Results of recent DREAM test: neutrons and BGO

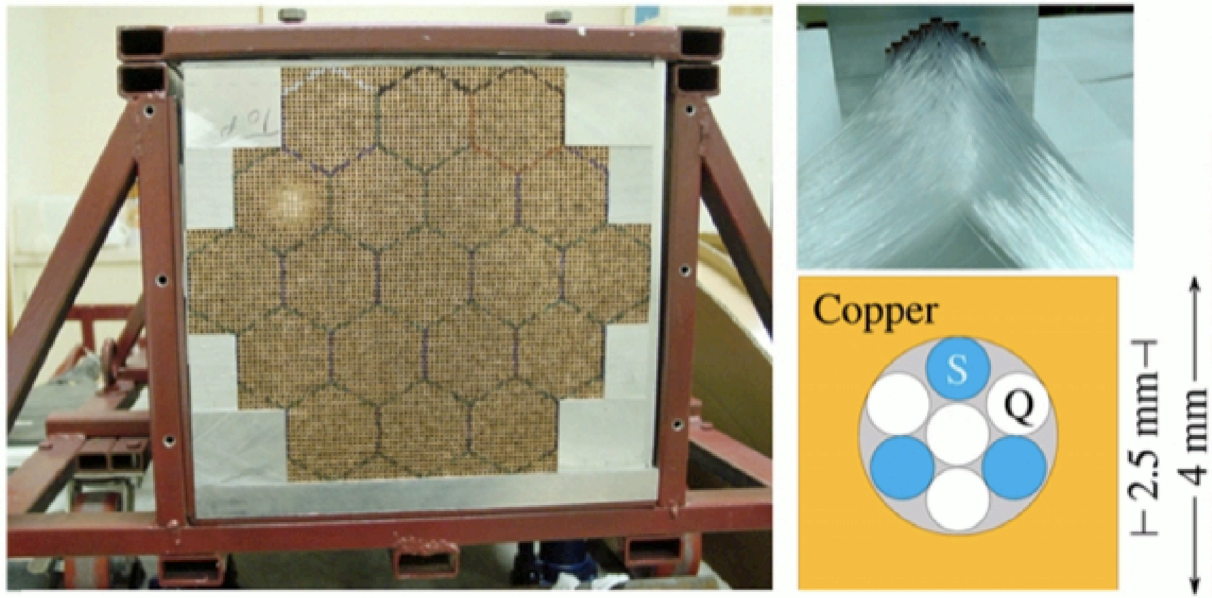
John Hauptman
4th Concept

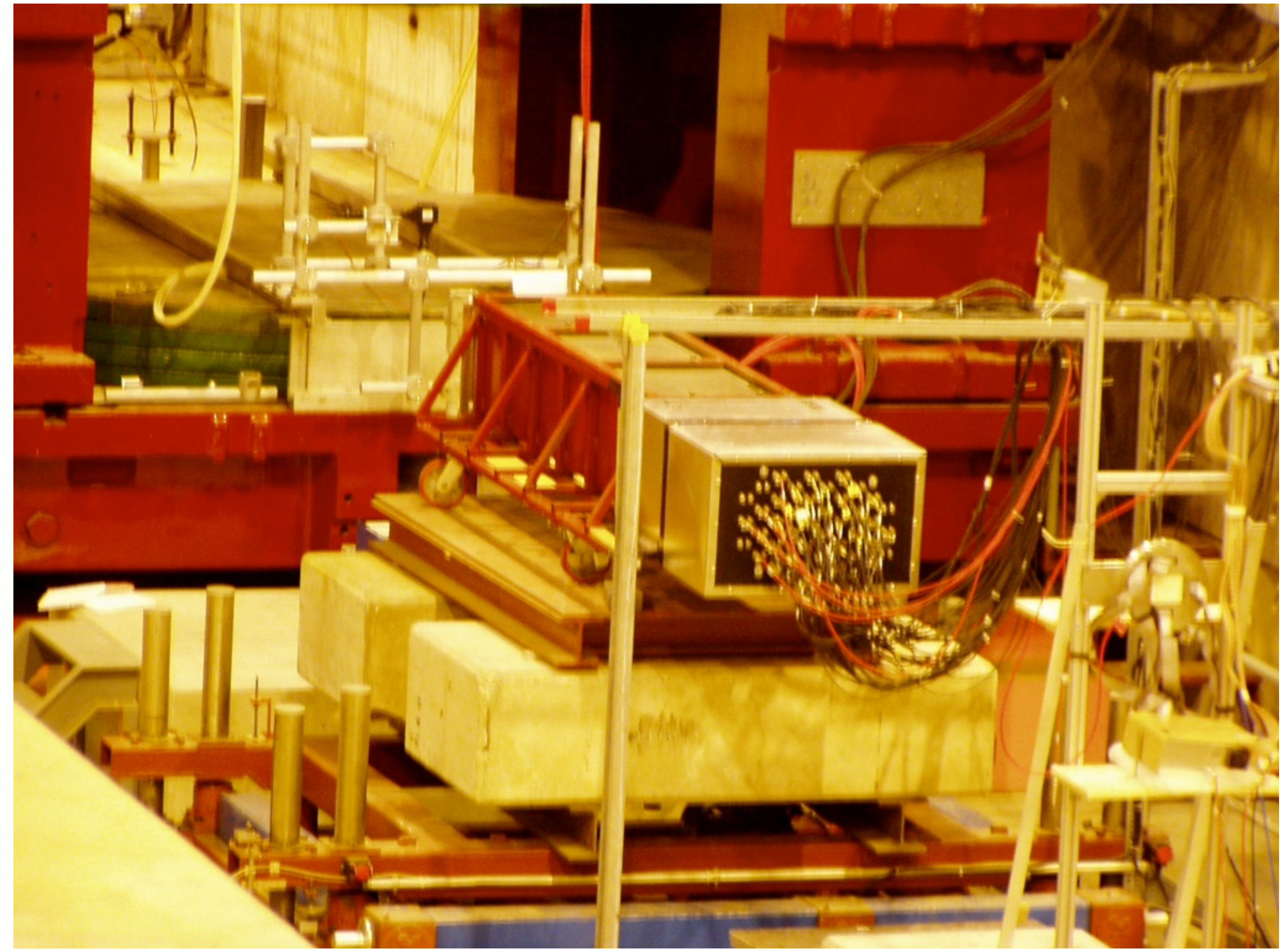
- CERN H4 beam test, June 18 - July 4, 2007
- $PbWO_4$: a single crystal and an array of 19 crystals
- neutrons in DREAM module:
  - differential measurement: n(r,t) for 3 channels
  - integral measurement: n(t) for the whole module
- BGO: a single crystal (borrowed from L3)

We are going after everything in dual-readout:

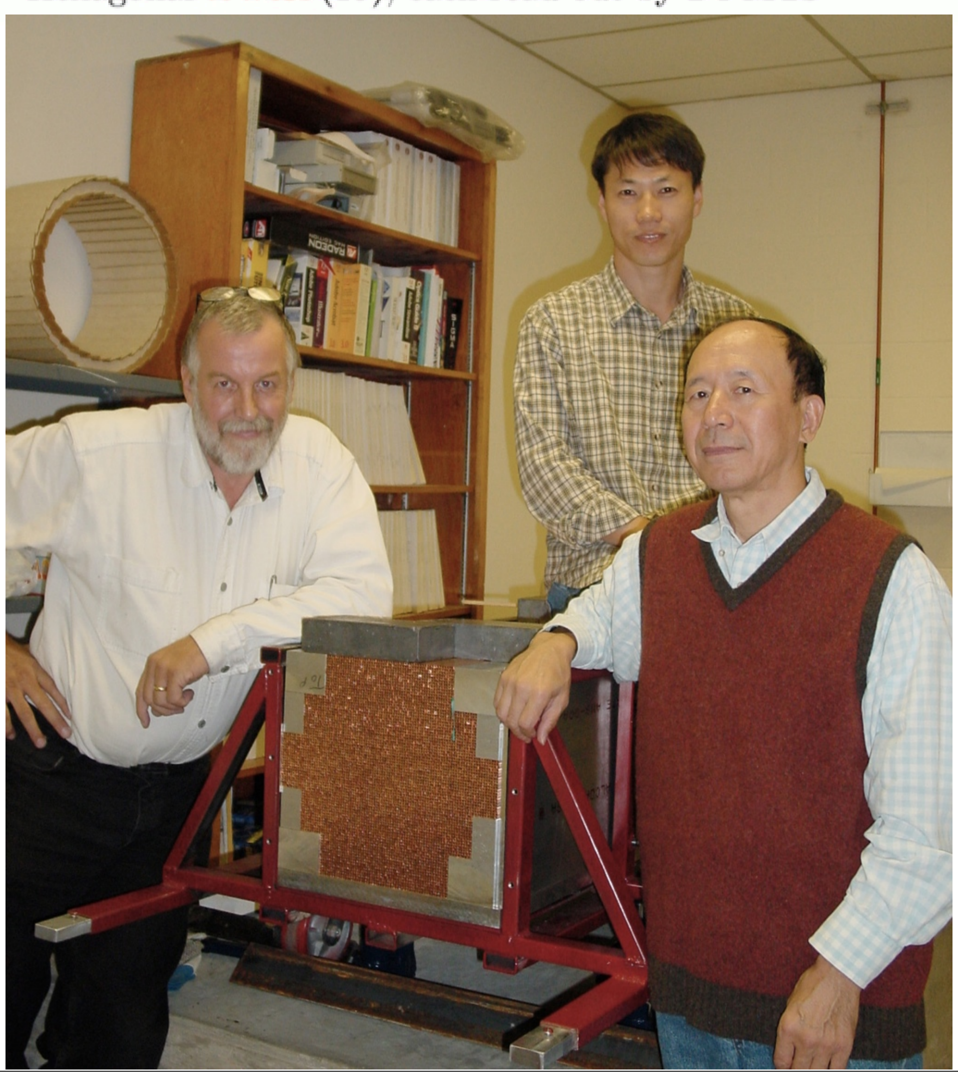
- dual crystal EM,
- dual fiber hadronic, including neutrons,
- dual readout particle ID methods.

