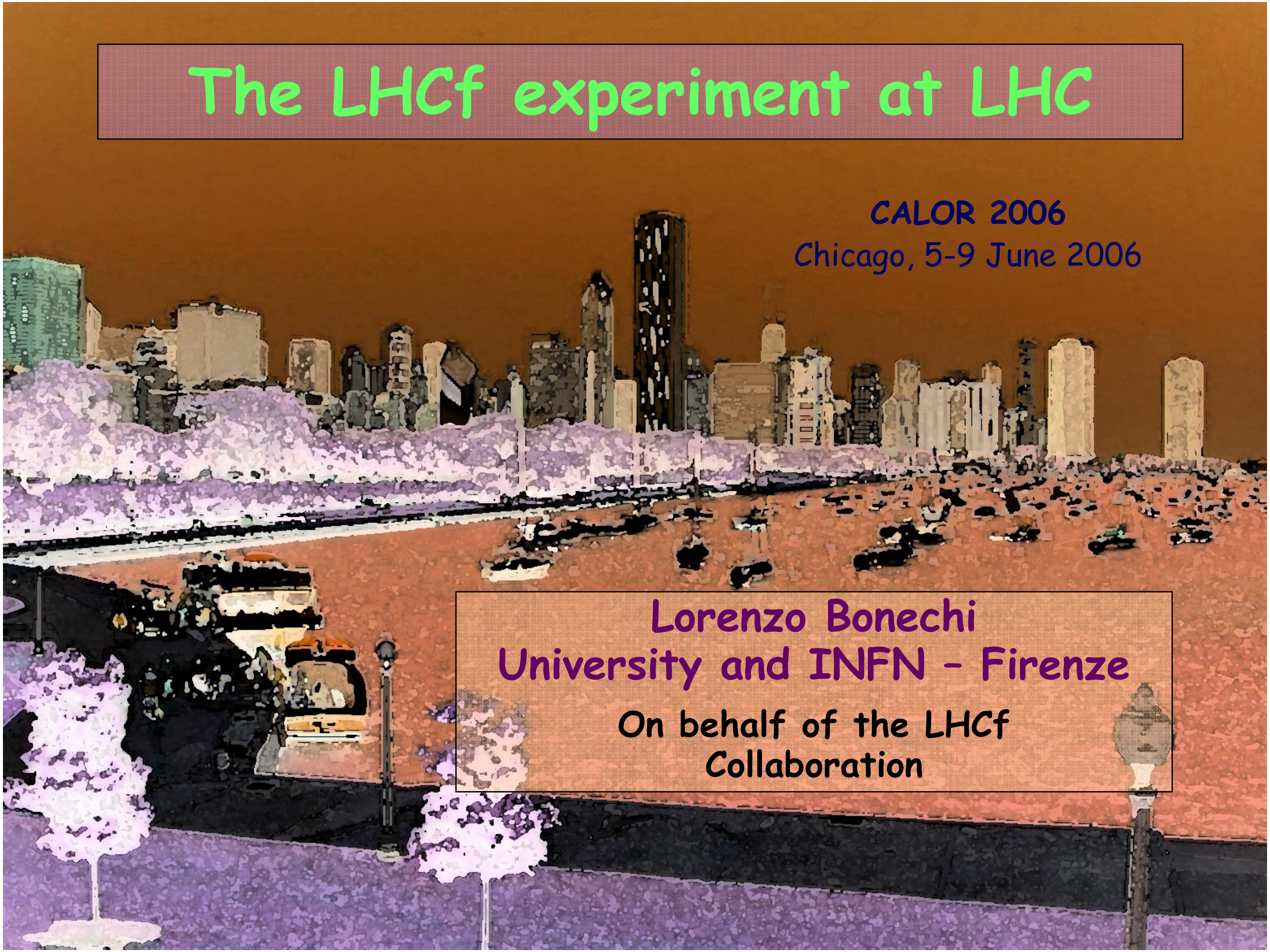
The LHCf experiment at LHC



CALOR 2006

Chicago, 5-9 June 2006

Lorenzo Bonechi

University and INFN – Firenze

On behalf of the LHCf Collaboration

The LHCf collaboration

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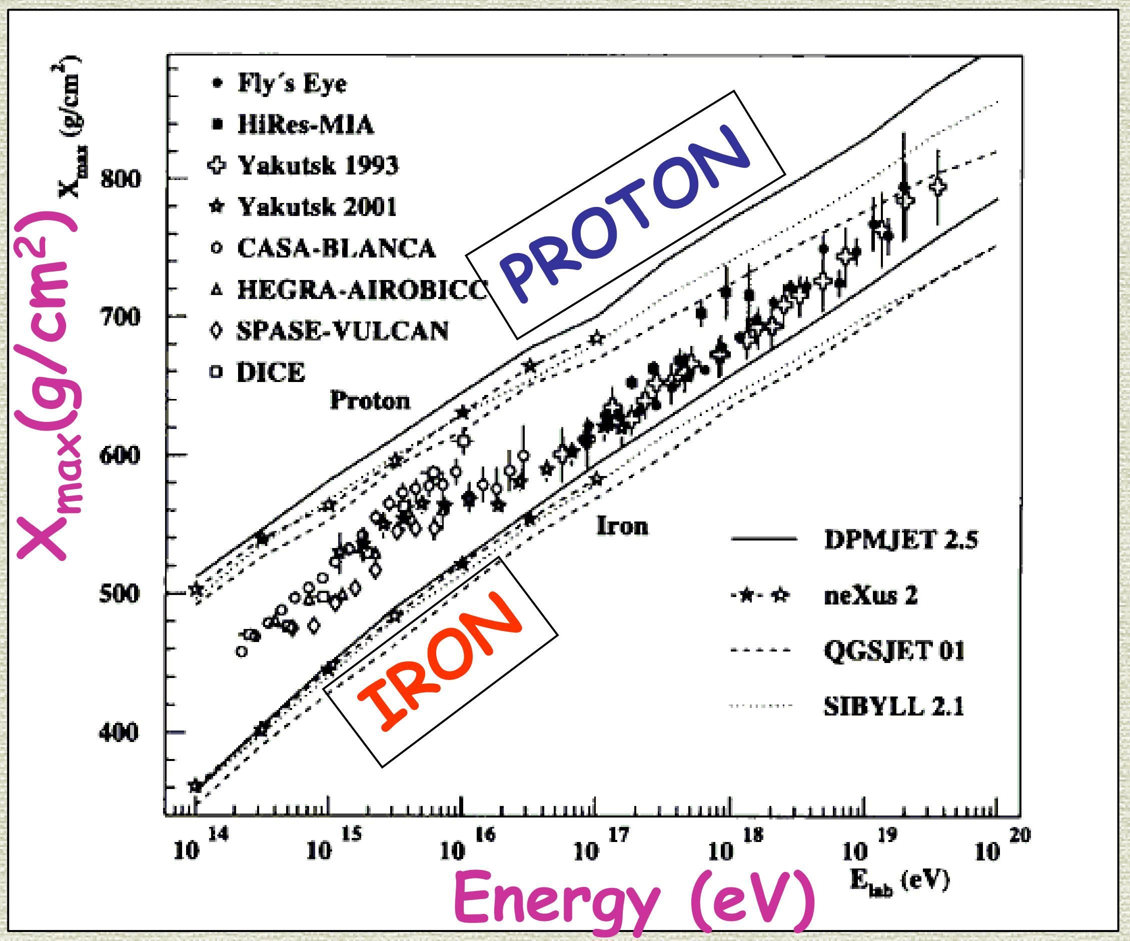
Outline

