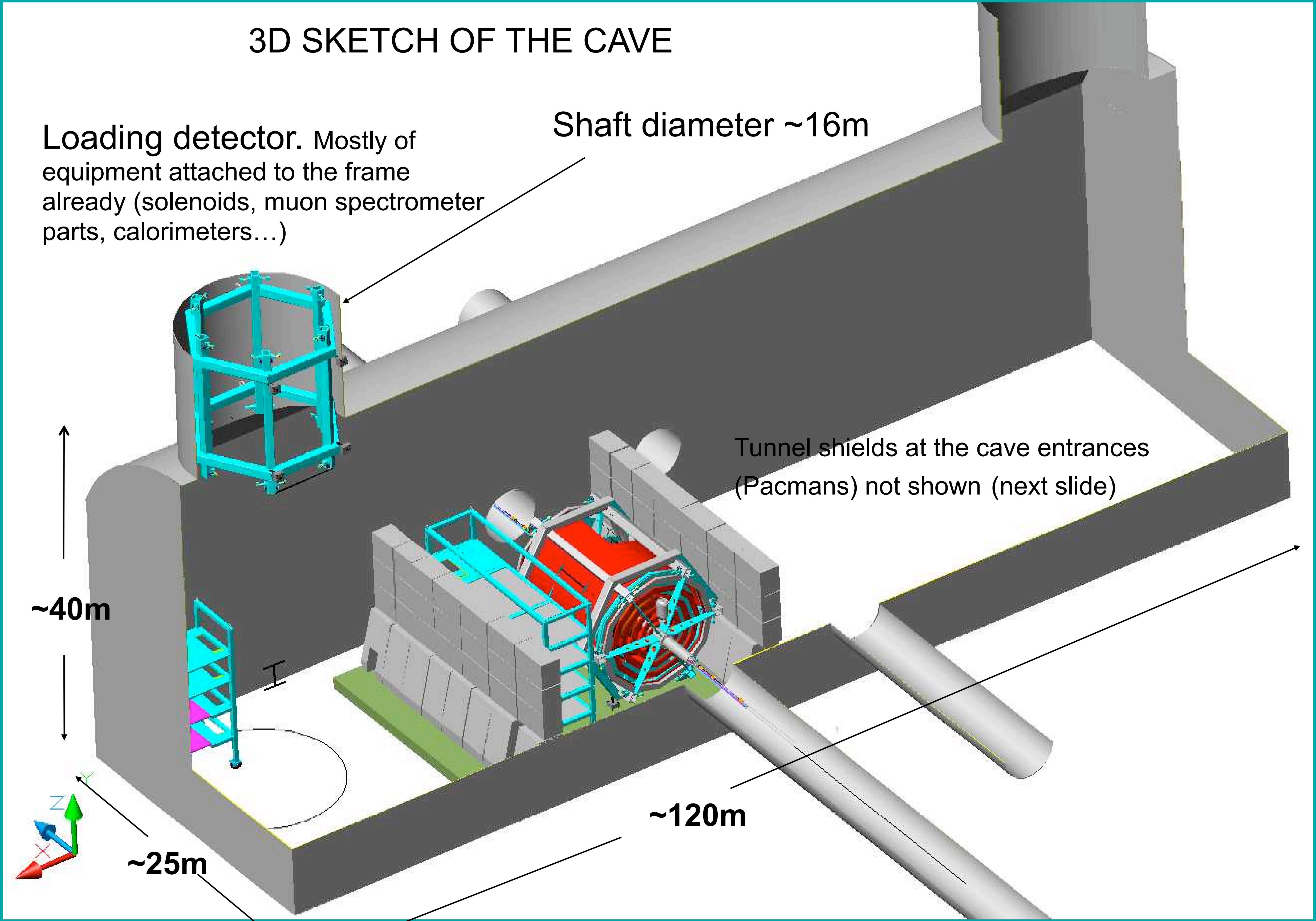
Directional kicker with TEM wave

Head on collision scheme if accepted, delivers undoubted benefits for HEP and for the beam optics.

