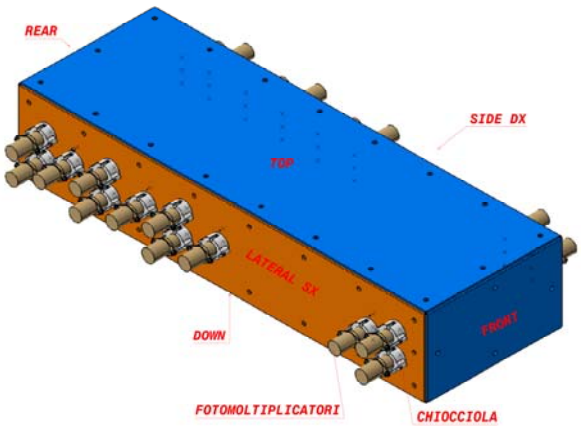


An instrumented absorber detector for hadronic interaction measurements

"The Smart Absorber of Crysbeam project"

Francesco Iacoangeli (INFN Roma)

WaveCatcher and SAMPIC International Workshop, Feb. 7-8, LAL Oray, France

The Smart Absorber

64Ch WaveCatcher readout

Multichannel Power Supply System

The Smart Absorber is a Cherenkov calorimeter optimized for study of hadronic shower evolution and for measurement of the hadronic cross sections at a high energy.

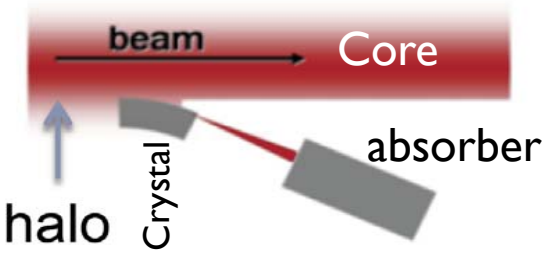
It is one of tree key elements of CRYSBEAM Project

Outline

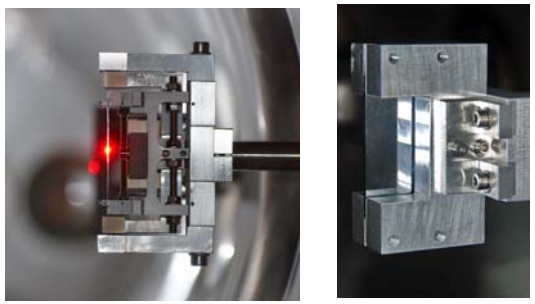
- The Crysbeam project
- The Smart Absorber
- The use of WaveCather : pro, cons and possible improvments

Crysbeam

CRYSBEAM basic idea



Experience of crystals with accelerator is well consolidated at CERN with UA9



UA9 crystals used for Beam Collimation

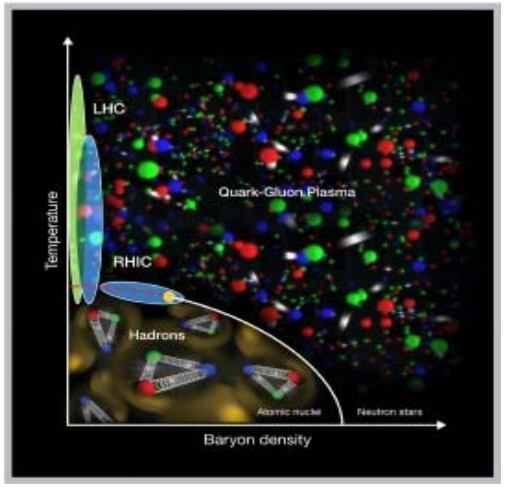
CRYSBEAM (and INFN) propose to demonstrate multi-TeV crystal extraction is feasible

Goal → Efficient crystal extraction of a multi-TeV hadron beam, *with **a bent crystal** in **channeling orientation,*** for fixed target experiments

Cutting-edge technology in crystal and particle detectors

Physics with a multi-TeV hadron beam

Phase diagram of hadronic matter



- QCD at **unprecedented** laboratory energies and momentum transfers
- Proton spin physics
- ***Quark-gluon plasma excitation in the target rest frame***
- Diffractive physics
- … and more with secondary beams

"Physics opportunities of a fixed-target experiment using LHC beams"
S. J. Brodsky, F. Fleuret, C. Hadjidakis, and J. P. Lansberg, Phys. Rep. 522 (2013) 239-255.

