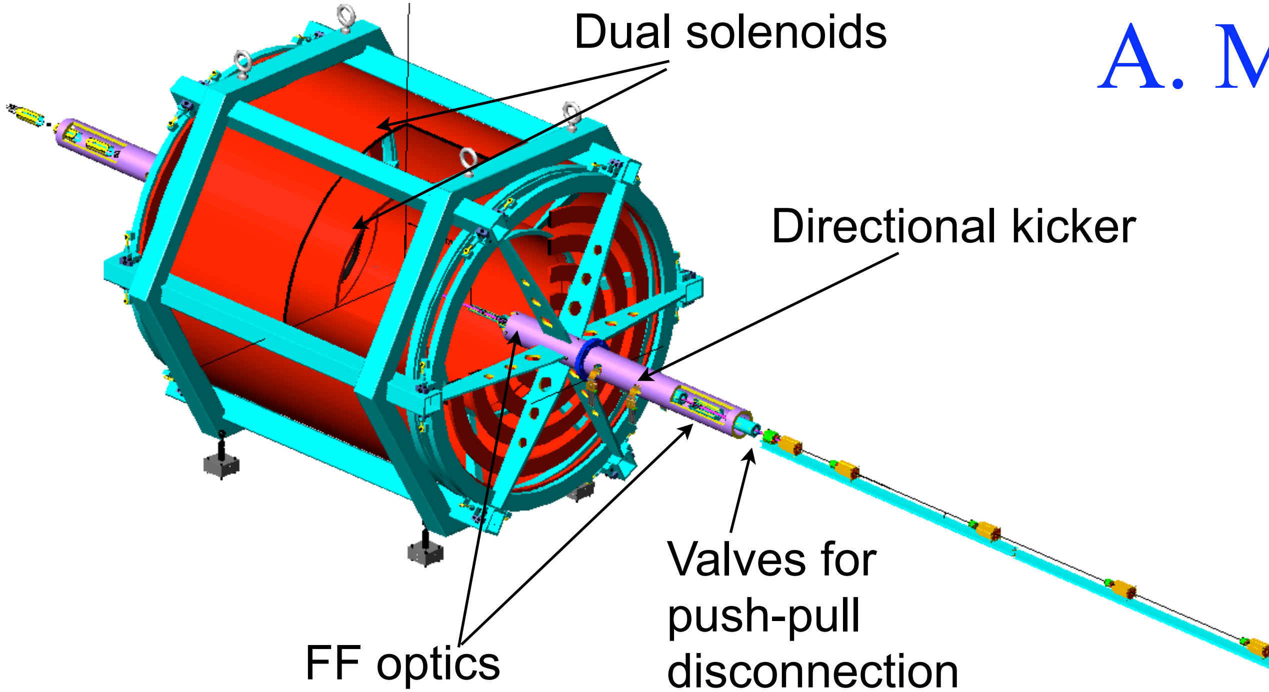
4th Concept Test Beam "plans"

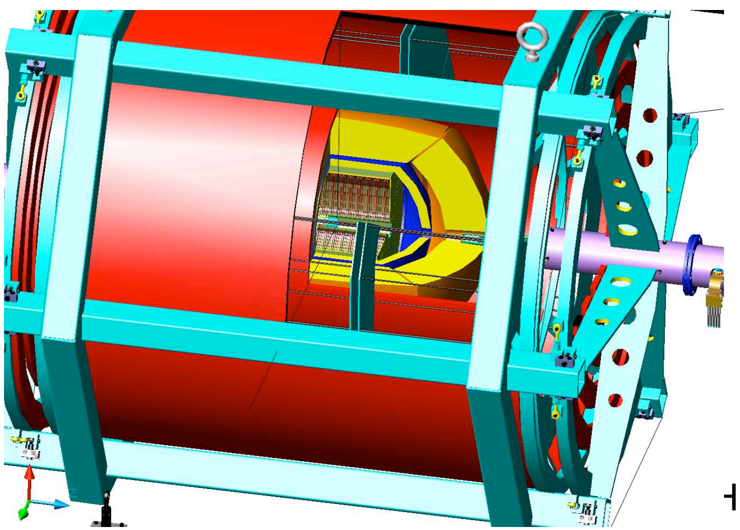
- Brief view of concept
- We have submitted an LCRD proposal to take the DREAM module to the next step in calorimetry, what we call "ultimate calorimetry", going from "dual readout" (scintillation and Cerenkov) to include the MeV neutrons that are correlated with binding energy loss fluctuations.
- Completely "scalable" modules.
- We are not without our problems.

A. Mikhailichenko

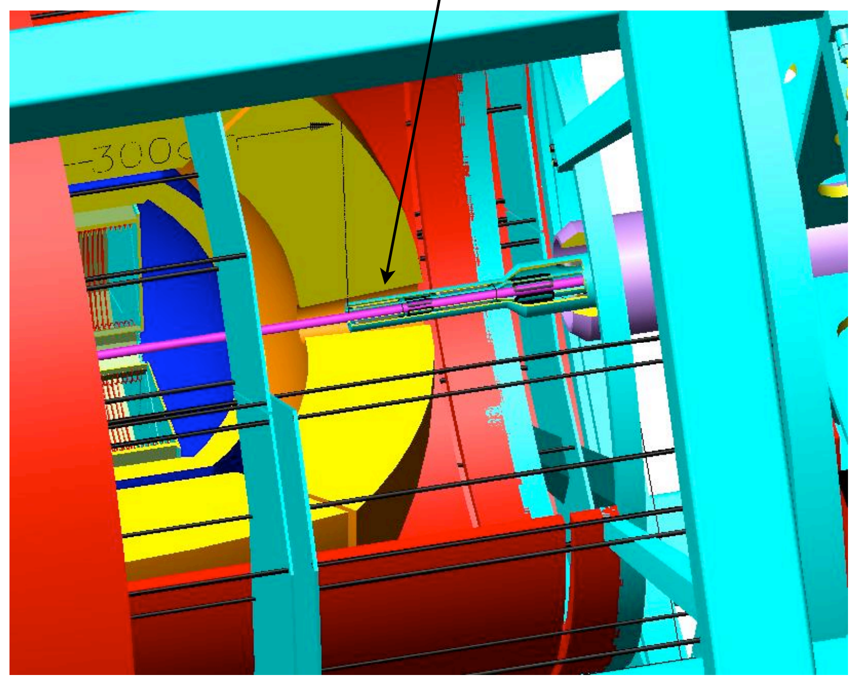


Final focus optics, mounted inside a cylinder attached to the detector by consoles.

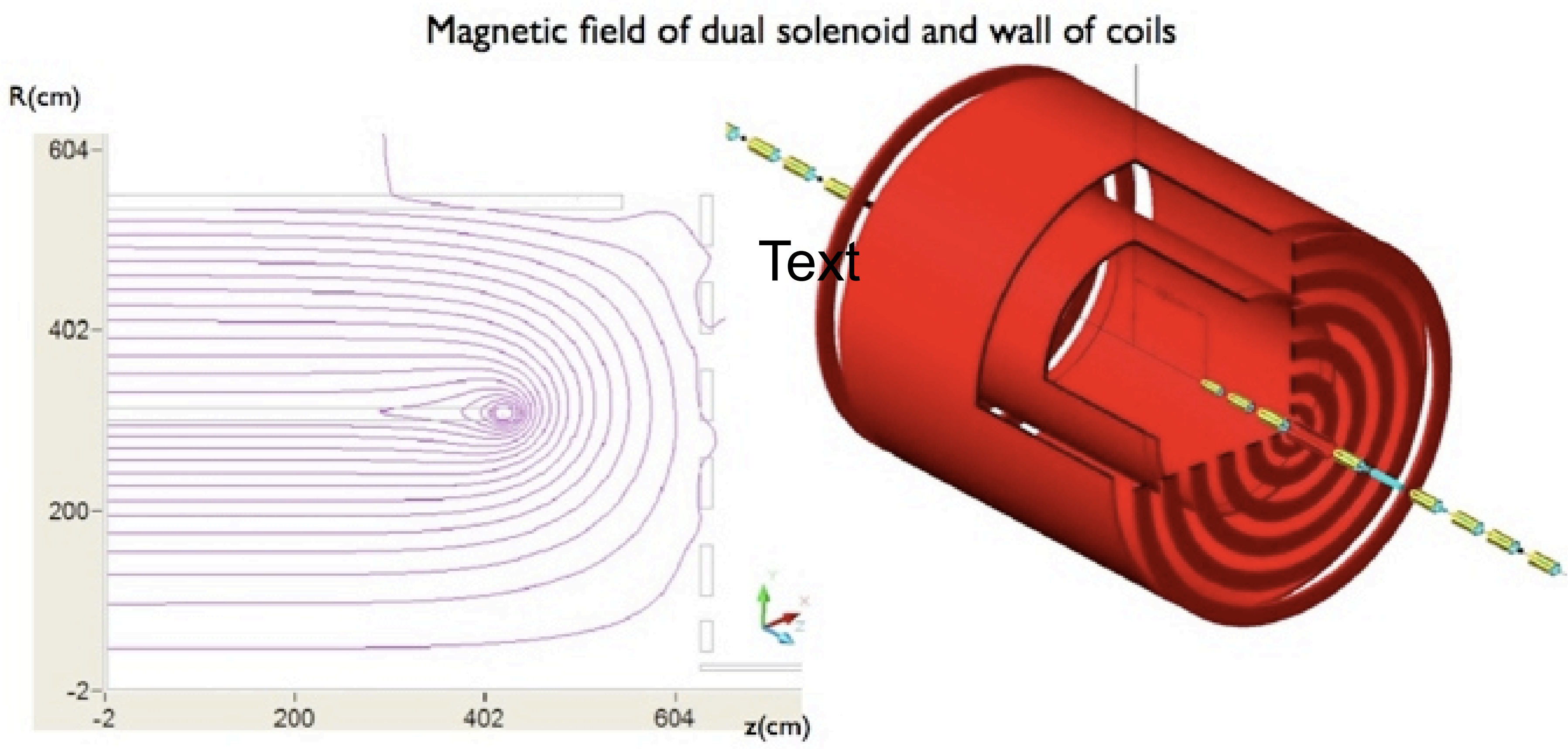
This reduces influence of ground motion.