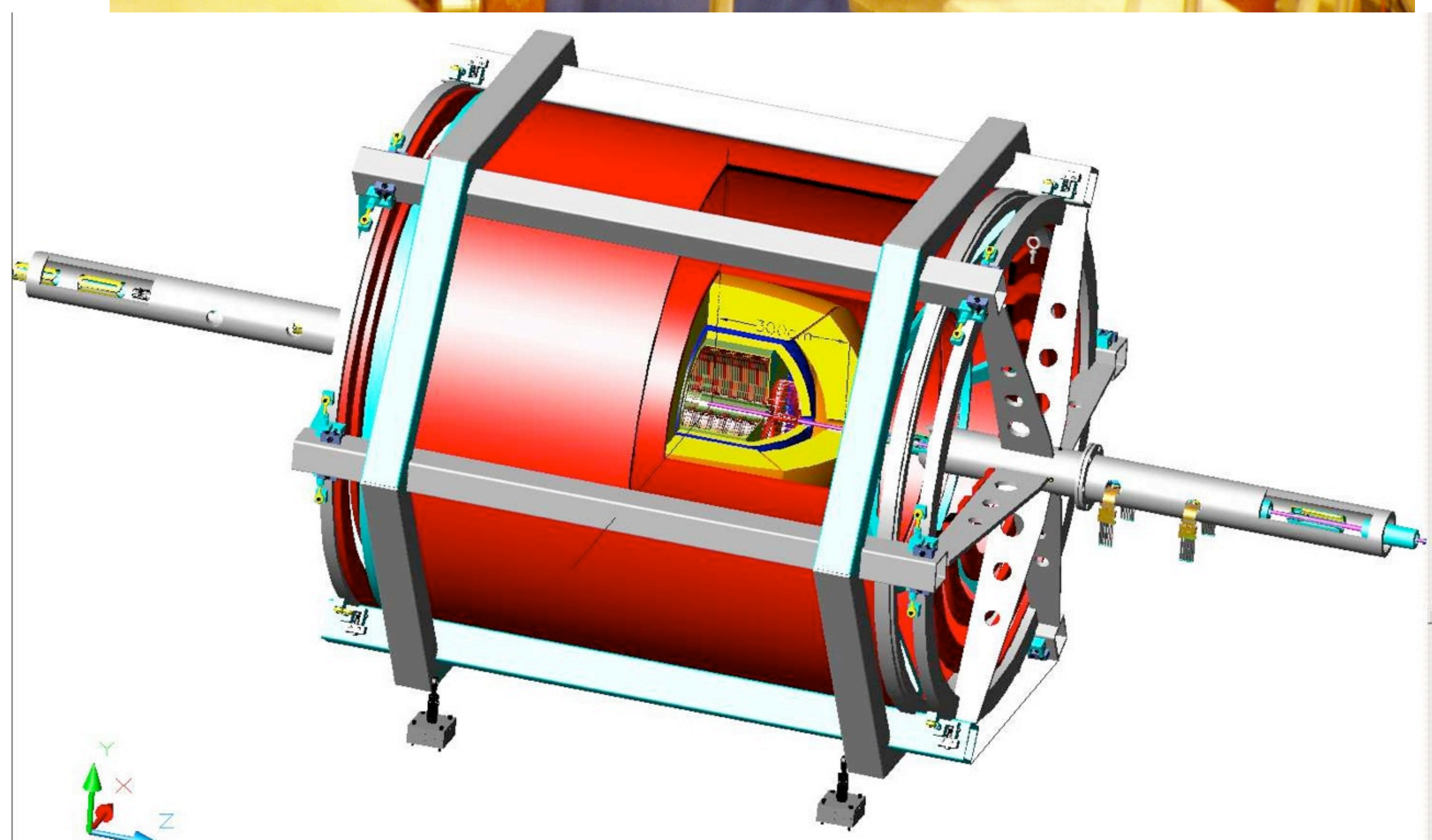
DREAM: Structure





- *Some characteristics of the DREAM detector*
  - Depth 200 cm (10.0 λ_{int})
  - Effective radius 16.2 cm (0.81 λ_{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



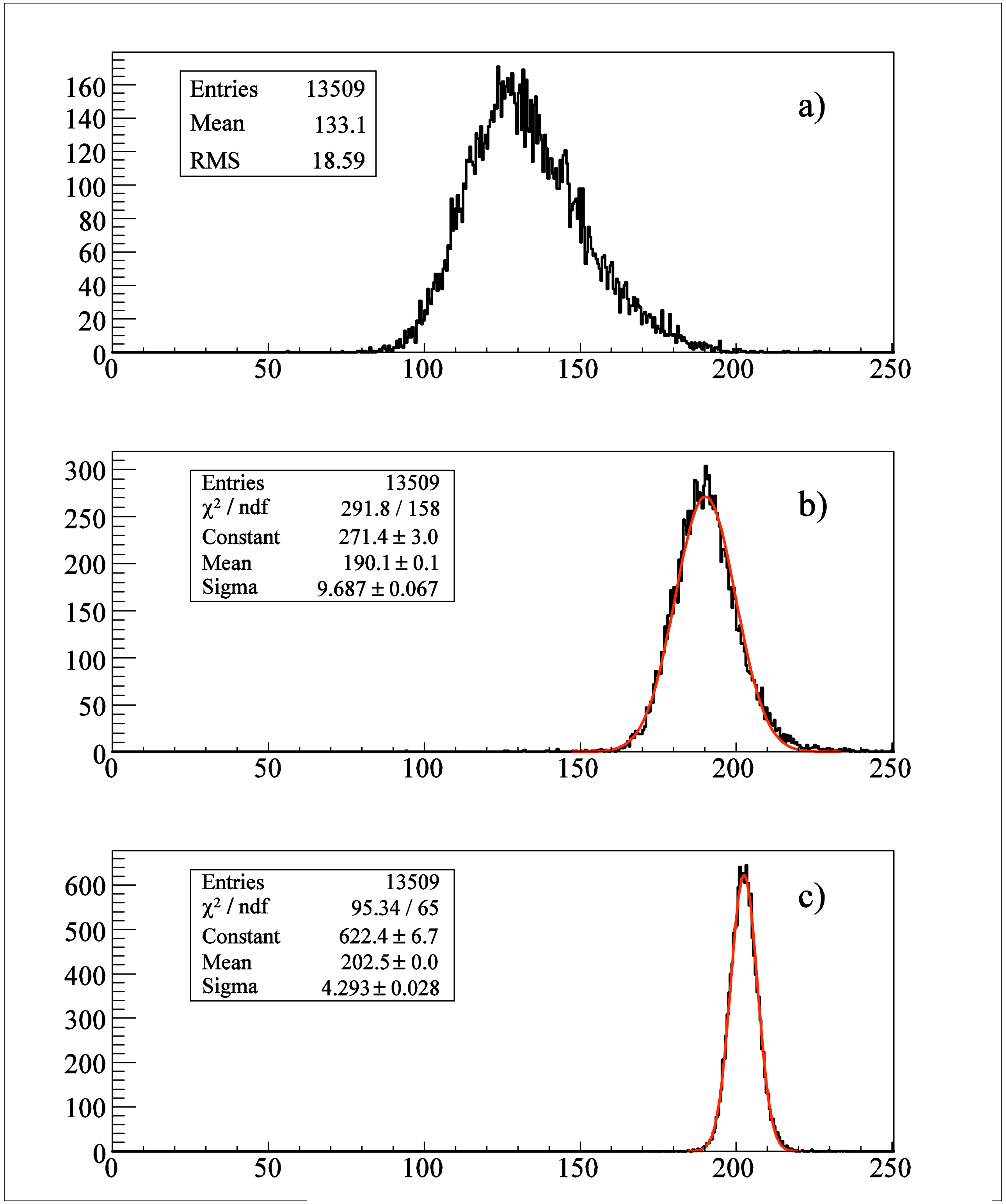


- Fiber dual readout well established, in both data and simulation;
- see Anna Mazzacane (Weds. pm) and Corrado Gatto (Mon. and also this session) and nine NIM papers (we plan four more).

This talk:

- measurement of neutrons in hadronic showers
- dual readout of scintillation and Cerenkov light in a BGO crystal

DREAM data 200 GeV π^-: Energy response



Scintillating fibers only

Scintillation + Cerenkov fibers

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

(4% leakage fluctuations)

Scint + Cerenkov

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

(suppresses leakage)

Data NIM A537 (2005) 537.

Neutrons linger in time: SPACAL 16 year ago; basis for "compensation"

Particle ID does NOT require segmentation!