INSTALLATION ON A PLATFORM



3D SKETCH OF THE CAVE



Loading detector. Mostly of equipment attached to the frame already (solenoids, muon spectrometer parts, calorimeters…)

Shaft diameter ~16m

Tunnel shields at the cave entrances (Pacmans) not shown (next slide)

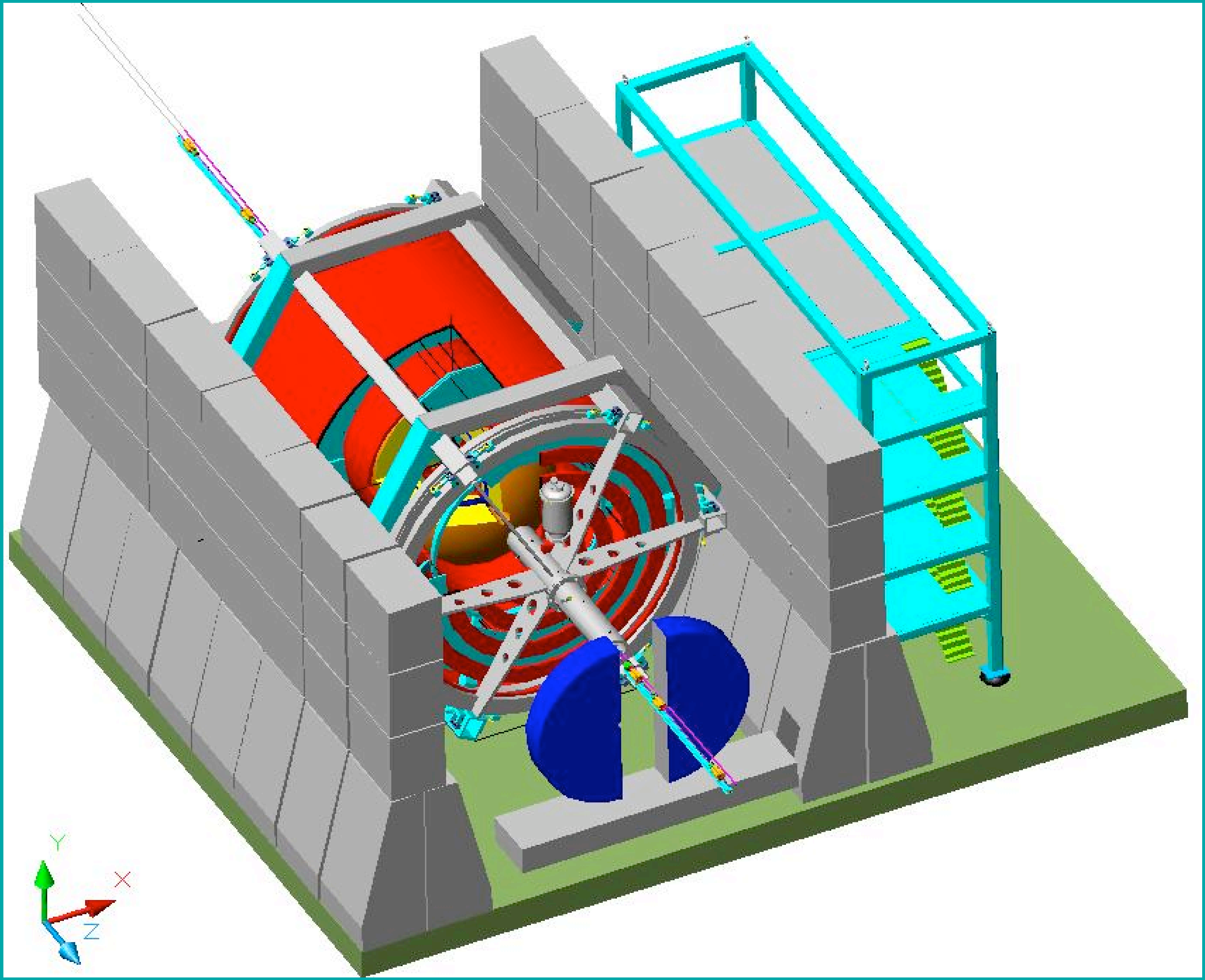
~40m

~120m

~25m

Cryogenic system must allow simultaneous operation of two detectors

The hut could be installed behind the wall also



MDI and field configuration summary

- 4th-concept allows easy installation into cave as **it has no heavy Iron;**
- Elements of FF optics mounted on detector frame allowing better protection against ground motion;
- Field can be made homogeneous to satisfy tracking requirements and measured accurately as there is no interference (or movement) from Iron (10^{-4});
- Modular concept of 4th detector allows easy exchange of different equipment, such as tracking chamber, vertex detector, sections of calorimeter, gamma-gamma collisions etc.;
- Detector could be manufactured at relatively low cost;
- Detector can be reassembled quickly to take advantage of asymmetric colliding e^+e^- beams;
- Detector allows relatively quick flip of magnetic field orientation for calibration of asymmetry; this is beneficial for collisions with polarized beams.
- 4th concept easily accommodates 14 mrad optics as well as zero crossing angle.

- Further work required for possible reduction of the BDS length (and cost). Maybe two detector scheme with beam switch yard will emerge as an option in the future.

Particle identification summary

(“particle ID efficiency is luminosity, too”)

The scientific goal of 4th is to build in from the start good-to-excellent particle identification capabilities, in addition to precision measurements in each independent detector subsystem.

Physics at an ILC will demand that whole events be understood, and that ensembles of events have high purity at high efficiency be well-defined.

We have not yet finished incorporating this code into ILCroot, but a table of independent particle identification measurements in 4th follows.

Particle identification of $e^\pm, \pi^\pm, \mu^\pm, K, p, \tau, W, Z$, and EM *vs.* non-EM, hadronic *vs.* non-hadronic,

