The LHCf experiment at LHC

Measurement of π^0 production cross section in the very forward region at LHC
Equivalent laboratory energy $\approx 10^{17}$ eV

- LHCf physics
- Description of the experiment
- Some results on simulation and beam test
- Conclusions

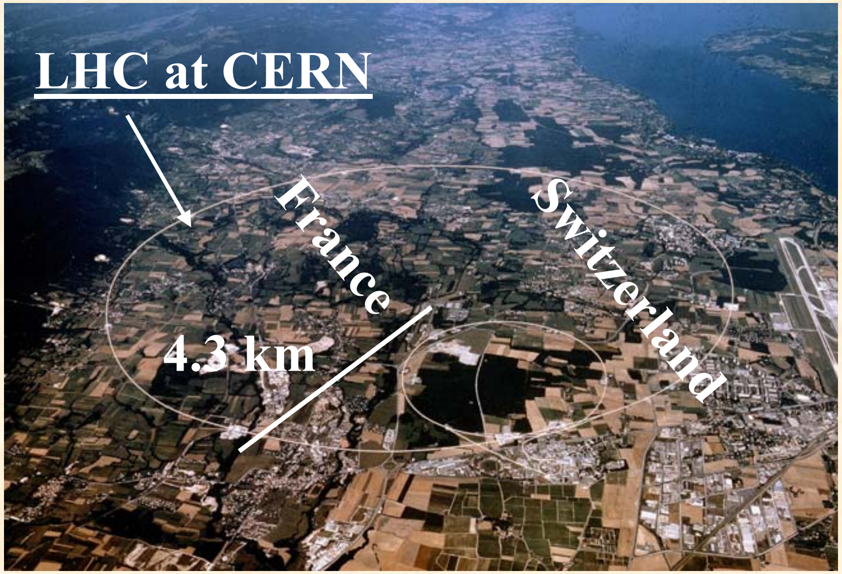
Oscar Adriani

INFN Sezione di Firenze - Dipartimento di Fisica dell'Università degli Studi di Firenze

The LHCf collaboration

O. Adriani[1], L. Bonechi[1], M. Bongi[1], R. D'Alessandro[1], A. Faus[2], M. Haguenauer[3], Y. Itow[4], K. Kasahara[5], K. Masuda[4], Y. Matsubara[4], H. Matsumoto[4], H. Menjo[4], Y. Muraki[4], Y. Obata[6], T. Sako[4], T. Tamura[6], K. Tanaka[6], S. Torii[7], A. Tricomi[8], W.C. Turner[9], J. Velasco[2], K. Yoshida[6]

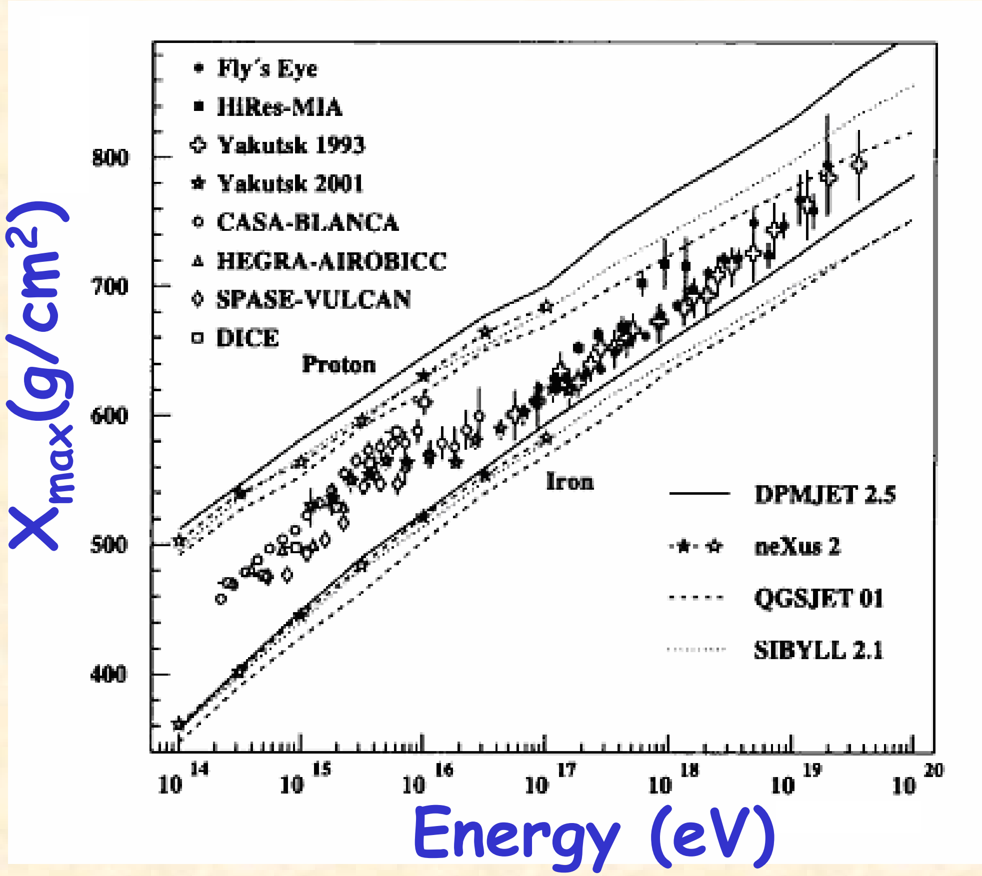
(1) INFN and Università di Firenze, Italia
(2) IFIC, Centro Mixto CSIC-UVEG, Valencia, Spain
(3) Ecole - Polytechnique, Paris, France
(4) STE laboratory, Nagoya University, Japan
(5) Shibaura Inst. of Techn., Saitama, Japan
(6) Kanagawa University, Yokohama, Japan
(7)Advanced Research Inst. for Science and Engineering, Waseda University Japan
(8) INFN and Università di Catania, Italia
(9) LBNL, Berkeley, California, USA



Experience from UA7 collaboration at CERN SPS (E_{Lab} = 10^{14} eV)

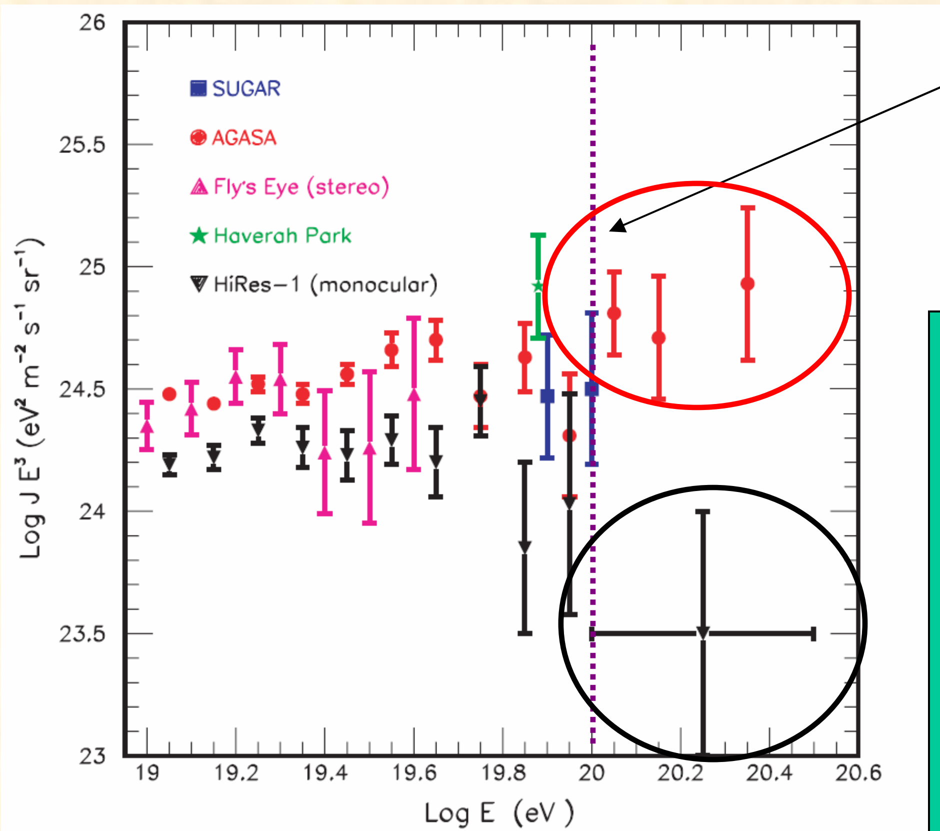
Main problems in High Energy Cosmic Rays ($E>10^{15}$eV)

1. Composition



2. Spectrum / GZK Cutoff

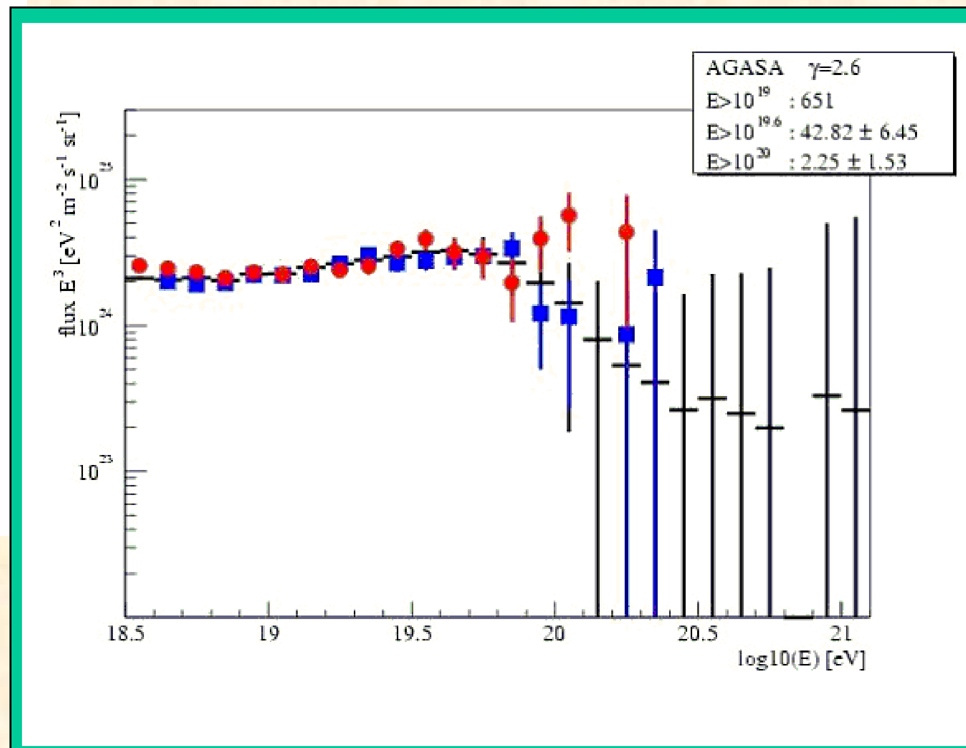
The Extreme Energy events



GZK cutoff: 10^{20} eV

super GZK events?!?

15% correction on the absolute energy scale!!!



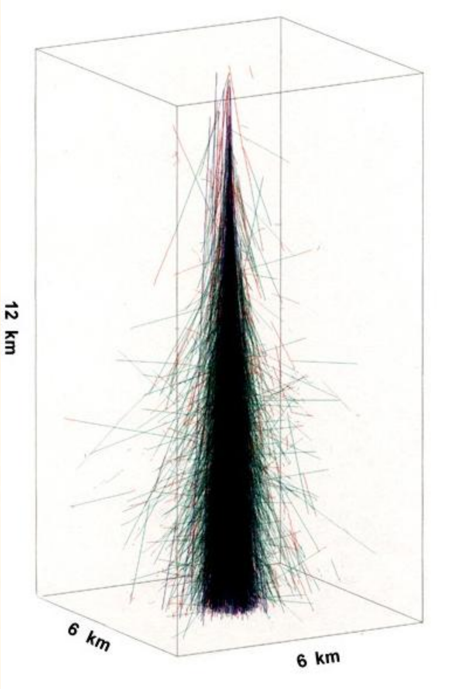
Composition: inferred from X_{max}

Spectrum: Energy is measured by counting the secondaries

Simulation plays a crucial role

→ Many dedicated talks in this conference!

LHCf is a tool to calibrate the simulation



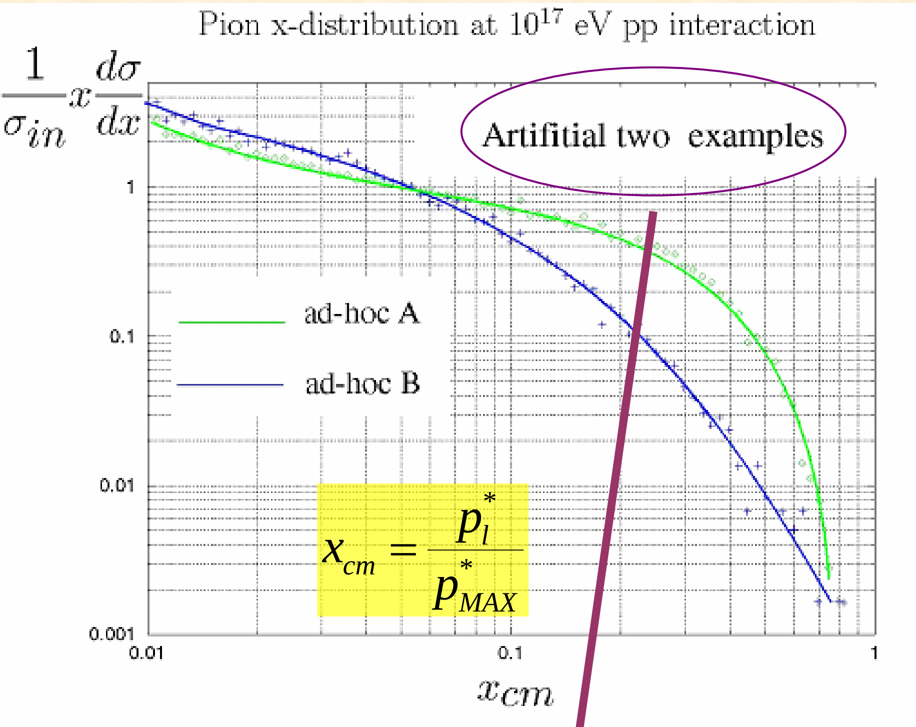
Development of atmospheric showers

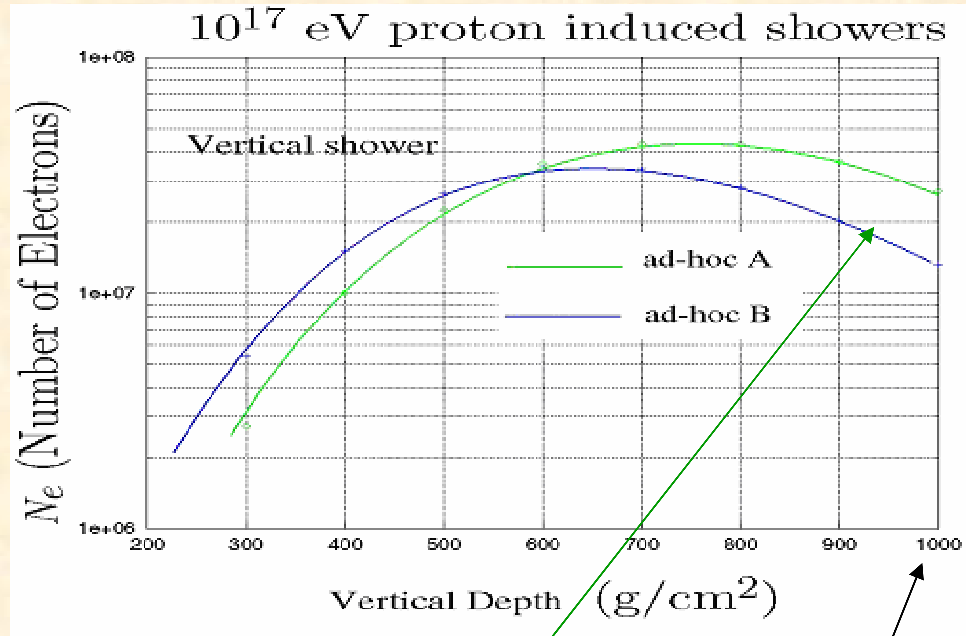
Simulation of an atmospheric shower due to a 10^{19} eV proton.