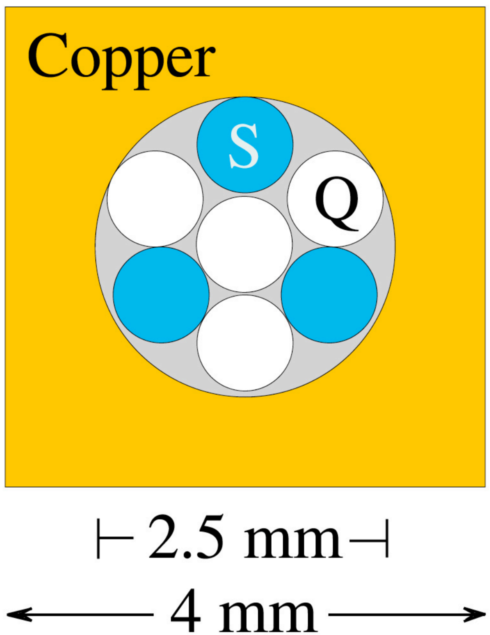
Hauptman



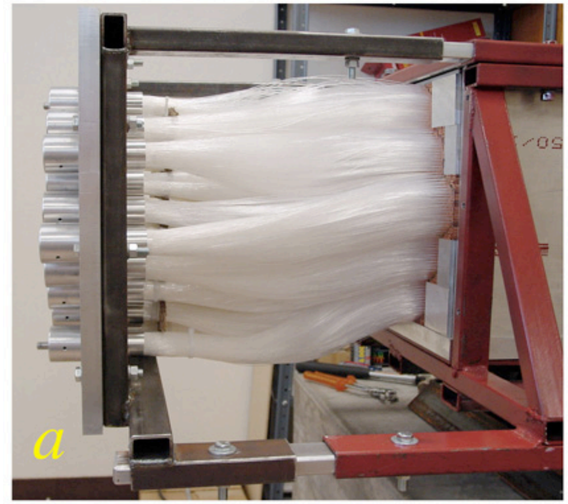
New magnetic field, new ``wall of coils'', iron-free: many benefits to muon detection, machine-detector interface, MDI, physics flexibility, asymmetric energy, etc.



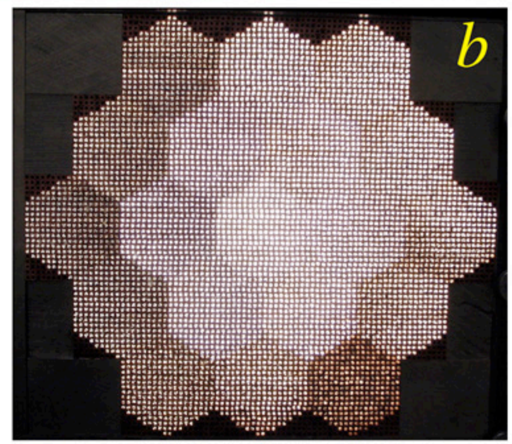
DREAM module: simple, robust, not intended to be "best" at anything, just test dual-readout principle



Back end of 2-meter deep module

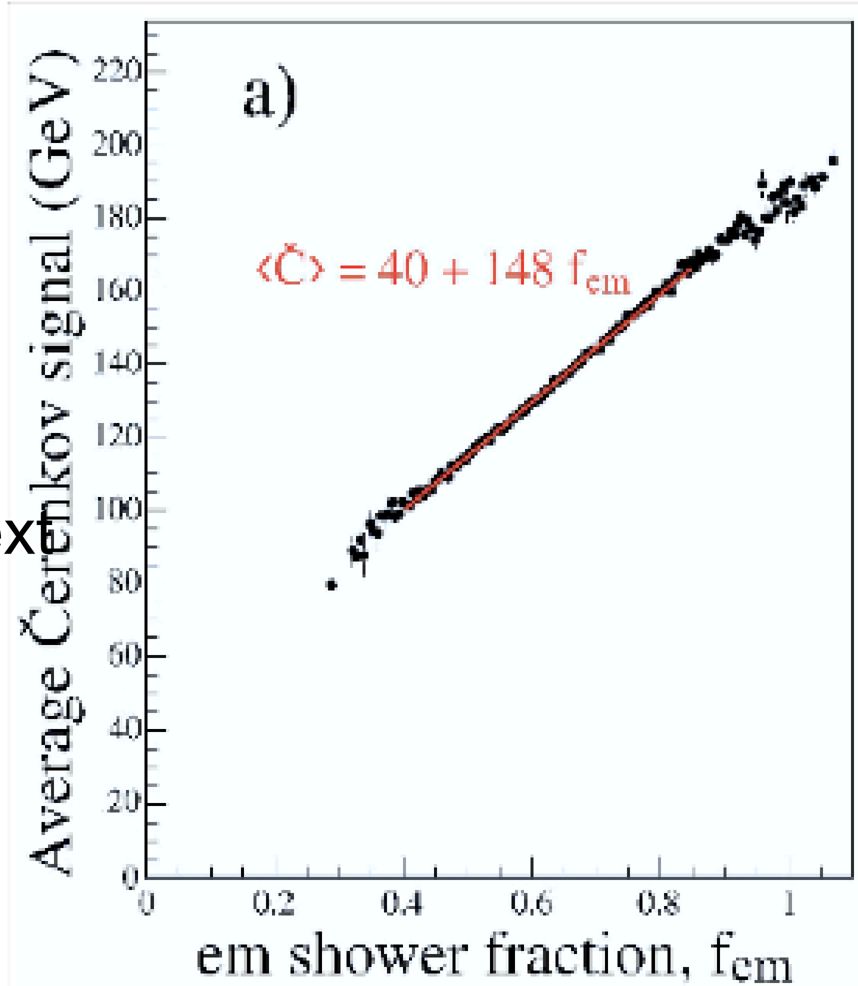


Physical channel structure



Dual-Readout Test Beam:

Measure every shower twice - in scintillation light and in Cerenkov light.



Text

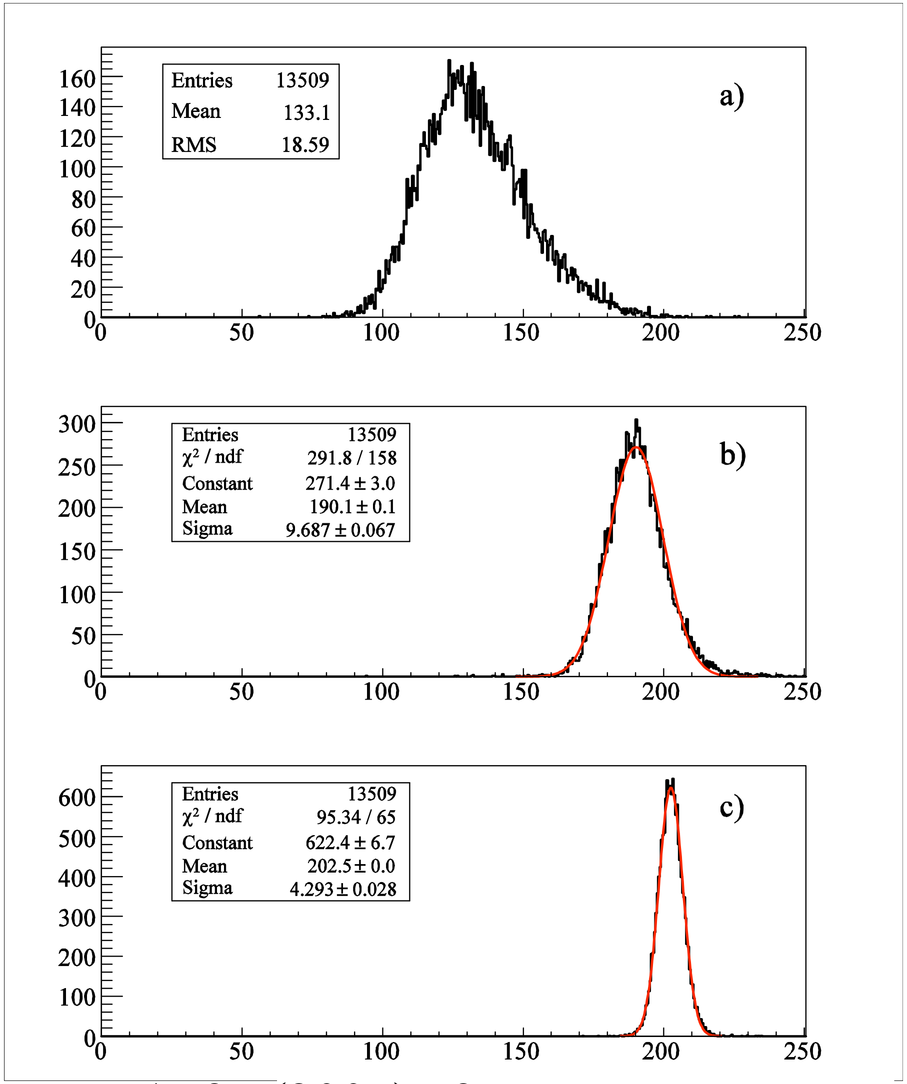
$$(e/h)_C = \eta_C \approx 5$$
$$(e/h)_S = \eta_S \approx 1.4$$

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

$$\rightarrow C/E = 1/\eta_C + f_{em}(1 - 1/\eta_C)$$

Data NIM A537 (2005) 537.