- **Introduction**
  - Problems in HECR physics: chemical composition, GZK cut-off
  - LHCf and HECR
- **The LHCf apparatus**
- **Beam test results**
  - CERN 2004
- **Summary and schedule**
  - Toward the 2007 LHC operation

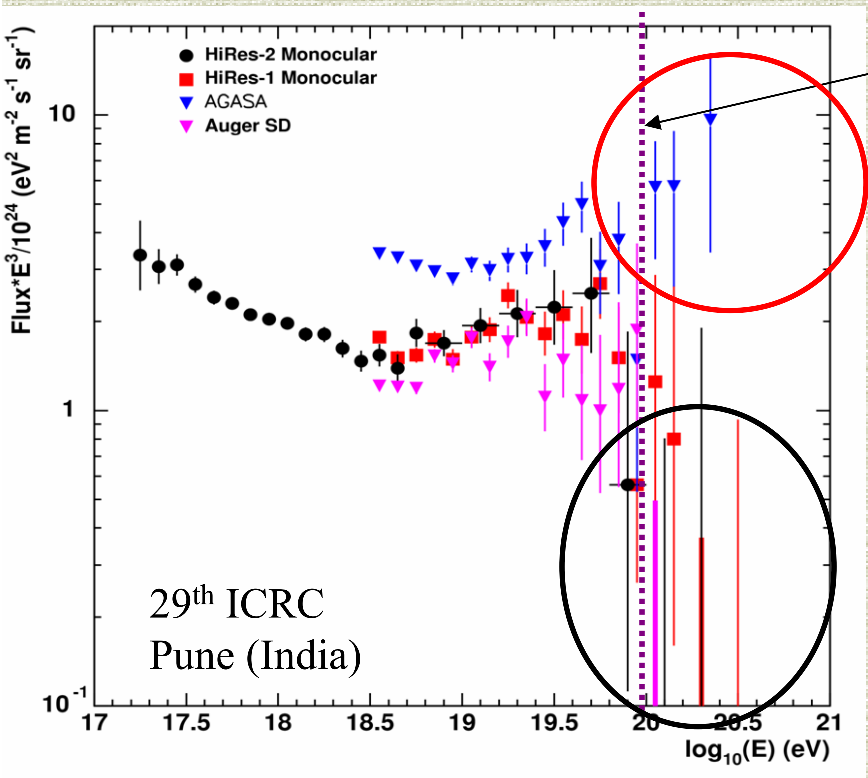
Introduction: cosmic ray composition



Knapp et al., 2003

Different hadronic interaction models lead to different conclusions about the composition of the primary cosmic rays.

Introduction: GZK cut off

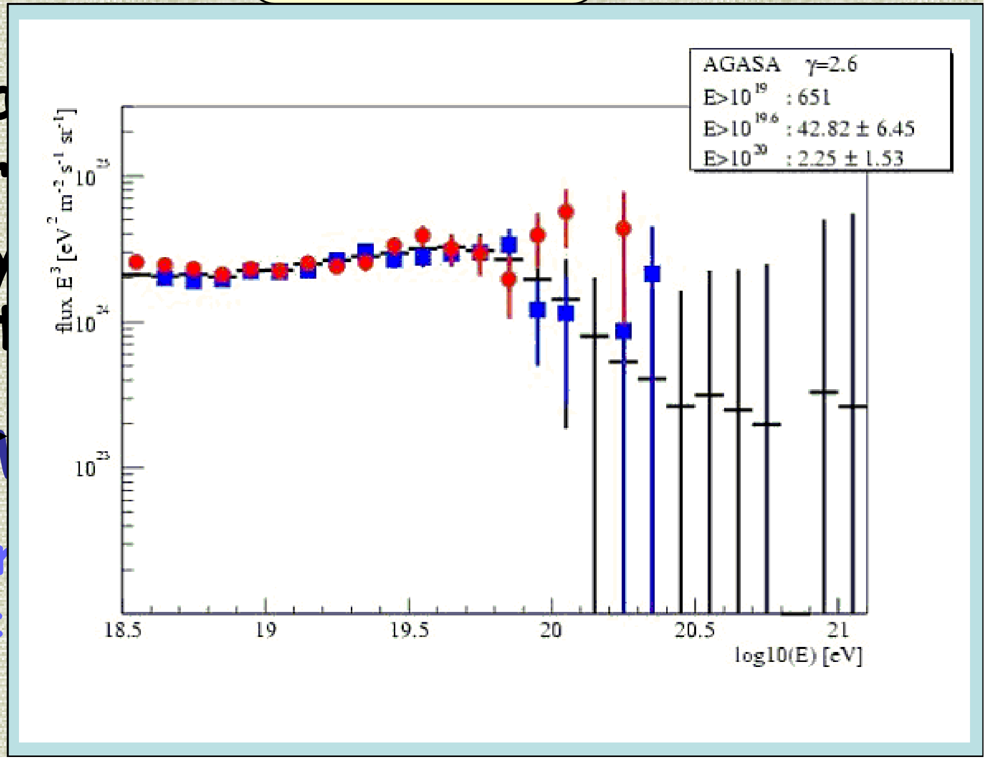


GZK cutoff: 10^{20} eV

Existence of the GZK cut off is one of the most important puzzle in HECR physics.

super GZK events?!?