e/π separation using time structure signals

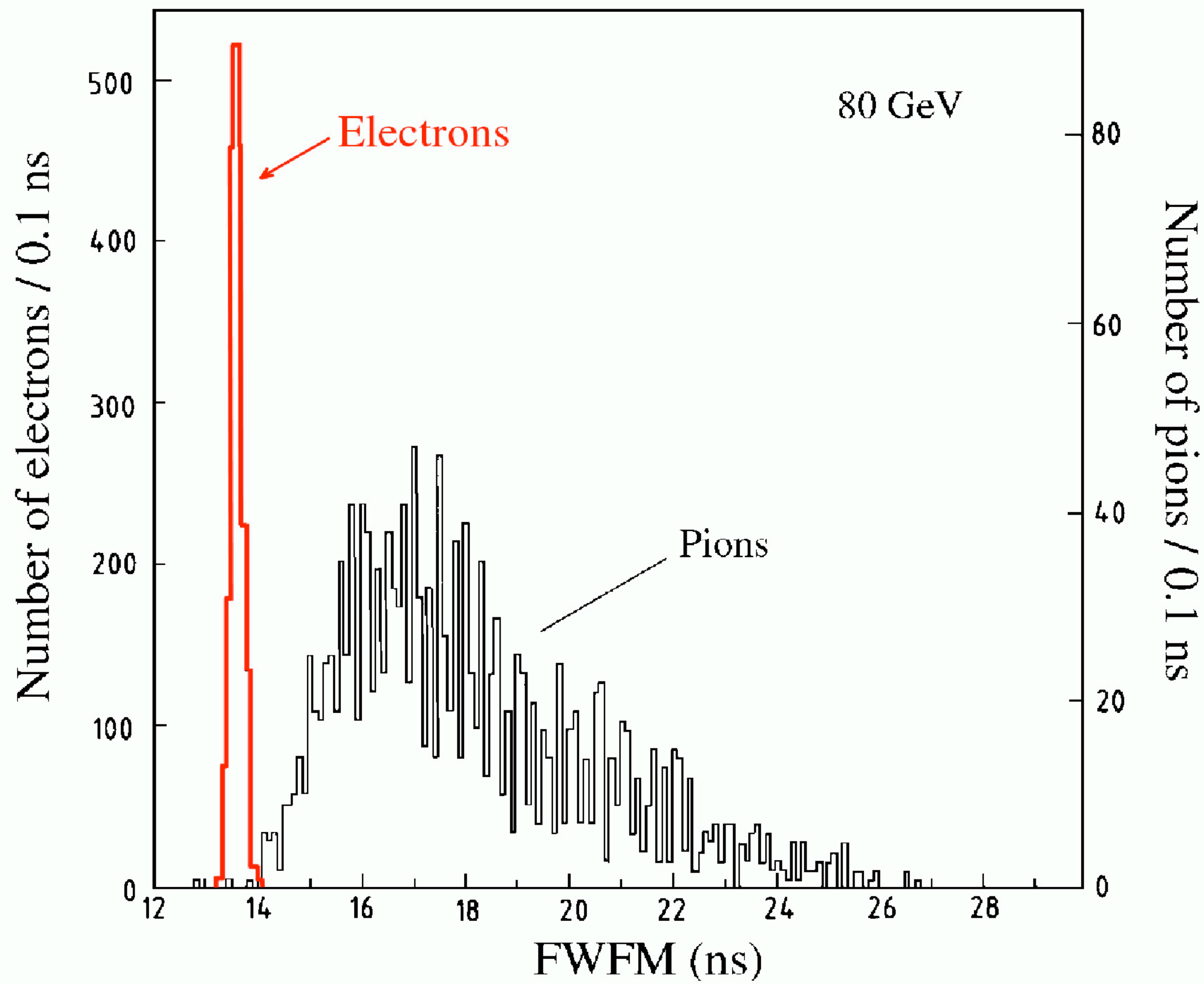
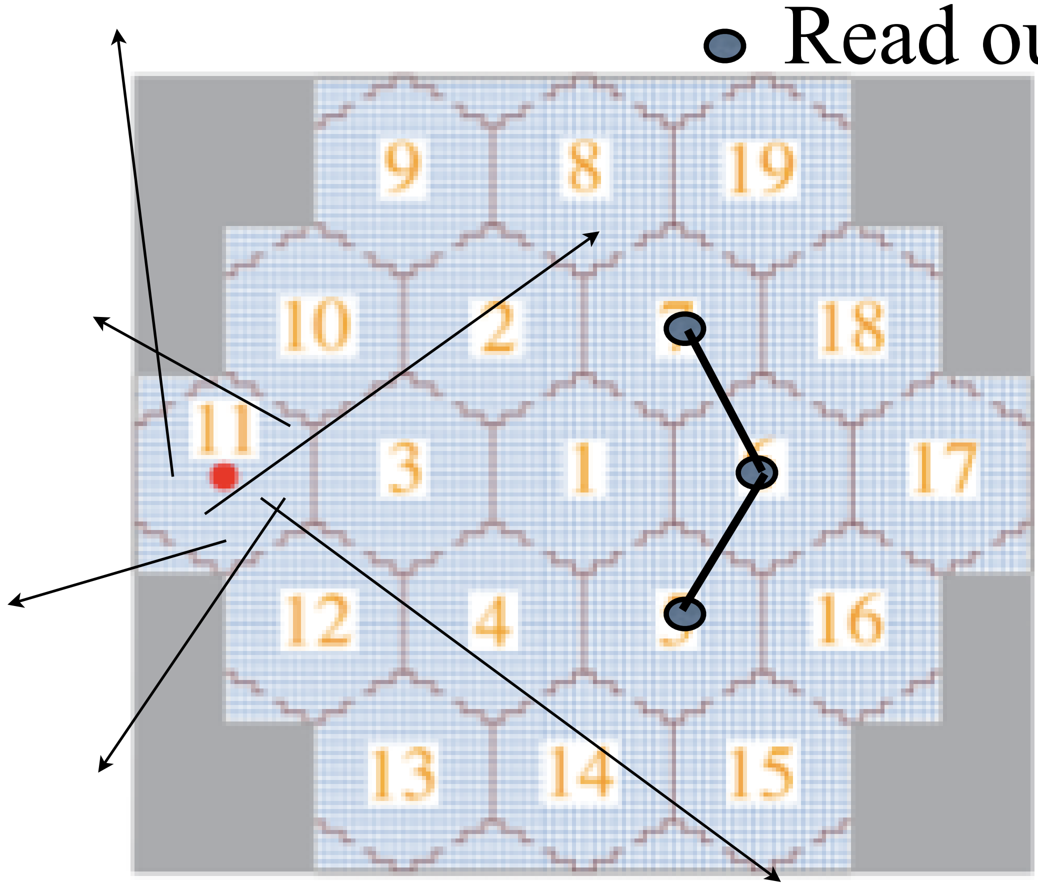


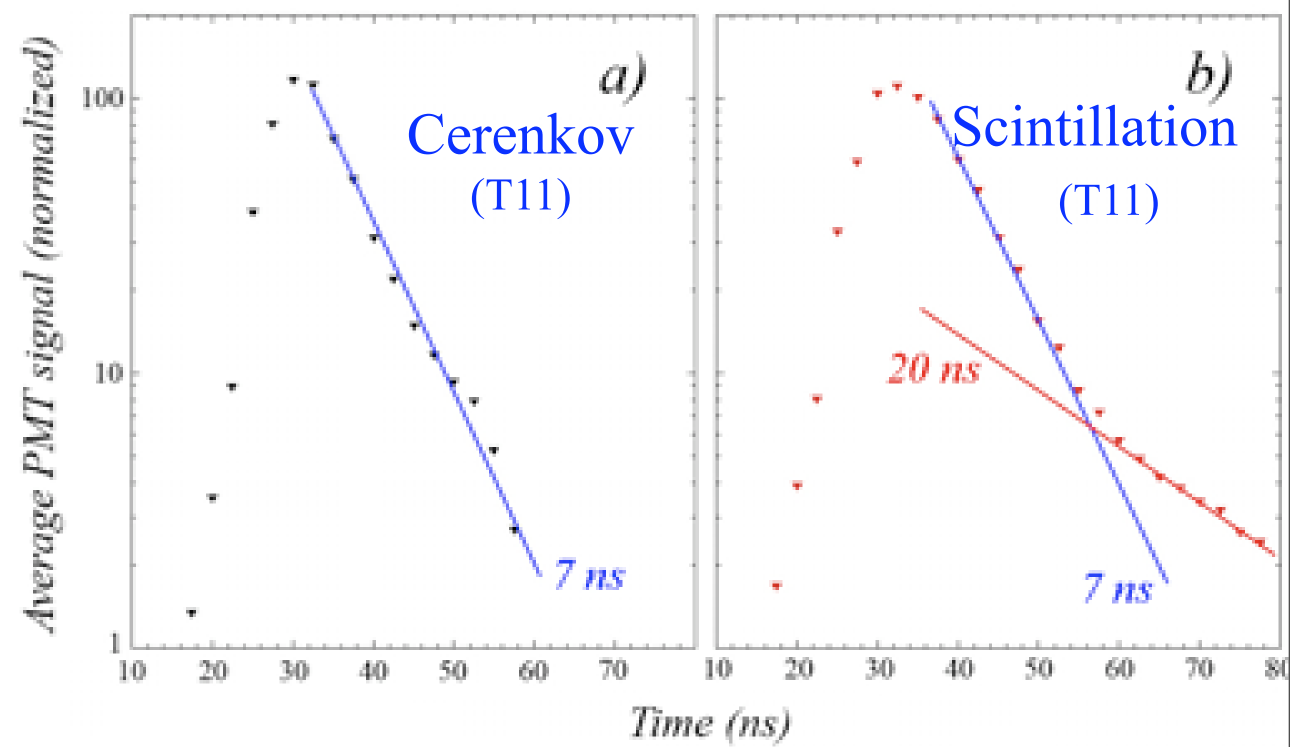
FIG. 7.33. The distribution of the full width at one-fifth maximum (FWFM) for 80 GeV electron and pion signals in SPACAL [Aco 91a].

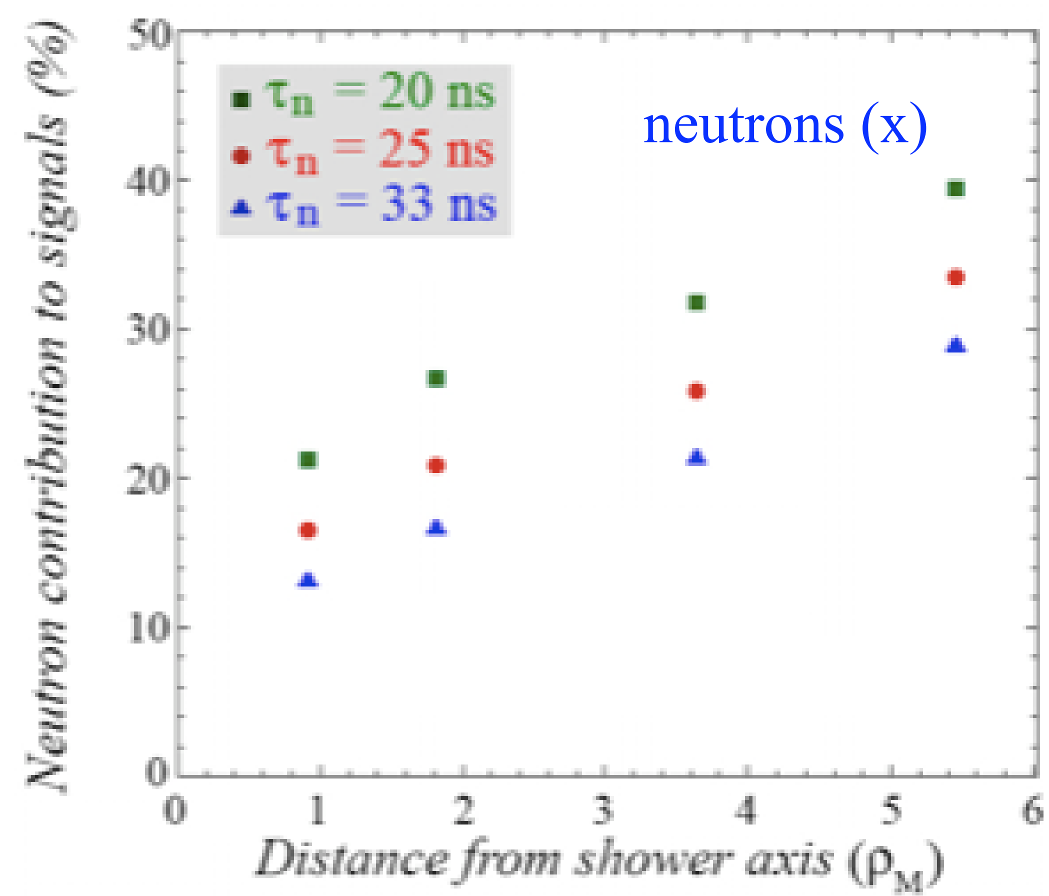
Differential measurement: individual channels in r and t

- 300 GeV pions into tower 11
- read out channels 10-3-12, 2-1-4, 5-6- into GHz digital storage scope.



