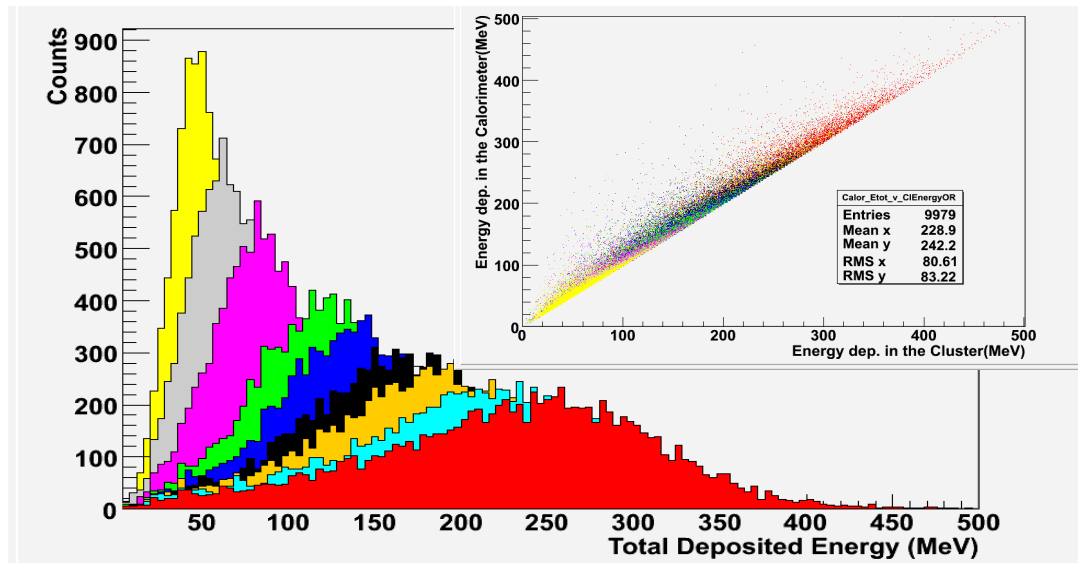
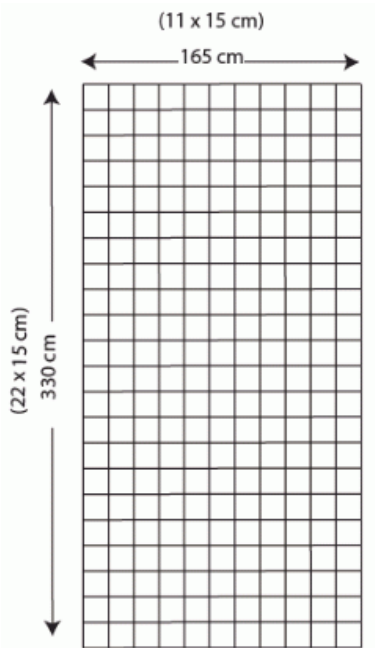


Hadron CALorimeter for SBS

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&
Gregg B. FRANKLIN
(Carnegie Mellon University)

Jlab Hall-A Collaboration Meeting
June 10th-11th 2010



Importance of HCAL

GEp, Gen, GMn, A1n, SIDIS, $(e, e' \varphi)$, etc...

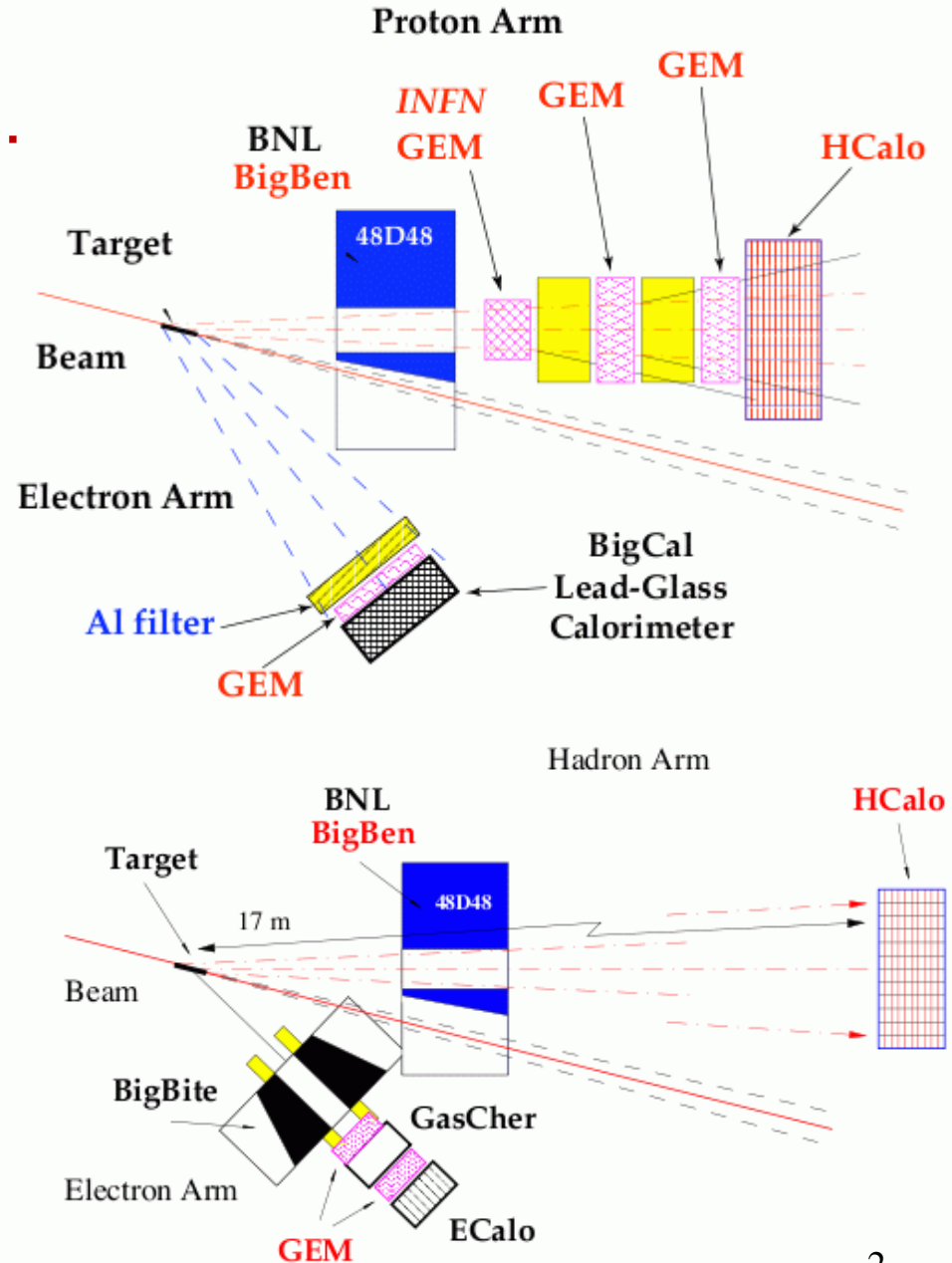
-GEp(5) Configuration

HCAL used for hadron
Trigger

-GMn Configuration

HCAL will replace BigHand for quasi-free
Neutrons and protons selection

Beam Time was reduced because
HCAL improved the exp. cond. !