Cosmic ray shower

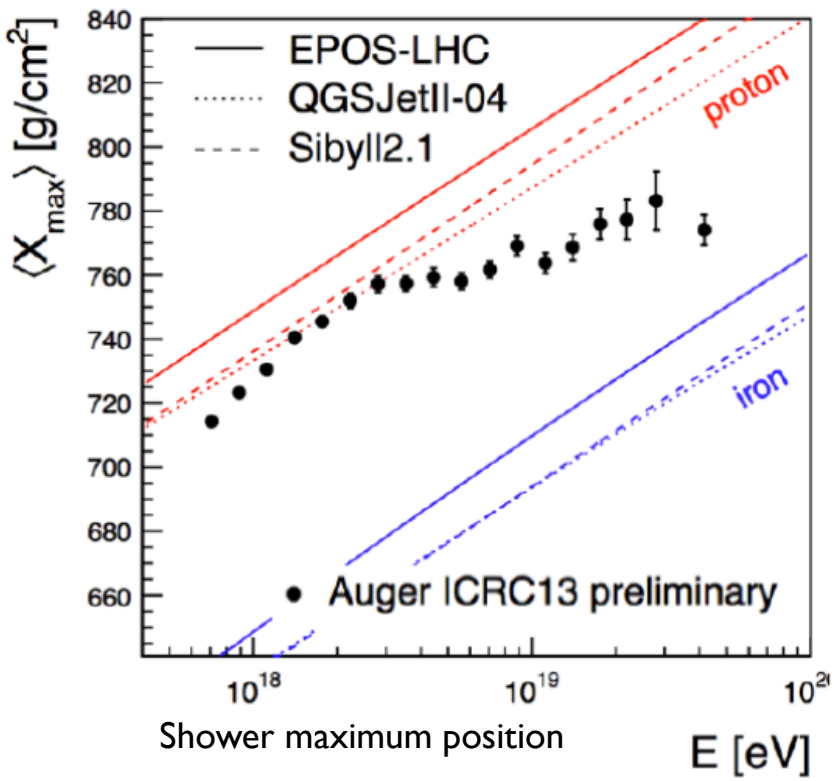
- What is the nature of the cosmic rays?

CRYSEBAM proposes experiments relevant for Cosmic Rays physics to demonstrate this technique is valid