DREAM data 200 GeV π^-: Energy response



Scintillating fibers

Scint + Cerenkov

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

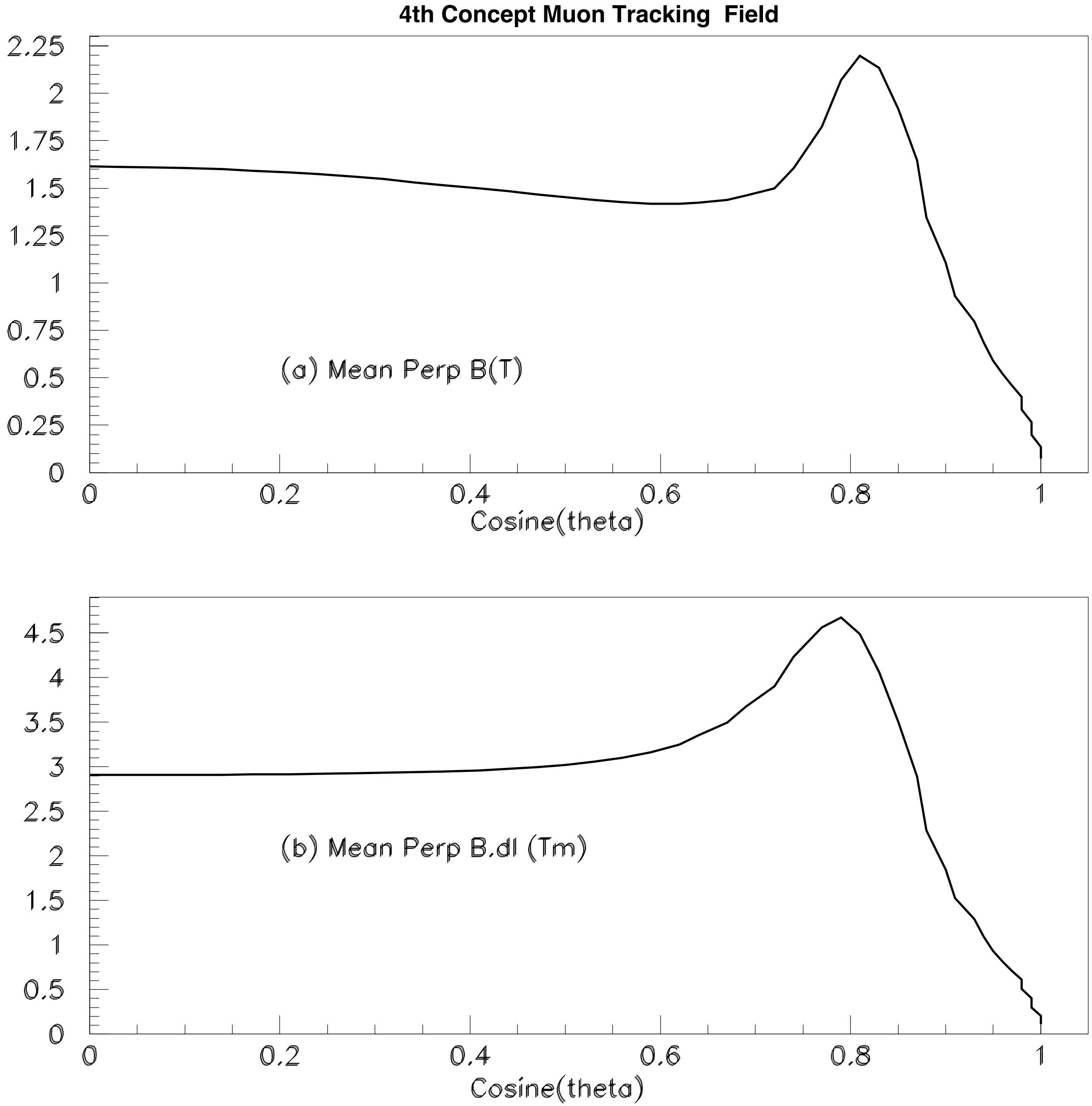
(4% leakage fluctuations)

Scint + Cerenkov

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

(suppresses leakage)

Data NIM A537 (2005) 537.



Dual solenoid

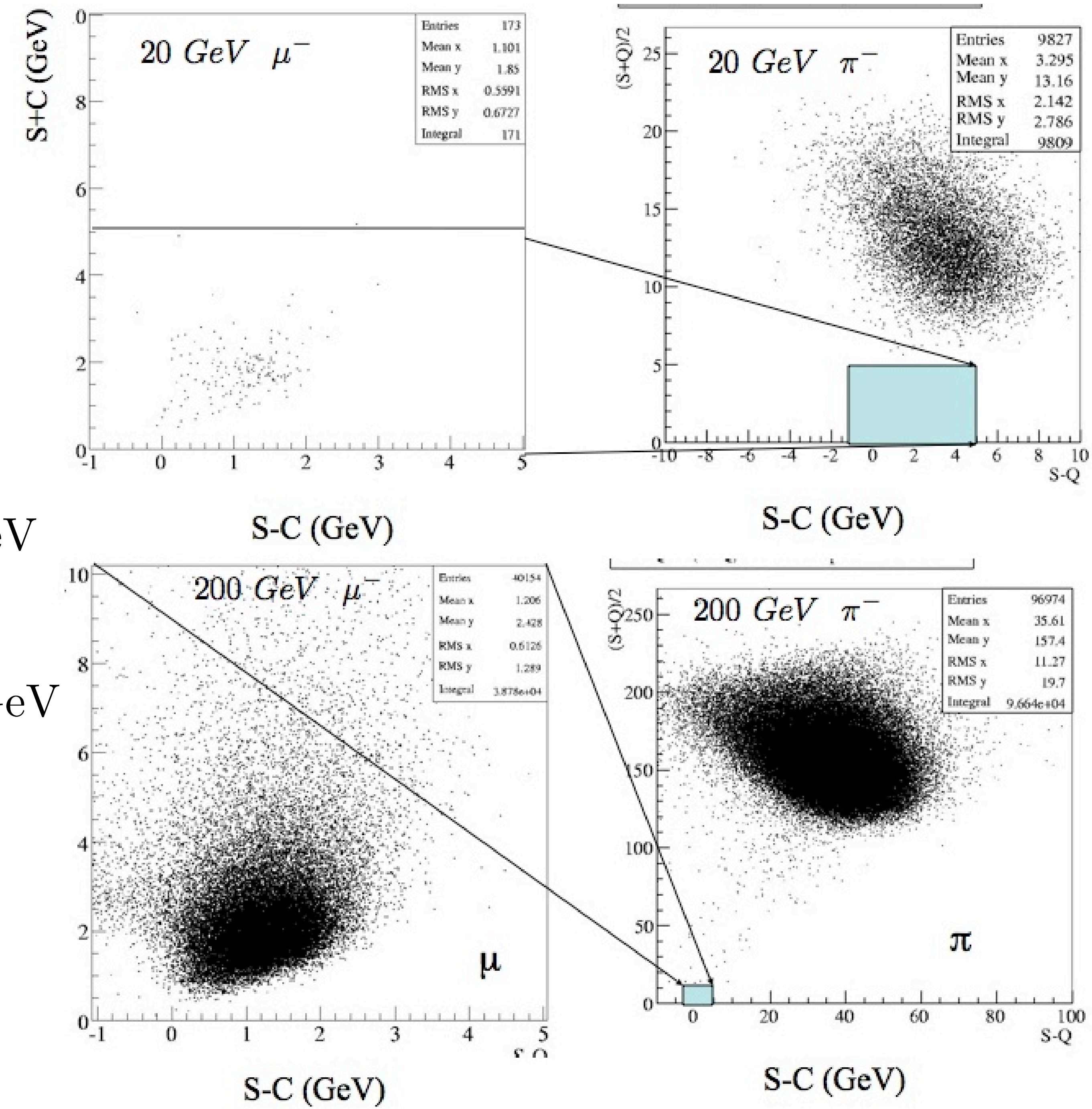
tracking along muon trajectories in the annulus between solenoids

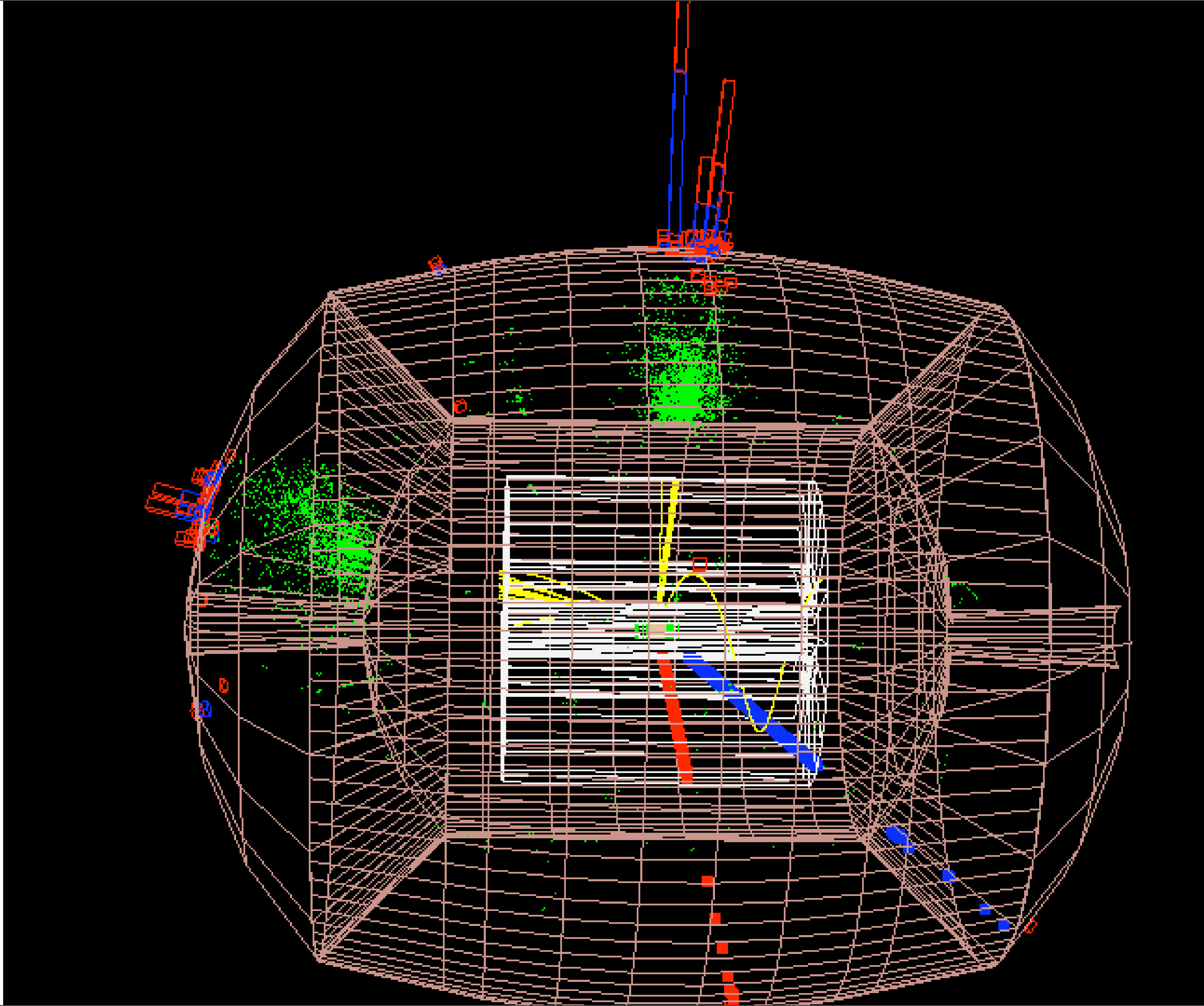
Dual readout of muons in DREAM module

$\pi^{\pm}$ rejection:

10^{-3} at 20 GeV

10^{-4} at 200 GeV

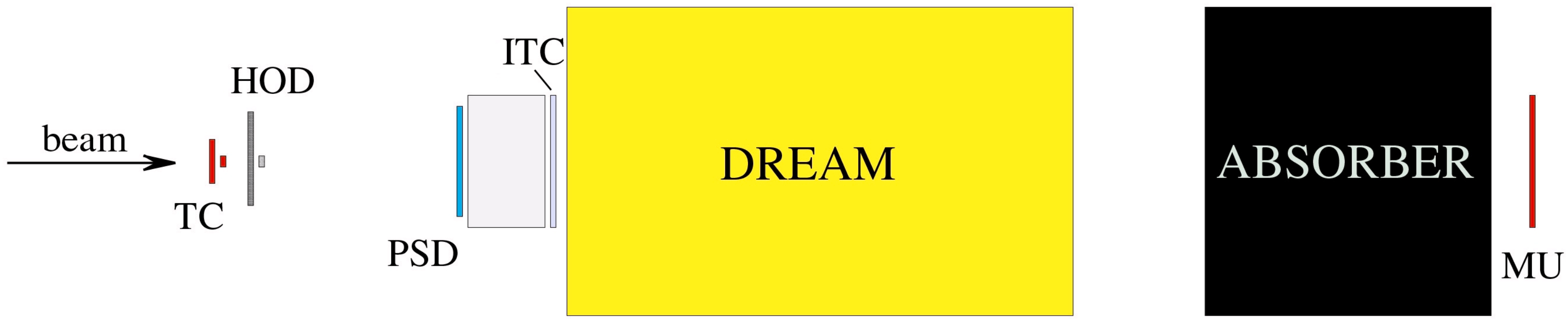




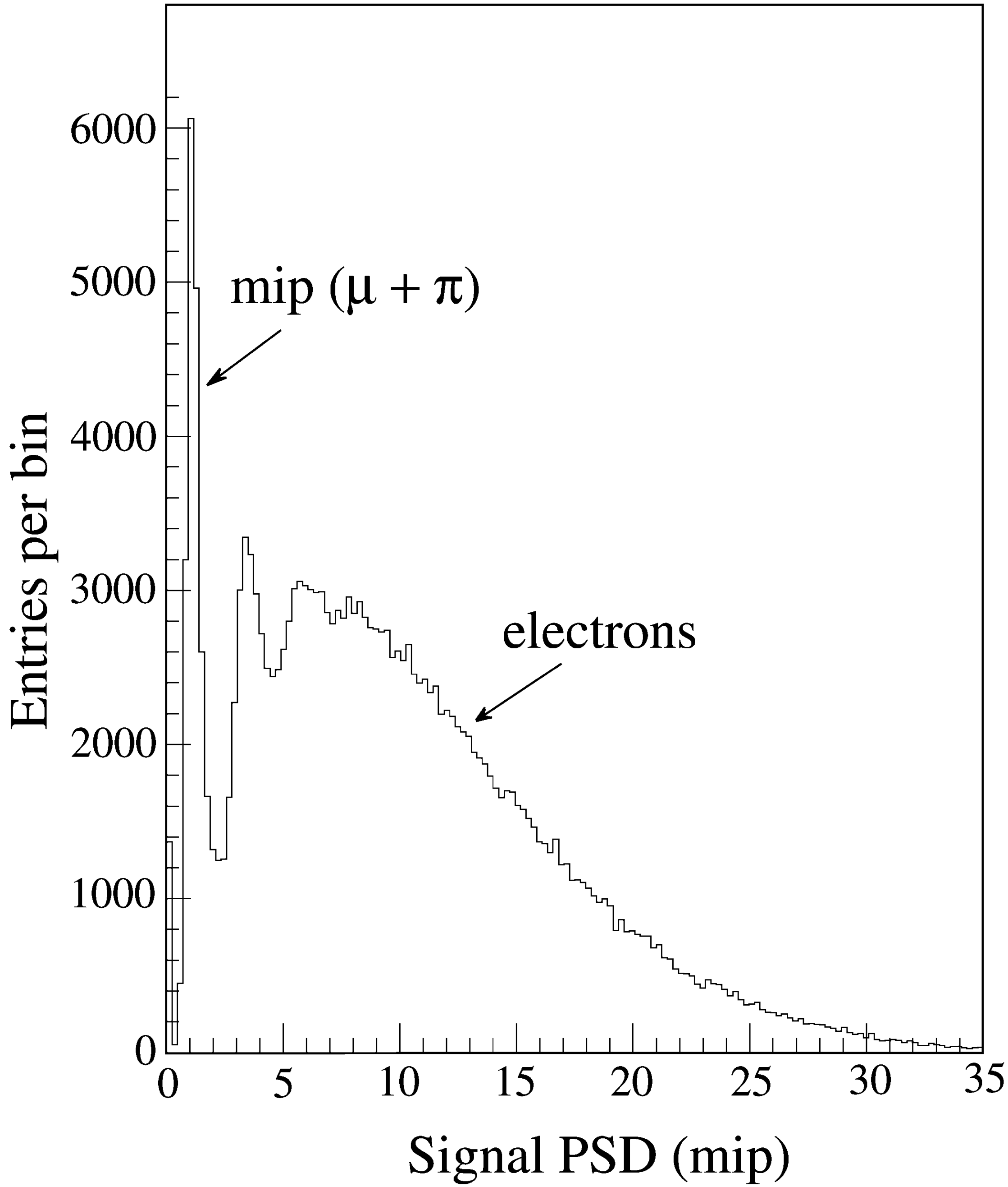
What we need:

- An x-y table to scan module across beam; the x-motion should be fast, and y-motion can be slow.
- A “jet beam” - 100 GeV pion beam into a plastic 0.1 interaction length plastic target ... upstream MIP counter and downstream multiplicity trigger.

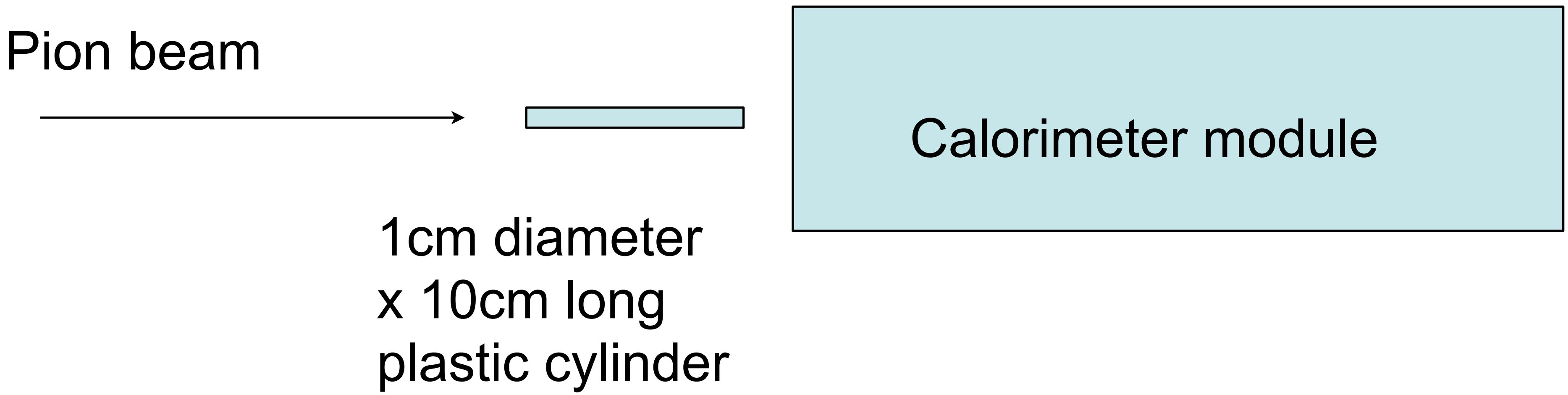
CERN beam test: species identification and “jet” trigger



PSD -preshower detector: 5mm Pb + scint
ITC - interaction counter: pulse height in mips (>25 a “jet”)


mip (μ + π)
electrons
Entries per bin
6000
5000
4000
3000
2000
1000
0
0
5
10
15
20
25
30
35
Signal PSD (mip)