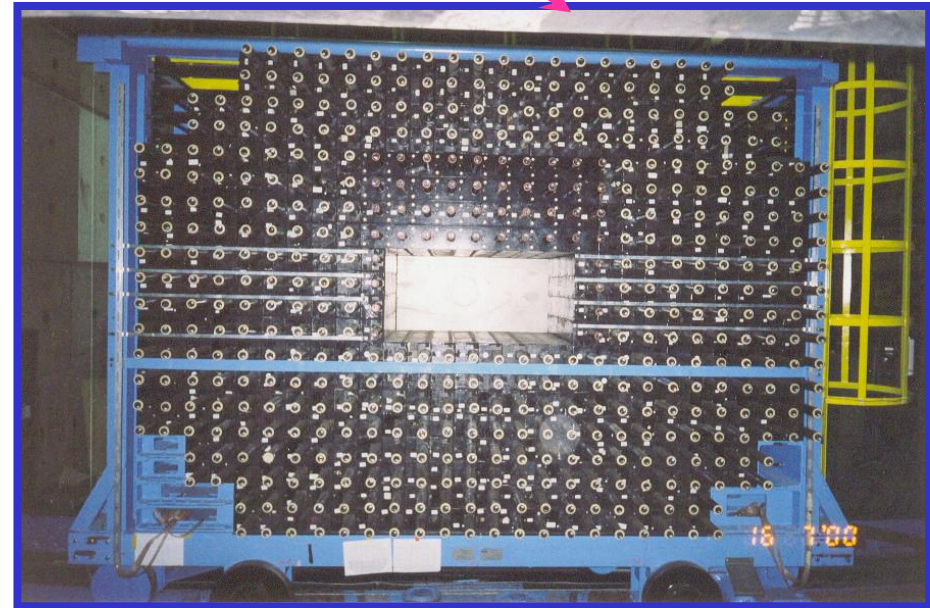
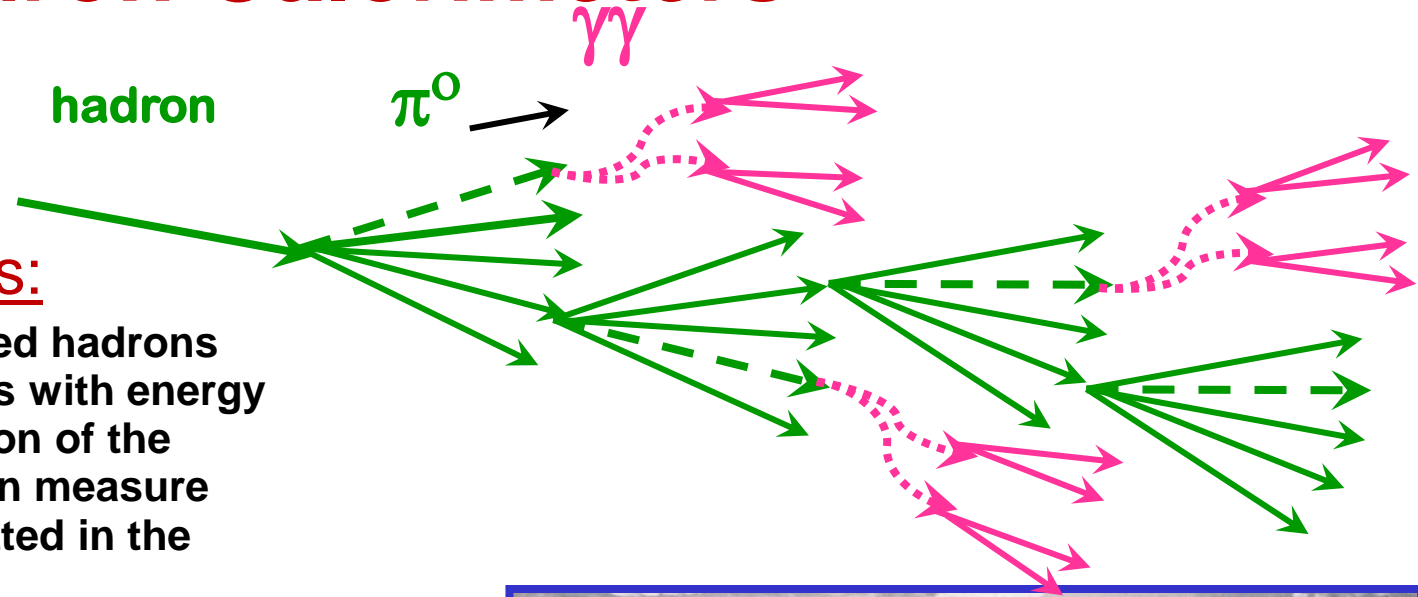
Hadron Calorimeters

Advantages of HCALs:

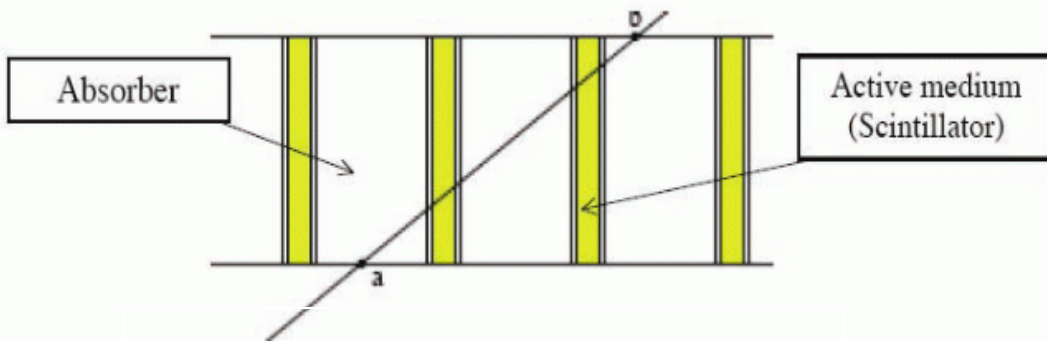
- Measure neutrals and charged hadrons
- Position Resolution improves with energy
- They can cover a large fraction of the acceptance and therefore can measure essentially all the energy emitted in the interaction.

Disadvantages...

- They are typically big, therefore cost is a serious concern.
- Large Energy Resolution
- Linearity can be an issue



• HCAL1 (COMPASS)



Module of a sampling calorimeter

Mainly one studies the energy deposited in the scintillator material.

COMPASS HCAL1 Module

• **HCAL1 (COMPASS at CERN)** is a sampling Calorimeter composed of interleaved layers of iron and plastic scintillator in which photonuclear cascades initiated by primary particles are developed.

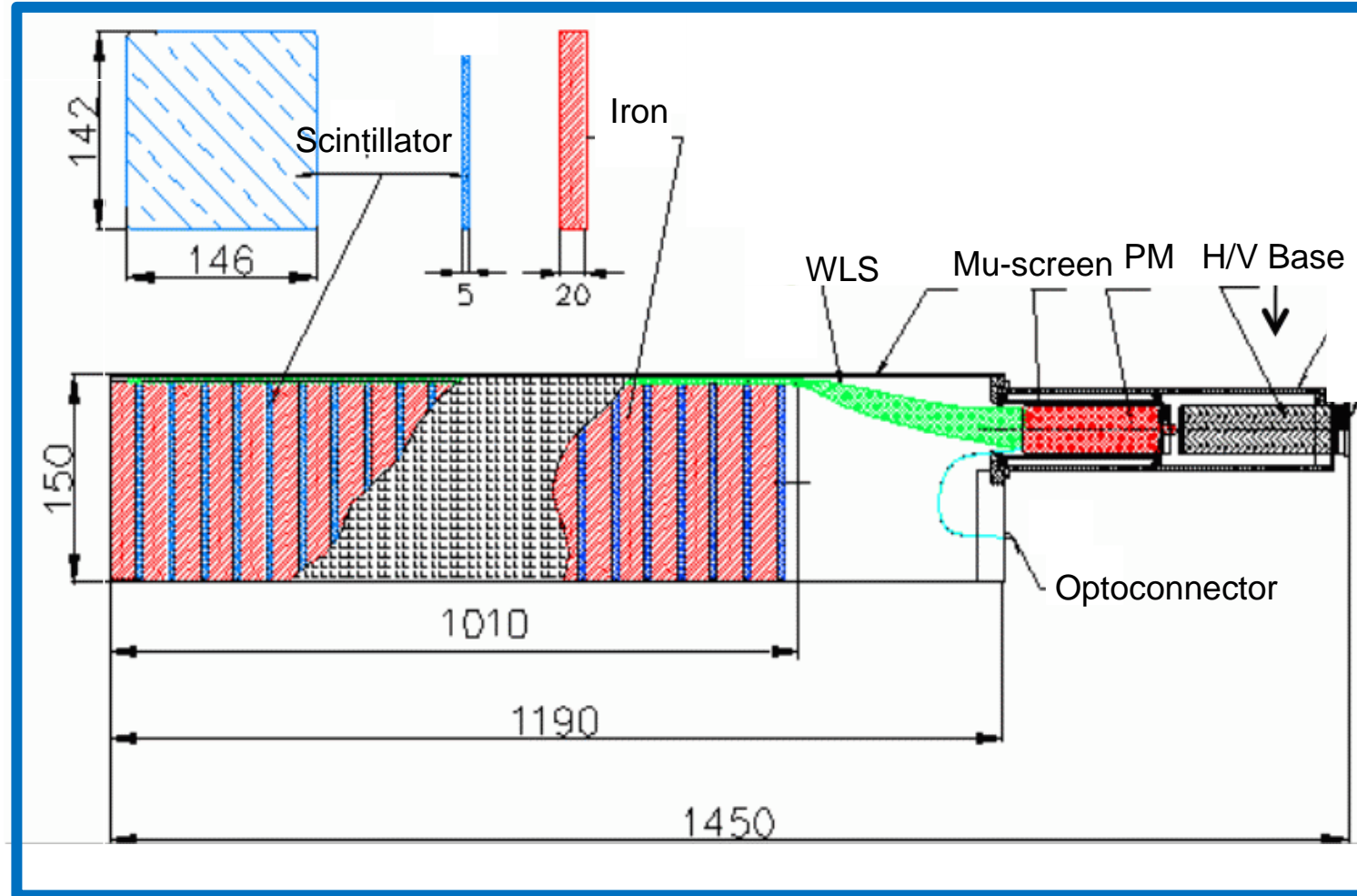
- 480 modules, 40 iron/scintillator layers per module, 1 module ~ 150 Kg