Lo
cr
by
St

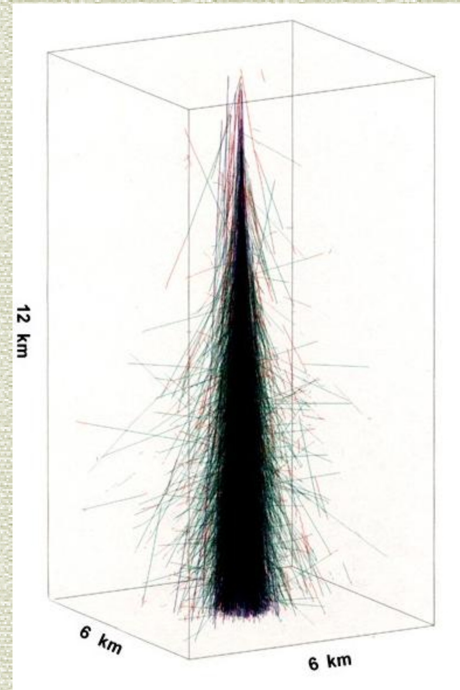


20% correction on the absolute energy scale!!!

HOW

Different hadronic interaction r
the primary cosmic

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 ($\theta \approx 0$)

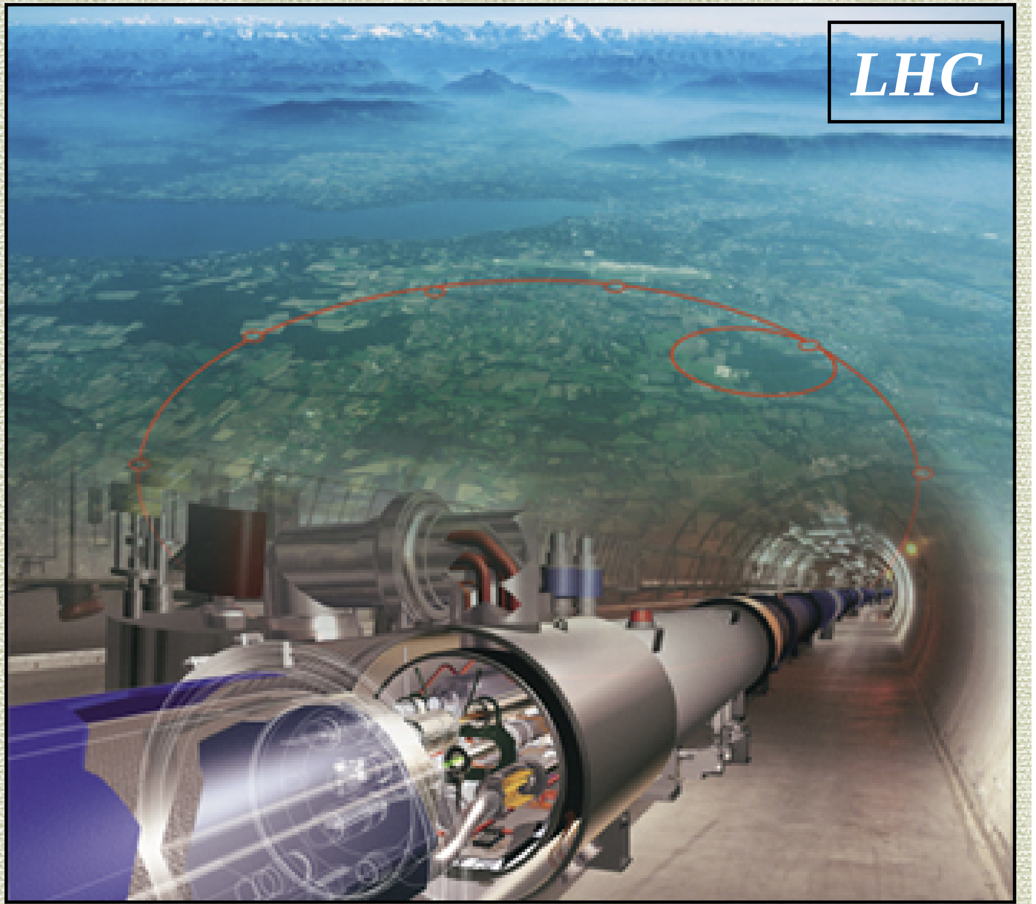
- In this forward region the highest energy available measurements of π^0 cross section were done by UA7 **($E=10^{14}$ eV, y = 5÷7)**