→Study interaction of hadrons with **different nuclei (targets of C,N,O,…)**

Cosmic Ray Mass composition

Pierre Auger Observatory



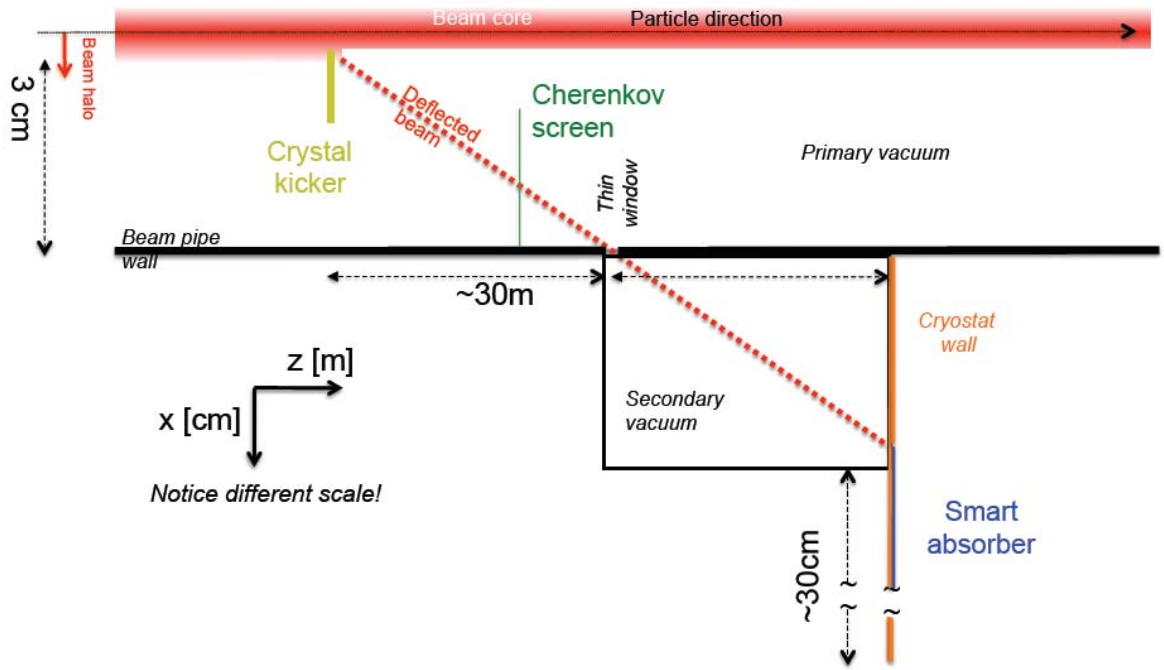
Shower maximum position

- Cosmic ray experiment observation depends on detailed **MonteCarlo code** to disentangle primary ray

- Data interpretation depends on MC used to described the shower

Measuring the cross section at various energies (100 GeV-10 TeV) on atmosphere-like target can help in those MC calibration

CRYSBEAM conceptual layout



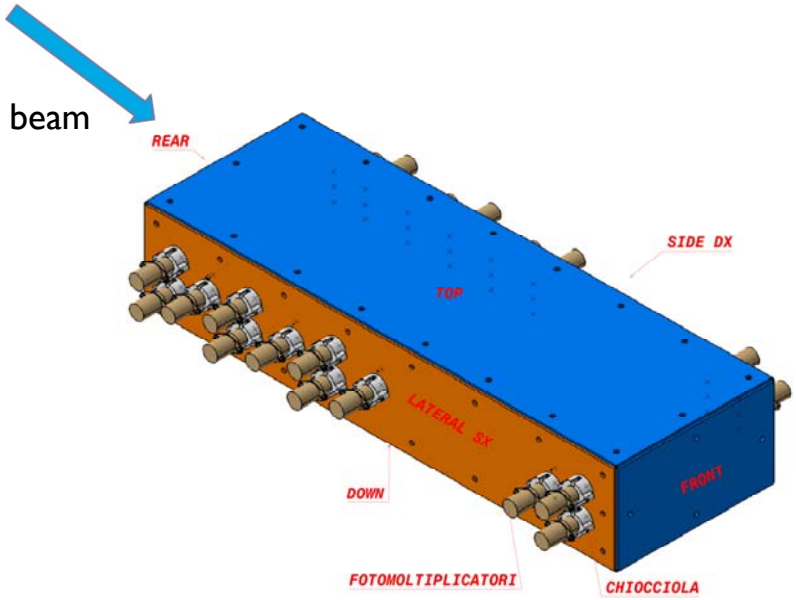
- **Crystal kick about 1 mrad** technically feasible.
- ***Detection and timing*** of deflected/extracted beam at the vacuum/air interface with a detector based on ***Cherenkov*** light emission.
- **Instrumented** beam dump in air to measure the hadronic shower structure (**the Smart Absorber**)