- 2.0 cm iron plates, 0.5 cm scintillator plates
 $4.7 \lambda_{\text{nucl}}$ and $0.25 \lambda_{\text{nucl}}$

- 14.2 cm x 14.6 cm

- 120 cm long Wavelength shifter readout along 1 side.

- Time resolution 1.4 ns



Cost estimate

“Suppose” we keep same modules
as COMPASS

242 modules	\$ 173 k
242 HV bases	36 k
HV Control	8 k
LED Monitoring	5 k
	<hr/>
	\$ 222 k

+ trigger electronics ?

+ stand ?

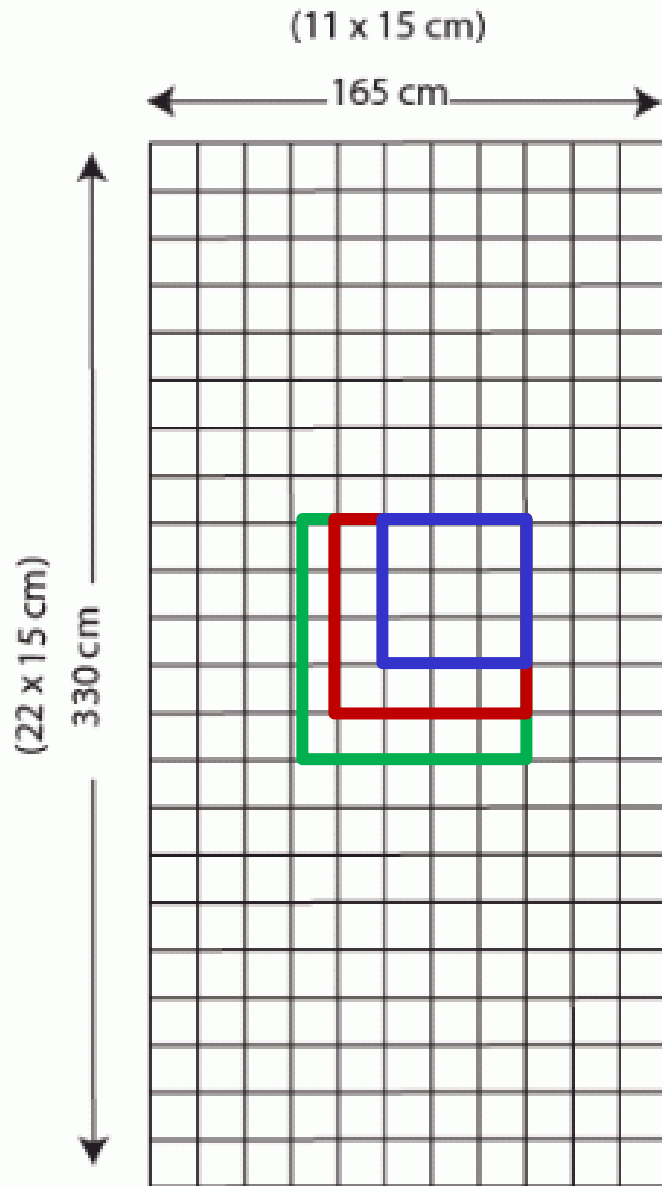
+ installation & testing?

BUT

**COMPASS design is for
10-100 GeV Jets**

**Need to do the design for
lower energies up to ~ 10 GeV/c
protons/neutrons, pions, etc...**

Geant4 and Geant3 developments

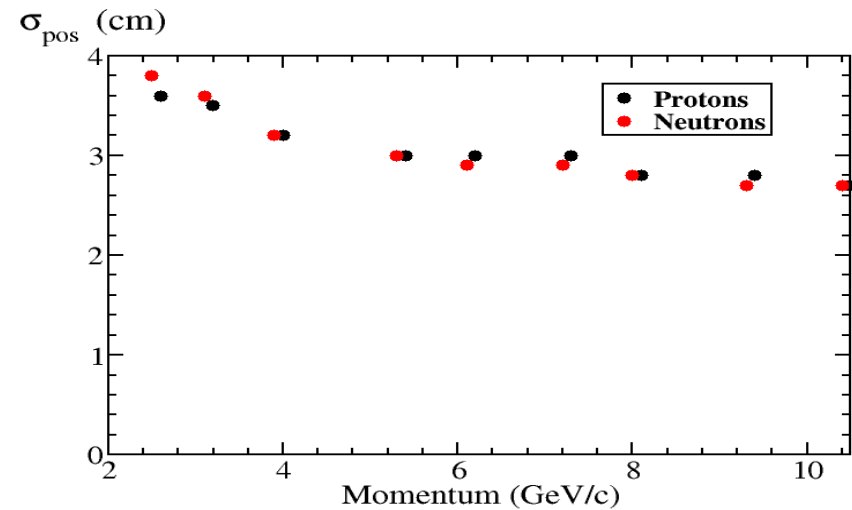
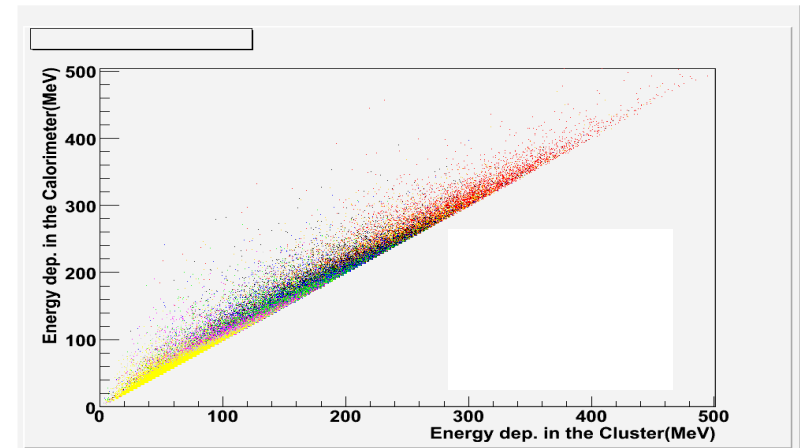
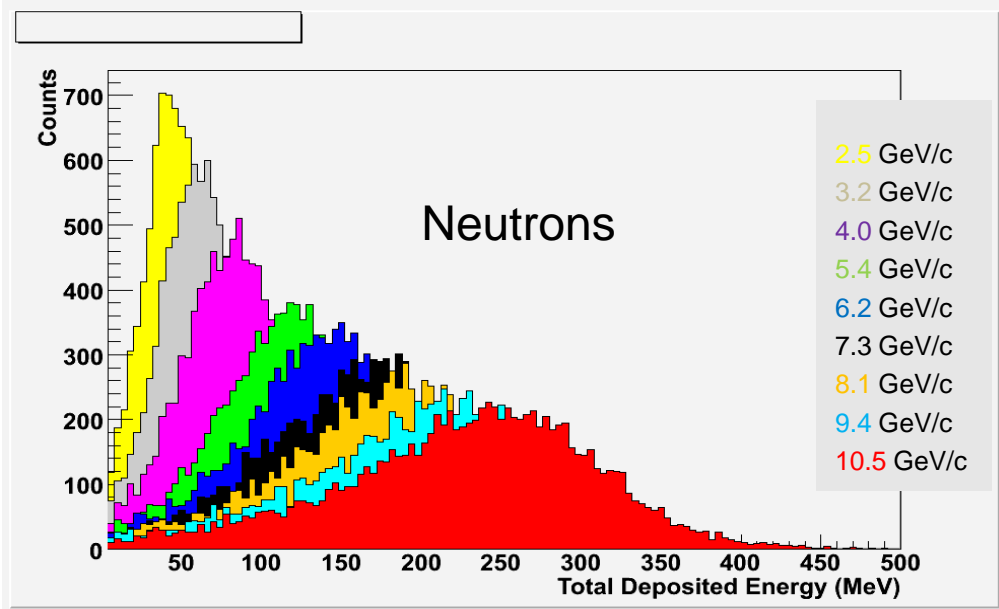
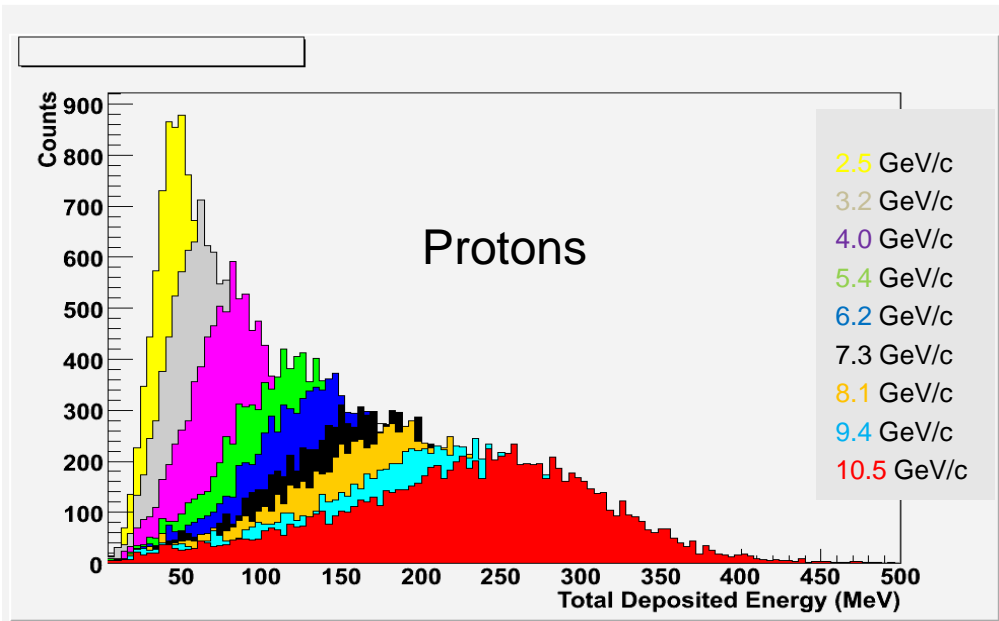