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

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

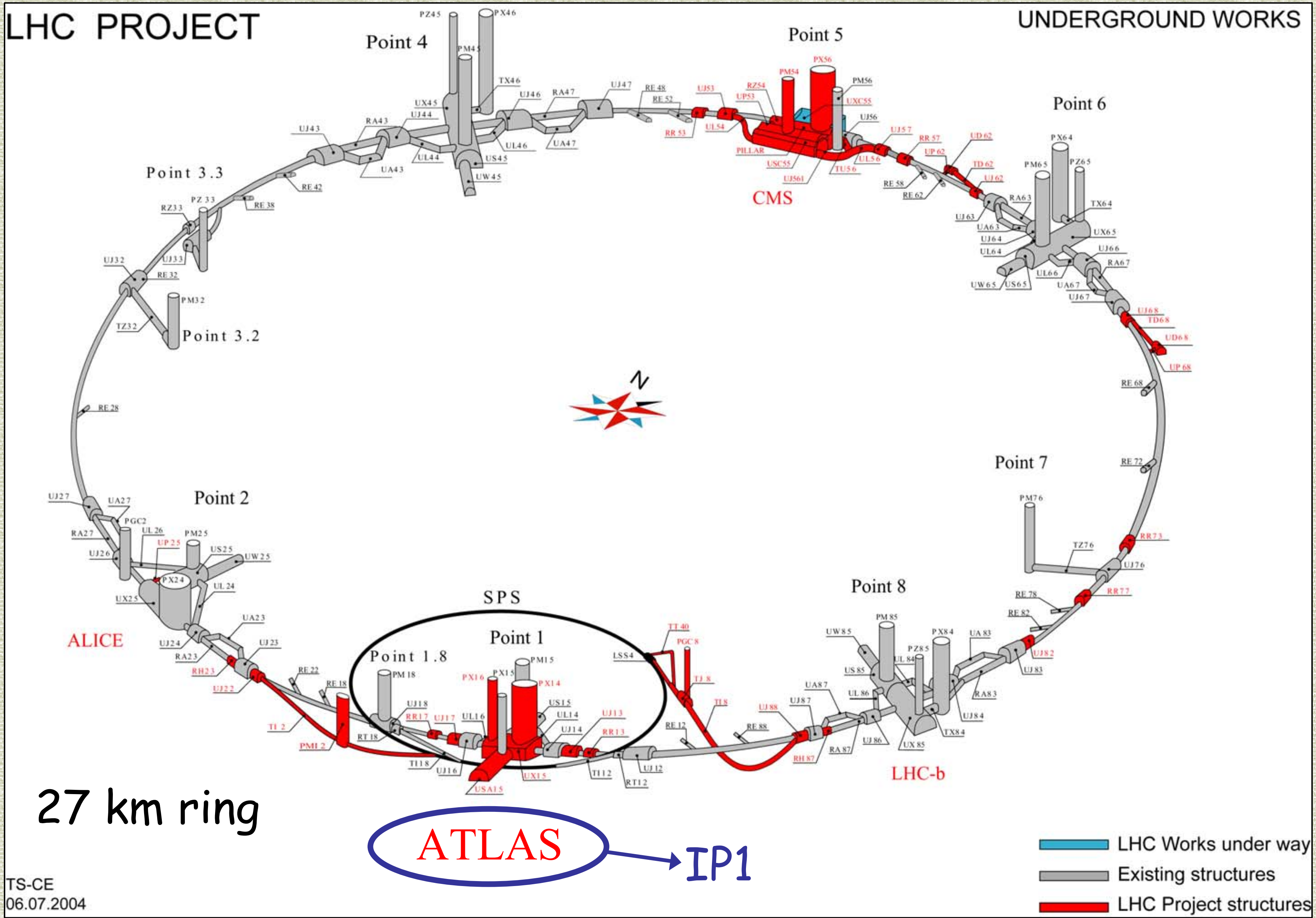
$E_{lab}=10^{17}$ eV   ($E_{lab}= E^2_{cm}/2\ m_p$)

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

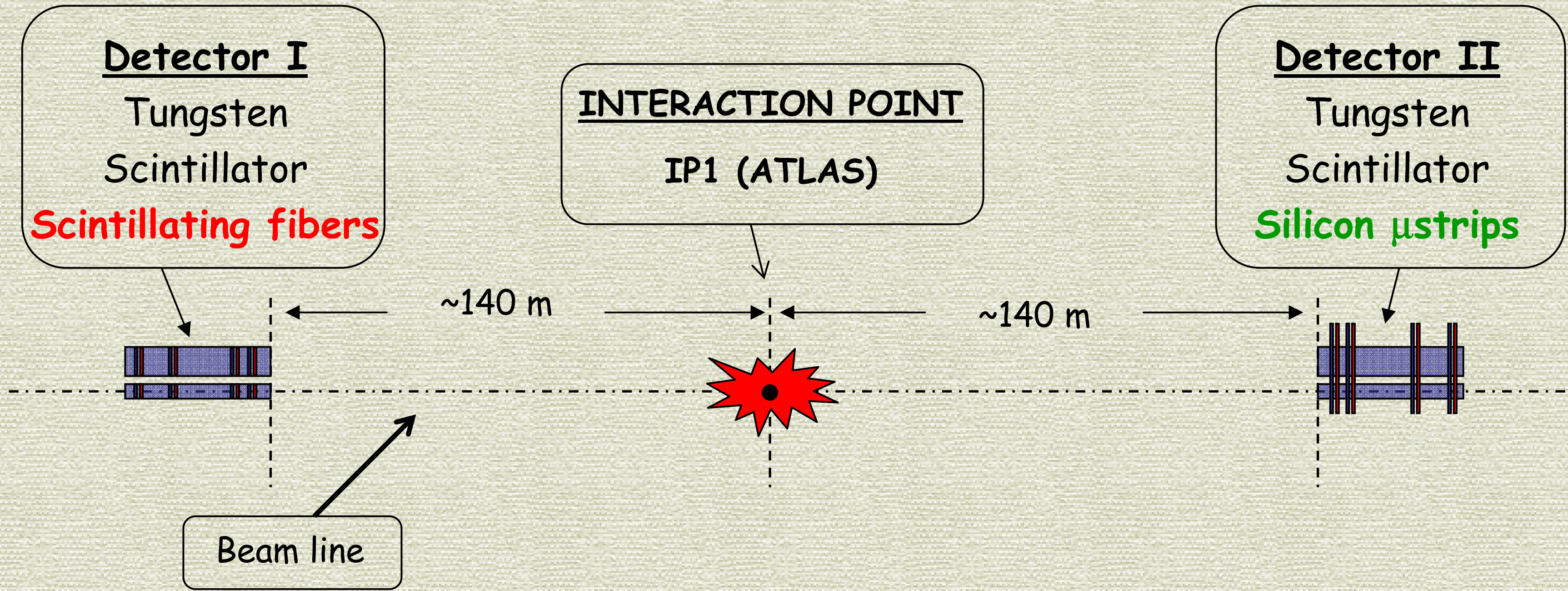
LHCf will cover the very forward part
May be also in heavy ion runs????

Part 2

The LHCf apparatus


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
LHC-b
N
27 km ring
ATLAS
IP1
LHC Works under way
Existing structures
LHC Project structures
TS-CE
06.07.2004

LHCf location in the IR1 of LHC



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

Two independent detectors on both sides of IP1

- ✓ Redundancy
- ✓ Background rejection

LHCf: general detector requirements

1. Single photon spectrum
2. π^0 fully reconstructed (1 γ in each tower)
3. Neutron spectrum

π^0 reconstruction is an important tool for energy calibration (π^0 mass constraint)

Basic detector requirements:

- ✓ minimum 2 towers (π^0 reconstruction)
- ✓ Smallest tower on the beam (multiple hits)
- ✓ Dimension of the tower → Moliere radius
- ✓ Maximum acceptance (given the LHC constraints)