Read out in time; dN/dr dt

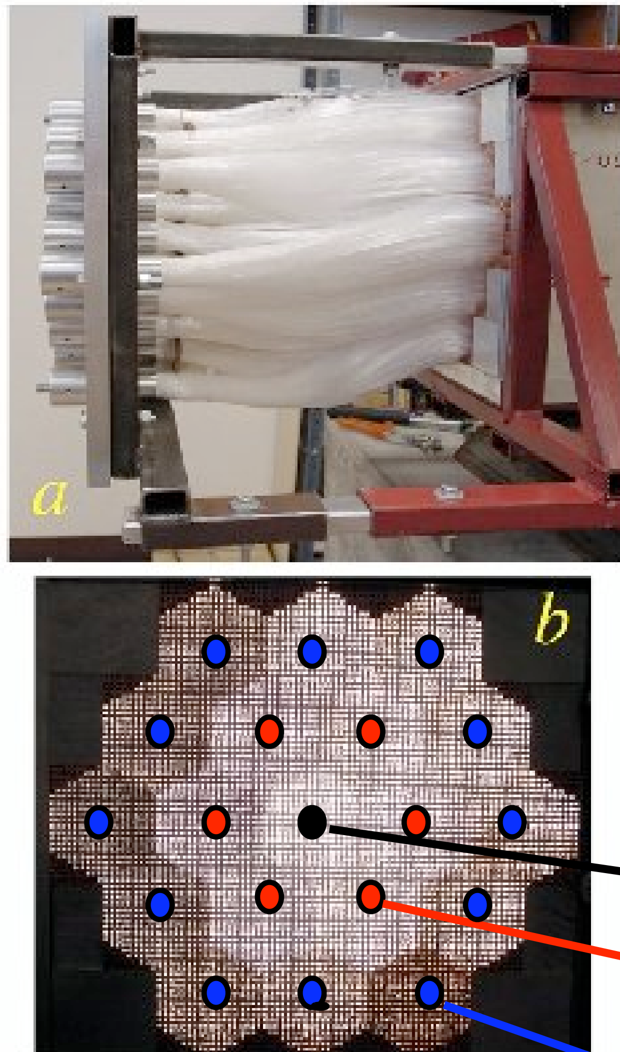




Most MeV neutrons escape the DREAM
mean free path ~ 30 cm at 8 MeV;
we only expect to see abouty 10% of the

Integral measurement: sum all channels in Scint and Cerenkov

Neutron or "hadronic" identification: 50-300 GeV pions



DAQ was 1 GHz 4-chan digital storage scope

transfer to counting house in fast air-core cables

Scintillating fibers

"Fast 1"

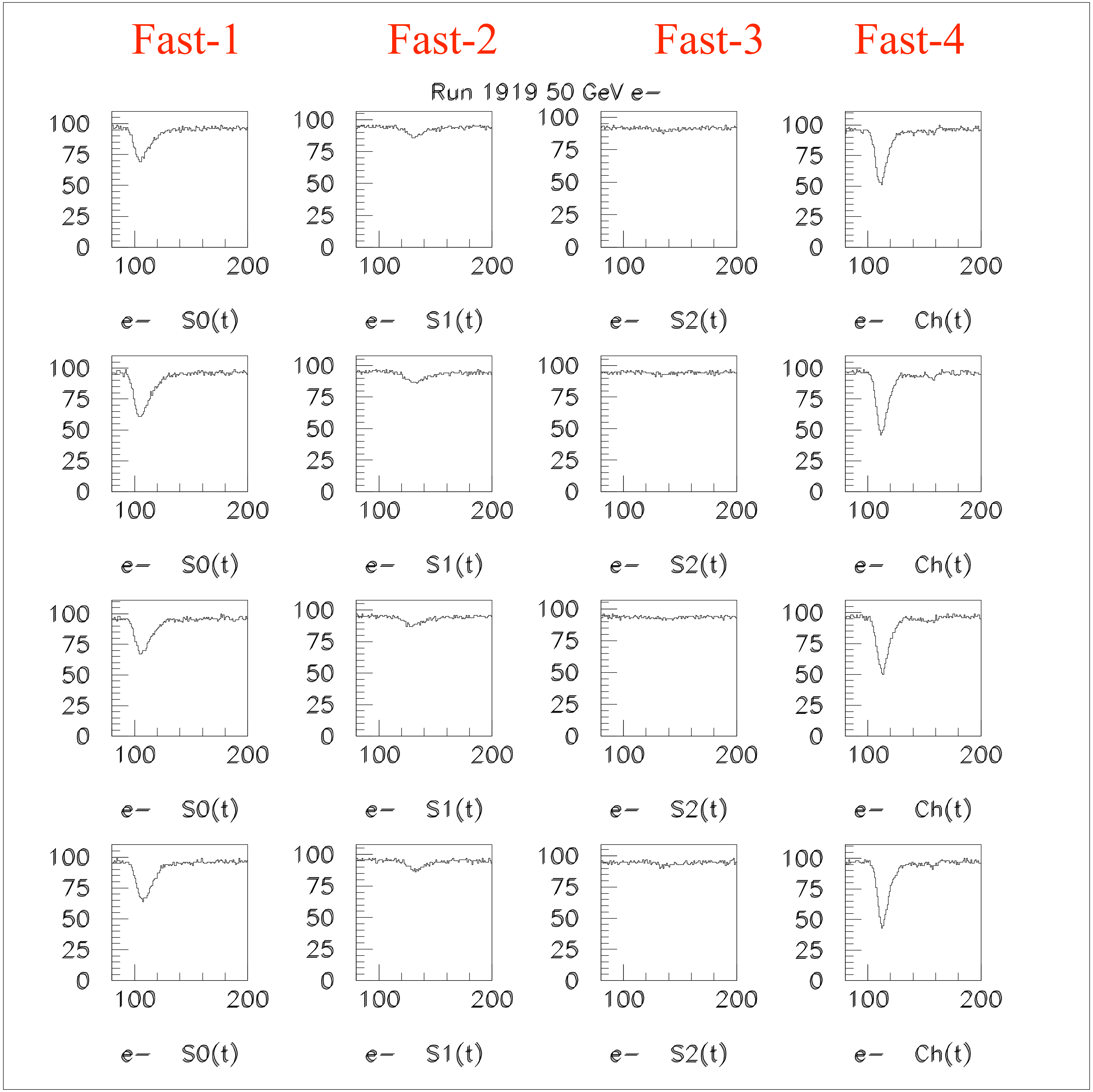
"Fast 2"

"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.