- The dominant contribution to the energy flux is in the very forward region ($\theta \approx 0$)
- In this forward region the highest energy available measurements of π^0 cross section were done by UA7 (**E=10^{14} eV, y = 5÷7**)

$$y = -\ln \tan \frac{\theta}{2}$$

Longitudinal development of showers





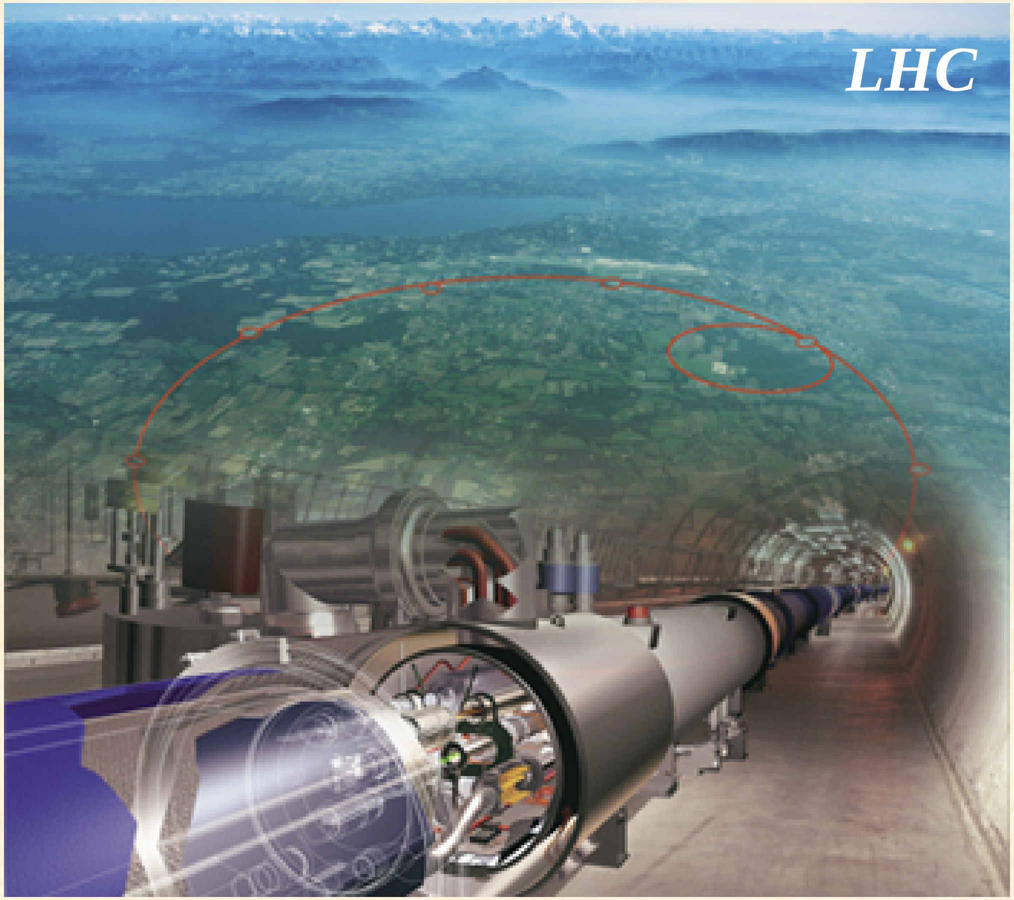
DPMJET, QGSJET, SIBYLL ...
are normally used

Factor 2 of discrepancy

Sea Level

The direct measurement of the π production cross section as function of p_T (x_{cm}) is essential to correctly estimate the energy of the primary cosmic rays

Summarizing…



Calibration of the models at high energy is mandatory

We propose to use LHC, the highest energy accelerator

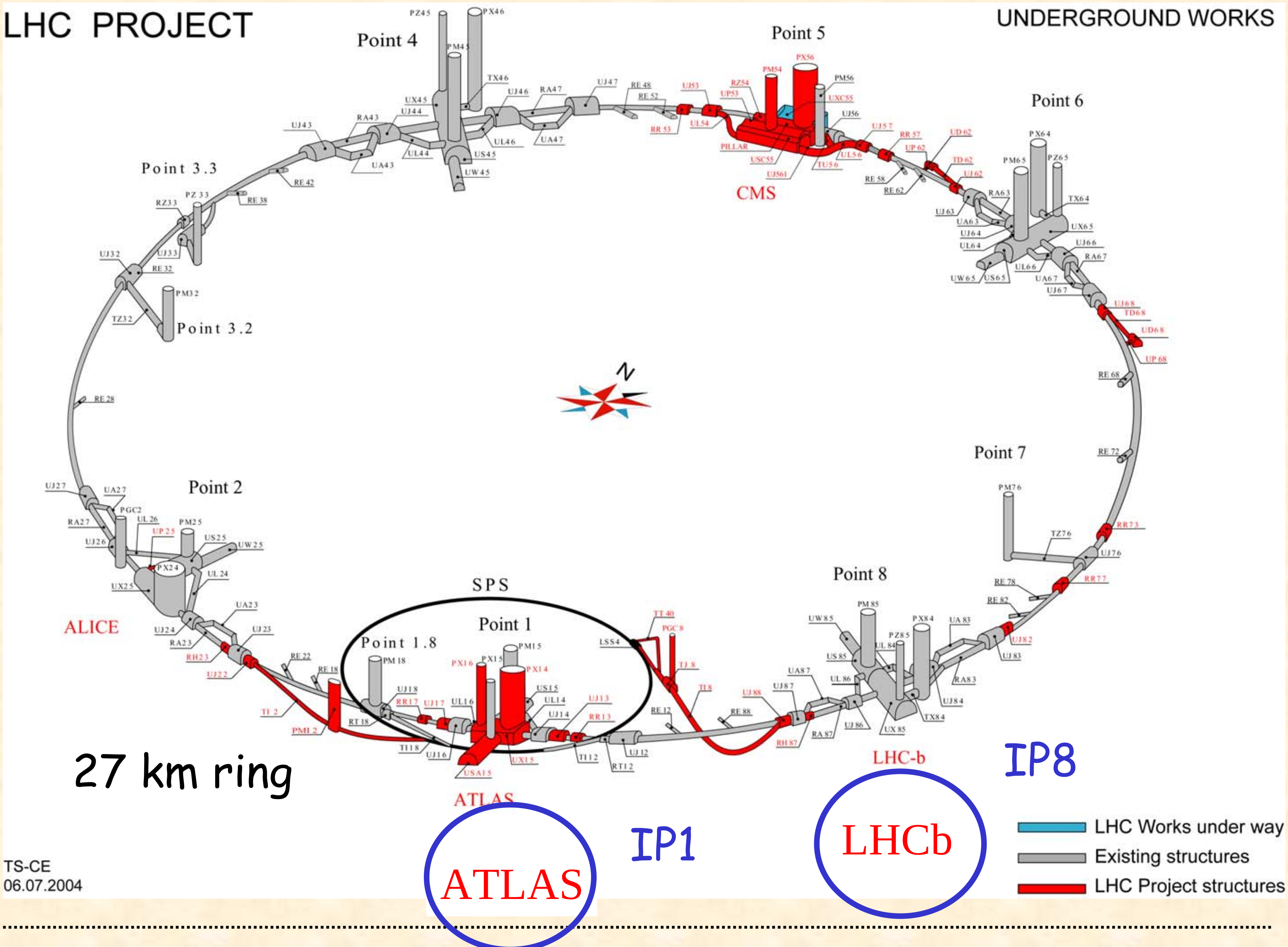
7 TeV + 7 TeV protons
14 TeV in the center of mass

$E_{lab}=10^{17}$ eV $(E_{lab}= E^2_{cm}/2\ m_P)$

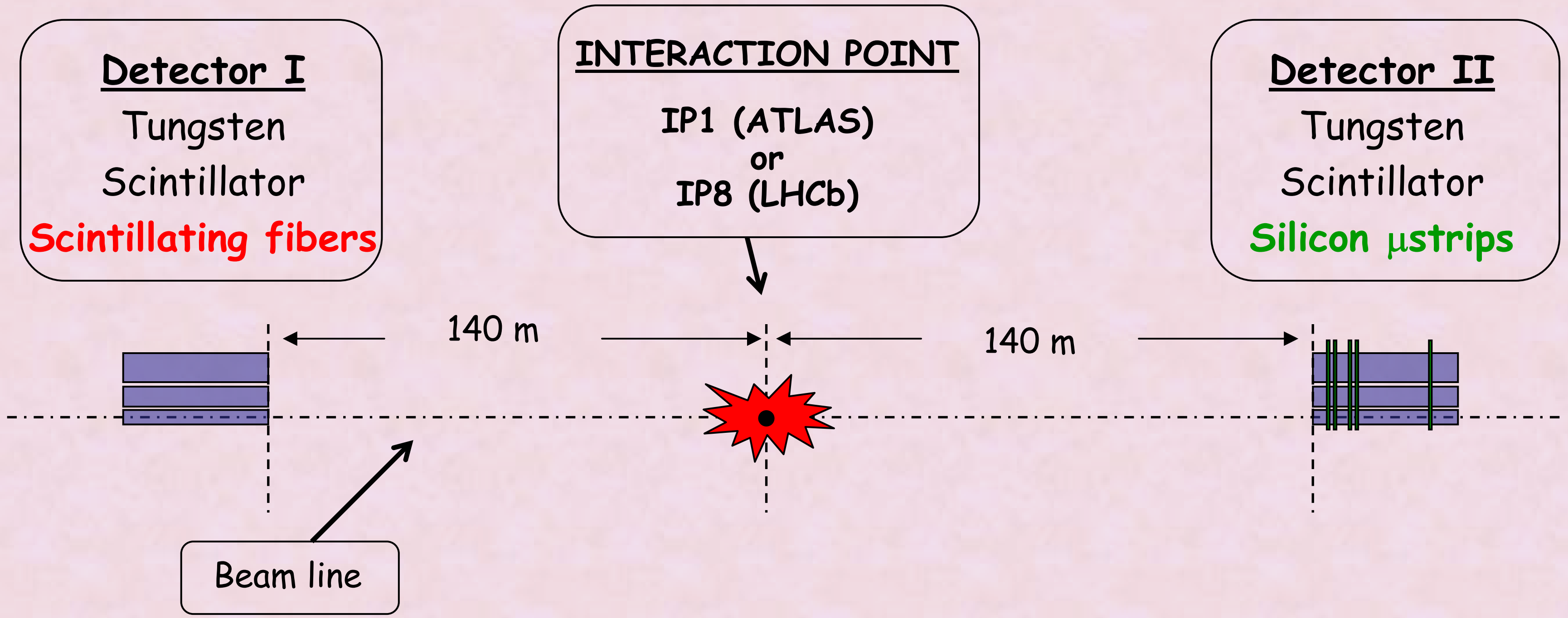
Major LHC detectors (ATLAS, CMS, LHCB) will measure the particles emitted in the central region

LHCf will cover the very forward part

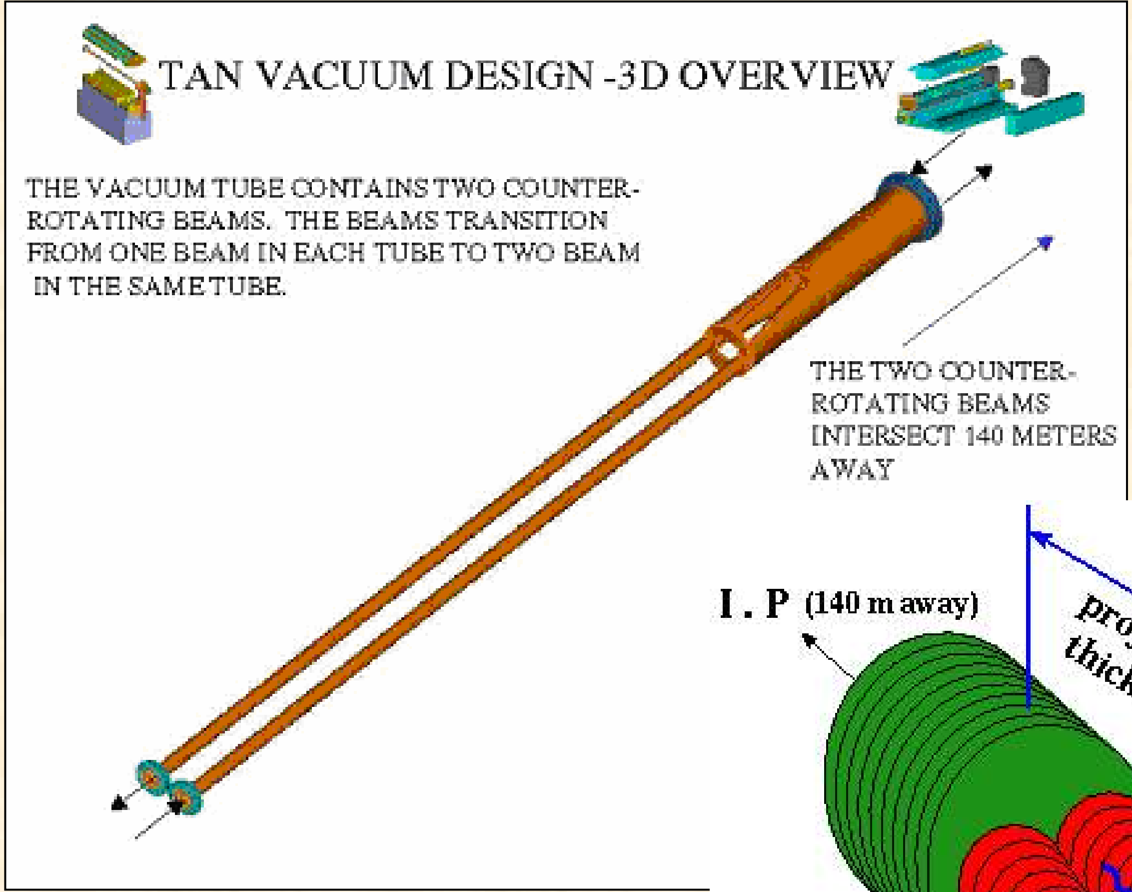
May be also Pb-Pb collisions????