- Geant4 simulations : J. Annand, F. Benmokhtar Bertini Binary Cascades generator.
- Reproduced Compass energy/position resolutions under their conditions: 100GeV pions, beam at the center of a 5x5 cluster, etc..
- Study of HCAL was done for different cluster sizes.
- Geant3 simulations: S. Abrahamyan (Yerevan Inst.) Background and Rate simulations. Simulates HCAL inside the Hall. (DINREG generator)
- Then came I. Savin et al., (Dubna Univ.) 4x4 cluster, Geant 4 simulations (LHEP hadronic interactions generator) -> report available for us.

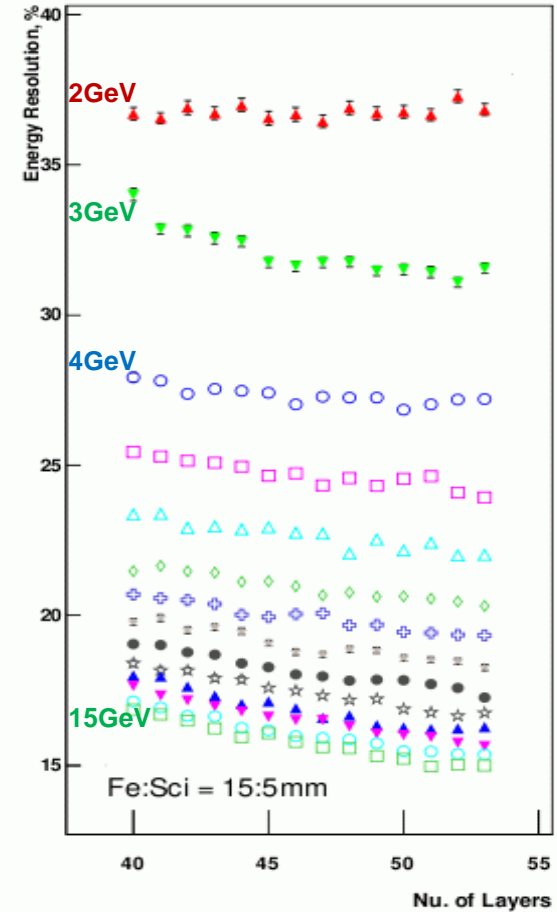
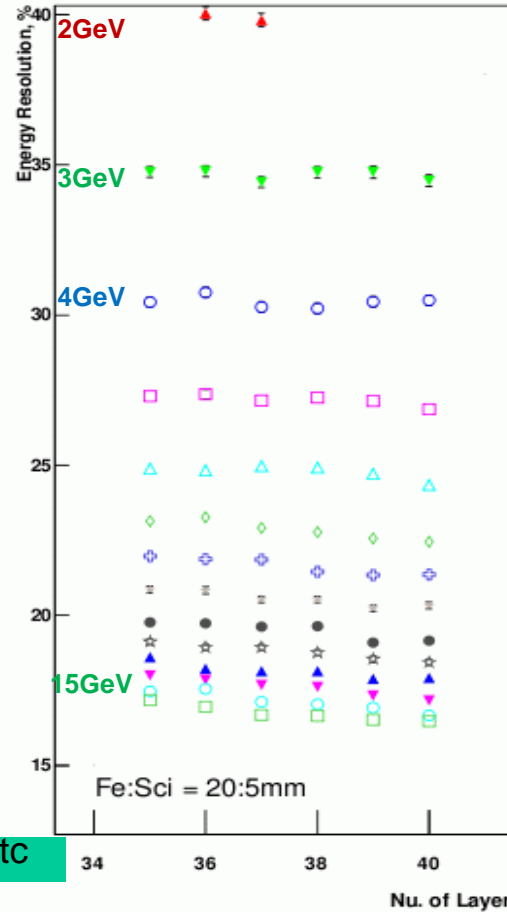
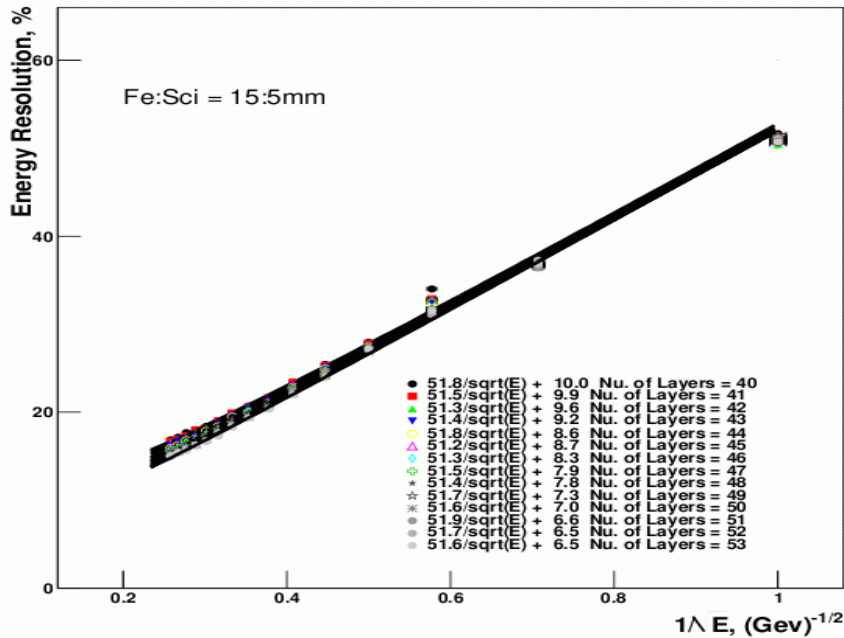
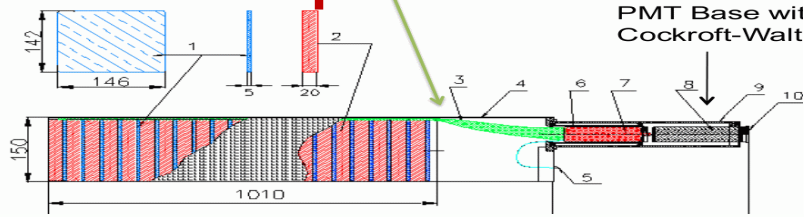
Some Simulations