Smart Absorber

The Smart Absorber

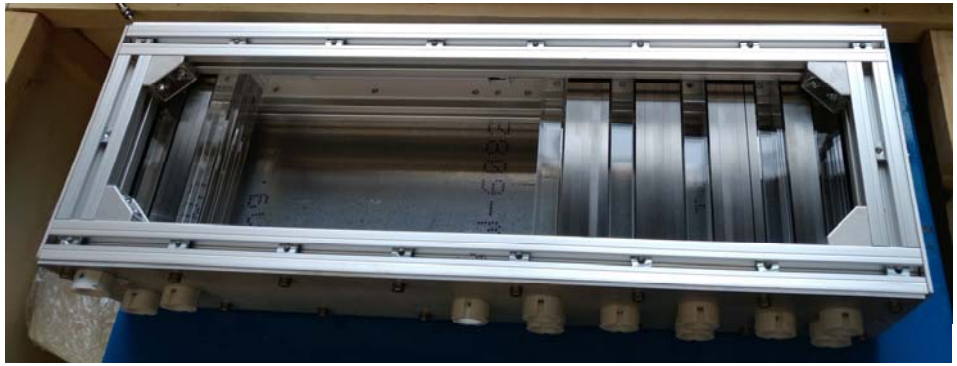
The smart absorber has been designed and built with alternating layers of tungsten and fused silica Cherenkov radiators.

incoming beam direction



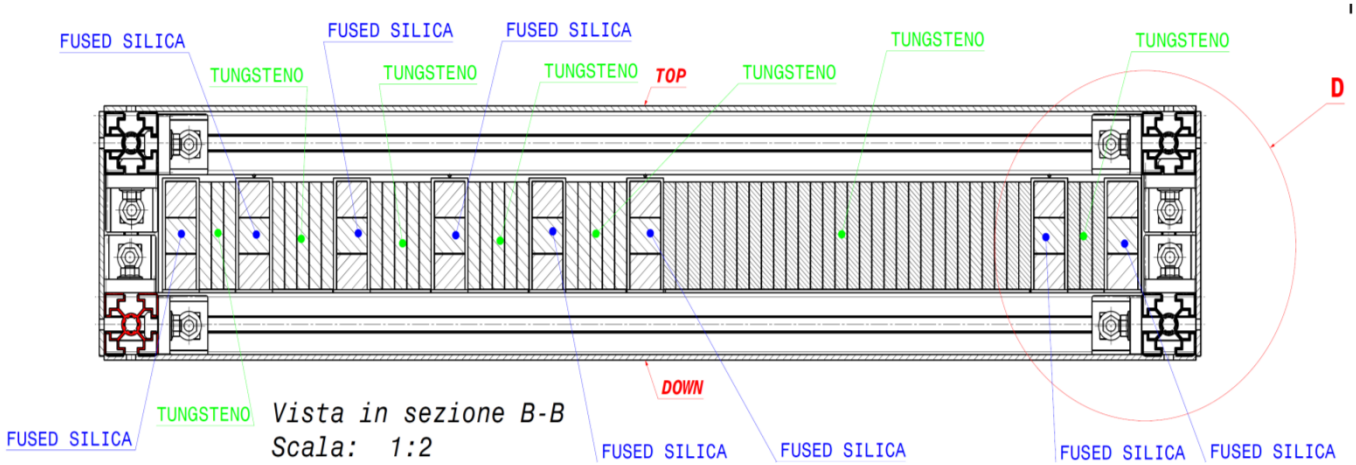
- Absorber dimensions 30 cm x 7,5 cm x 80 cm
- Cherenkov Radiators and tungsten layers for ~180 radiation length in total

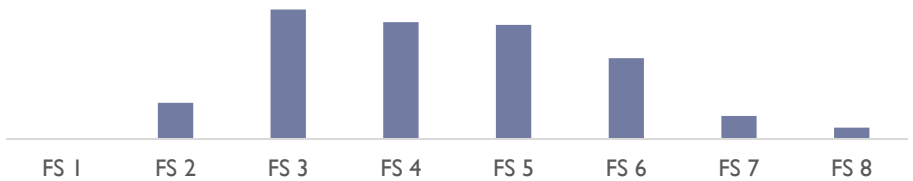
The Smart Absorber



- The detectors made up of 8 layers of Cherenkov radiators , placed between layers of tungsten absorber.
- Each Cherenkov layer is composed of 3 radiators of 2.5cm x 2.5cm x 30cm.
- Every radiator has separated optical readout based on PMT (24 channels in total).