LHC PROJECT
UNDERGROUND WORKS
Point 1
Point 1.8
Point 2
Point 3.2
Point 3.3
Point 4
Point 5
Point 6
Point 7
Point 8
SPS
CMS
ALICE
ATLAS
LHC-b
27 km ring
IP1
IP8
ATLAS
LHCb
LHC Works under way
Existing structures
LHC Project structures
TS-CE
06.07.2004

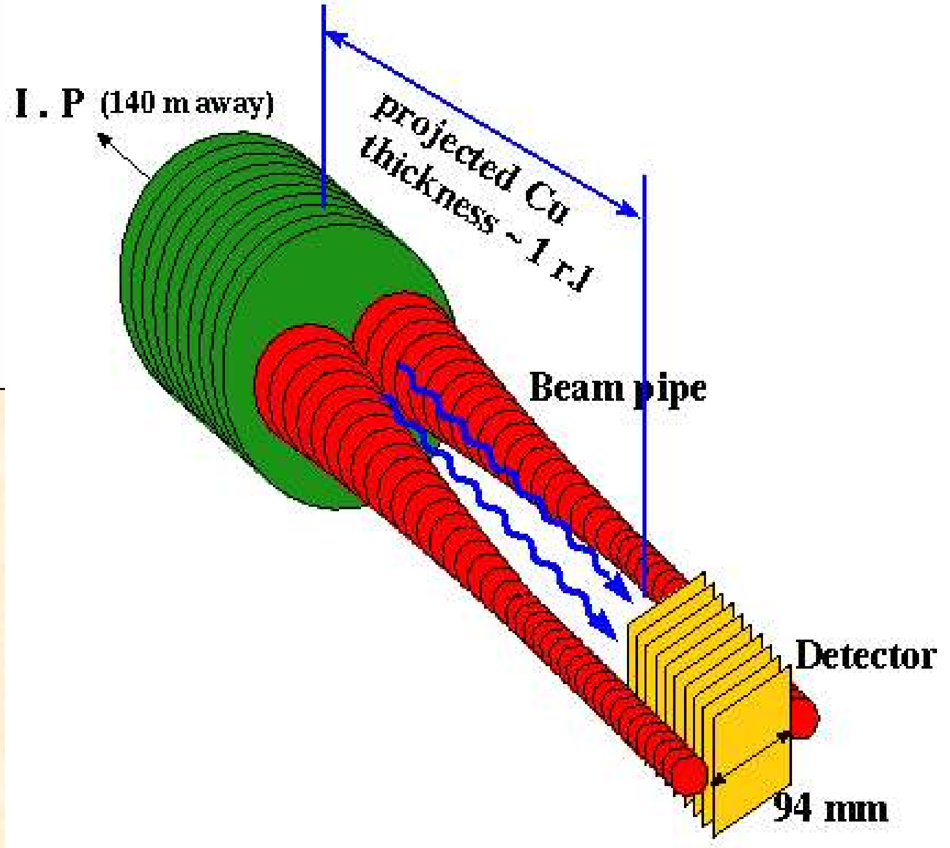
2 independent detectors on both sides of IPX



Detectors should measure energy and position of γ from π^0 decays → e.m. calorimeters with position sensitive layers



Calorimeters will be installed in the TAN region, 140 m away from the Interaction Point, in front of luminosity monitors



- Here the beam pipe splits in 2 separate tubes.
- Charged particle are swept away by magnets!!!
- We will cover up to y-> ∞

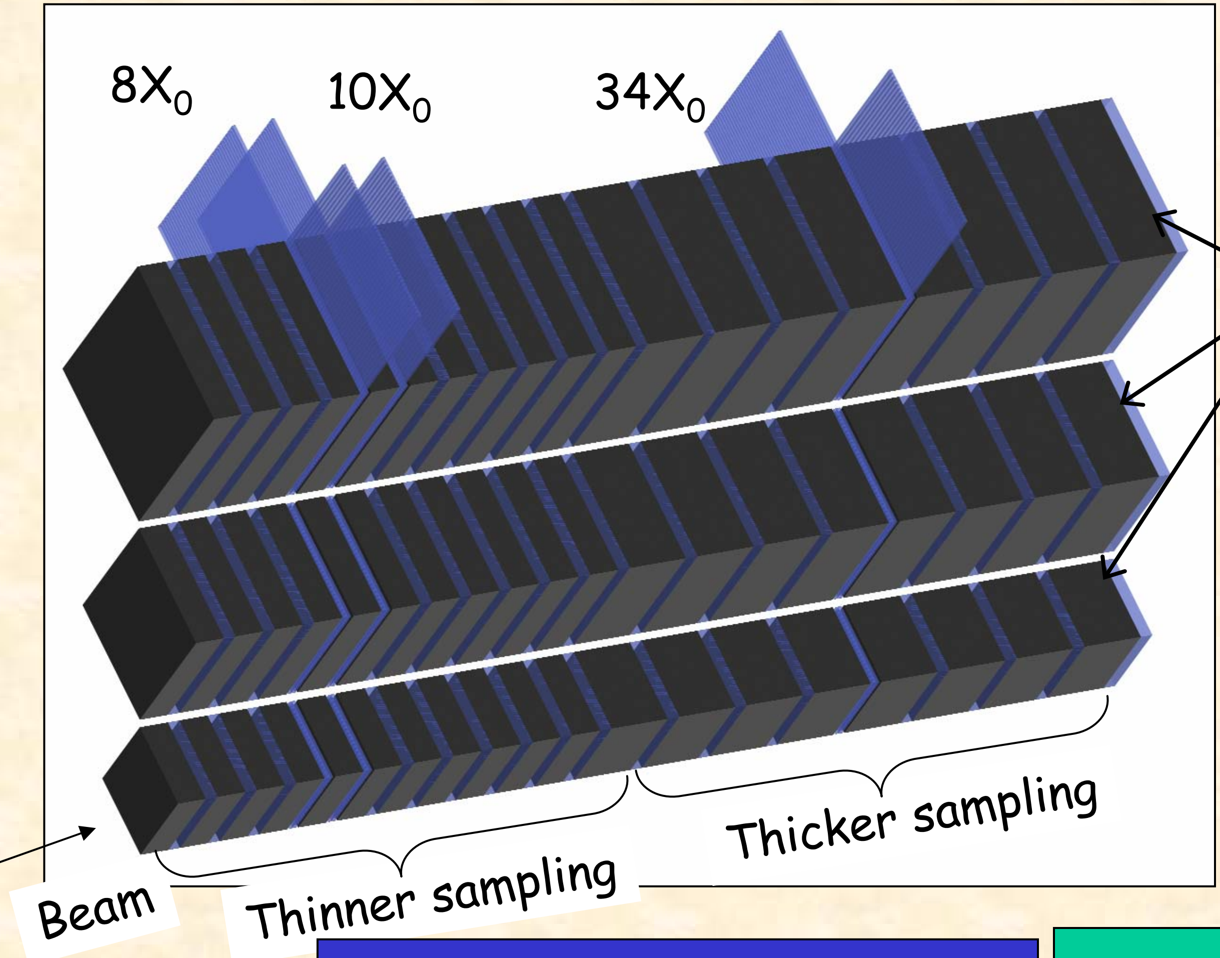
Basic structure is the same for both detectors:

1. Very deep calorimeter (54 X_0)
2. Tungsten/Plastic scintillator for energy measurement
3. 3 towers of different size: 2x2 cm^2, 3x3 cm^2, 4x4 cm^2

Significant difference in :

1. Position measurement
2. Geometry

Detector #1



3 towers with the same longitudinal structure but with different transverse dimensions

Dimensions max

(90 × 335 × 290) mm^3

Absorber

20 layers of tungsten, with different thickness (7 mm - 14 mm)

(W: X_0 = 3.5mm, R_M = 9mm)

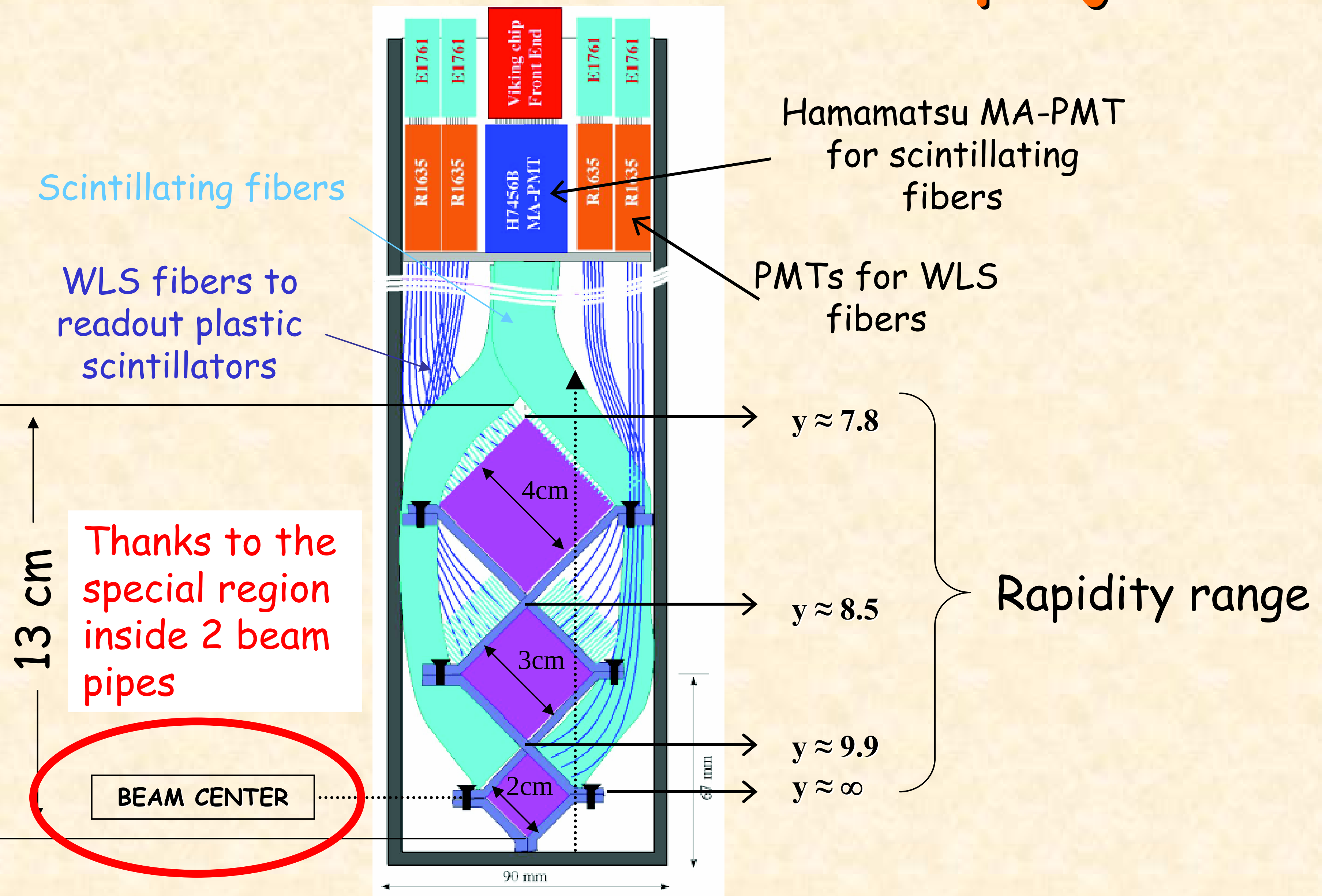
Scintillators

Trigger system and energy profile measurement: 3 mm plastic scintillator

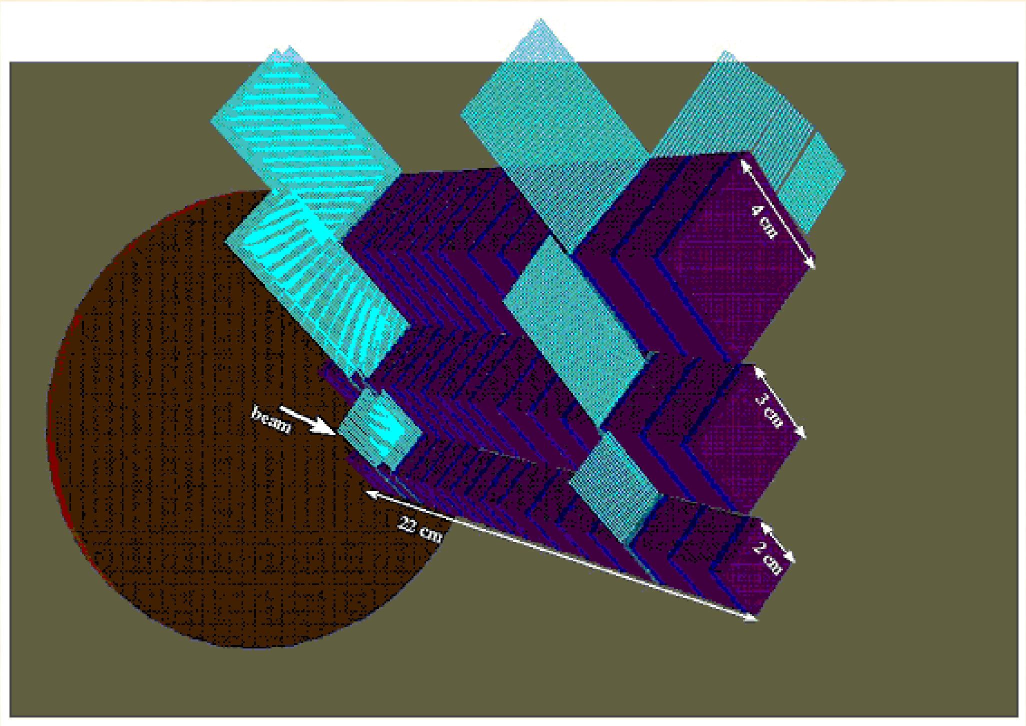
Scintillating fibers

3 double layers of 1 mm^2 scintillating fibers to measure the transverse shower profile

Detector #1: transverse projection



Why this 'strange' geometry?