“Jet” target for calorimeters

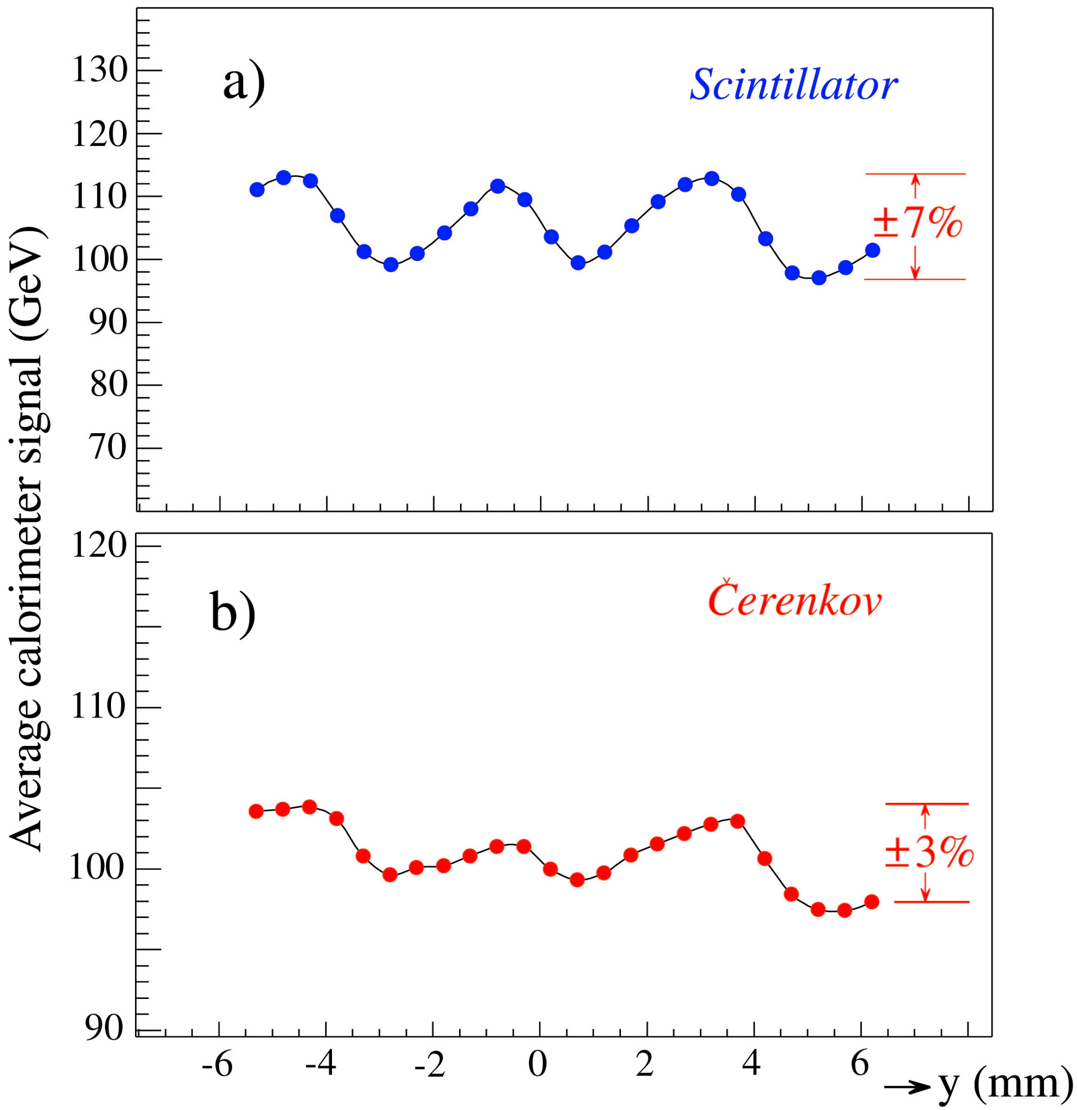


Could put veto’s around it; could put a “magnetic mirror” around it to direct side-going charged tracks into calorimeter.

Table x-y scan in beam test

$\sigma_{x,y} \approx 0.5$ mm

... for electron probing of calorimeter channels, important for a fine-spatial sampling fiber calorimeter, maybe more important for a PFA calorimeter ...



"challenges" (or dual readout is wonderful, but what are its problems)

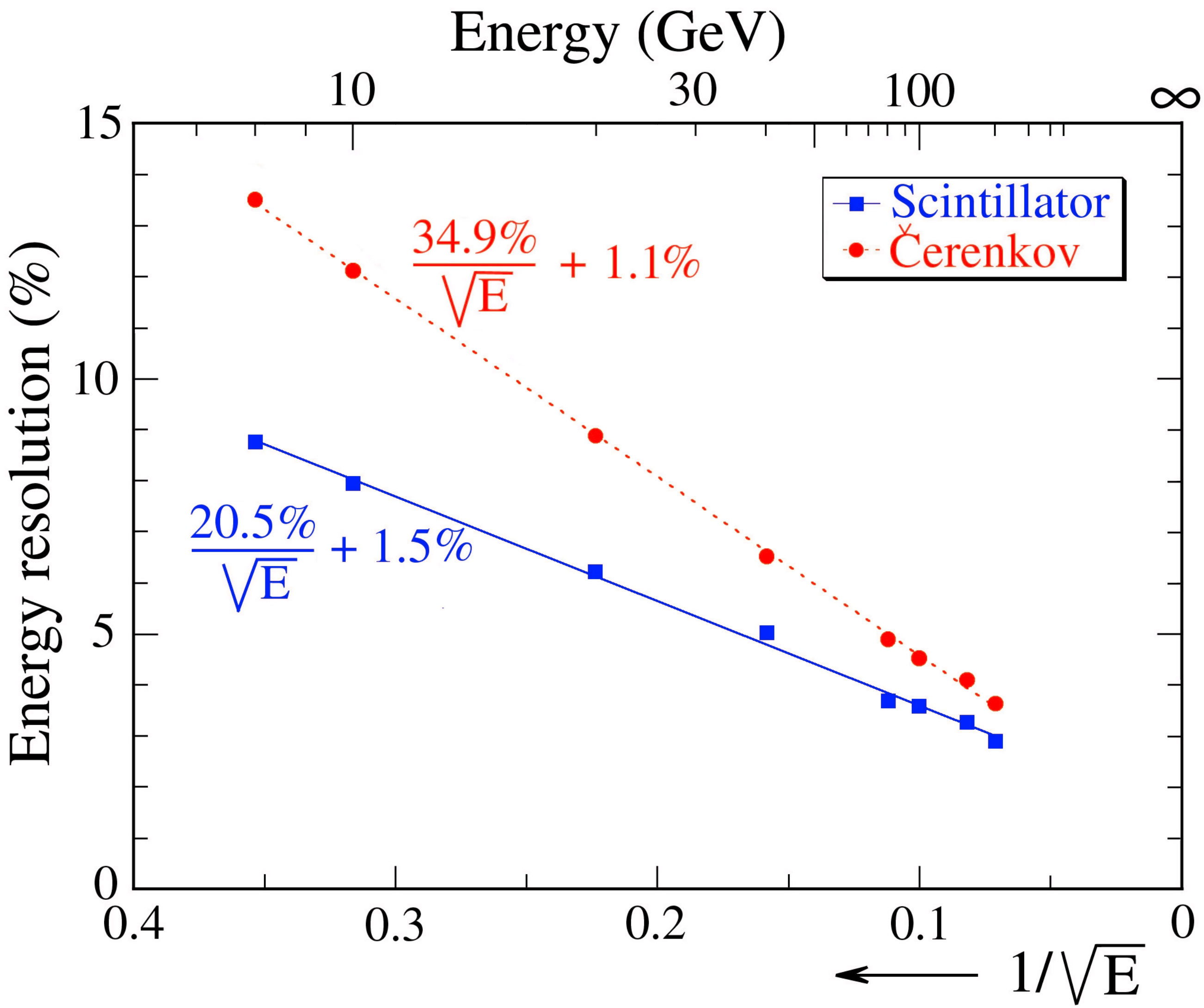
1. Electrons and photons limited by photo-statistics
   → study dual readout of single PbWO4 crystals, optimize DREAM.

2. Binding energy loss fluctuations next biggest contributor to energy resolution
   → study readout of MeV neutrons from hadronic shower.

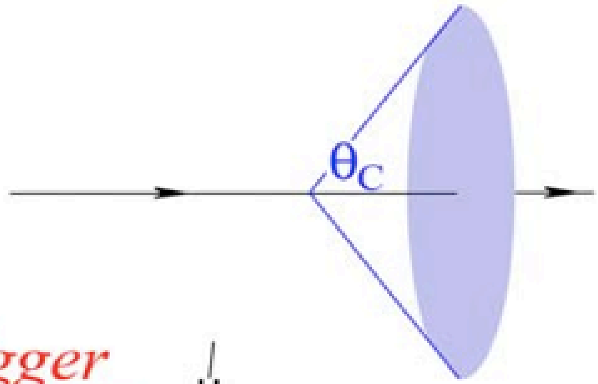
3. Readout to compact B-insensitive photo-converter
   → study SiPM with integrated electronics, FADC, etc.

4. Design 3-dimensional uniform fiber densities and optimize fiber volumes, numerical apertures, H-contents, attenuations, etc.
   → lots of physics and geometry here

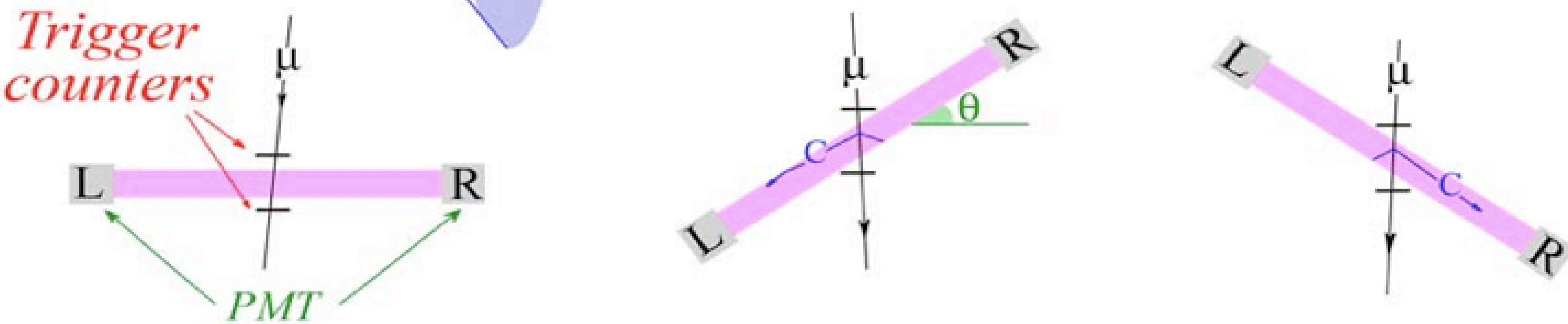
Electron energy resolution limited by Cerenkov photo-statistics



Identifying Čerenkov component on the basis of its directionality



$n = 2.2$, $\arccos \theta_C = 1/n \longrightarrow \theta_C = 63^o$



Calibration:

L = R

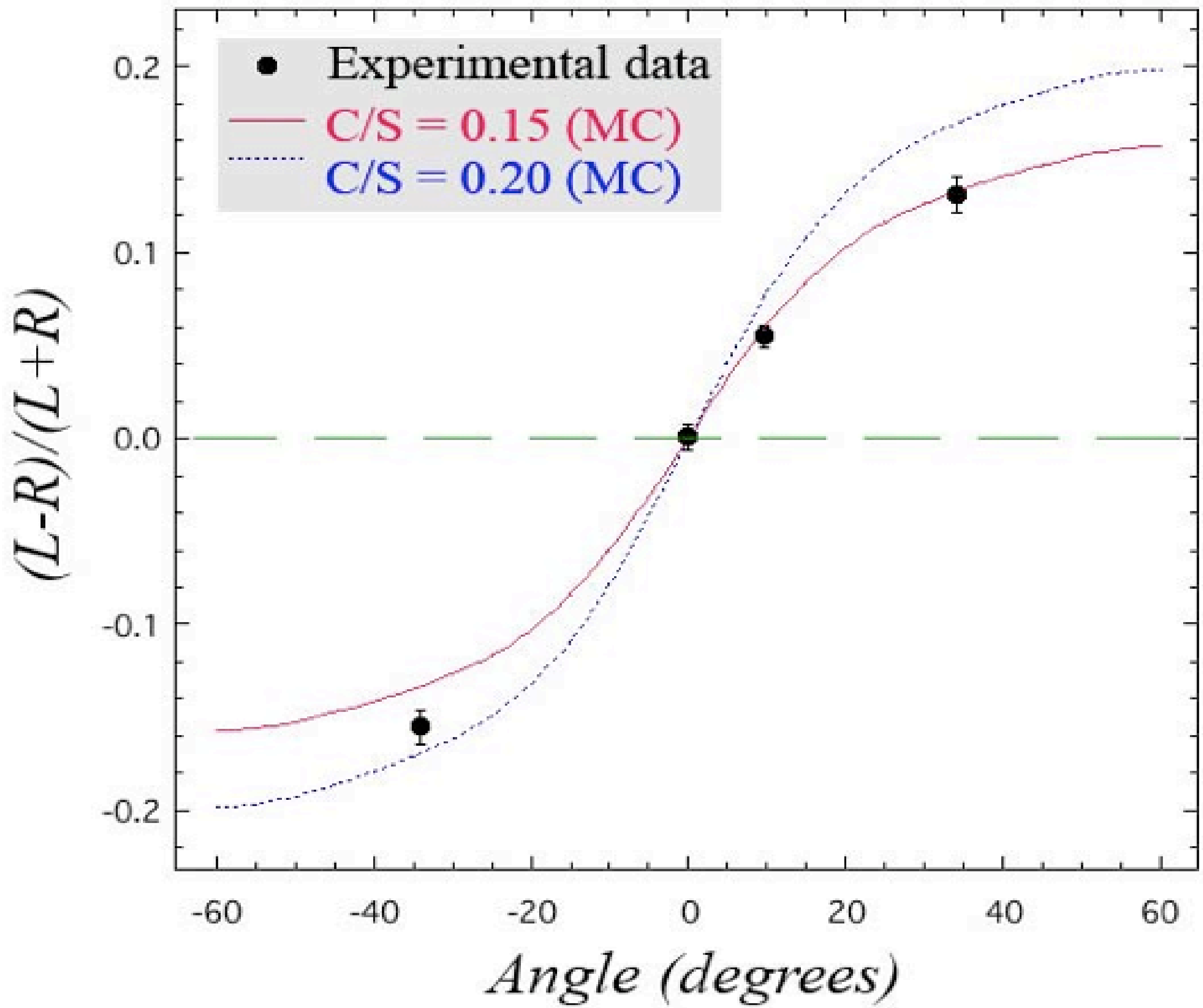
L > R

L < R

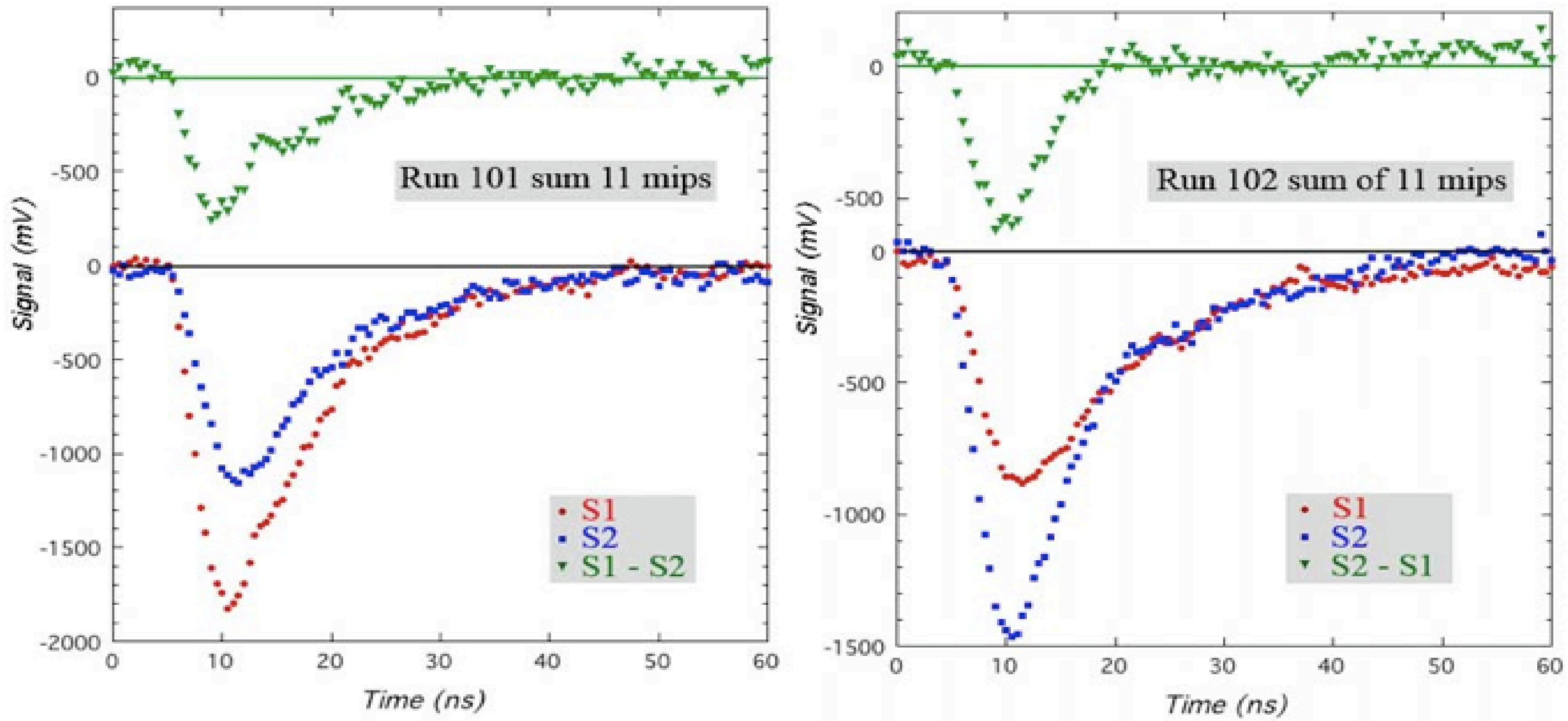
→ *Measure* $\frac{L - R}{L + R}$ *as a function of* θ

R. Wigmans Elba '06

Experimental results, light directionality in $PbWO_4$



Time structure of cosmic ray events in $PbWO_4$ (ΔE = 25 MeV)



Slope *dL/dt*
measures C/S

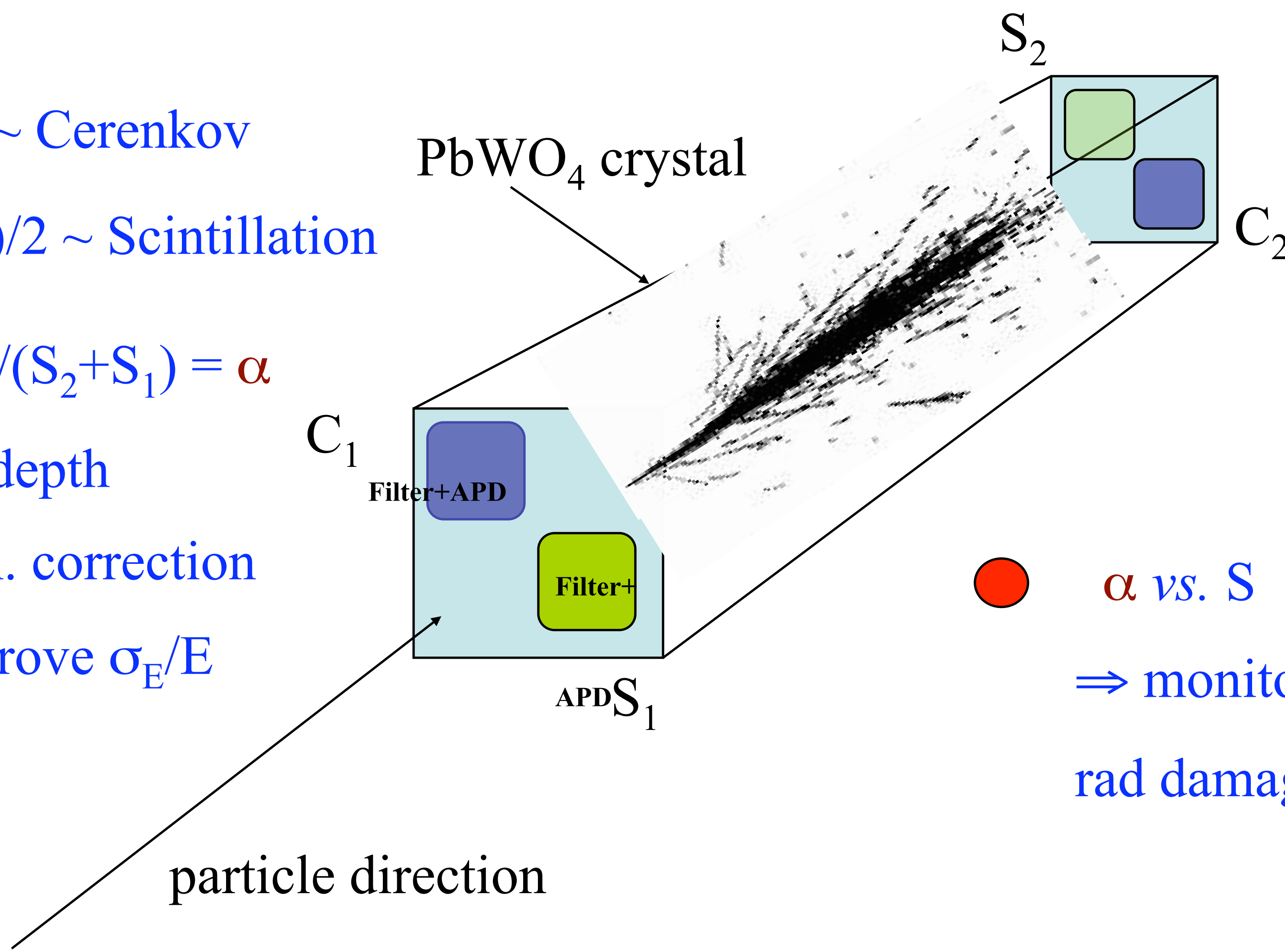
A dual-readout crystal

- C_2-C_1 ~ Cerenkov
- $(S_1+S_2)/2$ ~ Scintillation
- $(S_2-S_1)/(S_2+S_1) = \alpha$