Detector #1

2 towers ~24 cm long stacked vertically with 5 mm gap

Lower:2 cm x 2 cm area

Upper: 4 cm x 4 cm area

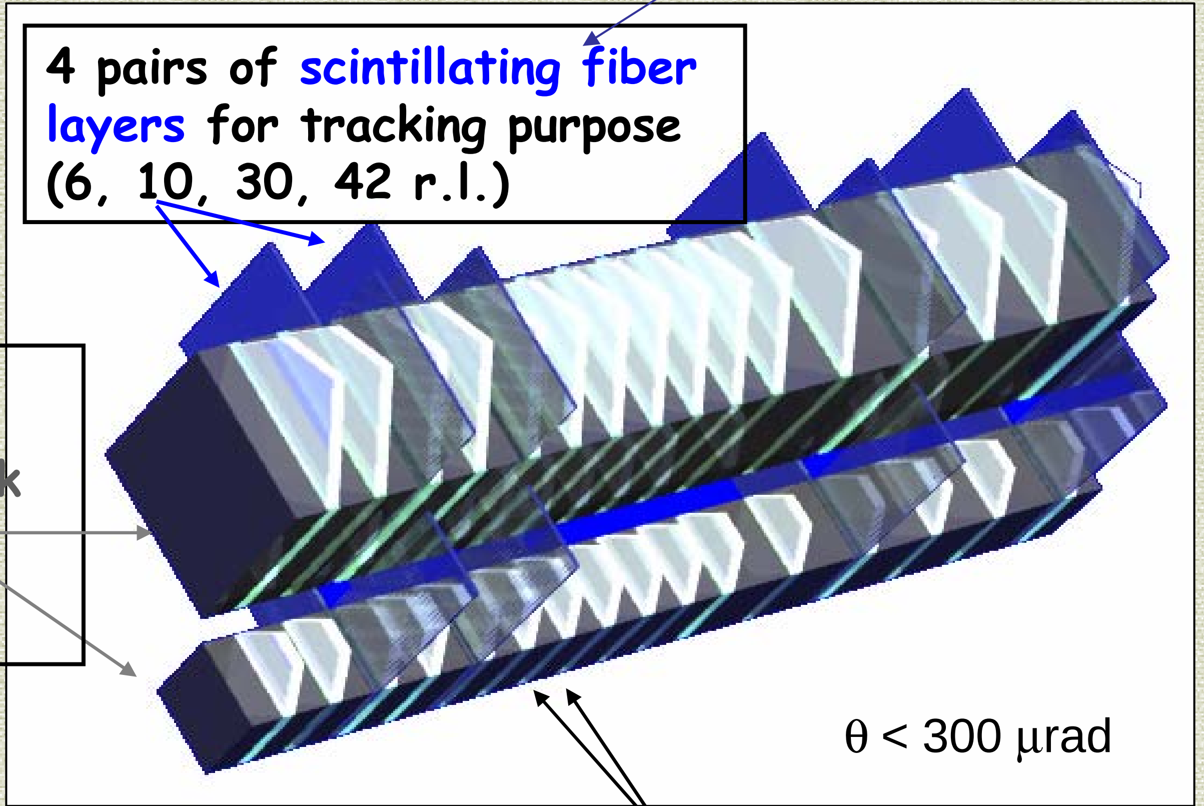
Absorber

22 tungsten layers 7mm thick
→ 44 X_0 (1.6 λ_I) in total

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

Impact point (η)

4 pairs of scintillating fiber layers for tracking purpose (6, 10, 30, 42 r.l.)



16 scintillator layers (3 mm thick)

Trigger and energy profile measurements

Energy

Detector # 2

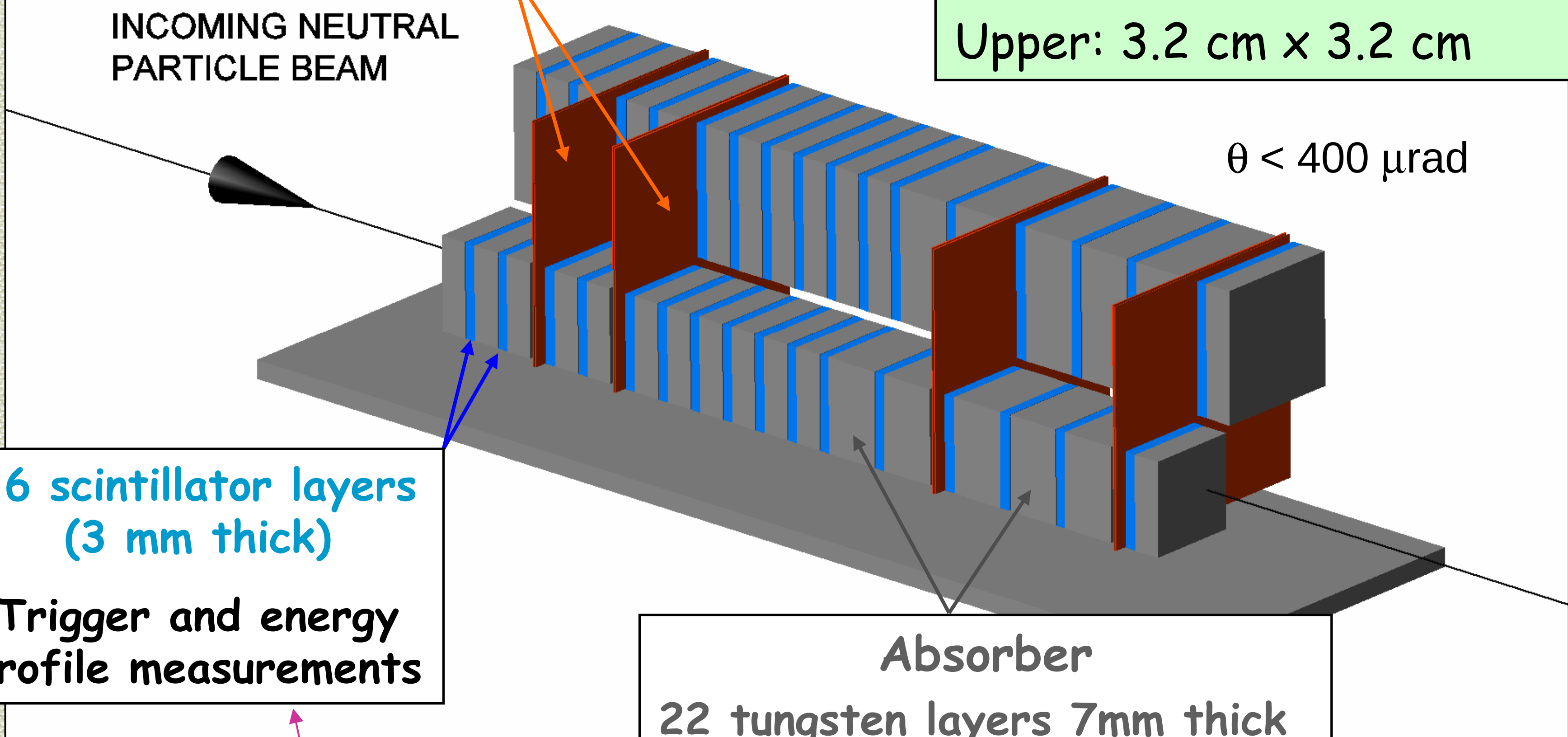
We use LHC style electronics and readout