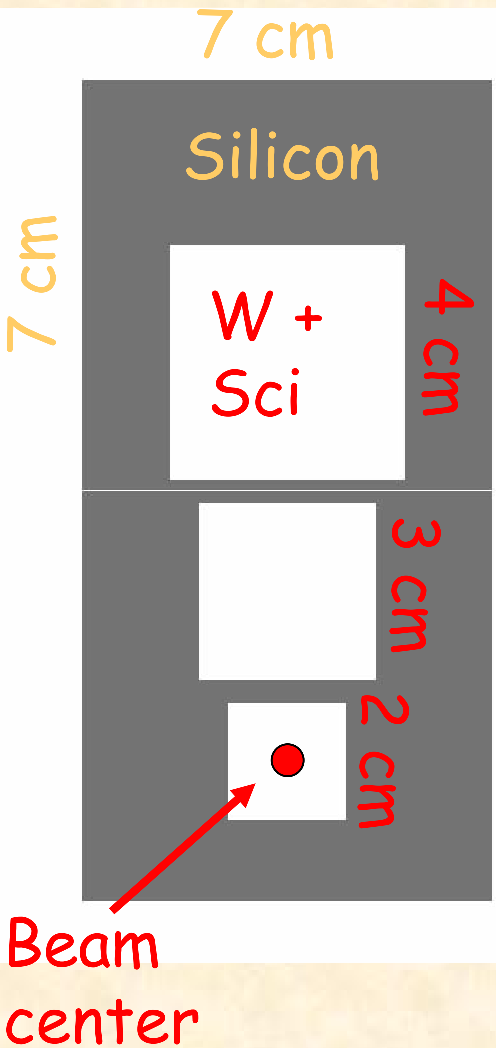
1) Less bending of fibers (limited transverse space)

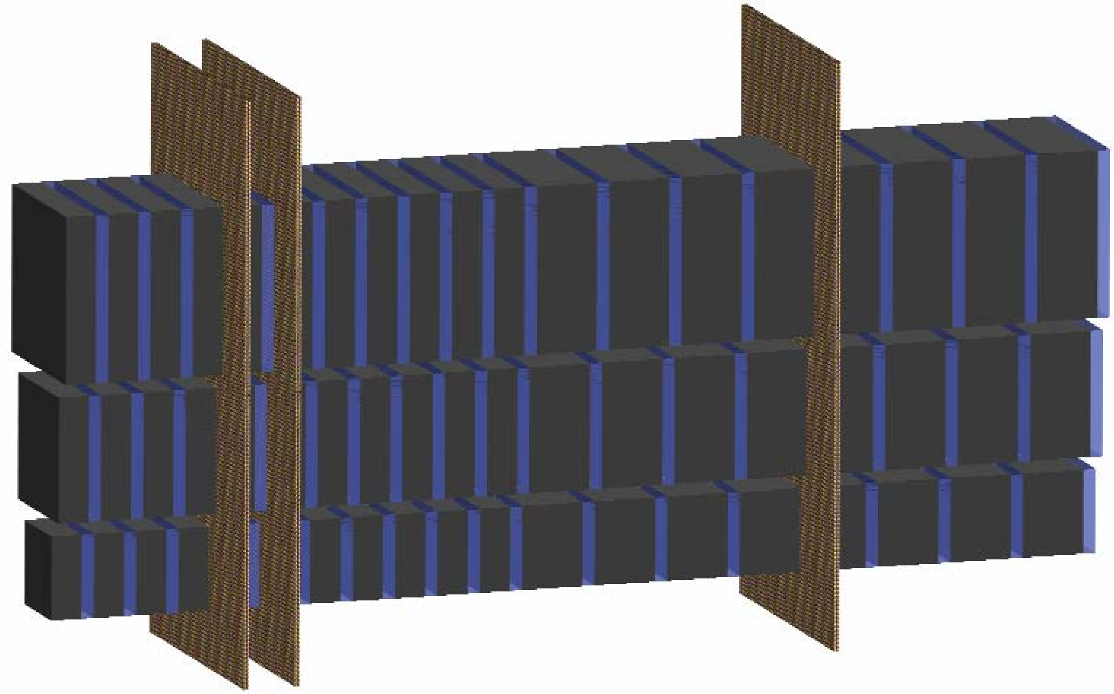
2) Different towers dimension (small one close to the beam, big one far away from the beam): minimization of multi hit events

3) Minimize the energy leakage from one tower to the adjacent one

4) Separation of the shower from 2 γ from π^0 decay: excellent tool to calibrate the energy measurement (invariant mass constraint)!!!!

Detector #2





SciFi are replaced by silicon μstrips detectors
70x70 mm^2
Pitch 80 μm
3 double layers (x-y)
1 double layer in front of the calorimeter?

Why these differences?

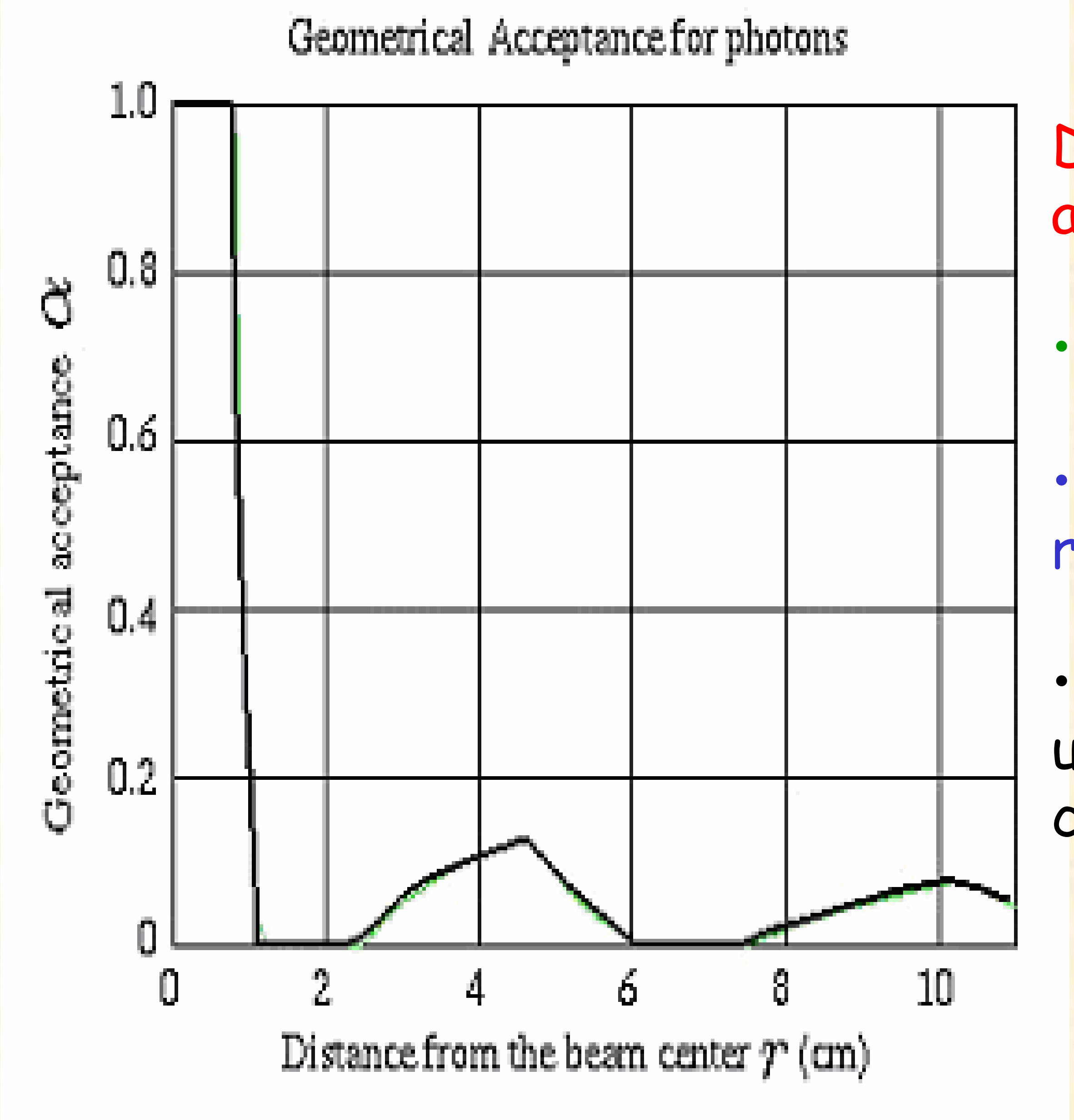
Advantages of Silicon μstrips:

- impact point measurement
- selection of clean events (1 γ)
- π^0 mass reconstruction (energy calibration)

Different geometry:

- different systematics
- different acceptance
- important for 'unknown' environment (LHC background????)

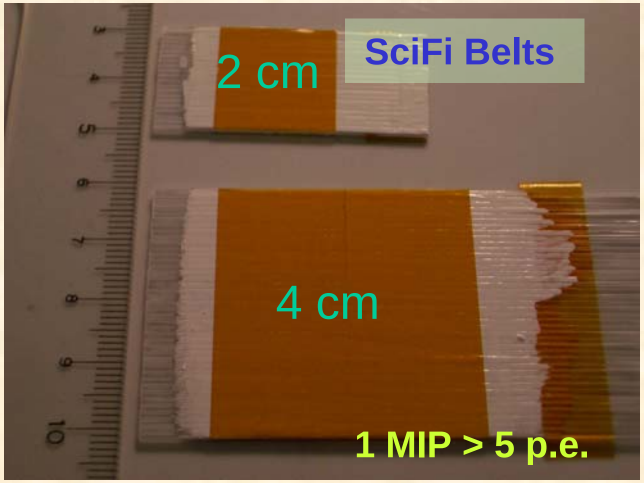
Common data taking/trigger (diffractive physics)

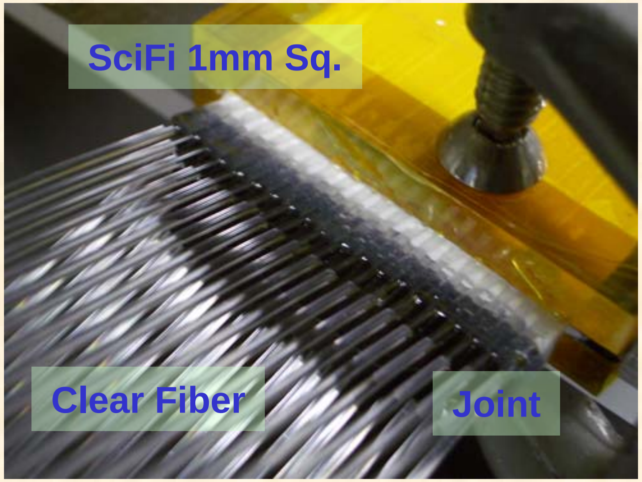


Detector #1 geometrical acceptance:

- Leakages are minimized
- Good position info is required
- Calorimeters are moved up and down (full rapidity coverage)

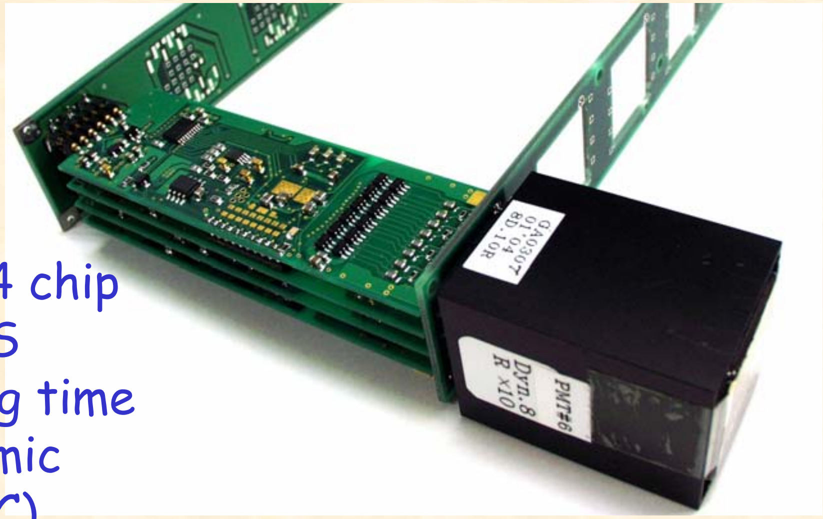
Scintillating fibers readout





Hamamatsu
64 ch (8x8)
8 dynode

MAPMT

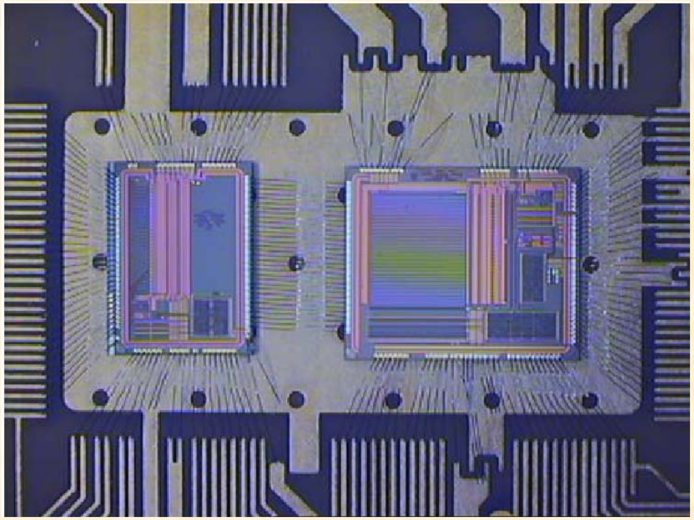


VA32HDR14 chip from IDEAS

- $1\ \mu s$ shaping time
- Huge dynamic range (30 pC)
- 32 channels

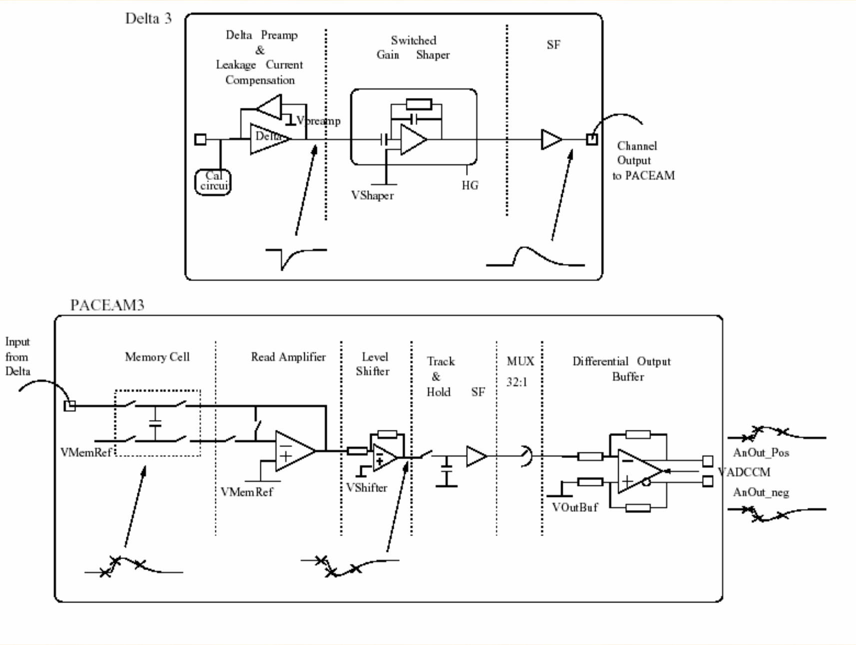
MAPMT+FEC

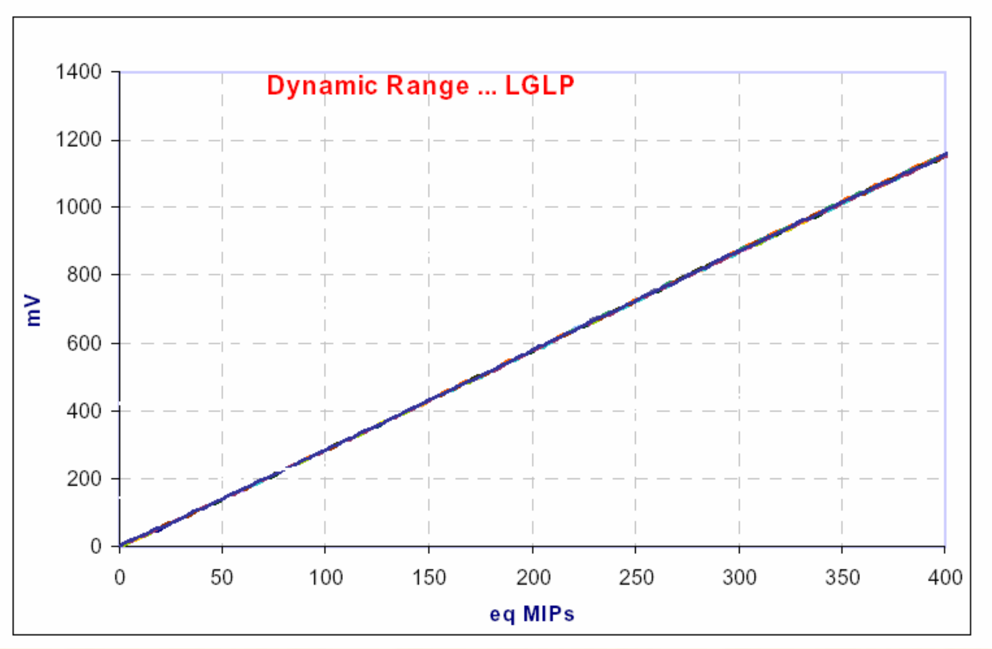
Silicon μstrips readout



Pace3 chips
(many thanks to CMS preshower!!!!)