First 4 raw data events

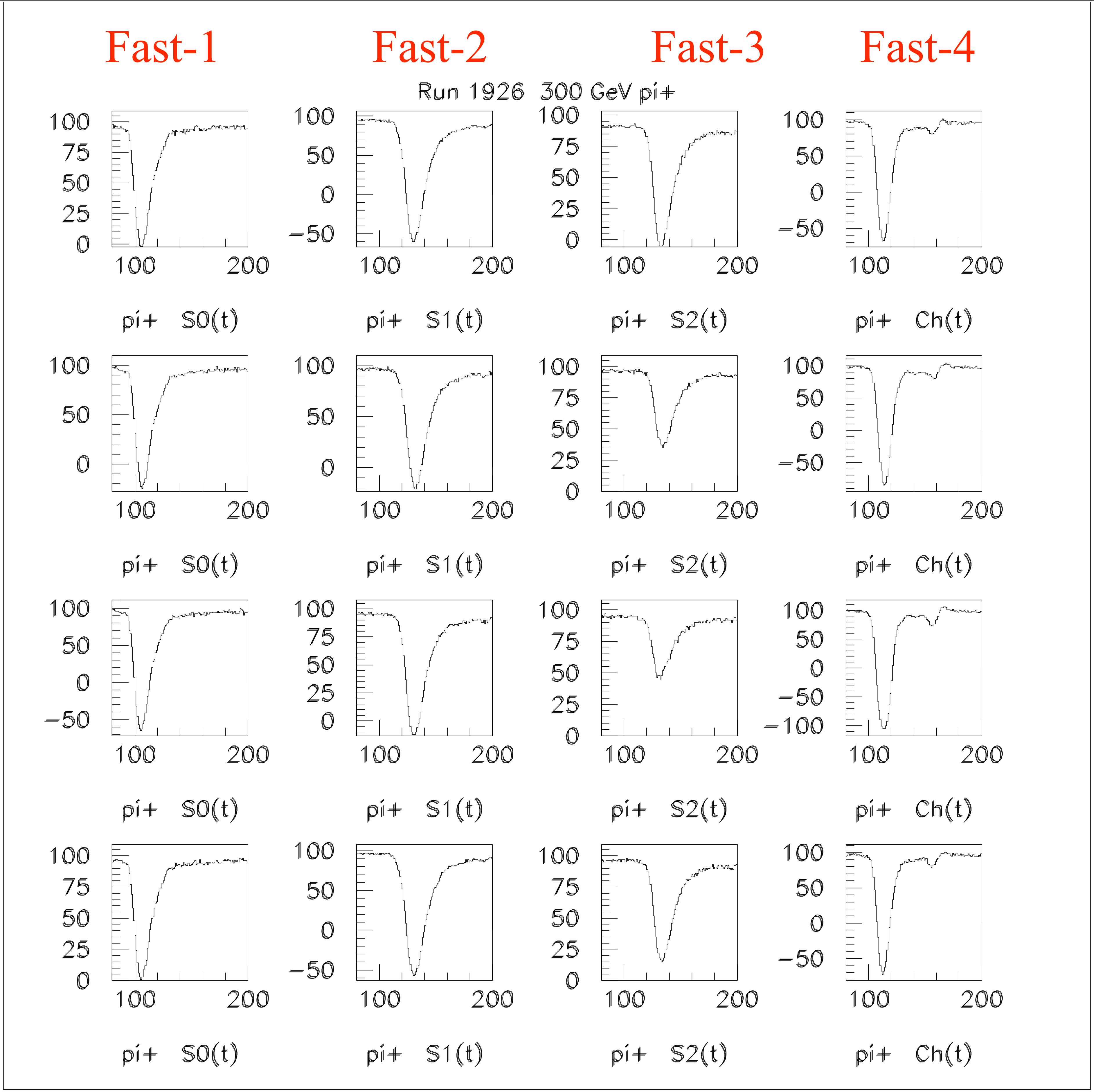
1

2

3

4

clearly electrons



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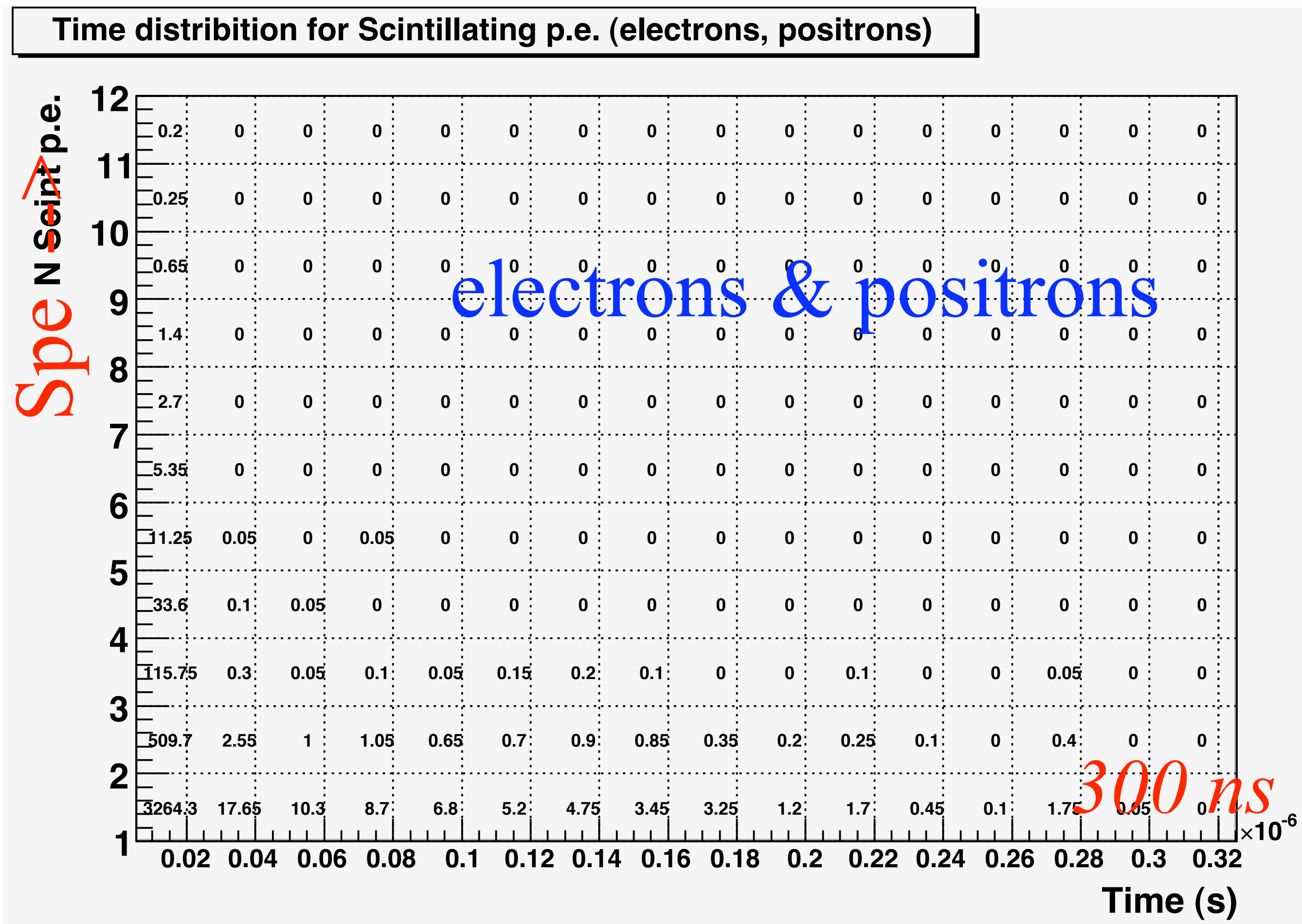
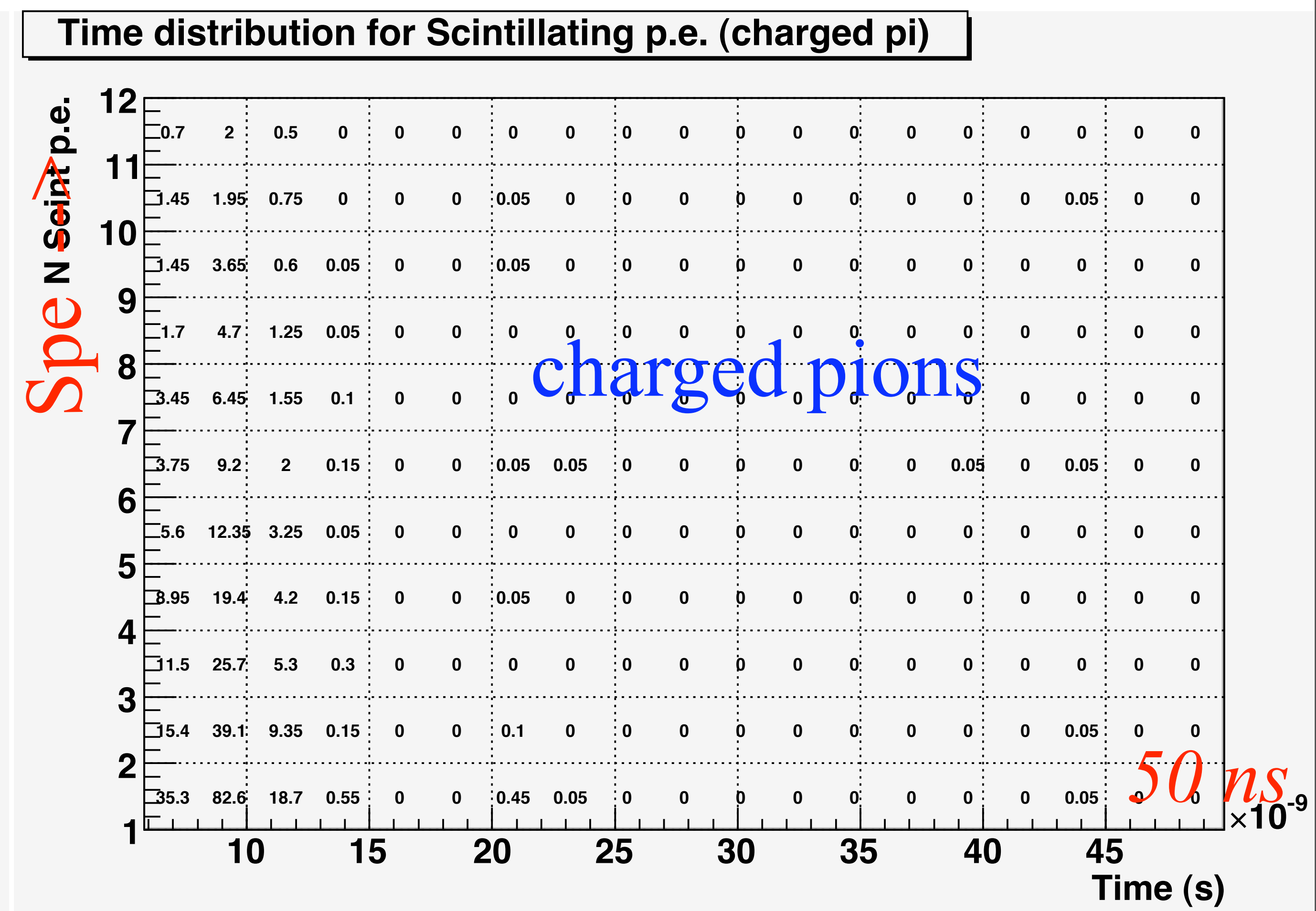
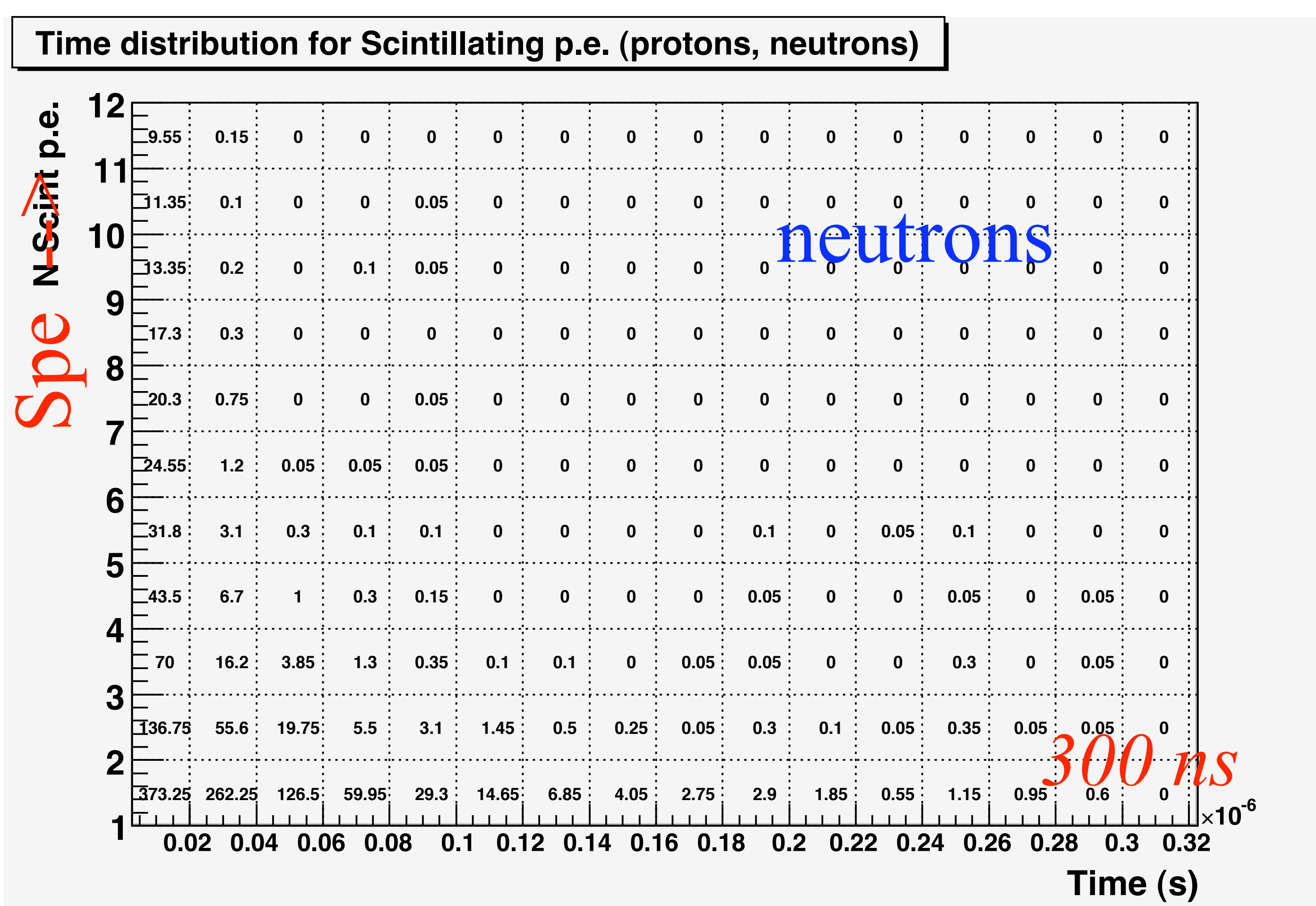
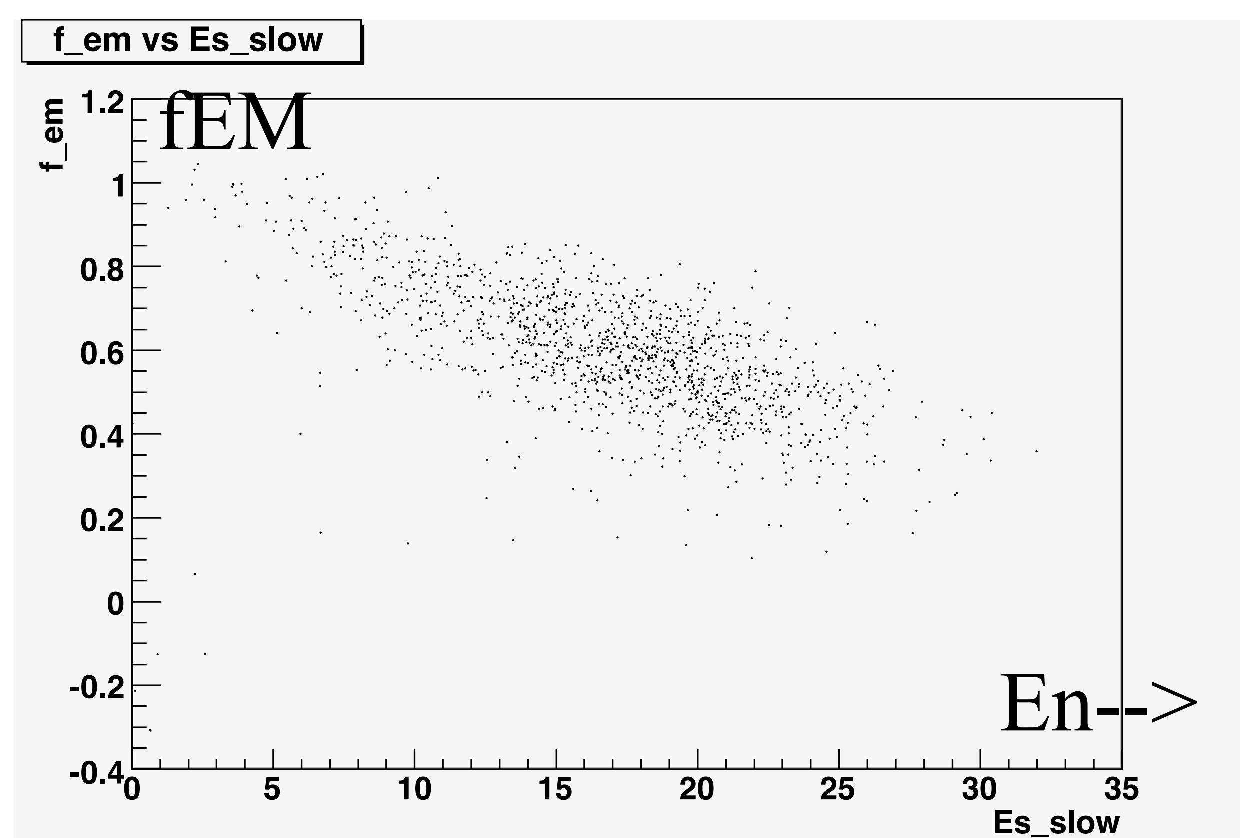