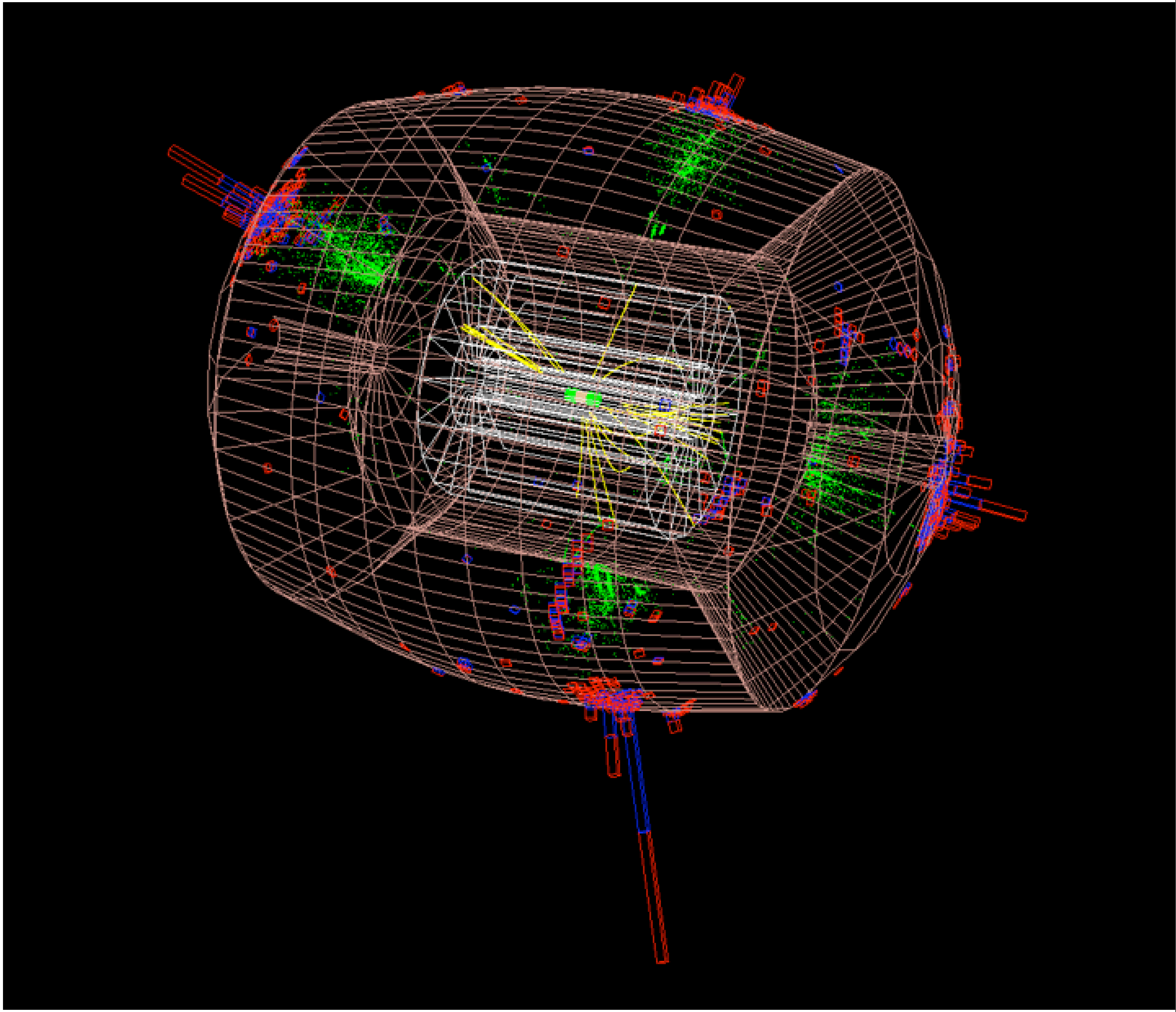
🟢 Demonstrated with data

🟡 Current testing

⚪ *To be tested*

Physical measurement	Partons/particles discriminated	Subsystems used	
C *vs.* S	$e^\pm$ *vs.* $\pi^\pm$ *vs.* $\mu^\pm$	dual-readout calor's	🟢
$\chi^2 \sim \frac{1}{n}\sum_i^n [C_i - S_i]^2/[k(C_i + S_i)]$ ($k \sim 0.10$)	EM *vs.* non-EM *vs.* "hadronic"	dual-readout calor's	🟢
$f_n \sim E_n/E_{\text{shower}}$ (slow neutrons in Spe(t))	"hadronic" *vs.* EM or "muonic"	scintillating fibers	🟢
$(S - C)$ *vs.* $(S + C)$	μ *vs.* π	dual readout calor's	🟢
Time-history of S fibers	EM *vs.* non-EM *vs.* "hadronic"	dual readout S fibers	🟢
dN/dx cluster counting	$e - \mu - \pi - K - p$ in GeV region	CluCou tracking	🟡
EM calor + tracking	$e - \gamma$	CluCou tracking, calor's	
$p_{\text{tracking}} \approx E_{\text{dual-readout}} + p_{\text{muon}}$	μ *vs.* tracks exiting calor.	CluCou, calor, muon	
$\tau^\pm \rightarrow \rho^\pm \nu \rightarrow \pi^\pm \gamma\gamma$	τ *vs.* hadronic debris	BGO dual-readout	
sub-ns time-of-flight	massive SUSY object	dual-readout BGO	⚪
$W, Z \rightarrow jj$ mass	W, Z *vs.* QCD jj	dual-readout calor's	

$$e^+e^- \to H^0 Z^0 \to b\bar{b}q\bar{q}$$



ILCroot

See Corrado Gatto talk

What are our needs, problems, and strengths?

Funding needs

- We have had zero funding this year (a US problem, mostly)
- Some European support for Lecce group
- LoI LCRD funding request (Oct'07) victim of US Congress

Technical & scientific problems

- MDI: find a shielding scheme for detector (personnel in staging area)
- Dual-solenoids: develop ways of building large superconducting solenoids, maybe along the lines developed at Budker Institute.
- Dual-readout calorimeters: build a hadron-containing fiber module incorporating all DREAM improvements, with a crystal dual-readout module in front.

Strengths

- We are a small, growing, and efficient group with good ideas