- 32 channels
- 25 ns peaking time
- High dynamic range (> 400 MIP)
- 192x32 analog pipeline





Which are the expected performances?

Counting rate for γ
Energy resolution
Maximum energy
Counting rate for π^0
Neutron identification/rejection
Kinematical regions covered
....

Simulation

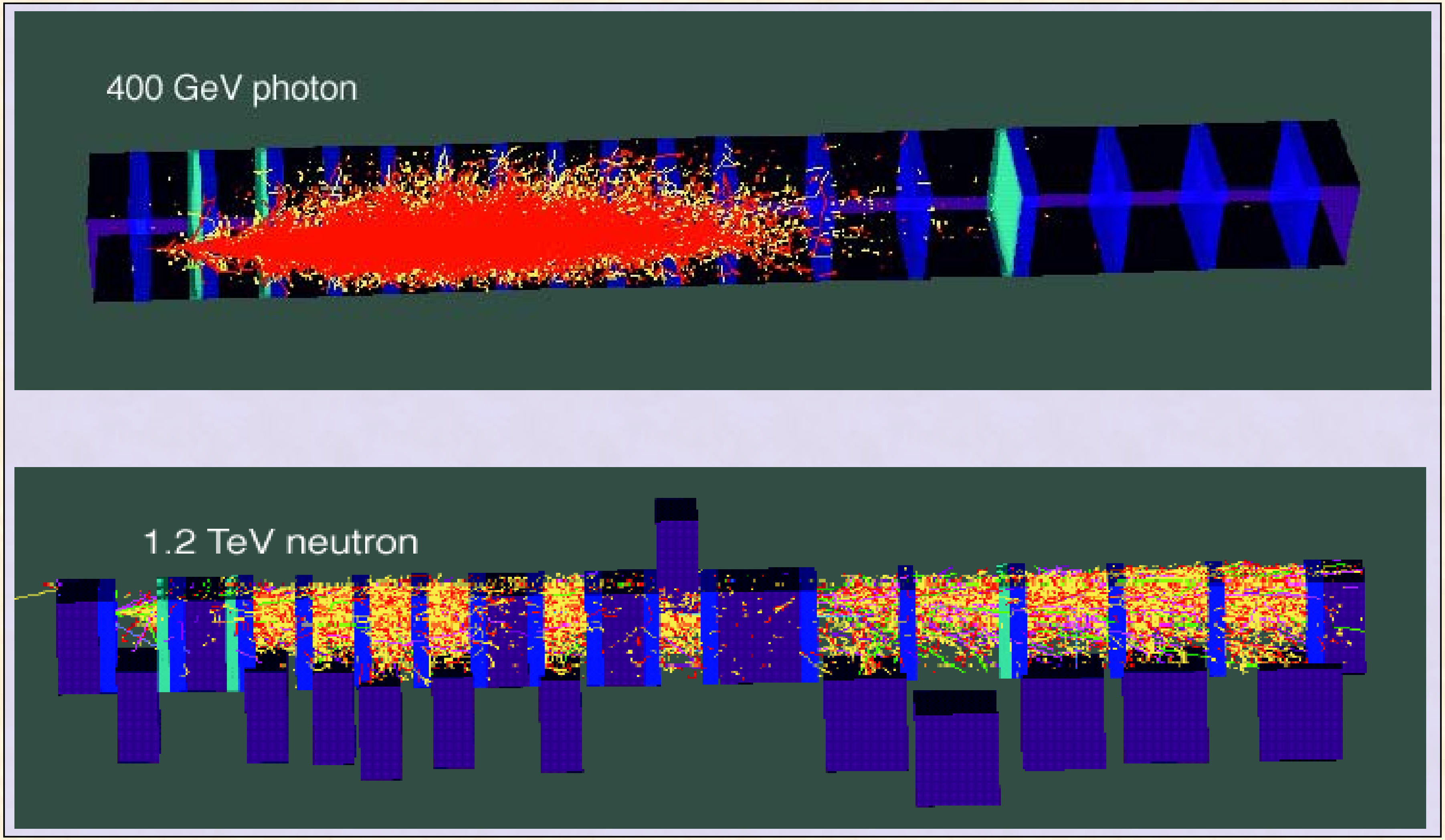
Beam Test

Few results on the simulation

2 independent simulations:
a) “custom” program (Japan)
b) Fluka based program (Italy)

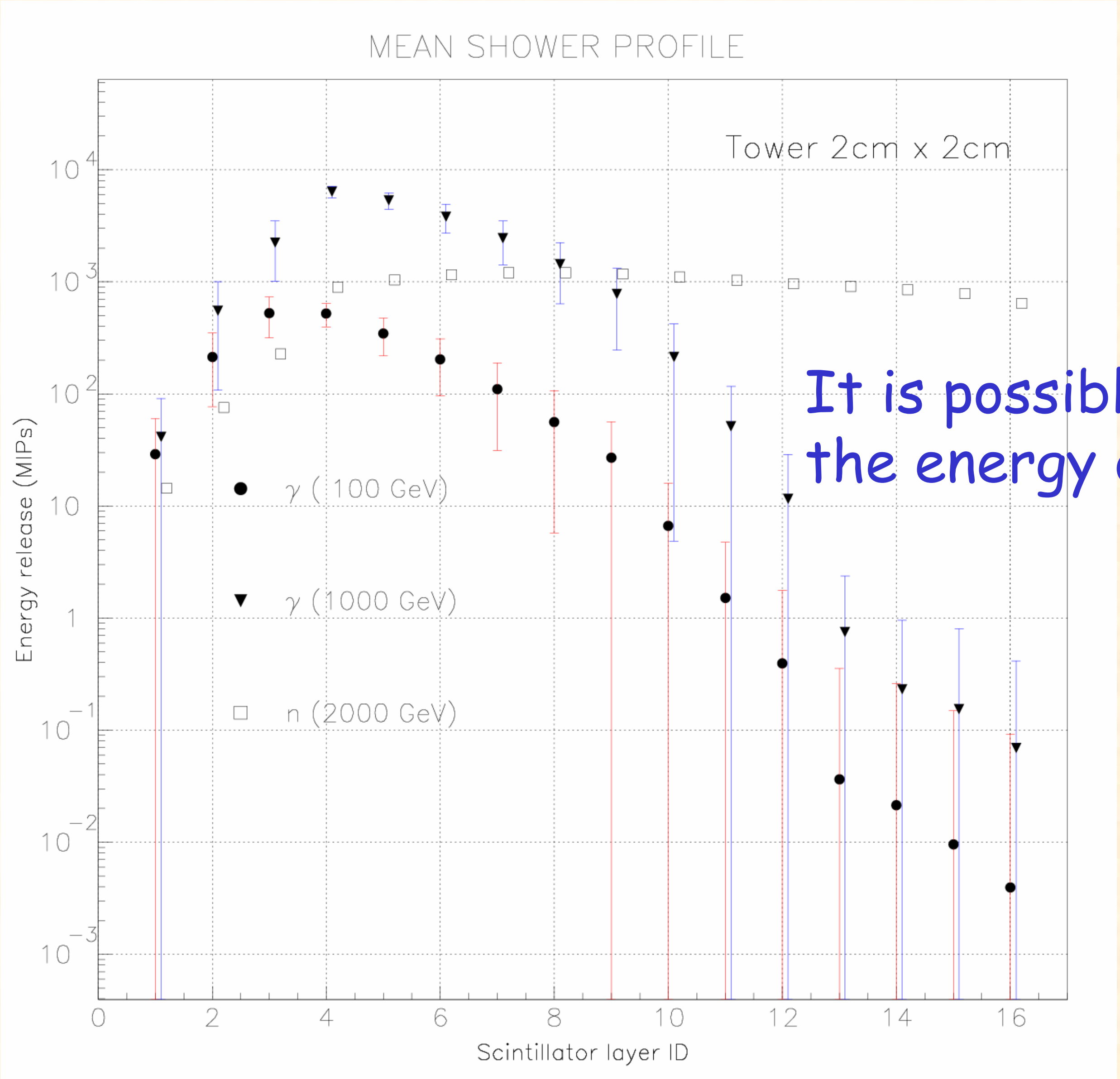
Cross check of results!

Particle discrimination



Longitudinal shower profile (γ/n)

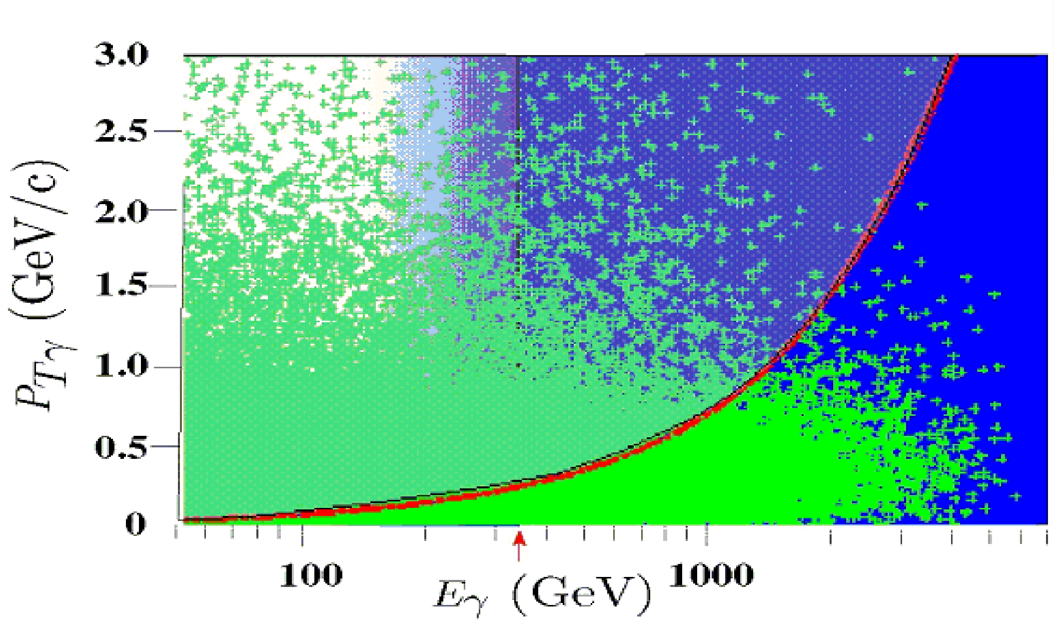
Fluka

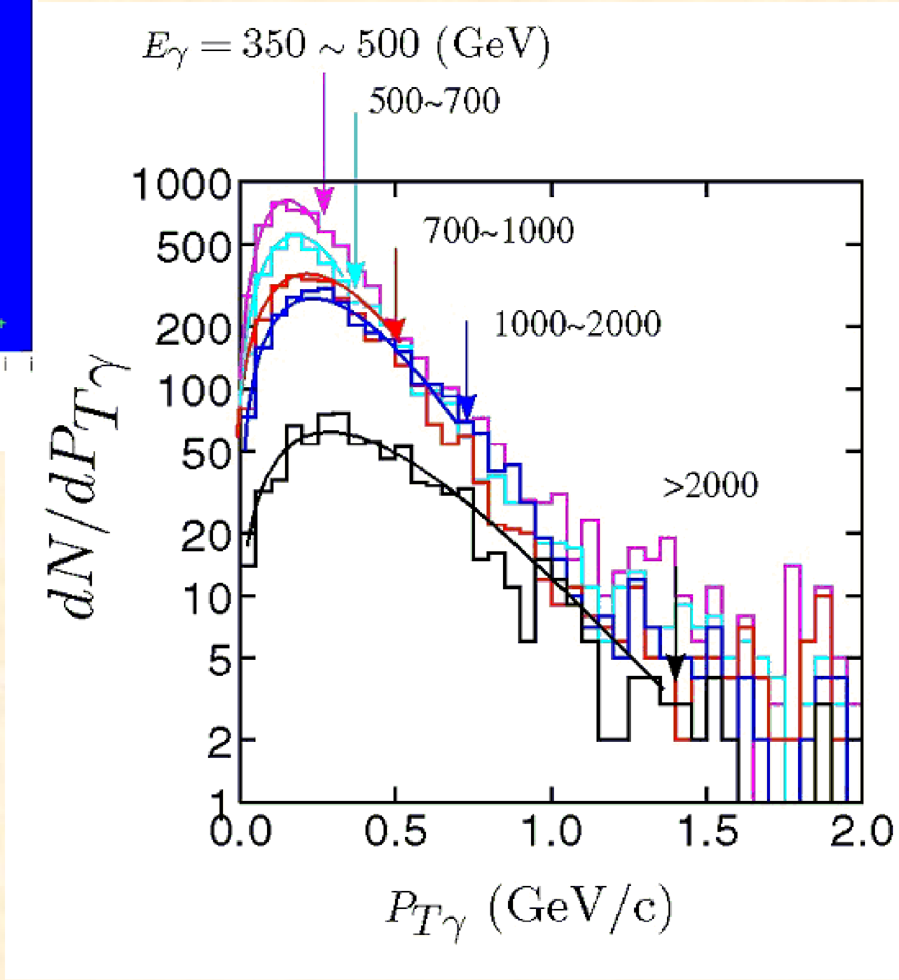


It is possible to measure the energy of neutrons???