FLUKA simulation in ILCroot

e's and pi's are finished with quickly; neutrons persist out to ~200 ns



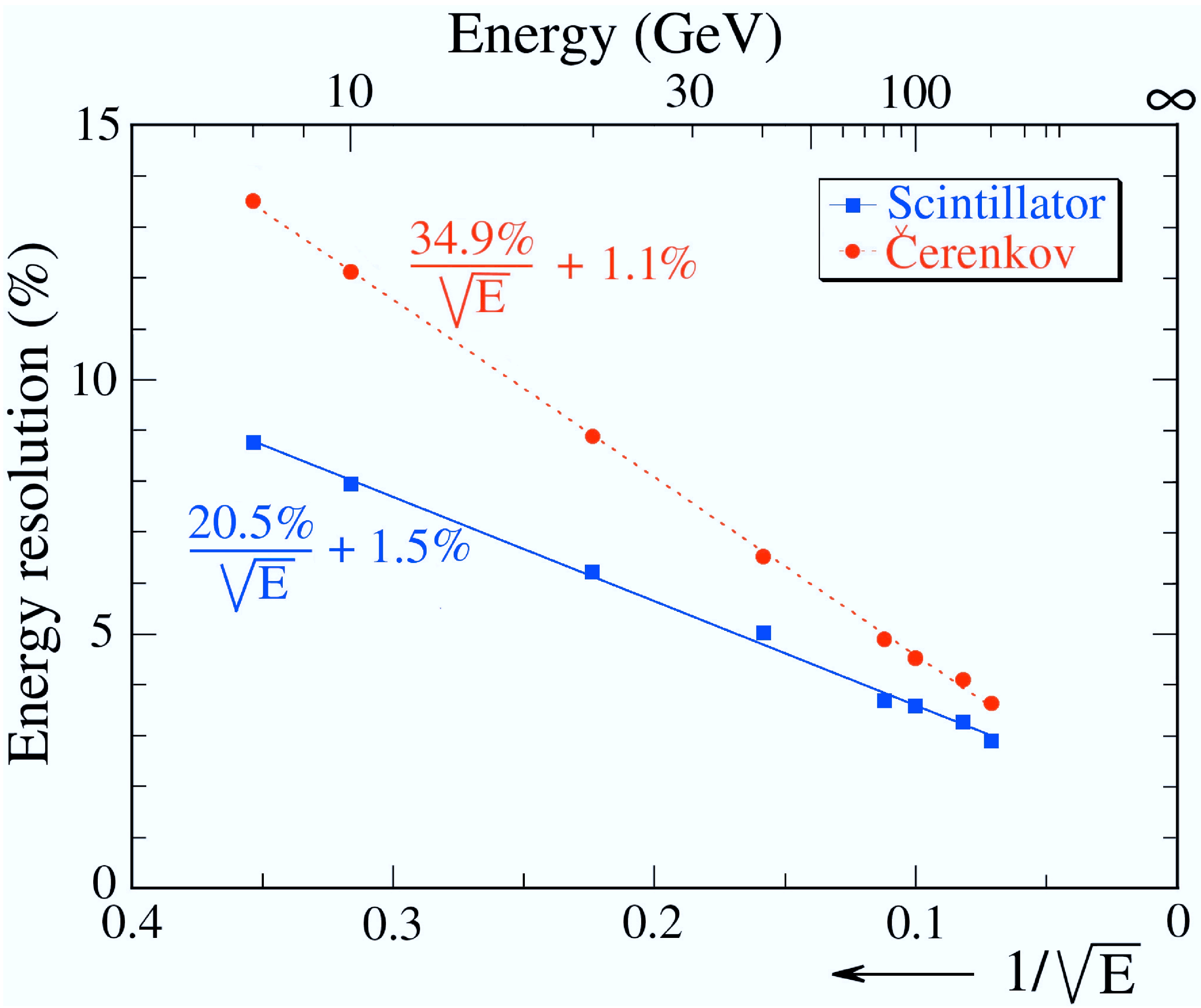


Improve EM resolution and segmentation for photons and $\tau^- \to \rho^- \nu \to \pi^- \pi^0 \nu \to \pi^- \gamma\gamma\nu$

- Fibers limit Cerenkov pe yield;
- A continuous medium, e.g. crystal or glass, is not so restricted; try PbWO4 (free), then try BGO (free);
- Devise schemes for dual readout of scintillation and Cerenkov light in crystal;
- Solves problem of good electron/gamma measurement; in 4th design as a "front end" calorimeter, also dual readout (i.e., "hadronic capable").
- Finer transverse segmentation

These are all ideas from Wigmans.