The Smart Absorber





Yielded ligth in fused silica layers for 6.5 TeV protons beam

The layers of fused silica Cherenkov radiators and the thickness of the tungsten layers are optimized , thanks to GEANT 4 simulation, to best follow the hadron shower evolution.

Optical readout

Hamamatsu R7378A

Figure 3: Dimensional Outline and Basing Diagram (Unit: mm)

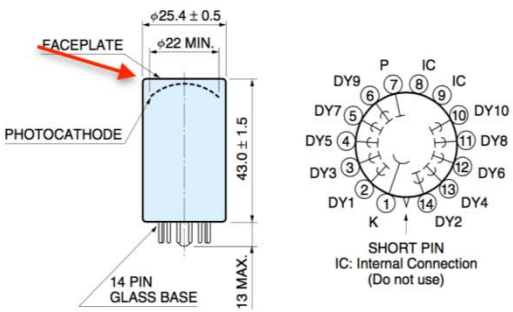
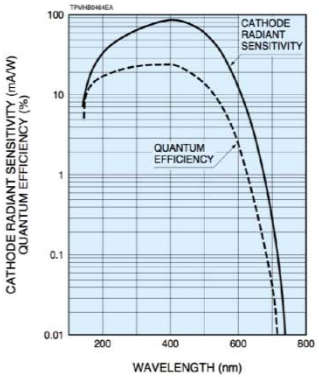
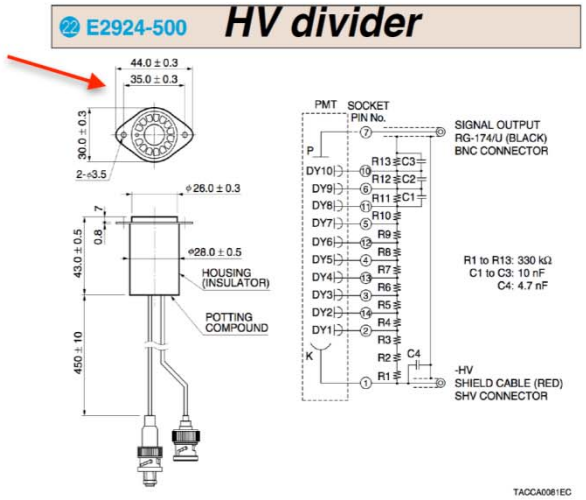