1 TeV γ fully contained

Single photon detection





Portion of P_T photon spectrum measurable by LHCf for various energy ranges

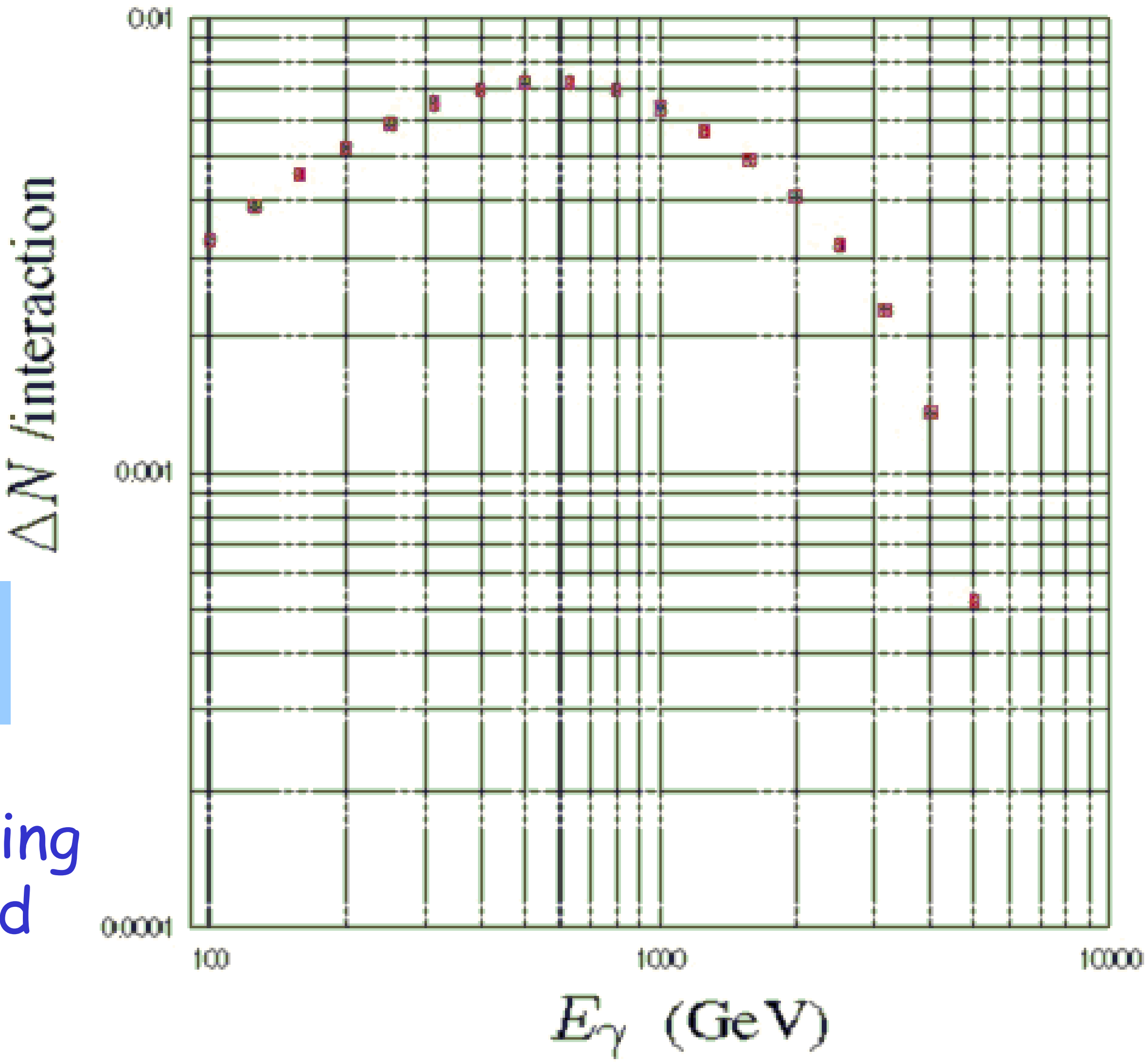
Single γ detection

1 γ with 100 GeV<E<1 TeV every 15 LHC interactions (<100 μsec)

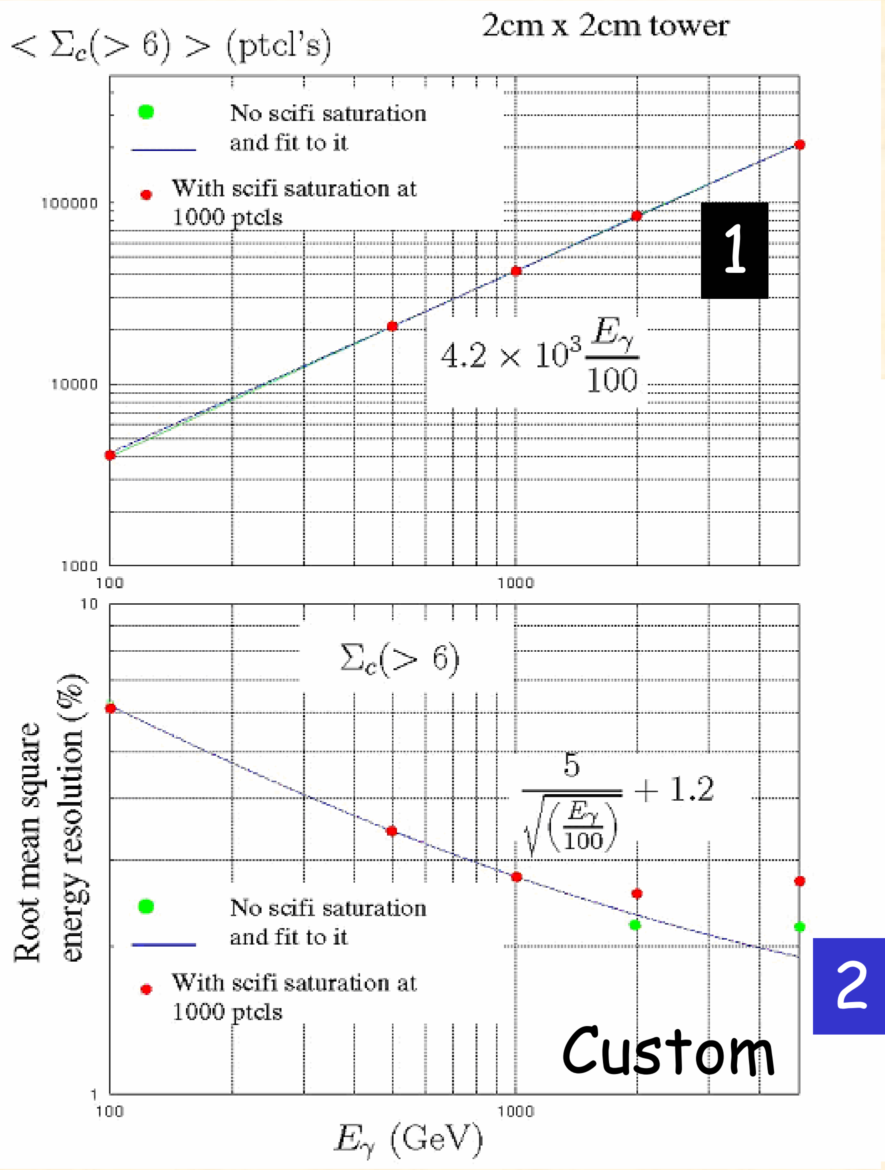
1 γ with E > 1 TeV every 50 LHC interactions

Few hours of data taking at $L=10^{29}$ $cm^{-2}s^{-1}$ should be enough

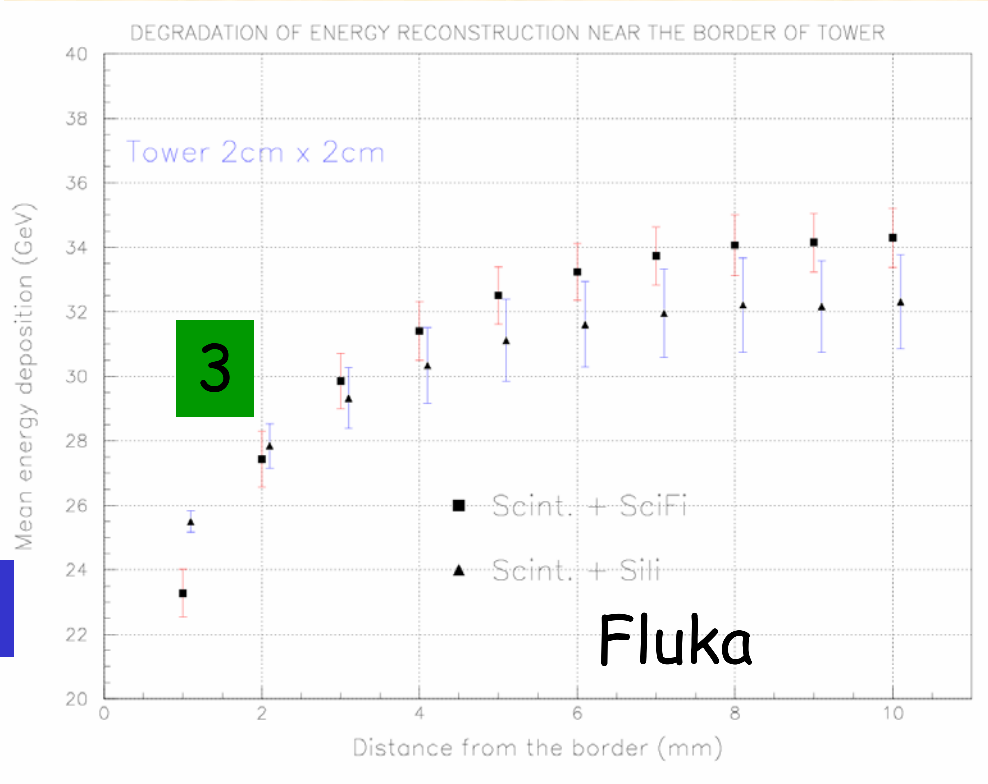
The number of observable photons per interaction in each energy bin with the standard detector configuraion



Energy reconstruction and resolution

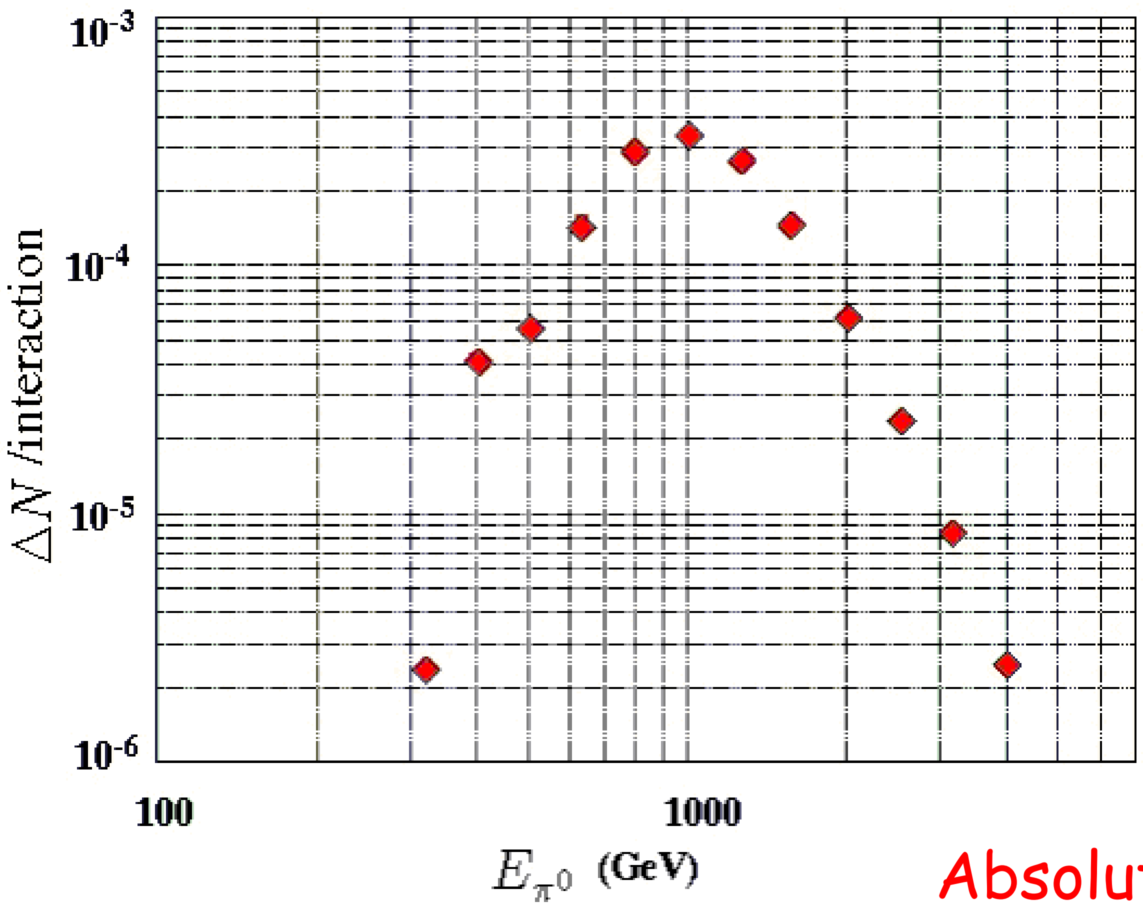


1. Linearity up to > TeV
2. $\Delta E/E \sim 2\%$
3. 15% energy loss @ 2 mm from the edge (small tower)



2 photons from π^0decay

The number of observable pi zeros per interaction in each energy bin with the standard detector configuraion