Electron energy resolution independently in Cerenkov and Scintillator fibers

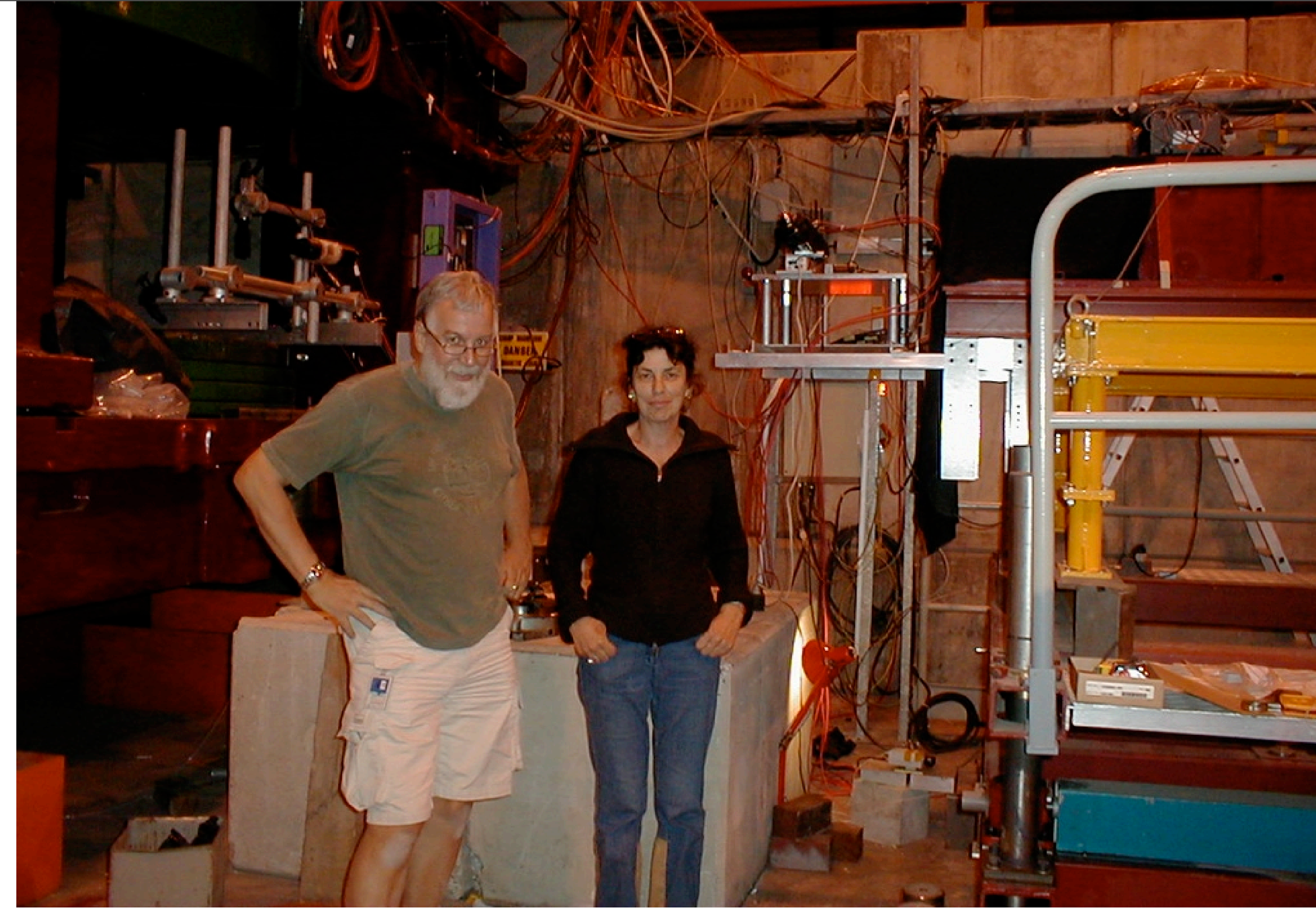


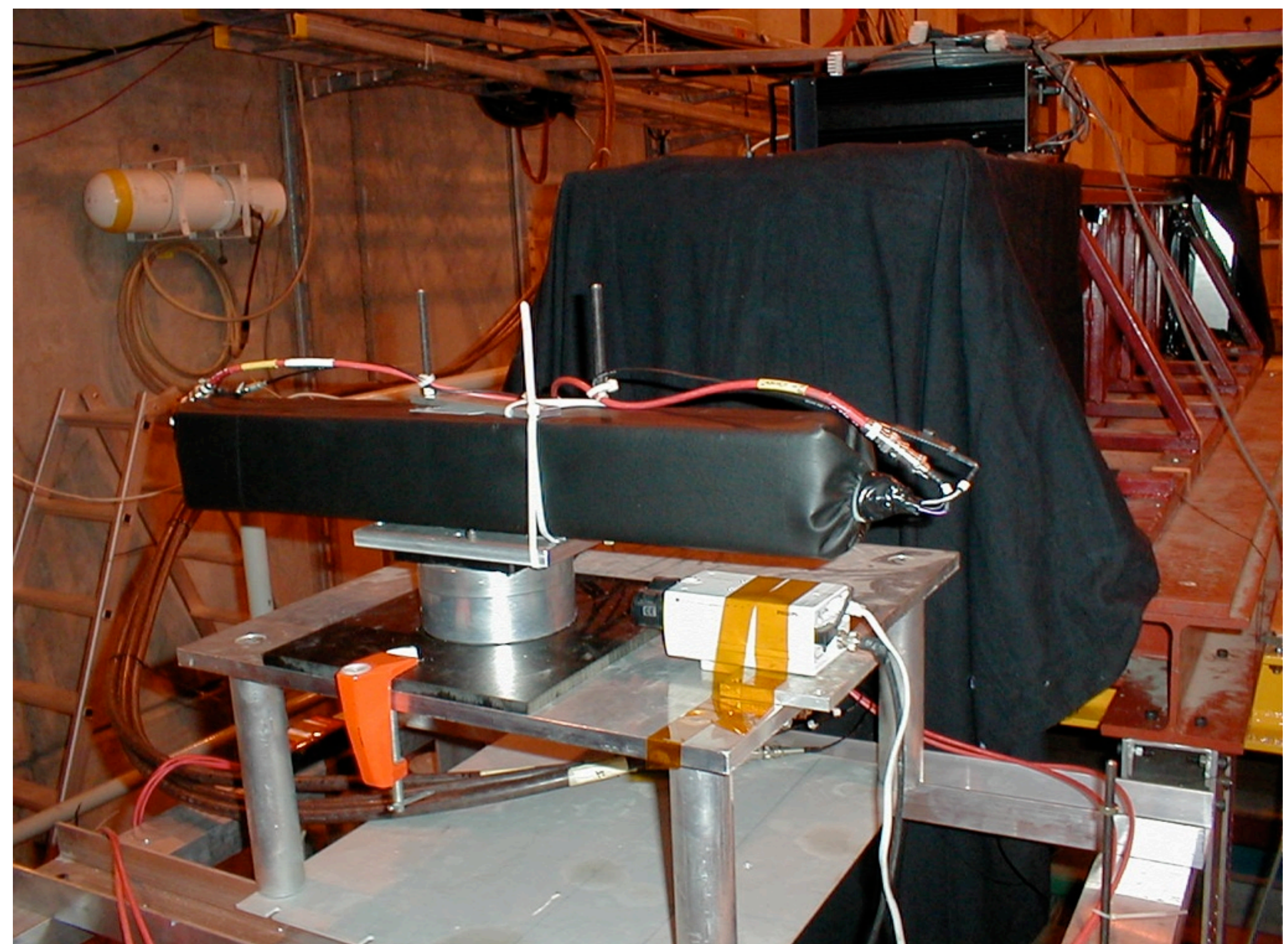
- Cerenkov limited by photoelectron statistics: ~8pe/GeV gives resolution of 35%/√E
- Limits EM fraction resolution
- Limits hadronic resolution

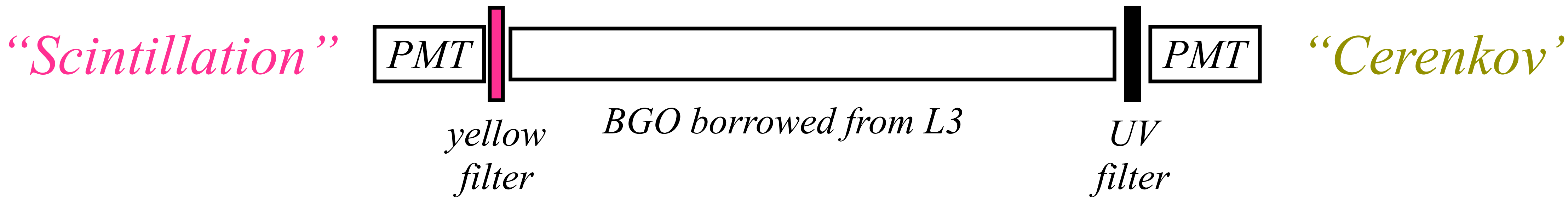
$$C/S = \frac{f_{em} + (1 - f_{em})/\eta_C}{f_{em} + (1 - f_{em})/\eta_S}$$