F. Benmokhtar , J. Annand

- Similar responses for protons and neutrons:
- Efficiencies (Peak/4) >95%
- Energy resolution: 20 -> 40%
- Position resolution: 2.5->4 cm



Optimization of the module (I. Savin et al.)



$$\frac{\sigma(E)}{E} = \frac{a}{\sqrt{E}} \oplus b \oplus \frac{c}{E}$$

Statistical fluctuations

Constant term (calibration, non-linearity, etc)

Noise, etc

Energy Resolution versus number of layers for different energies (I. Savin et al.,)

15:5 mm of Fe:Scin give better energy resolution than 20:5 mm, usage of 50, keeps total length unchanged.

Conclusion

- HCAL for SBS can be constructed of modules similar to that of the HCAL1 at COMPASS, but with 50 layers of refined sampling

Fe:Sci = 15:5mm.

- With these modules one can expect to have the energy resolution as a function of proton energy determined by:

$$\frac{\sigma(E)}{E} = \frac{51\%}{\sqrt{E}} \oplus 7\%$$

- Total dimensions **stay the same.** (>1m length)

- Study the cost?

What's next?

- G. B. Franklin (CMU) and I. Savin (Dubna) are discussing the possibility of shipping a couple of existing modules for testing in the US.
- Estimate final costs and mass productions/tests of the modules.
- Choice of WaveLength Shifter, and also test of positioning: 1 side? 2 sides (or even 4 sides of the module?)
- Try to achieve better timing resolution. <1.4 ns (electronics/etc...)

Manpower:

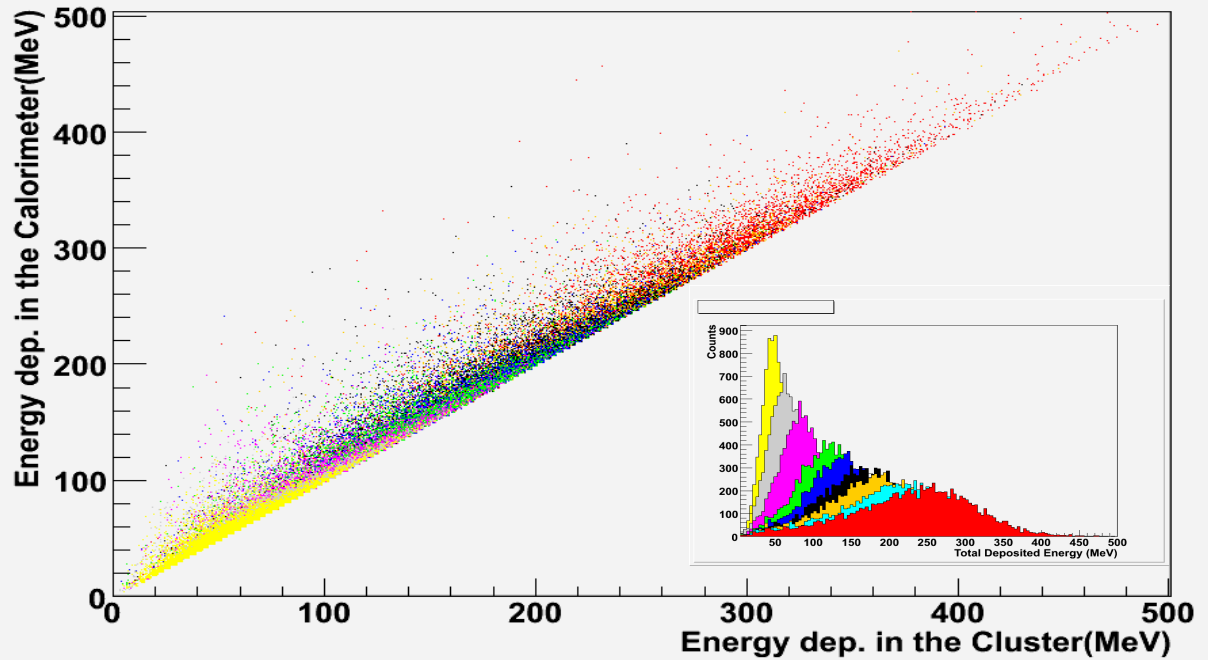
- **CMU:** Design, tests, etc...
F. Benmokhtar (soon CNU) , G. Franklin, B. Quinn
(we are looking to hire a postdoc)
- **Glasgow:** J. Annand (simulations, Geant4)
- **Yerevan:** S. Abrahamyan (simulations, Geant3)
- **Dubna:** I. Savin, V. Krivokhizhin and N. Vlasov
Expertise + provide prototype modules, design

BACKUPS

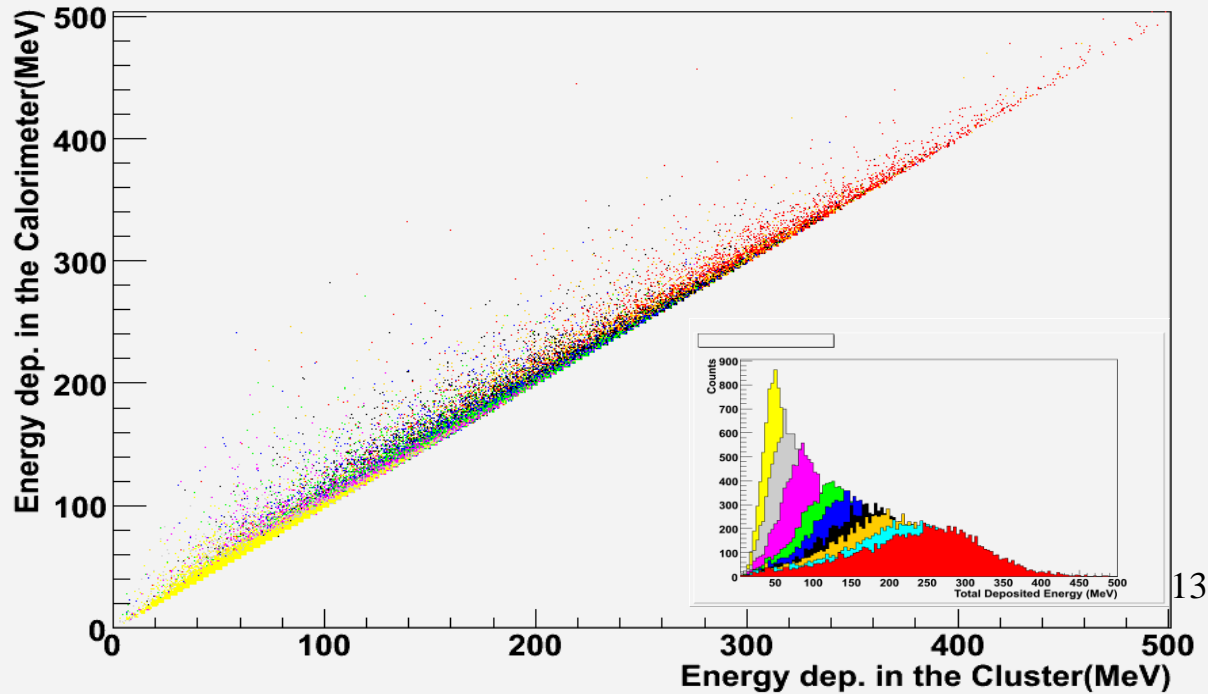
Protons

Total deposited Energy in the calorimeter versus Total deposited energy in the Cluster