  ~light depth

  ⇒atten. correction

  ⇒ improve σ_E/E



- α *vs.* S

  ⇒ monitors

  rad damage

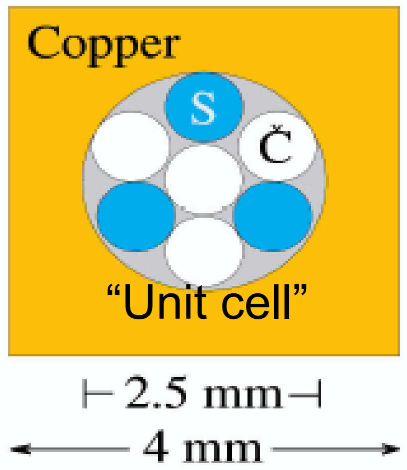
DREAM module

3 scintillating fibers
4 Cerenkov fibers

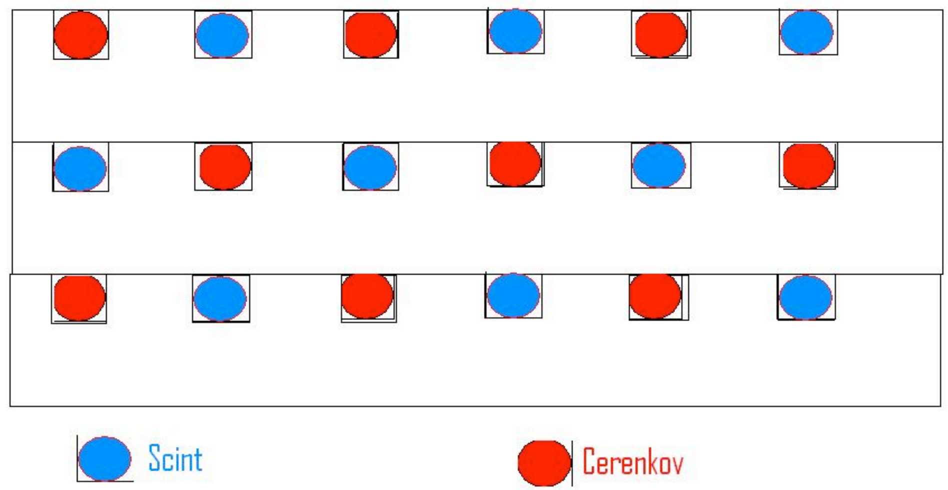
ILC-type module

2mm W, Pb, or brass plates;
fibers every ~2 mm

(Removes correlated fiber hits)



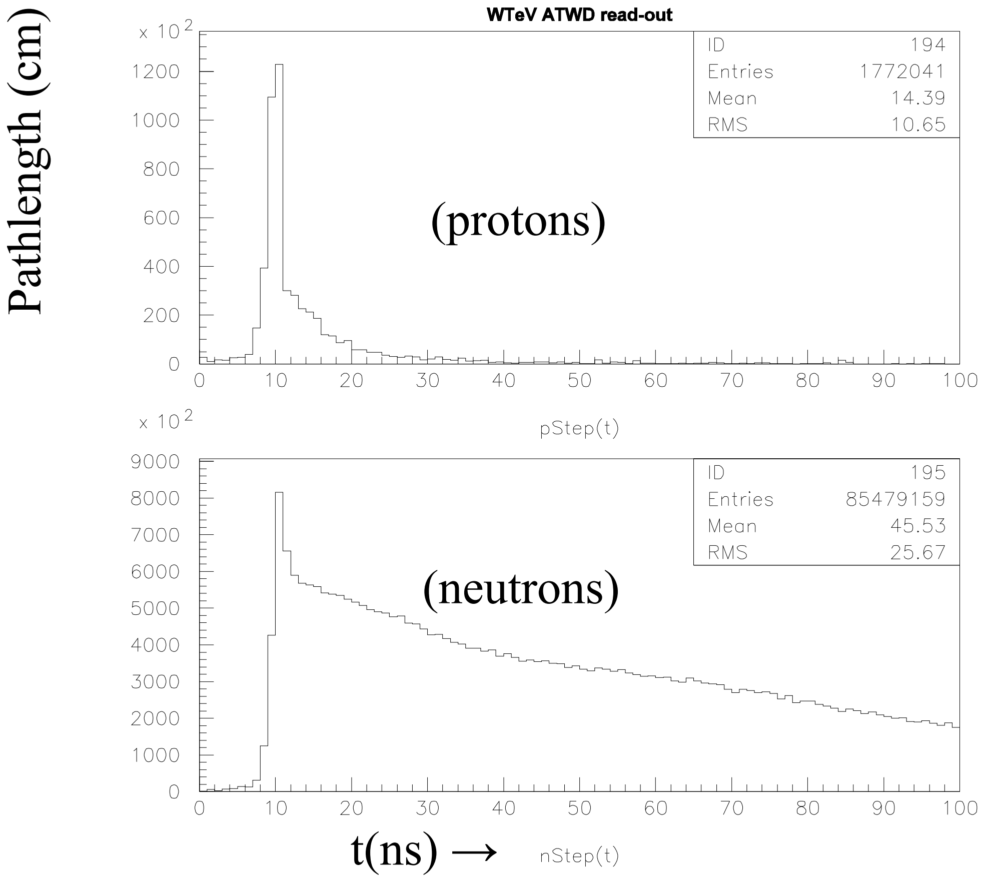
→



Binding energy loss fluctuations:

correlated with MeV neutrons

[1] Measure MeV neutrons by time.



Velocity of MeV neutrons is ~ 0.05 c

(1) Scintillation light from np→np scatters comes late; and,

(2) neutrons fill a larger volume

[2] Measure MeV neutrons by separate hydrogenous fiber

- A hydrogenous scintillating fiber measures proton ionization from np→np scatters;
- A second scintillating non-hydrogenous fiber measures all charged particles, but except protons from np scatters;
- This method has the weakness that the neutron component is the difference of two signals.

[3] Measure MeV neutrons with a neutron-sensitive fiber

- Lithium-loaded or Boron-loaded fiber (Pacific Northwest Laboratory has done a lot of work on these)
- Some of these materials are difficult liquids
- Nuclear processes may be slow compared to 300 ns.
- But, most direct method we know about.

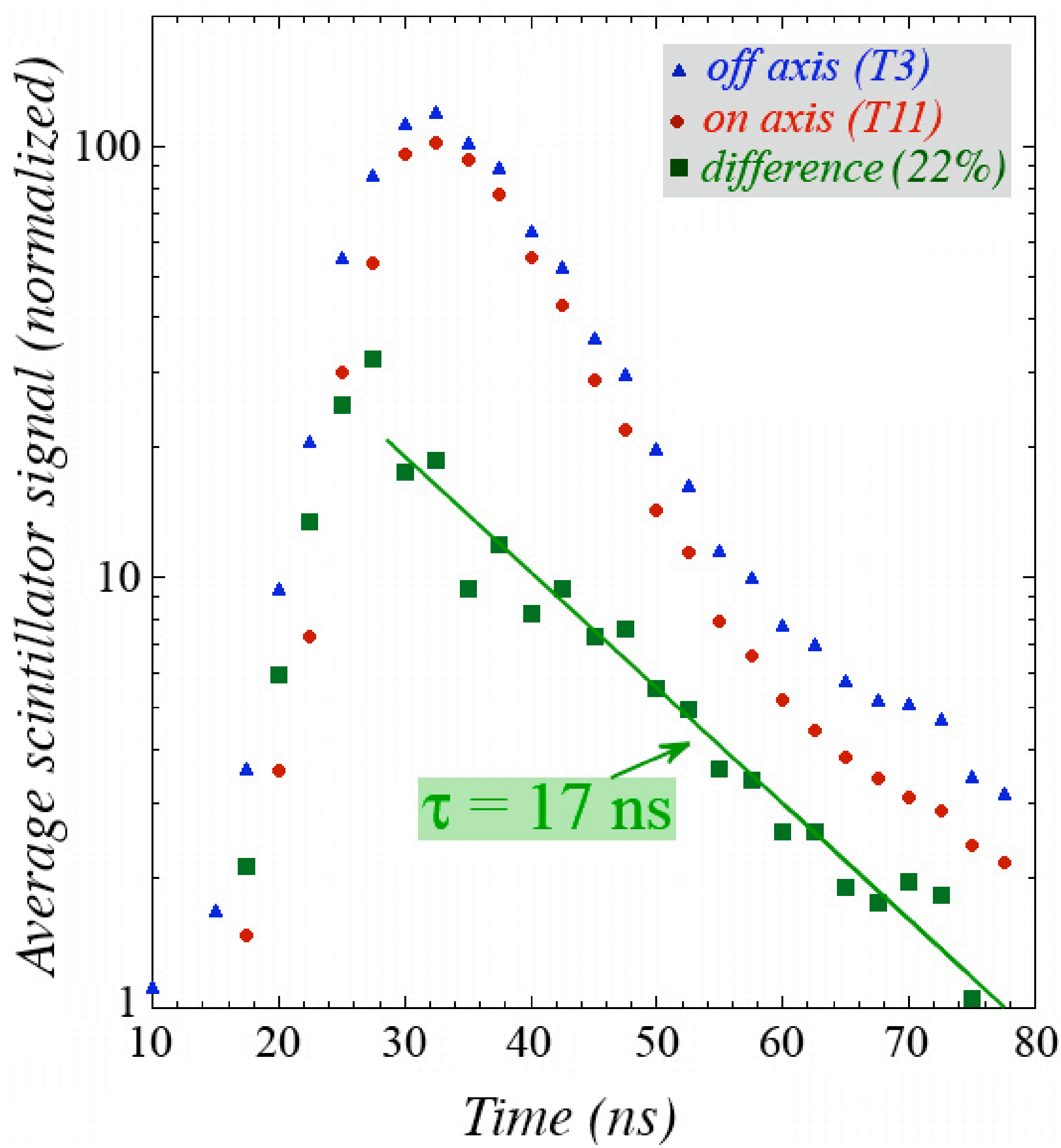
[4] Measure MeV neutrons using different Birk's constants

- Birk's constant parameterizes the reduction in detectable ionization from heavily ionizing particles (essentially due to recombination)
- Use two scintillating fibers with widely different Birk's constants.
- Two problems: (i) hard to get a big difference, and (ii) neutron content depends on the difference of two signals.