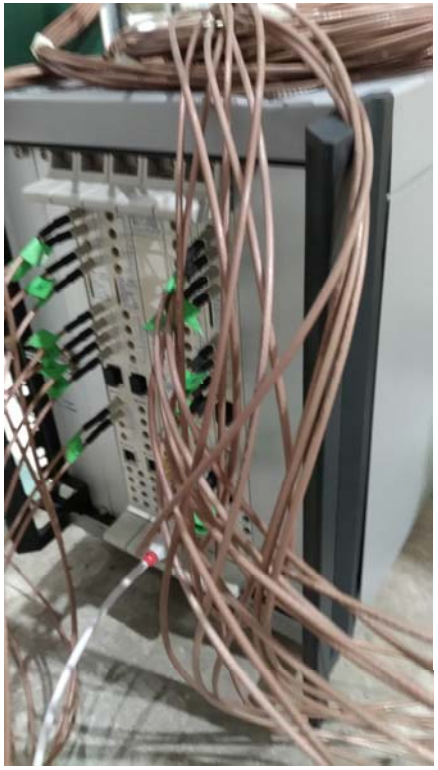
Figure 1: Typical Spectral Response



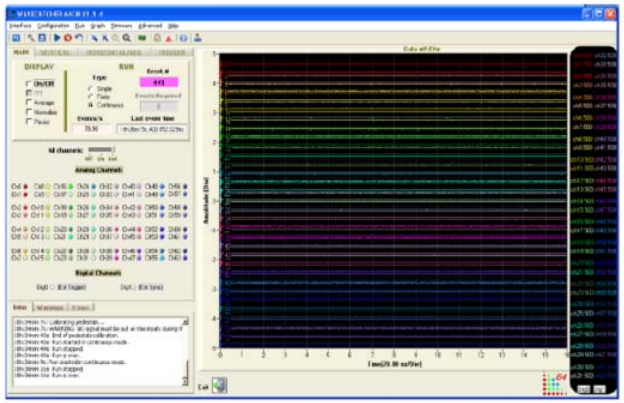


- Good spectral response for Cherenkov (200nm)
- Fast response (anode pulse rise time ~1,5ns)
- Already tested for on-beam instrumentation (UA9 CpFM)

Readout system



- 64 channels Wavecatcher System, usb connected with external PC
  - A waveform digitizer
  - 3.2 Gs/s sampling rate
  - 12 bits
  - < 10ps rms sampling time precision