Cluster 3x3

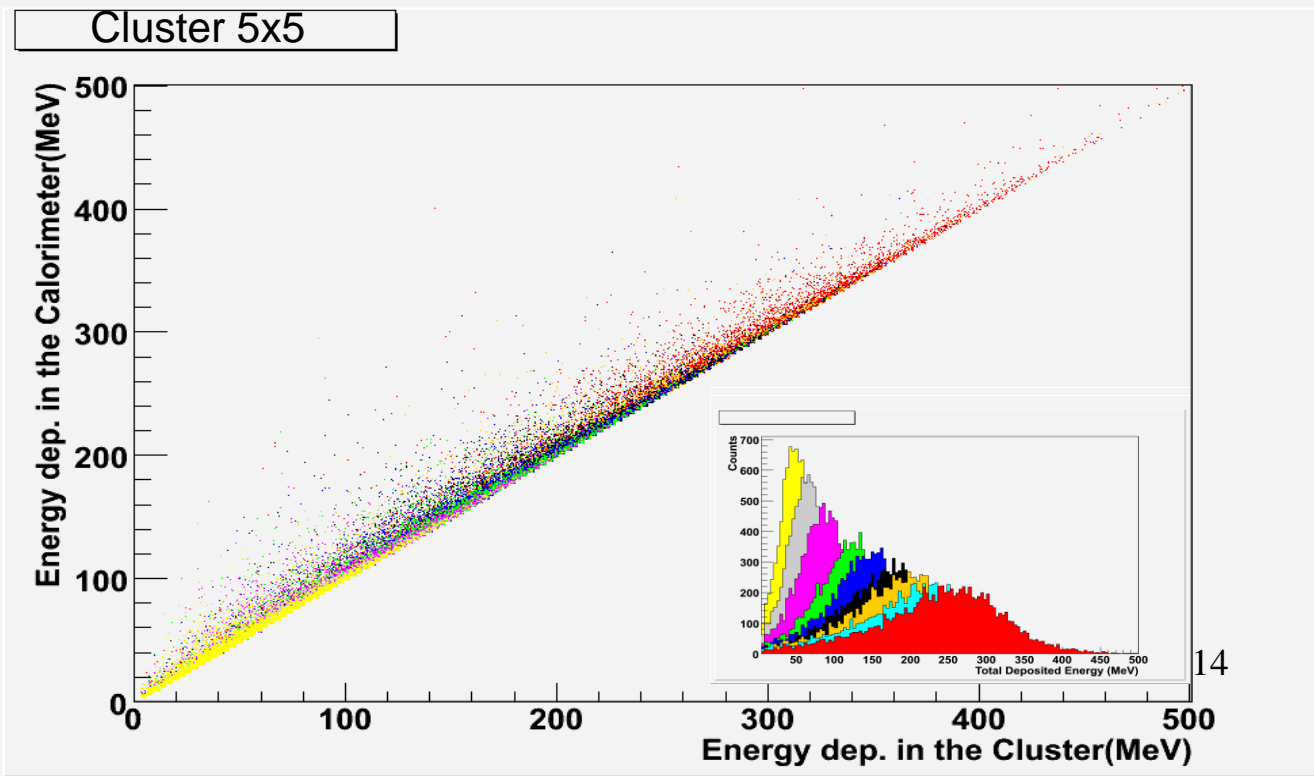
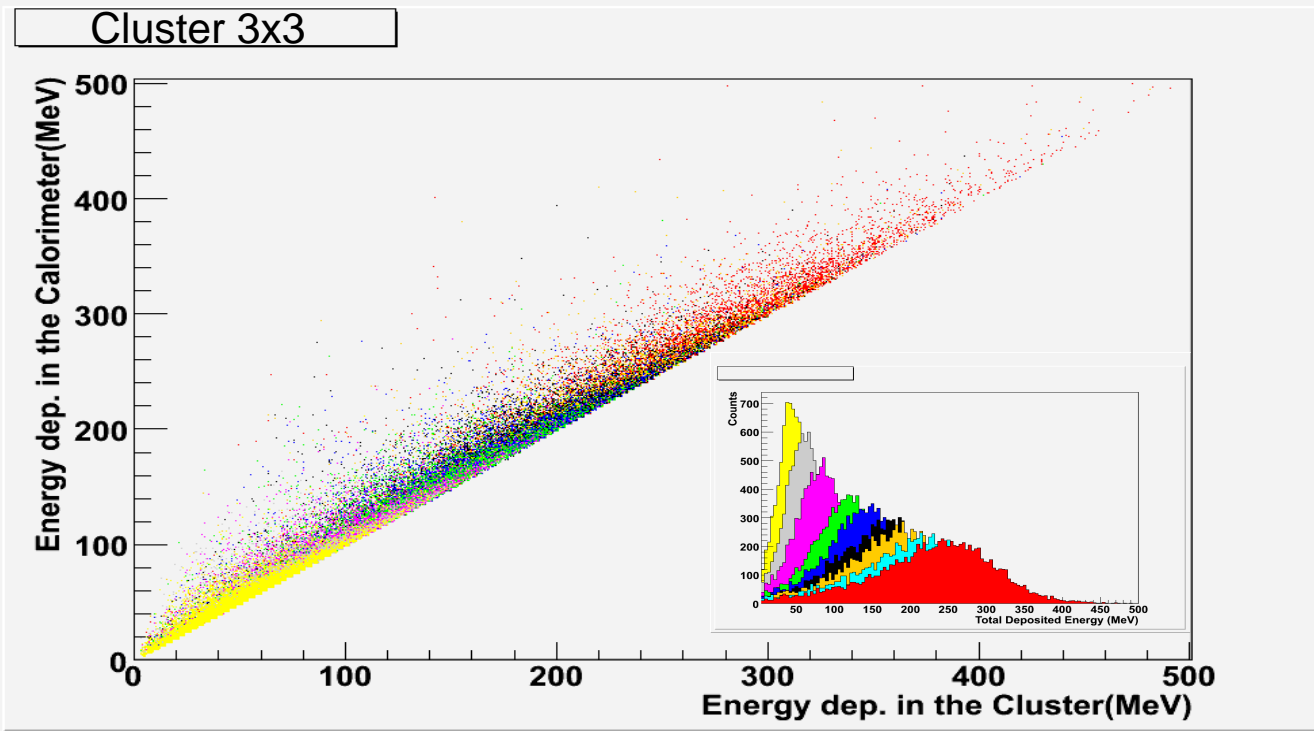


Cluster 5x5



Neutrons

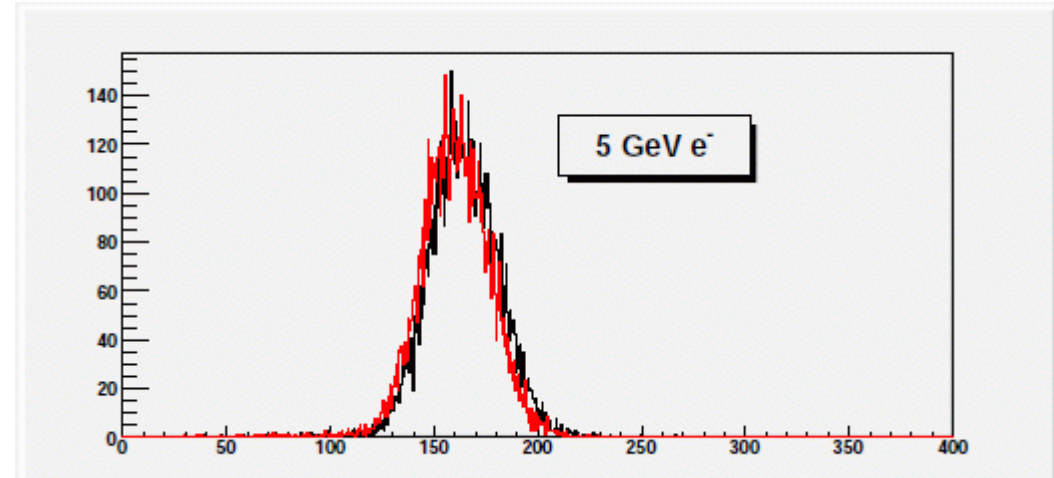
Total deposited Energy in the calorimeter versus Total deposited energy in the Cluster