So we really don't know what to do yet ... maybe try two of these.

Preliminary measurements of neutrons in DREAM module at CERN

H4 beam Nov. 2006



Pion beam into tower 11, look at time history in tower 3.

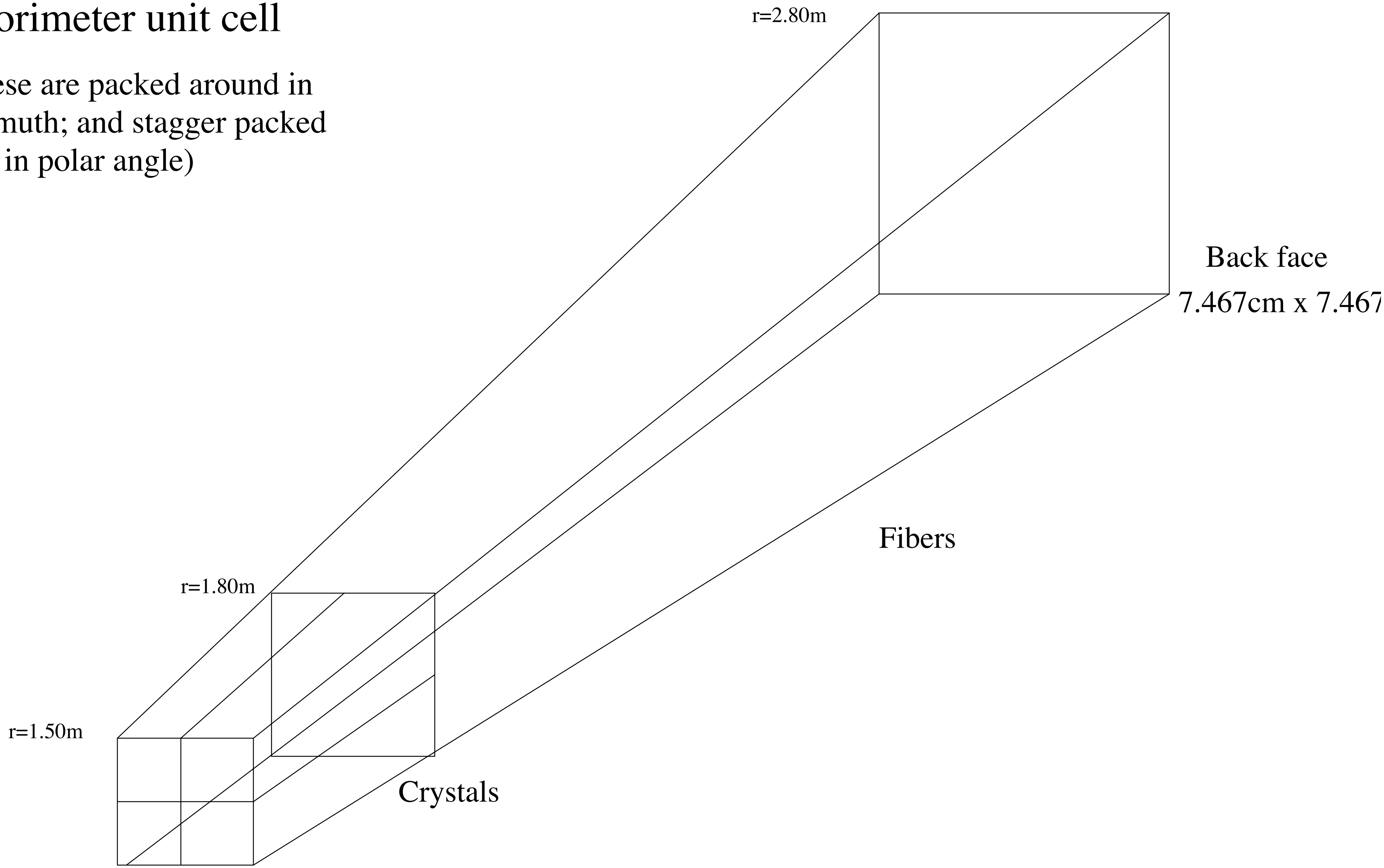
See an excess in time ...

B-insensitive photo-converter: SiPM

- We are watching closely developments with SiPM
- Wish for a single unit, plug onto back of fiber module, Cerenkov & scintillation fibers routed to separate SiPMs, digitize at 500MHz, send out bits.
- But ... $/mm^2 and dark rates are not favorable for a large area fiber calorimeter.

Calorimeter unit cell

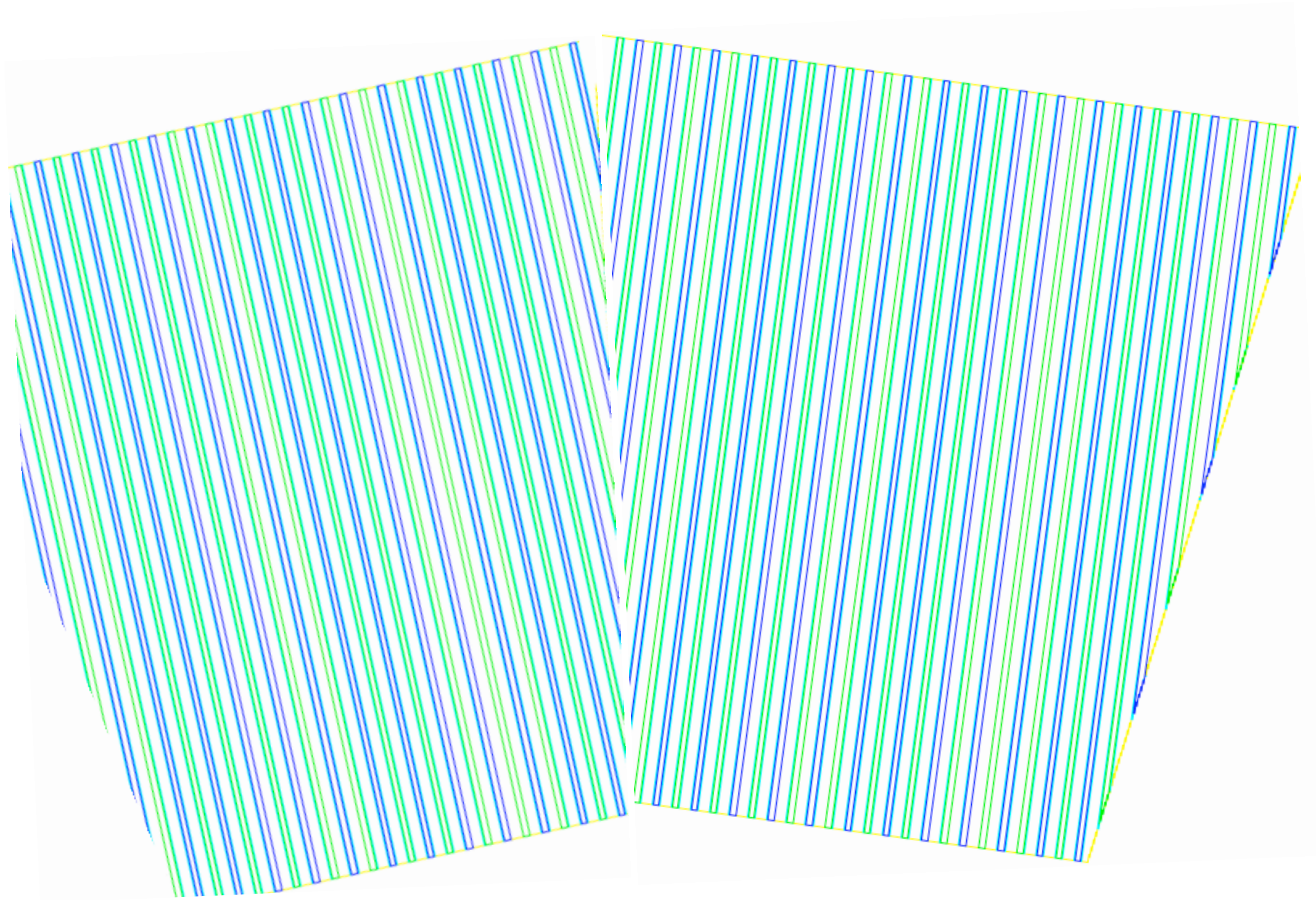
(these are packed around in azimuth; and stagger packed out in polar angle)



Front face is 4cm x 4cm

Crystals are 2cm x 2cm x 30cm

Achieving spatially uniform S and C fiber volume densities in 3-dimensions (to 1%)



Sorry, not too good at drawing, but this is a "truncated pyramid"

"Two identical scalable modules"

How? When?

- take our time with the design of the scalable test module. Done $t_0 + 6$ months
- try to incorporate everything ... time, wavelength, third fiber ... maybe SiPMs
- first 1/2 tonne scalable module ready $t_0 + 12$ months