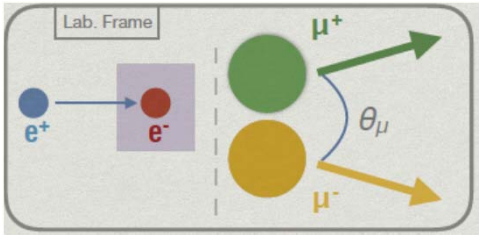


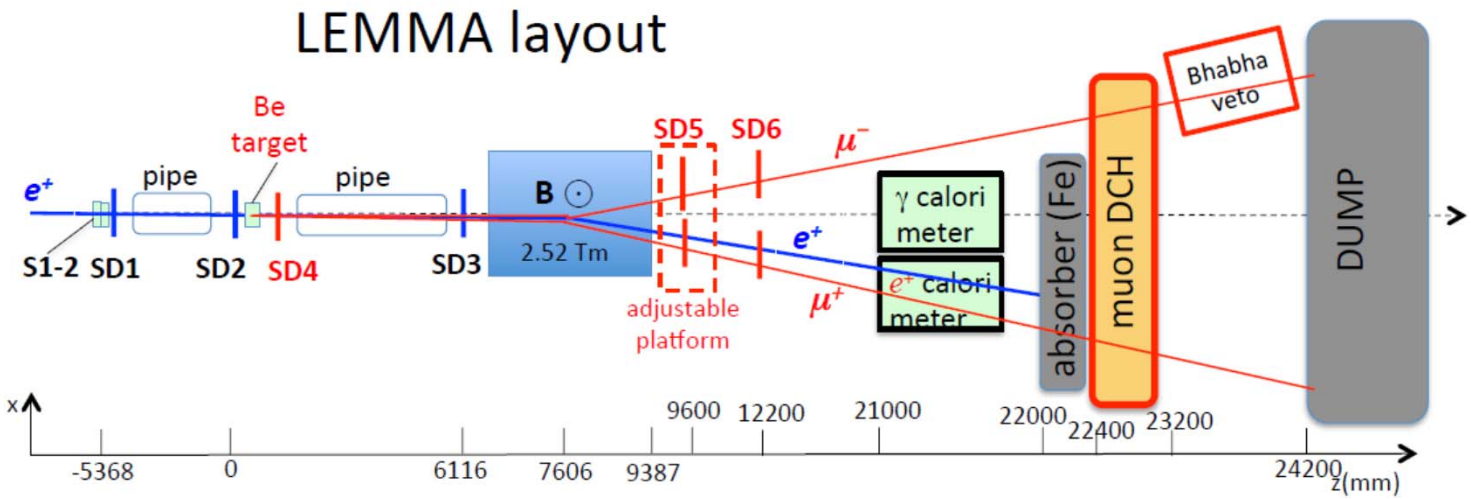
D. Breton, PhotoDet2012

The first test on LEMMA experiment

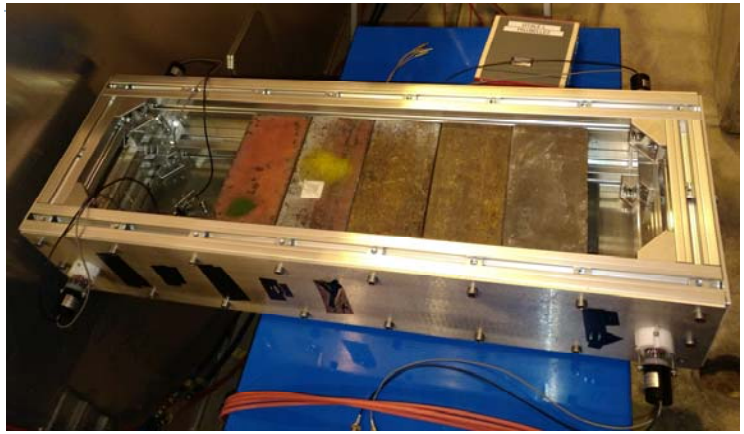
A first version of Smart absorber, with only 4 channels and with iron instead of tungsten , was used as Bhabha veto during LEMMA (Low EMittance Muon Accelerator) test beam at H4 beam line, CERN, North experimental area.

LEMMA: direct μ-pair production from e+e- → μ+μ- just above production threshold (√s=212MeV), by using a beam of ~45 GeV e+ on a thin target





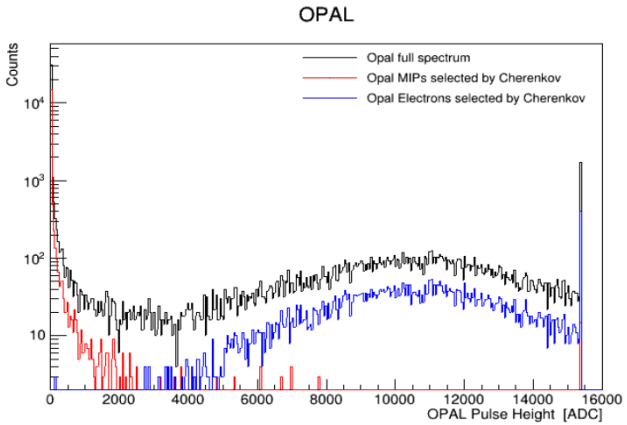
Lemma test beam



- only 2 layers of fused silica ,(the first and the last one) and 50 cm of iron absorber (~30 radiation length ,~ 3 pion interaction length)

- Used as veto to separate μ and e

- Only 4 channels (2 front and 2 back) readout by 8-channels WaveCatcher



Amplidute spectrum of lead glass calorimeter with end without veto

- Data was integrated on LEMMA DAQ and used for offline analysis

- Preliminary analysis shows the Smart Absorber can used to cut Bahbah events

WaveCatcher

WaveCatcher Pro & Cons

Pro:

- High performance waveform digitizer with very low cost per channel
- Good time precision
- High configurable trigger logic
- Useful measurements tools
- Ready-to-use GUI interface
- UA9 already uses this electronics for some instruments (CpFM)

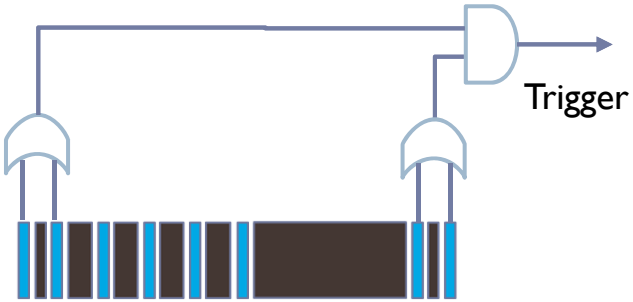
Cons:

- Long dead-time between acquisition (is not a critical issue for our application)
- Some PC interface instability (I guess due to USB driver)

WaveCatcher possible improvement

- The logic trigger features are very useful and enable self-triggered application:

  - More complex trigger logic , like coincidence of more channel in OR



  - Majority trigger function even in >8 channels board

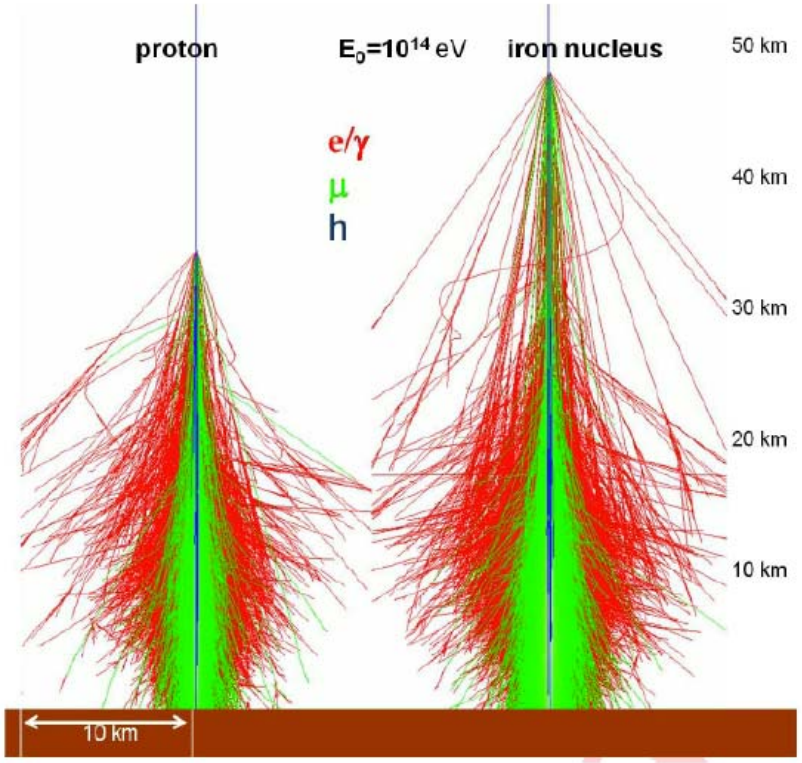
- Zero-suppression functions

☺ A minor improvement :

- The front panel holes for MCX connectors is too small for my connector. A larger front panel holes would increase the compatibility

SPARE

Ultra High Energy Cosmic Rays



-When UHECR enters the Earth's atmosphere it produces a extensive cosmic ray showers.
It is possible by analyzing these showers to discover many of the traits of the original CR.

→Observations of Comsic Ray at ground level (i.e. Pierre Auger Observatory , HiRes..

Cosmic ray experiment observation depends on detailed **MonteCarlo code** to disentangle primary ray

Requirements and methods of CRYSBEAM

	ELEMENT	REQUIREMENTS	METHODS
	Crystal Kicker	Orient lattice planes parallel to the beam within $\theta_C(7\,TeV) \approx 2\ \mu rad$ inside the vacuum beam pipe.	Finely polished, low miscut silicon crystals. Goniometer for ultra-high vacuum.
	Cherenkov Screen	For deflected particles measure flux at ***5%***, timing ***<1ns***, beam-spot ***≈ 250 μm***	Fused silica slab transverse to beam. Cherenkov light internally reflected through optical micro-guide
	Smart Absorber	Measure particle cross sections on nucleus A σ_{tot}**(p-A)** and σ_{tot}**(Pb-A)** as in Cosmic rays collisions	Several Chrenkov radiator layers to follow the hadron shower evolution.