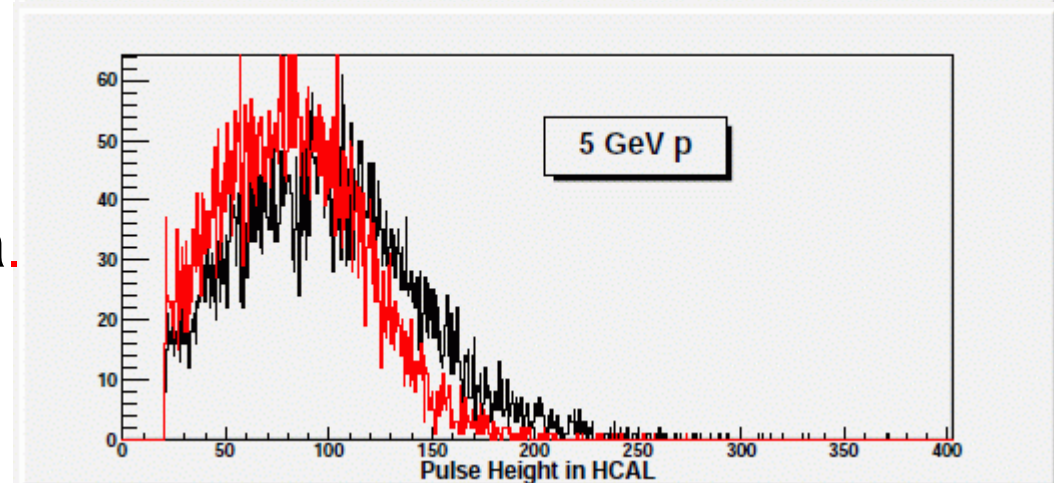
Birk Effect, Geant4 development

Light output depends not only on de-positated energy but also on the density of ionization along the charged particle track. At high ionization densities the scintillation is quenched.

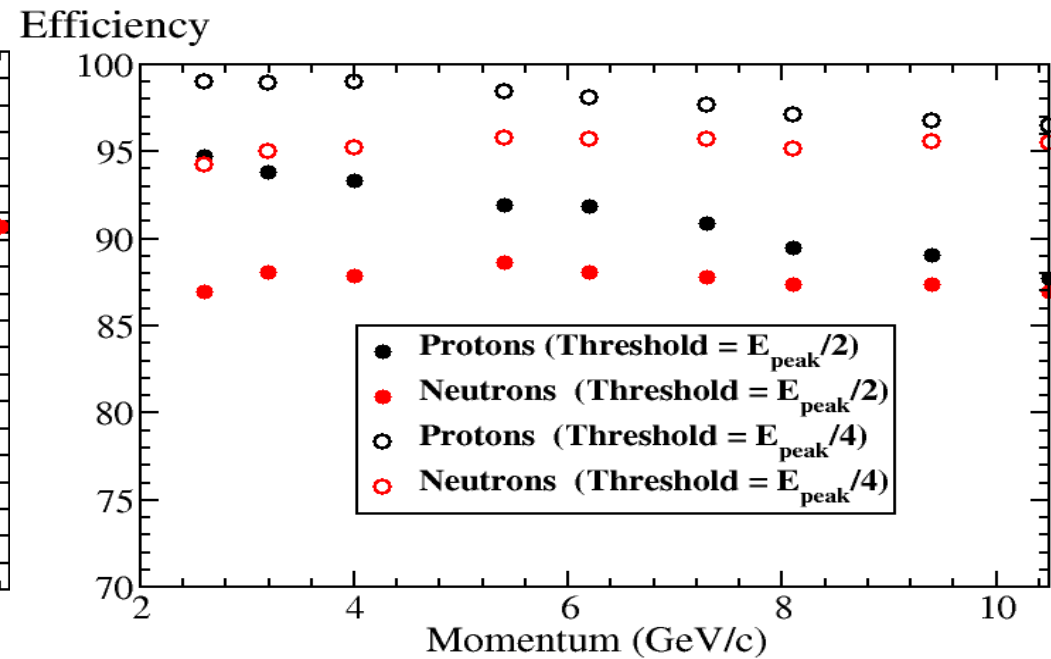
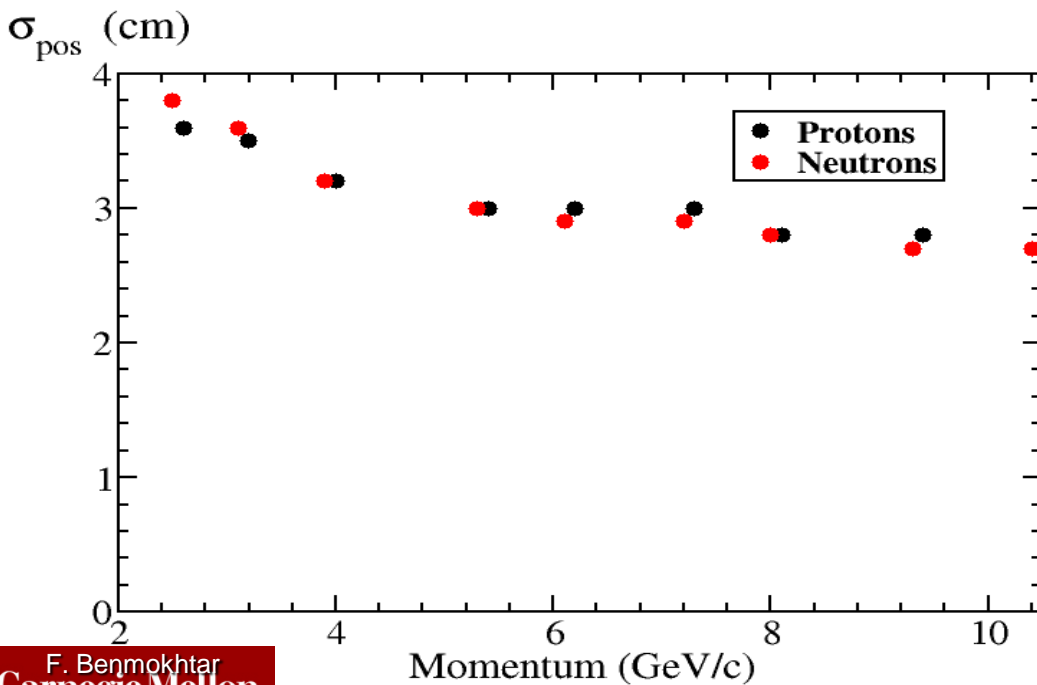
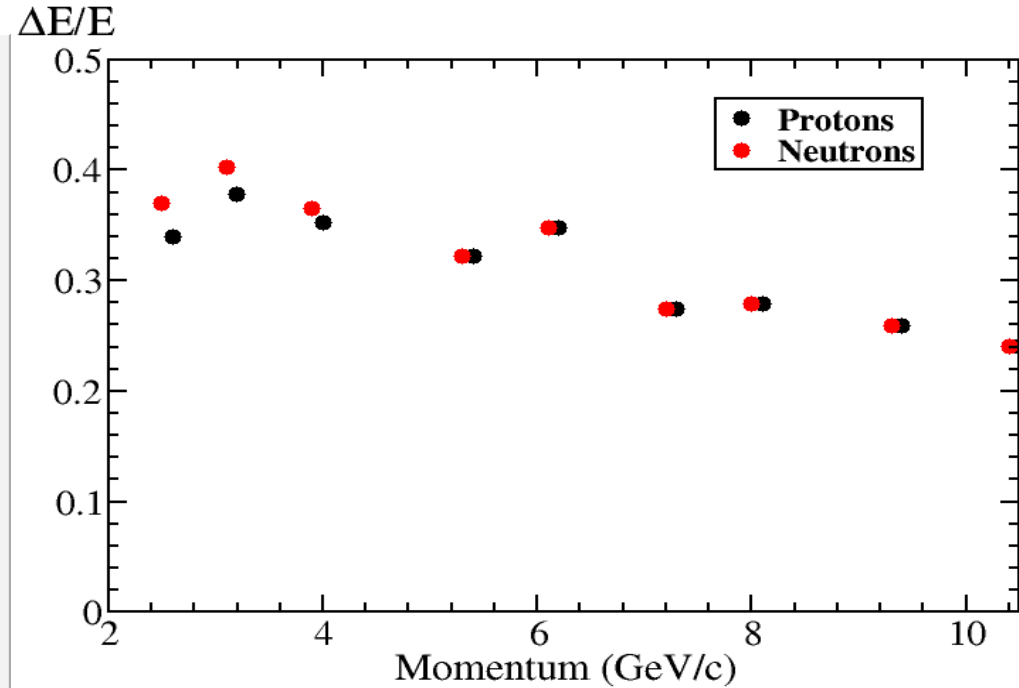
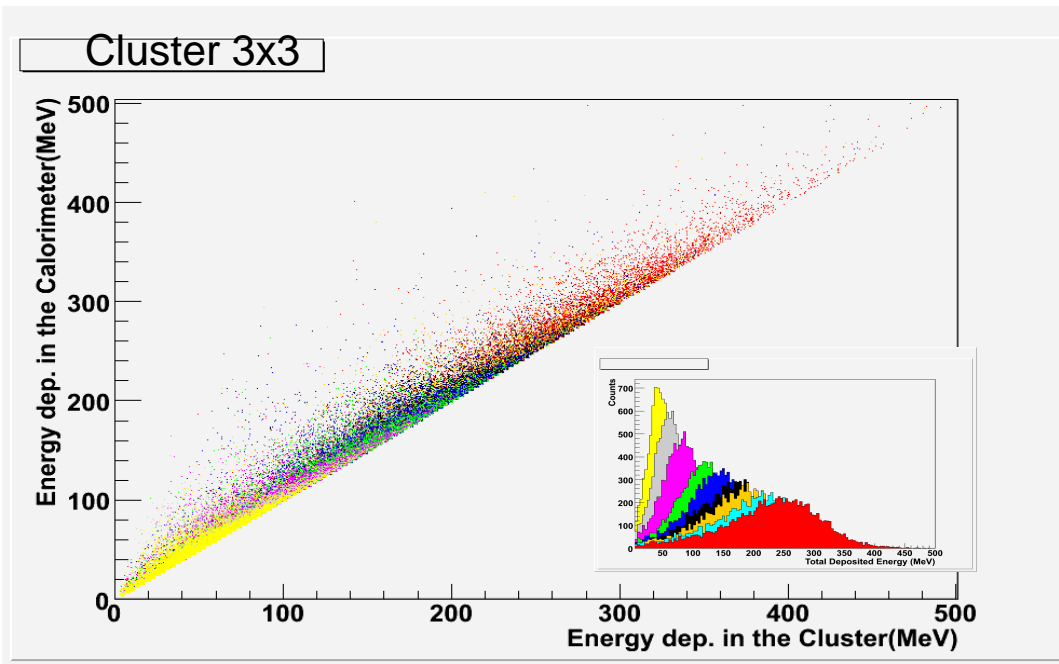
- Birk doesn't change electron deposited energy spectrum,