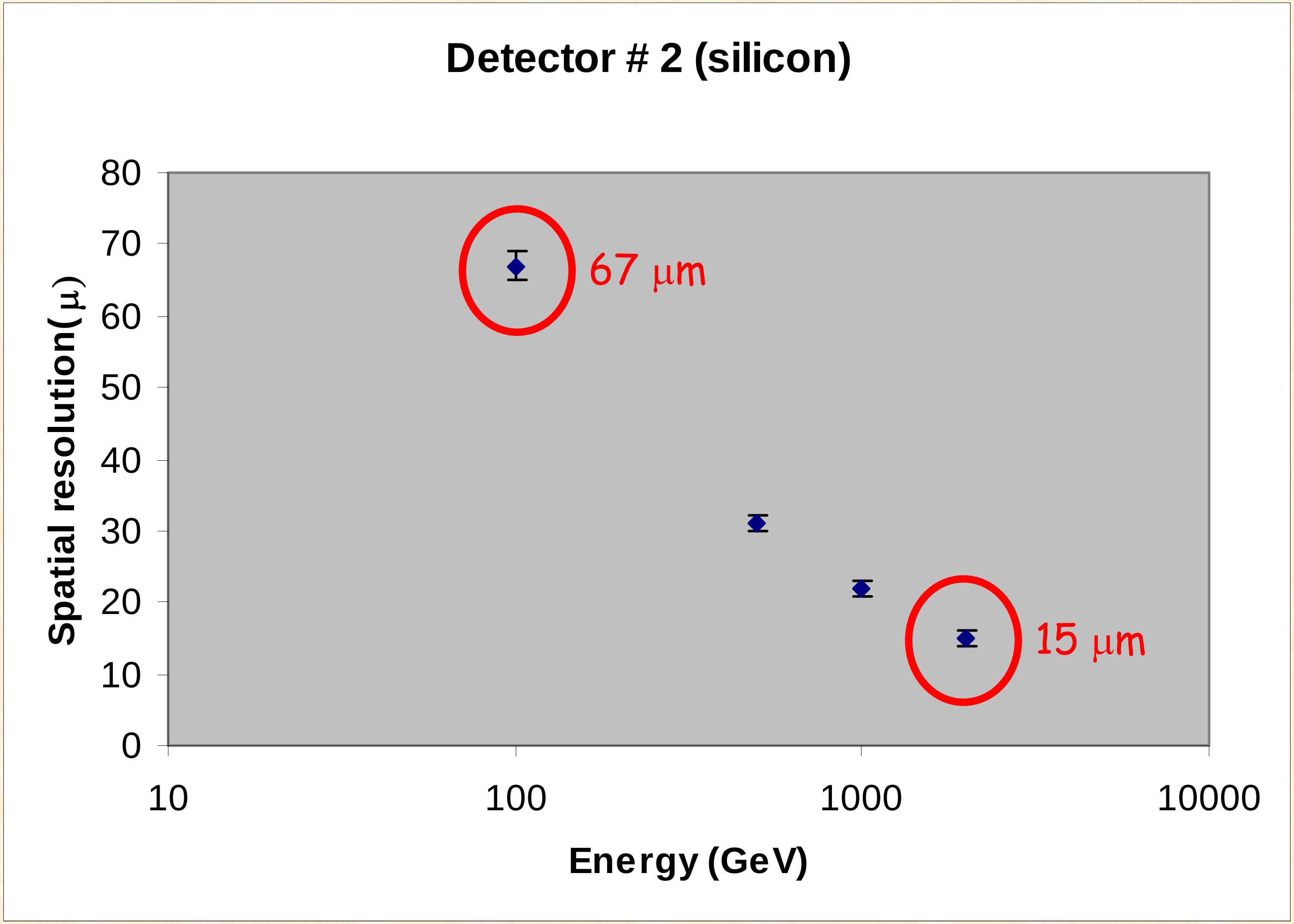


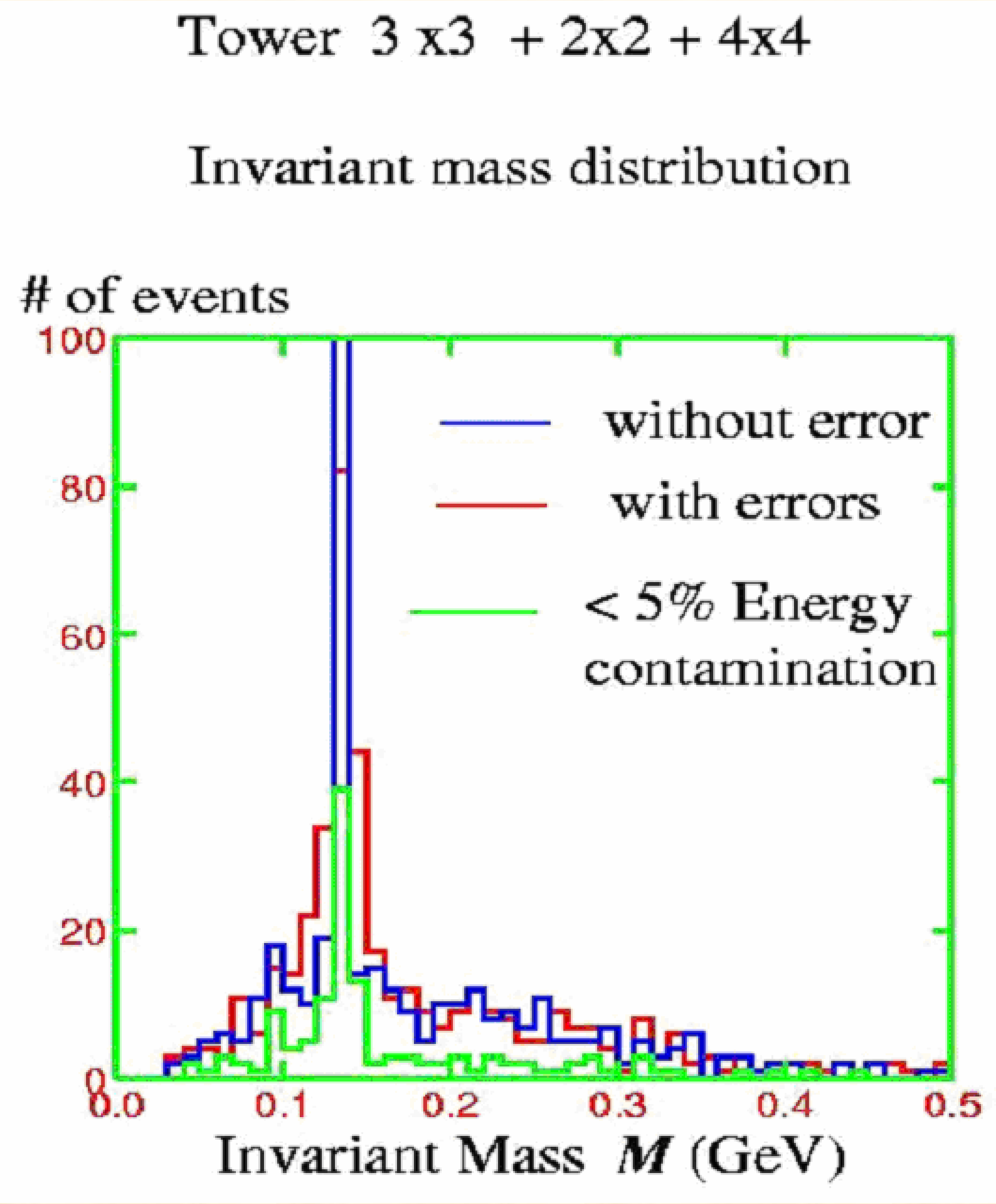
We require 2 γ in 2 different towers

1 π^o with E>1 TeV every 1000 LHC interactions (<10 ms)

Absolute Energy Calibration!!!!

Spatial resolution for photons





Tower 3 x3 + 2x2 + 4x4
Invariant mass distribution
# of events
100
80
60
40
20
0
0.0
0.1
0.2
0.3
0.4
0.5
without error
with errors
< 5% Energy contamination
Invariant Mass M (GeV)

ΔM ~ 2-3 MeV

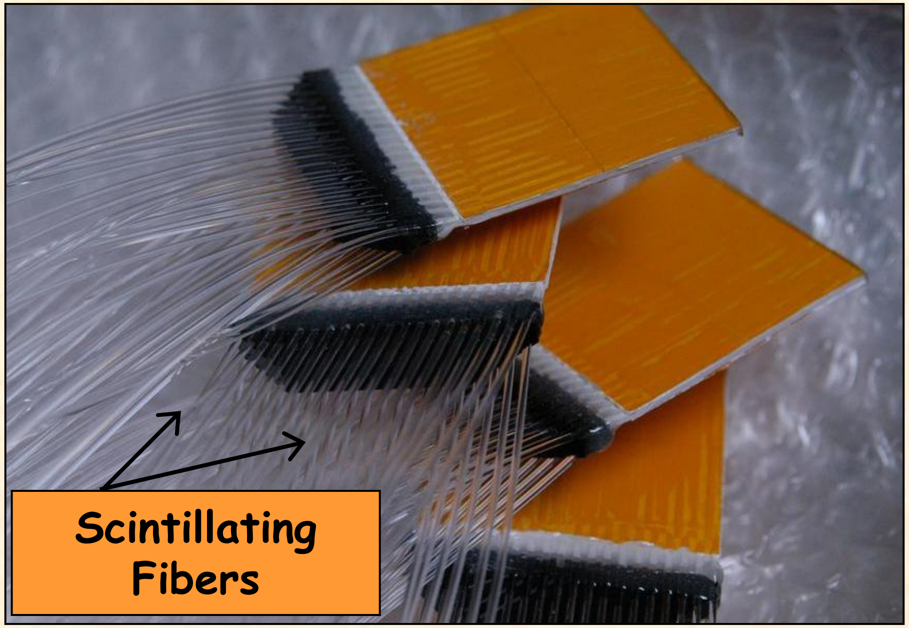
Beam test results

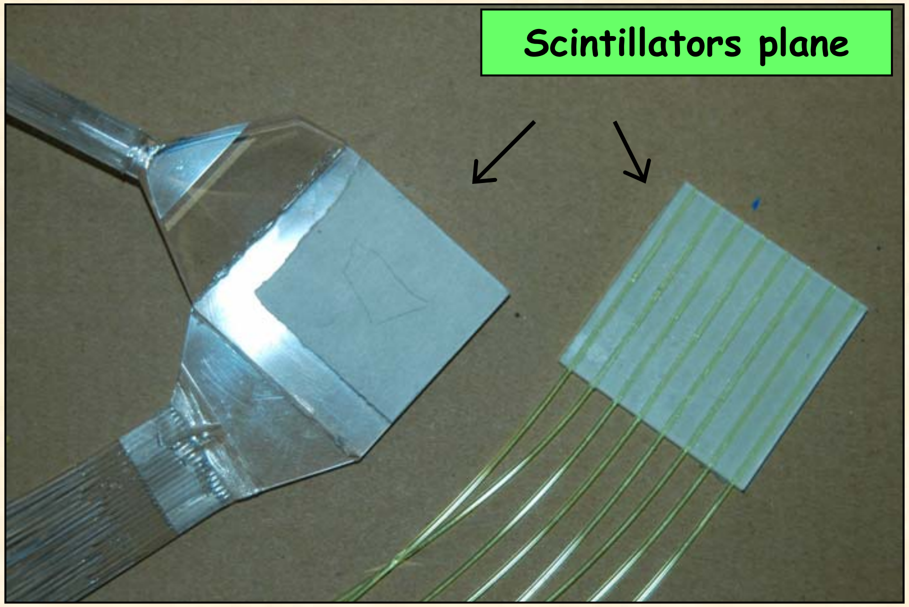
Necessary to verify the simulation (small tower 2x2 cm^2!!!)
SPS-H4 July-August 2004
2 TOWERS (2×2 and 4×4)cm^2 + Tracking system to determine the impact point on the towers

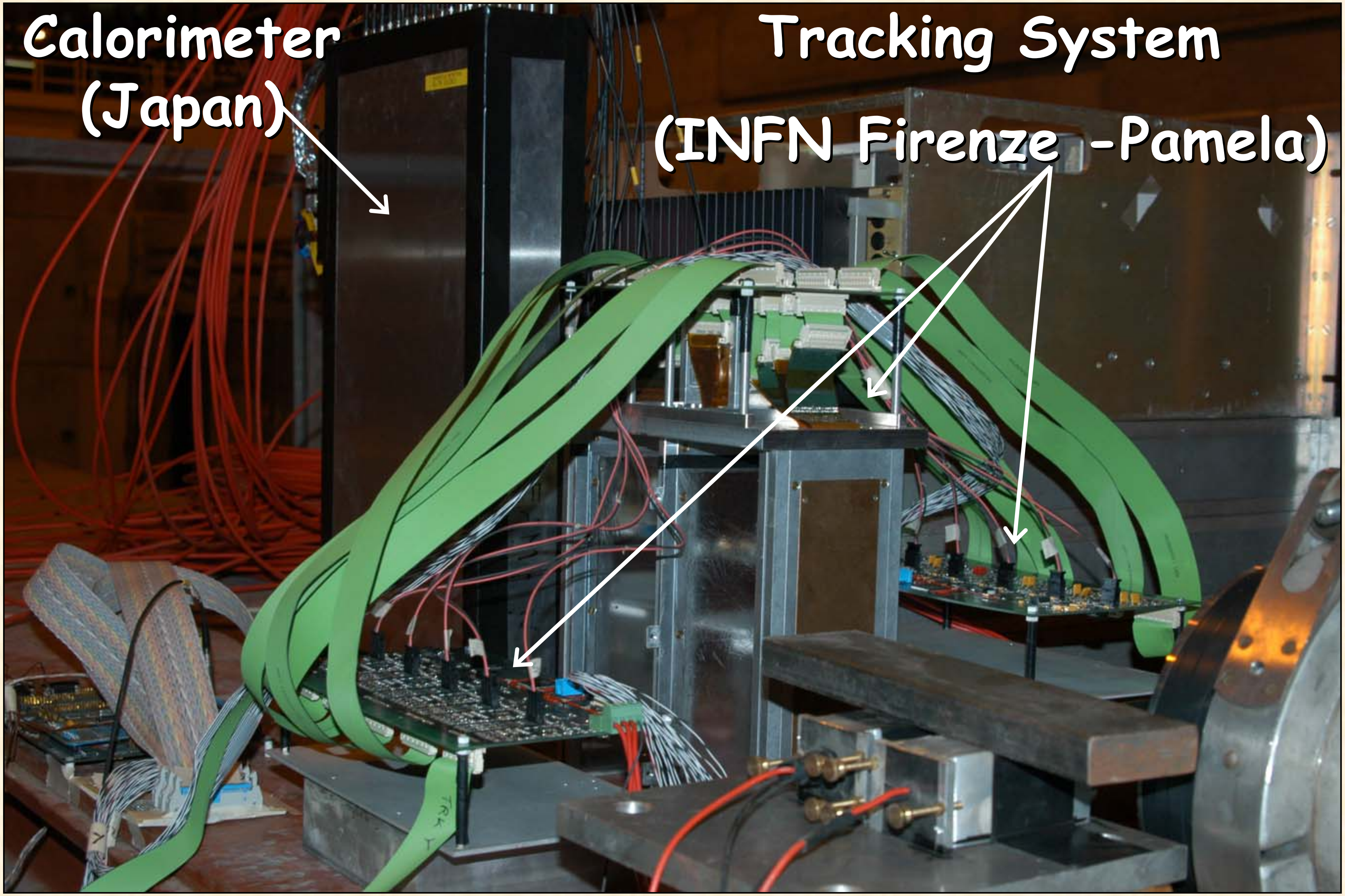
ELETTRONS	(50÷250) GeV/c
PROTONS	(150÷350) GeV/c
MUONS	(150) GeV/c

x-y Scan (To study the systematics as function of the distance from the edges)

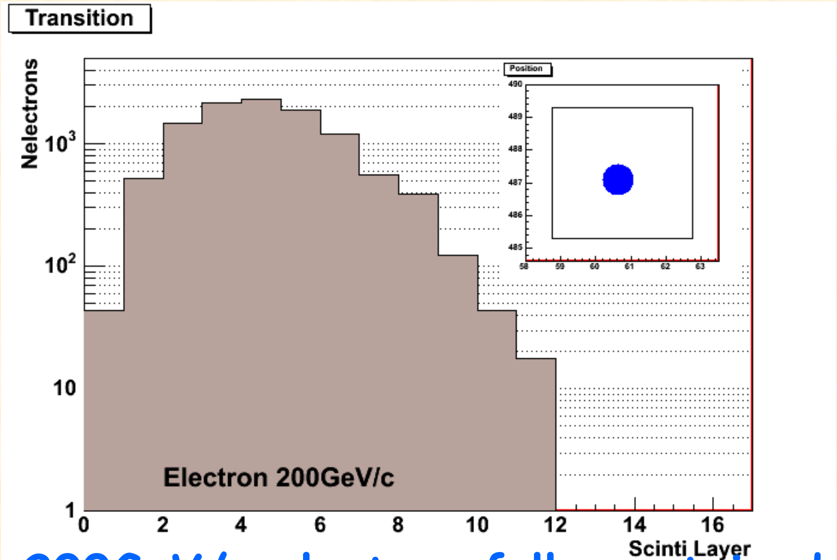
Prototypes under test



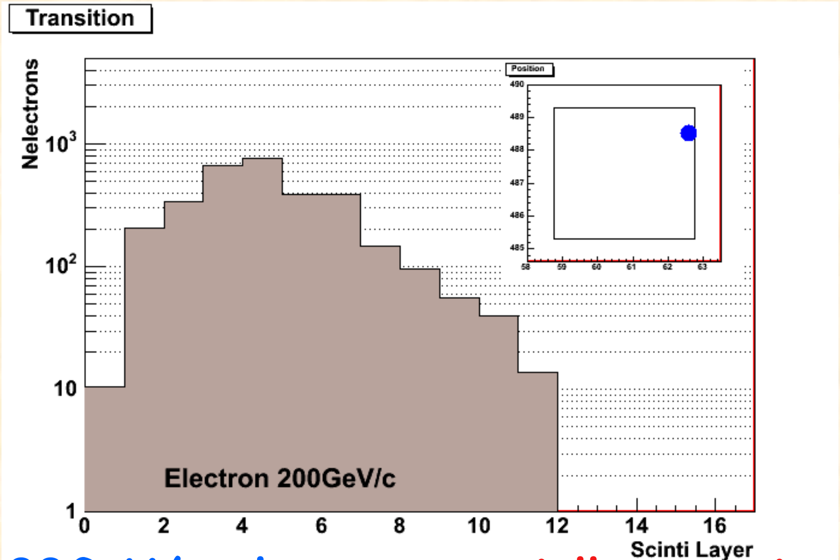



Calorimeter
(Japan)
Tracking System
(INFN Firenze -Pamela)