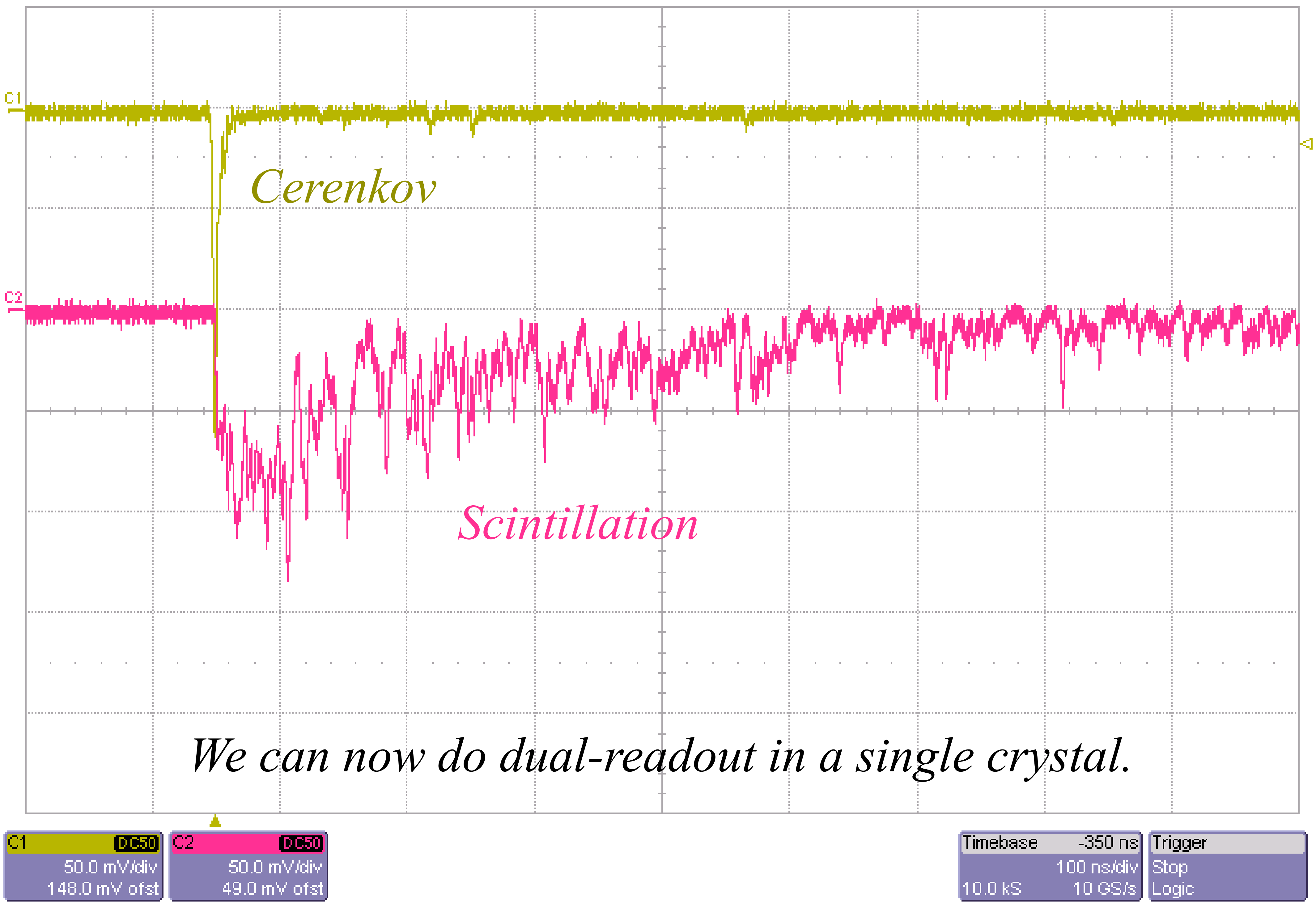
Dual-readout of BGO crystals

BGO crystal, its housing, and in the beam in front of DREAM module







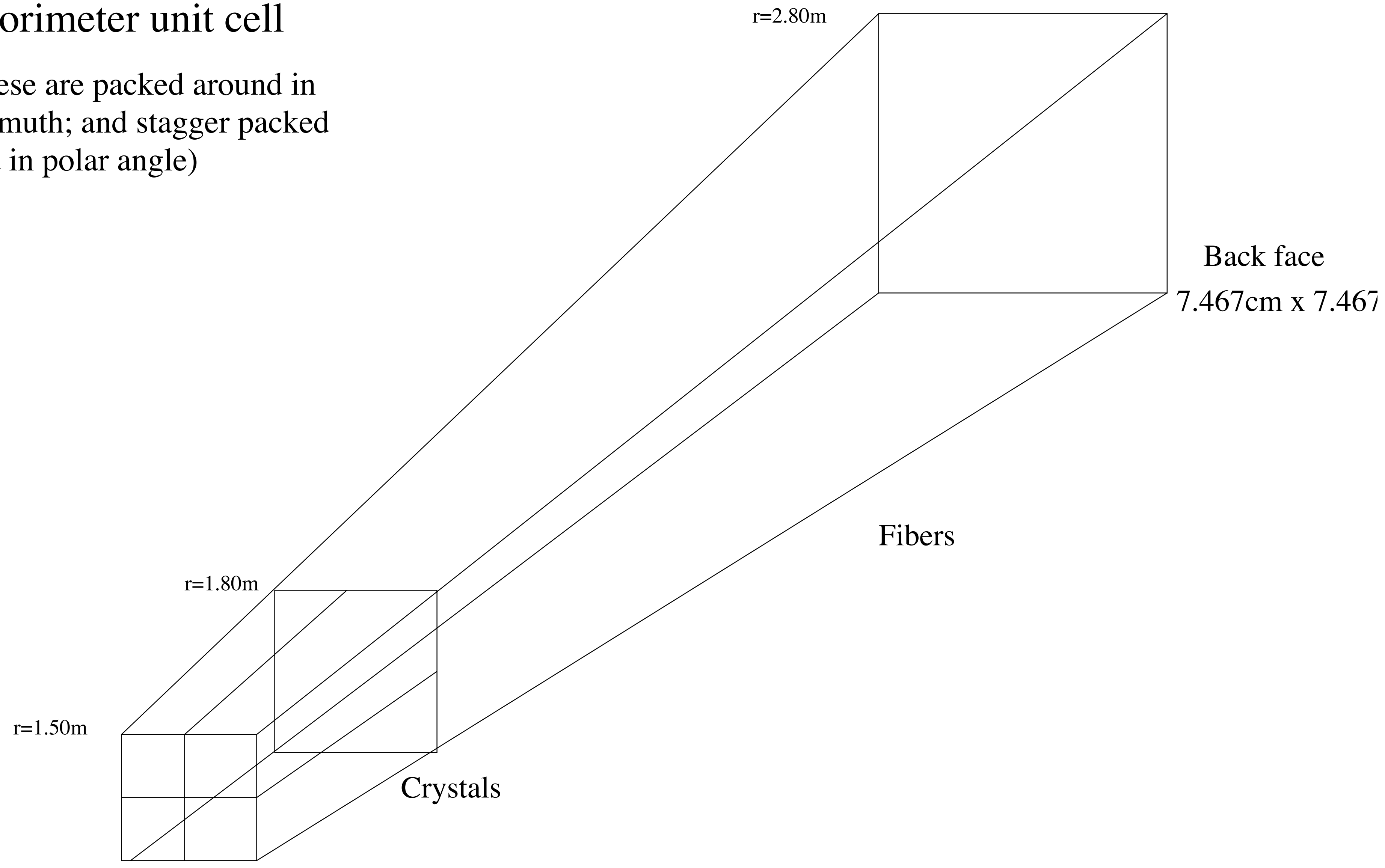


Data from A. Cardini

4th Concept calorimeter configuration

Calorimeter unit cell

(these are packed around in azimuth; and stagger packed out in polar angle)



Front face is 4cm x 4cm

Crystals are 2cm x 2cm x 30cm

A “scalable” module; excellent electron & photon measurement; excellent hadron measurement.

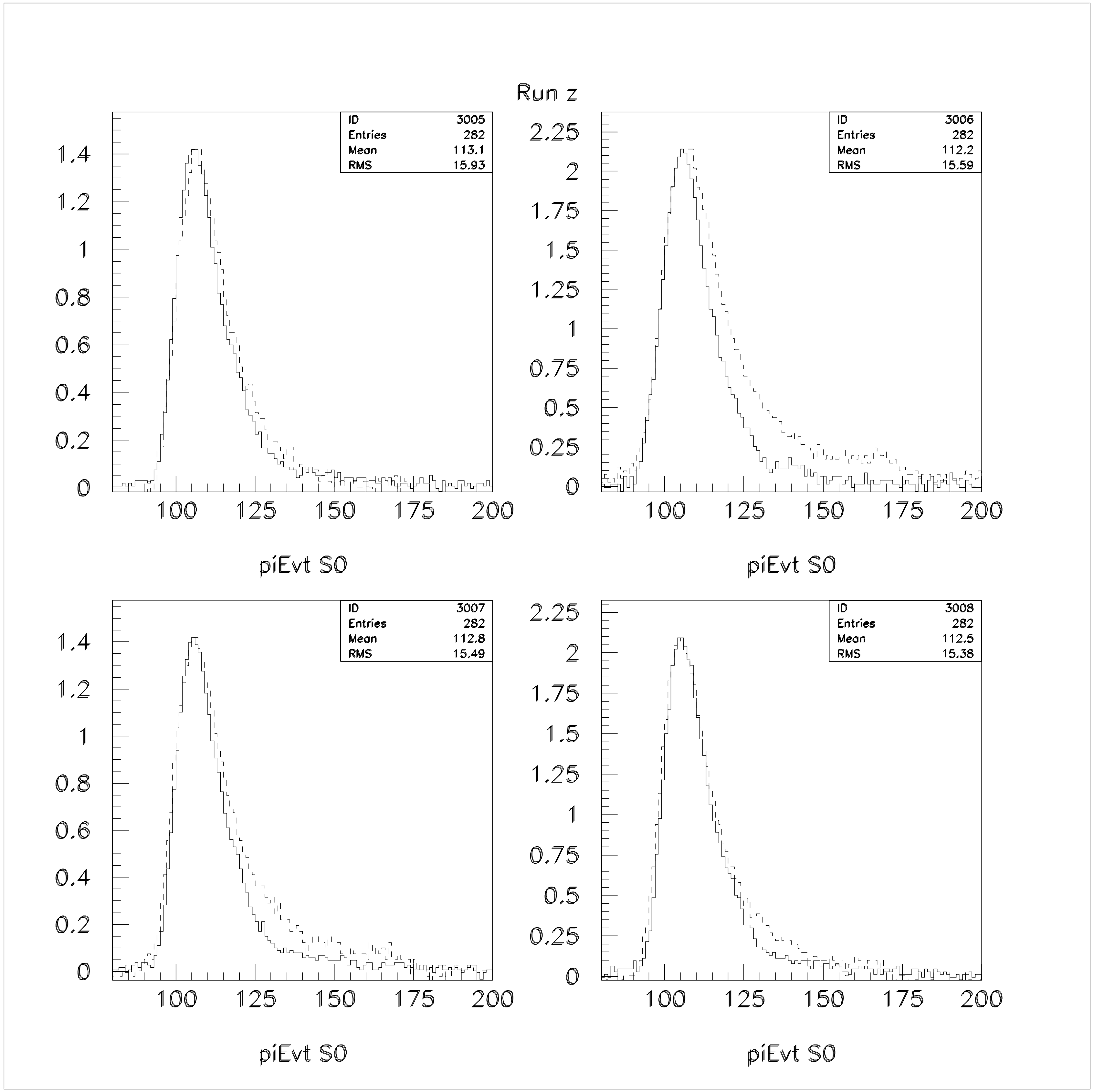
These are proof-of-principle tests for the event-by-event

- measurement of neutrons in a fiber dual readout calorimeter

- dual readout of a crystal

Both are incorporated immediately into ILCroot;
see C. Gatto, next talk.

Extras



S0 - S2 pulses:

S0 ~ n x 1
S2 ~ n x 12

neutrons are hard but measureable