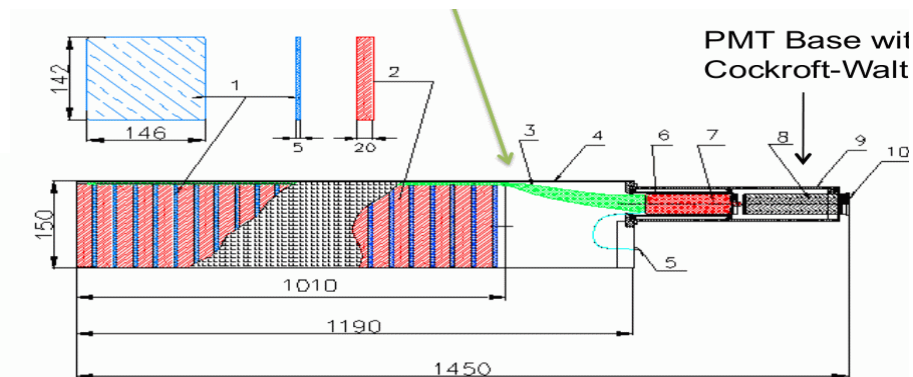
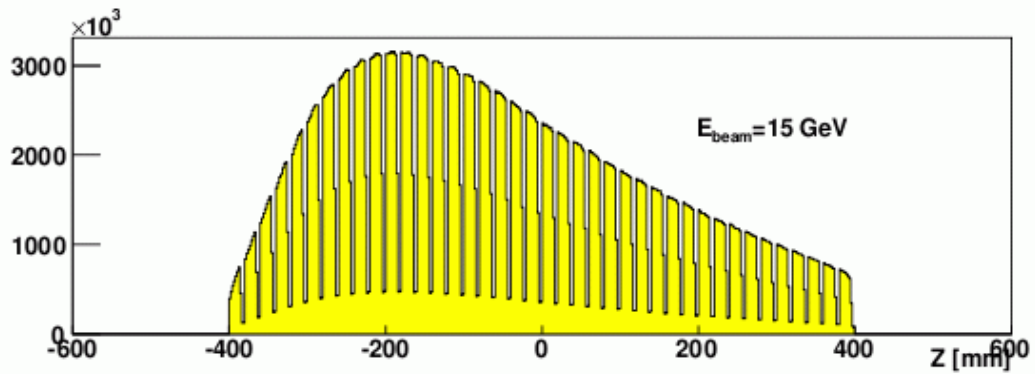
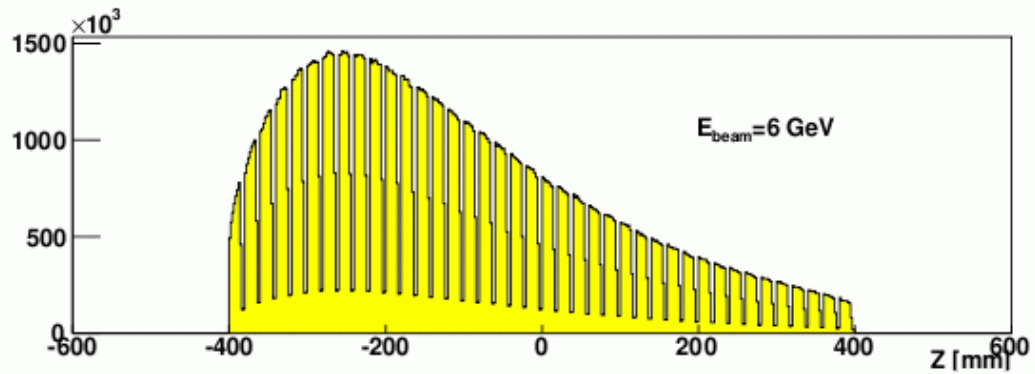
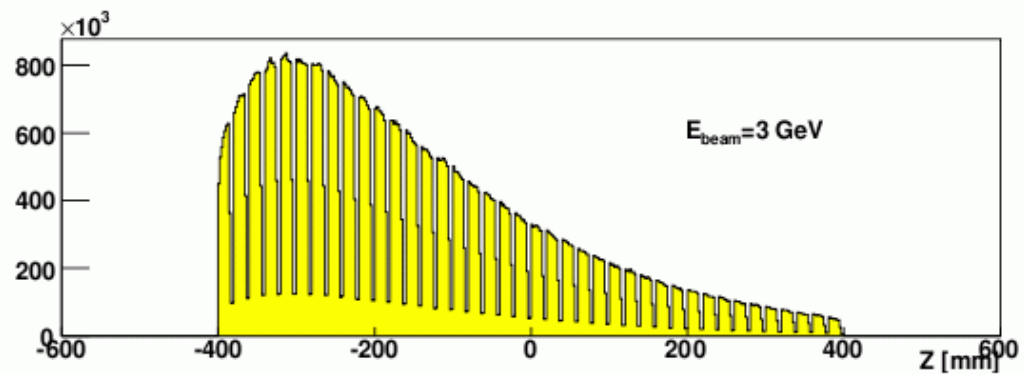


- But squeezes the proton spectra.



Geant4 simulation Results





Protons

-Compass got a 1.4ns time resolution.
Simulations can just get us intrinsic timing.
One needs to do real tests for complete timing study.

Requirements:

- Chose reasonable length for the module
- Light guide material CO-95 or CO-120 organic glass-> need better?, positioning...

-PMT search:

- Non Uniformity of light collection ~5%

- Communicate with the **Dubna** group
- DAQ: See **Ole Hansen's talk**

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