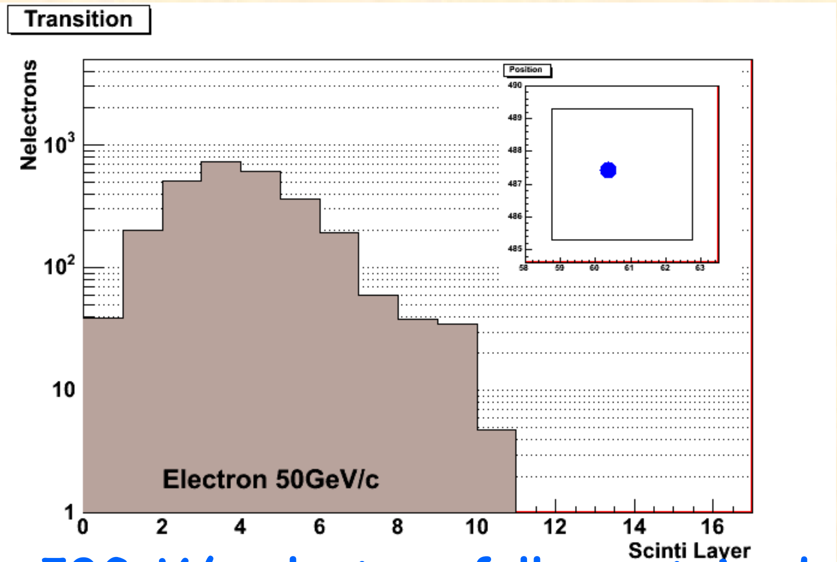
Some results: longitudinal profile of the showers



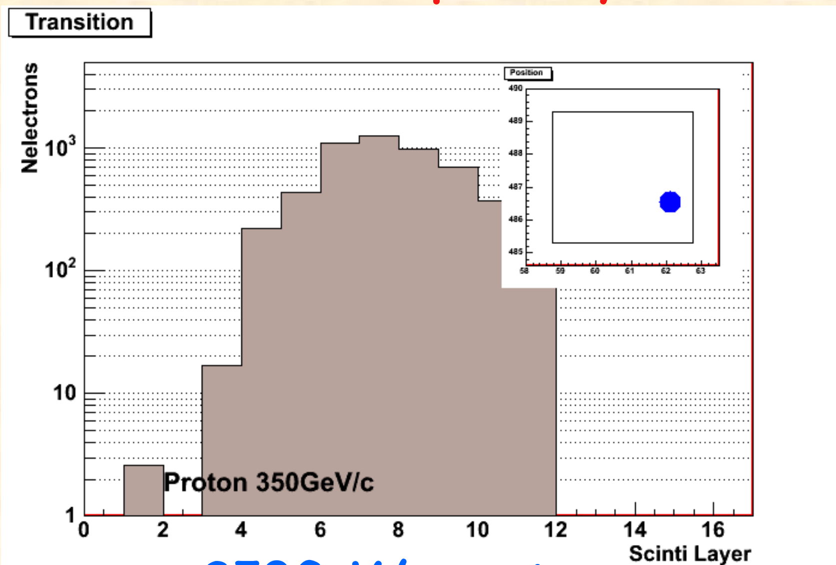
200GeV/c electron fully contained



200GeV/c electron partially contained



50GeV/c electron fully contained

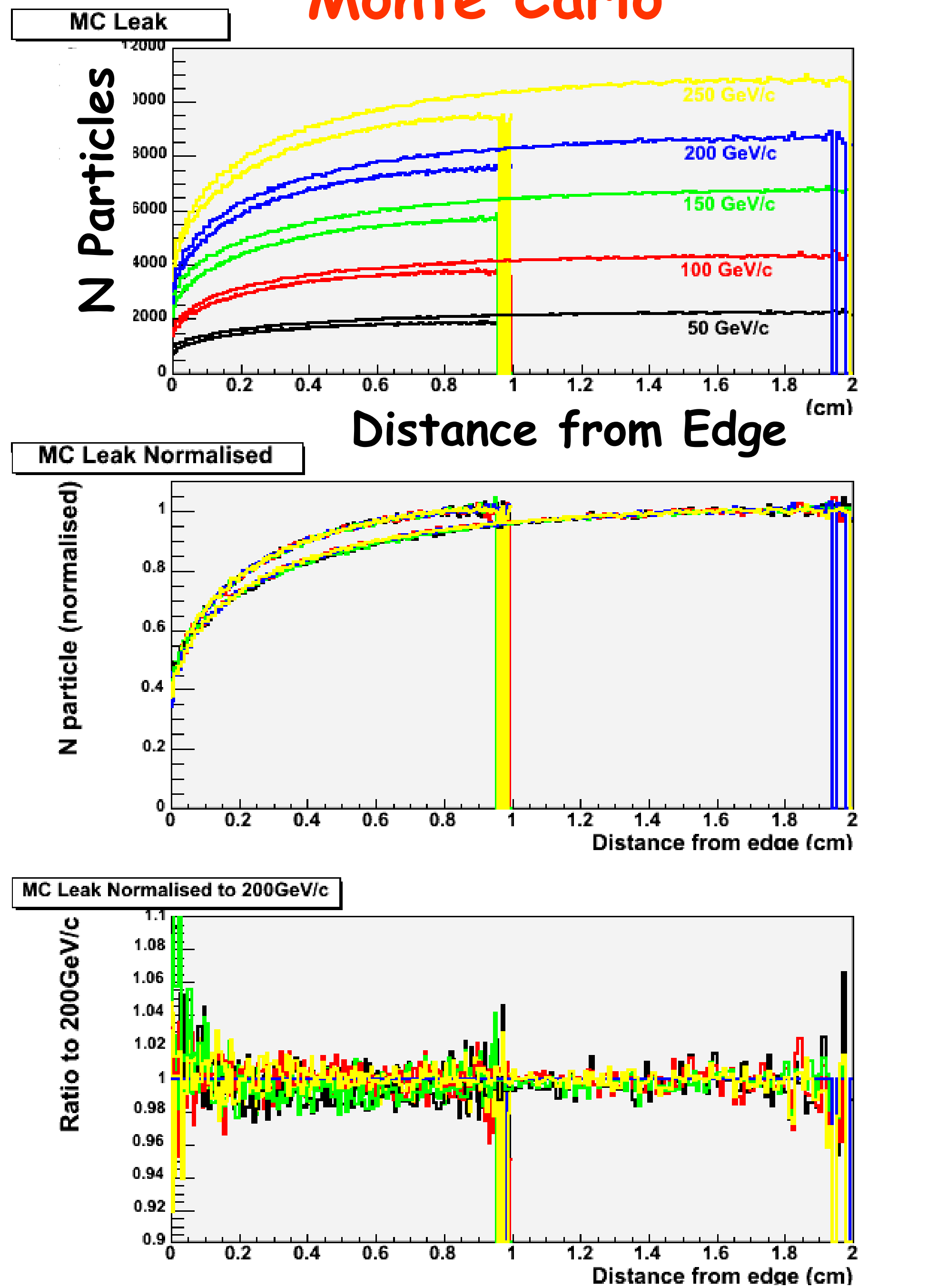


350GeV/c proton

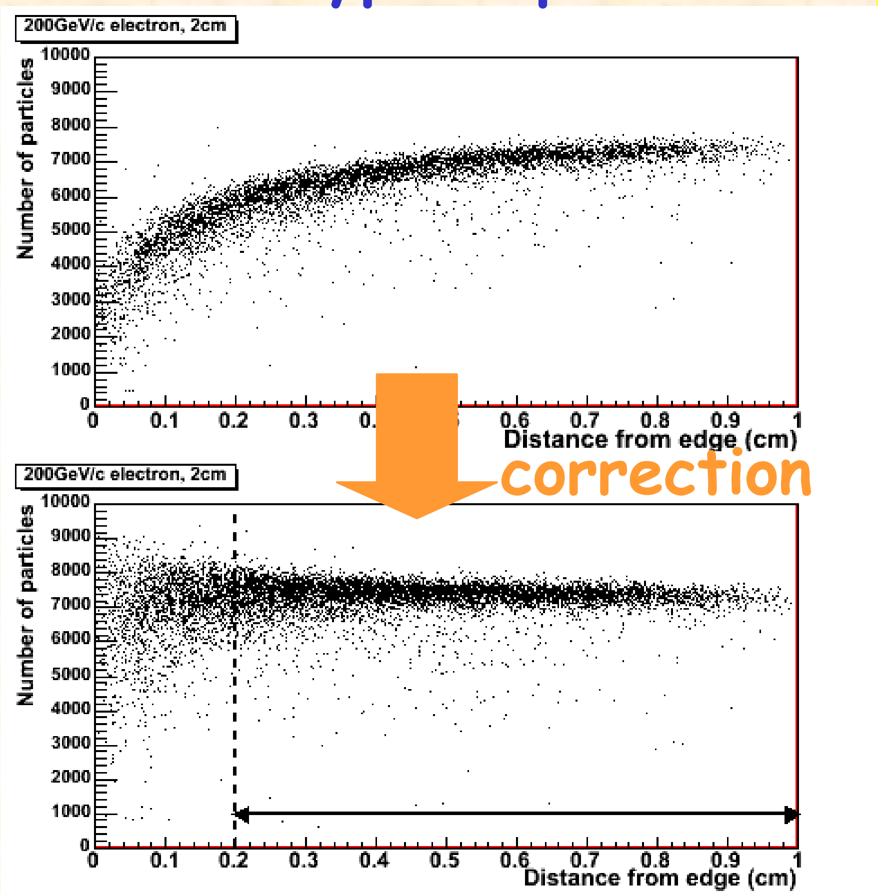
Leakage Correction

MC predicts that the leakage is energy independent!

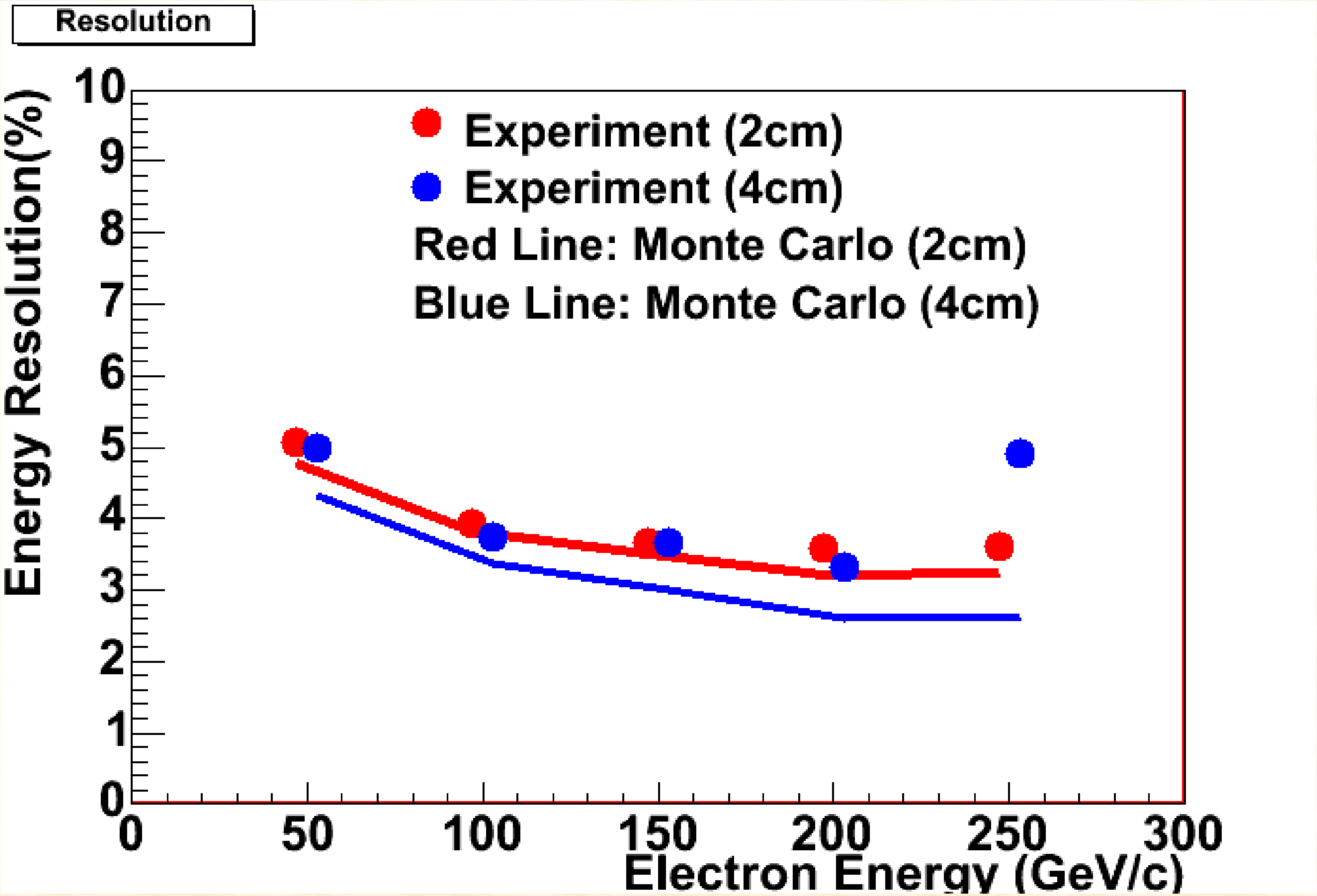
Monte Carlo



Prototype Experiment



Energy Resolution



LHCf - *schedule*

- Experiment approved in Japan in the framework of the study of UHECR (TA)
- May 2004: LETTER OF INTENT to LHC Committee (LHCC)
- Experiment was approved by LHCC (with request of beam test)

Next steps:

- September 2005: INFN formal decision
- October 2005: Technical Design Report to LHCC
- 2006: Construction of the 2 detectors
- **April 2007: Data taking at LHC**