4 pairs of silicon microstrip layers (6, 10, 30,42 r.l.) for tracking purpose (X and Y) → impact point

2 towers 24 cm long stacked on their edges and offset from one another

Lower: 2.5 cm x 2.5 cm

Upper: 3.2 cm x 3.2 cm



16 scintillator layers (3 mm thick)

Trigger and energy profile measurements

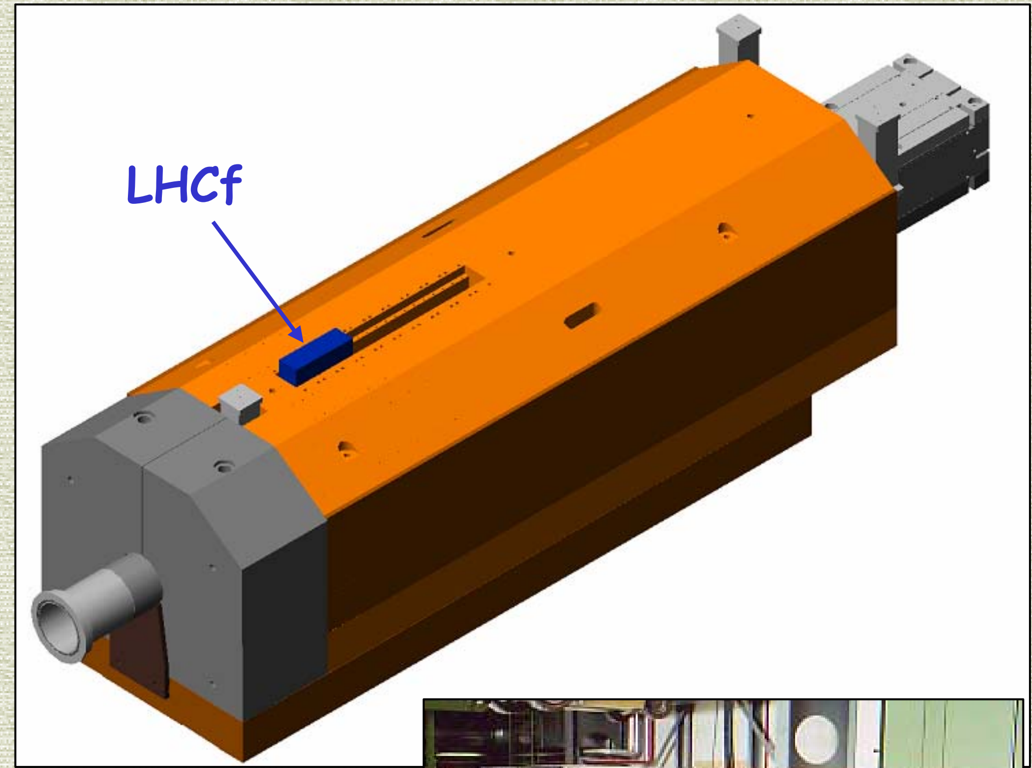
Absorber

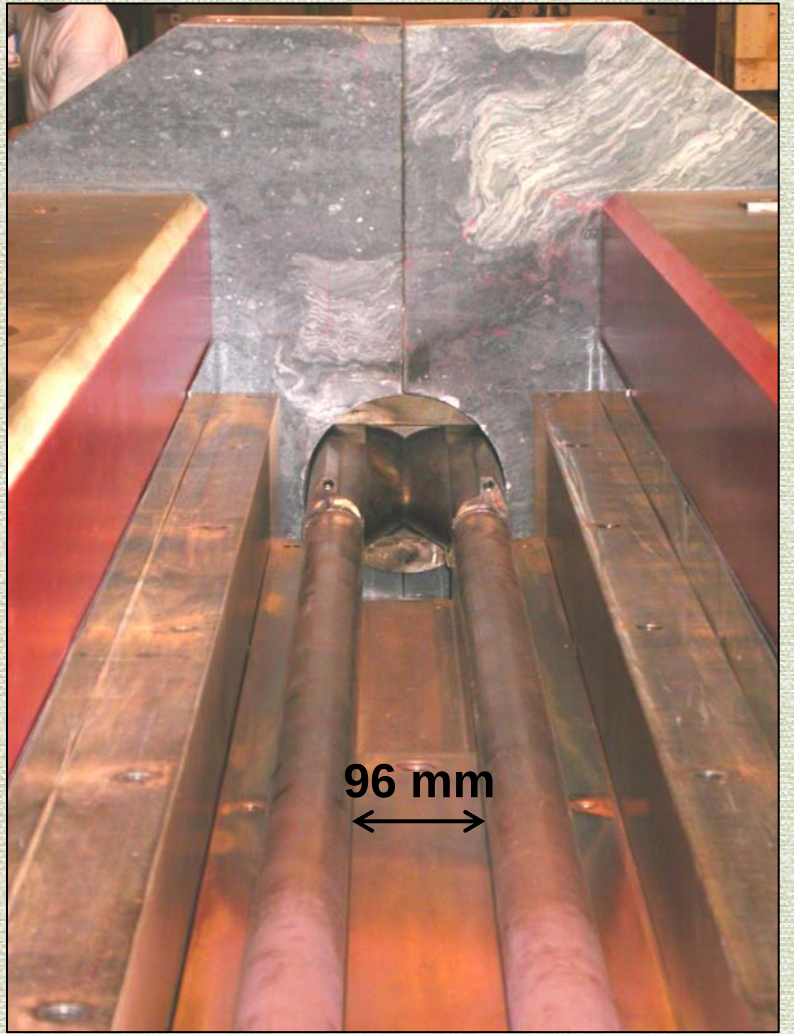
22 tungsten layers 7mm thick → 44 X_0 (1.6 λ_I) in total

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

Energy

Installation of the detectors in the TAN absorbers at 140m from IP1





Part 3: beam test results

Necessary to verify the simulation (small tower 2x2 cm^2: dimensions comparable with the Moliere radius!!!)

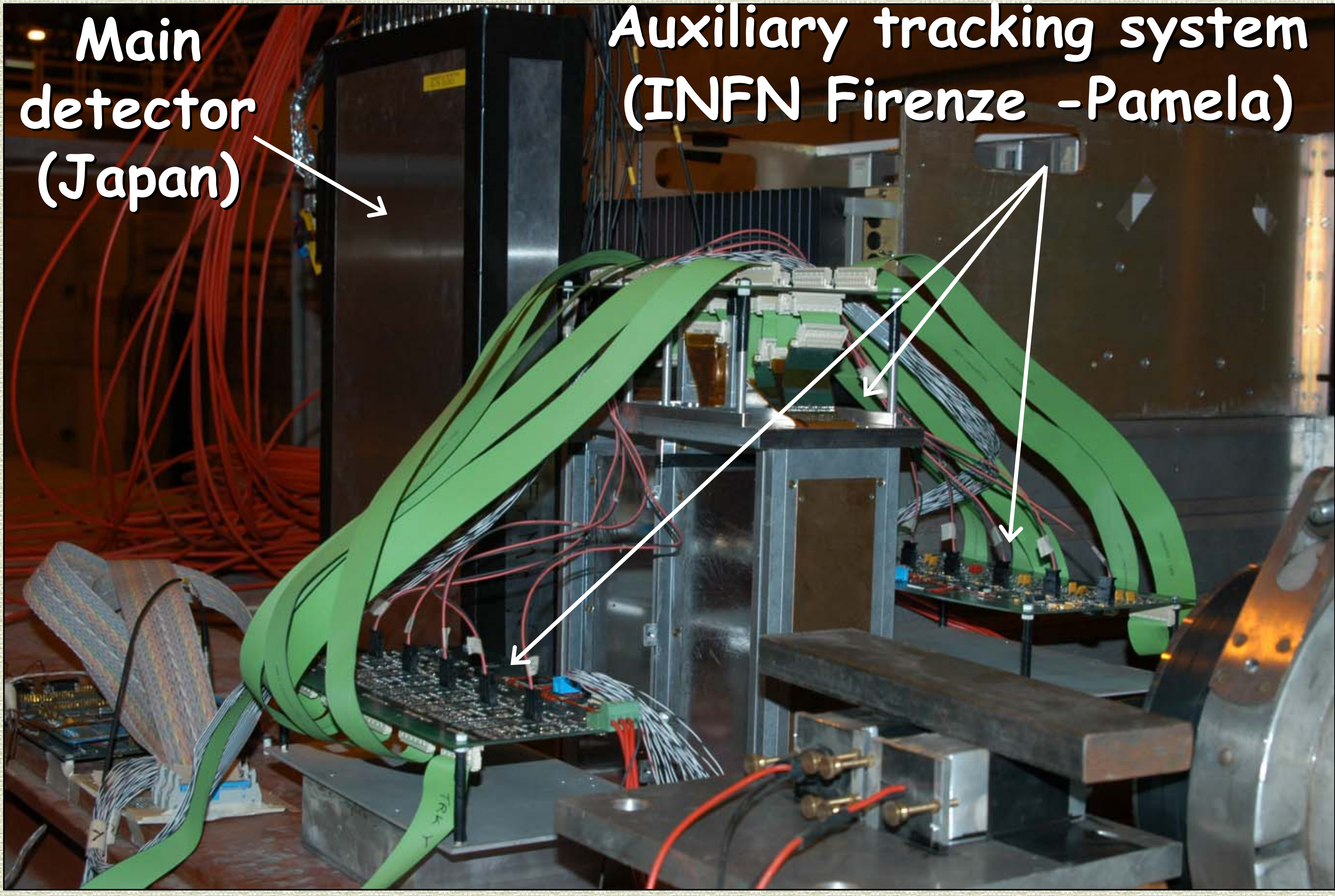
SPS-H4 July-August 2004

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

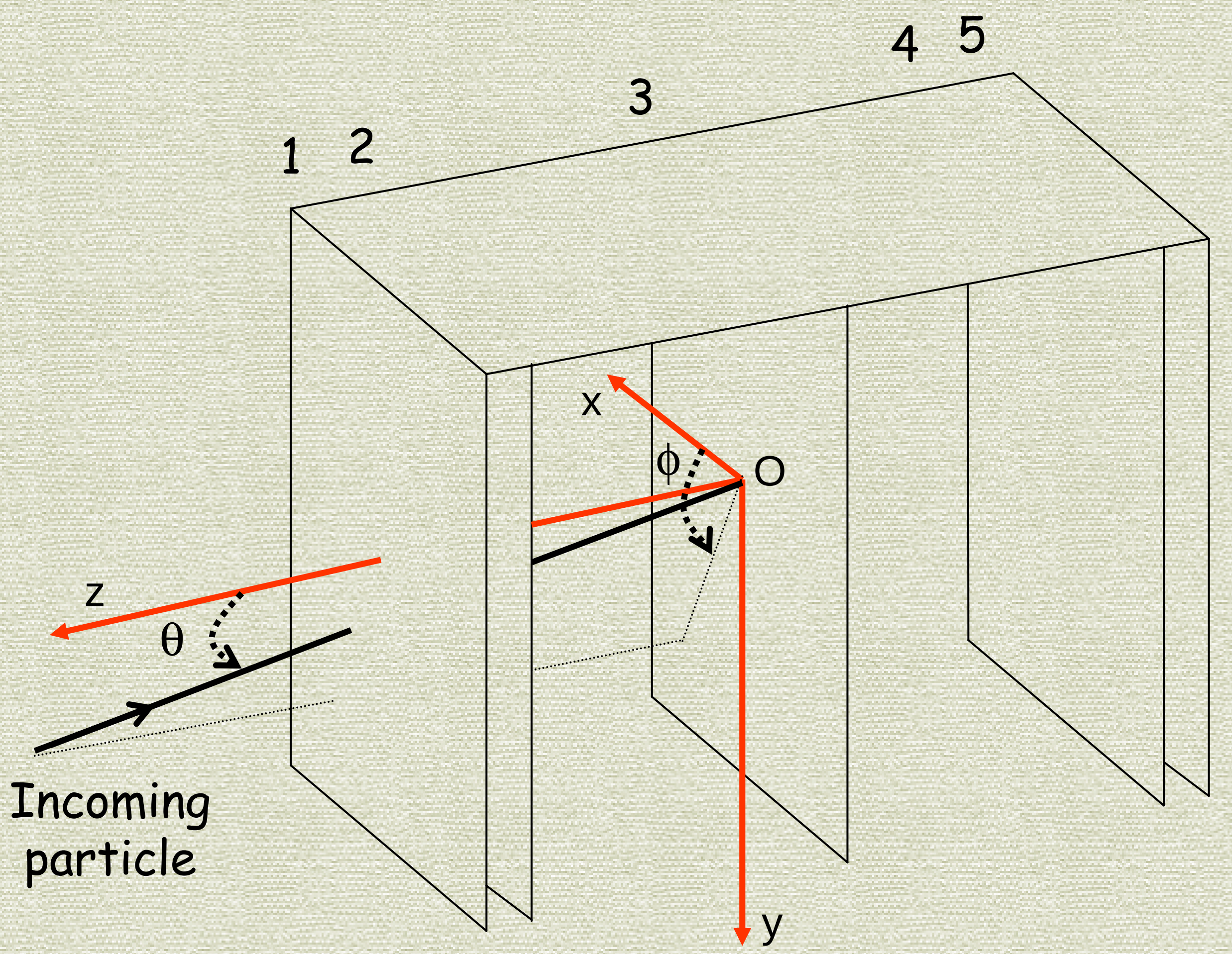
x-y Scan (study of the leakage effect as function of the distance of the particle impact point from the edges)

Prototypes under test

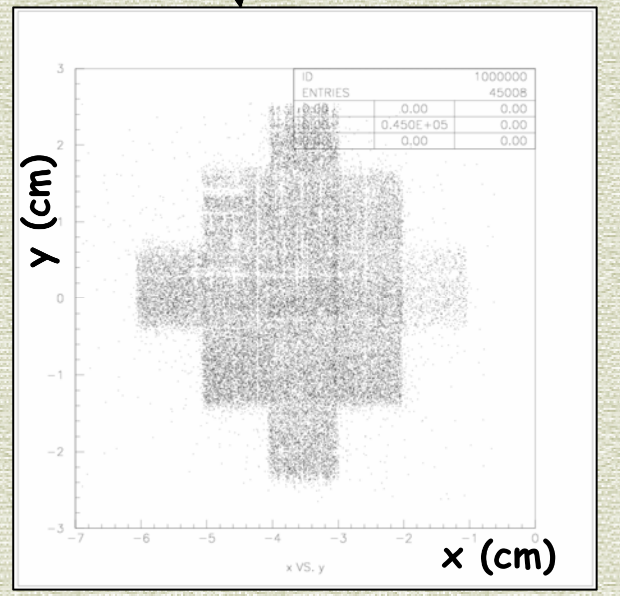


Main
detector
(Japan)
Auxiliary tracking system
(INFN Firenze -Pamela)

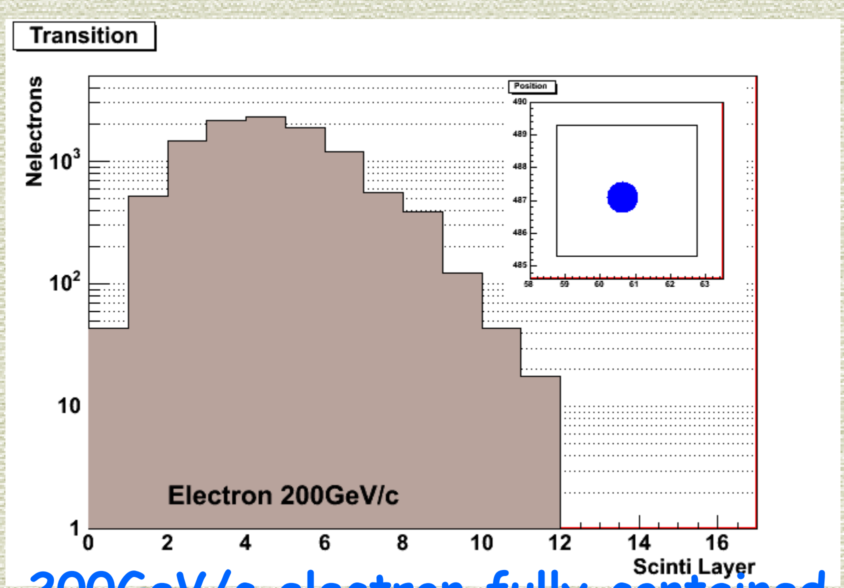
Impact point reconstruction



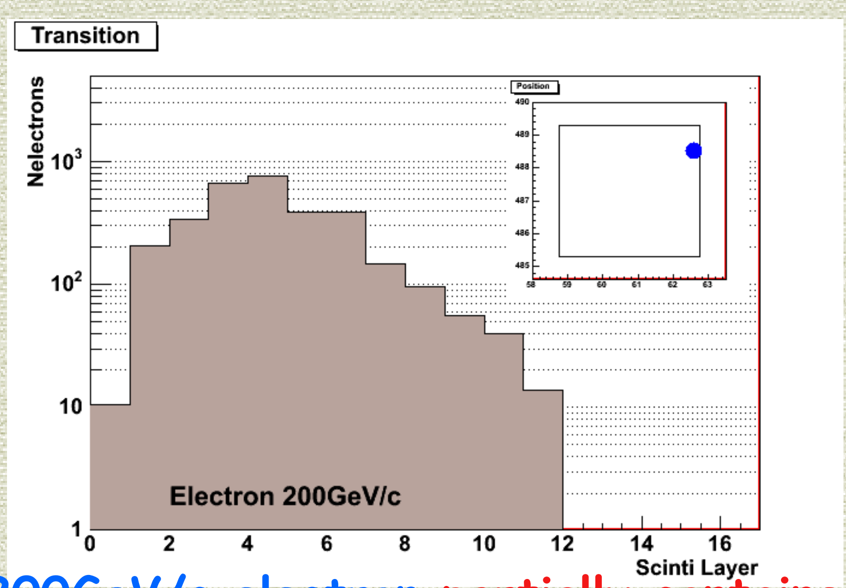
Positions scanning



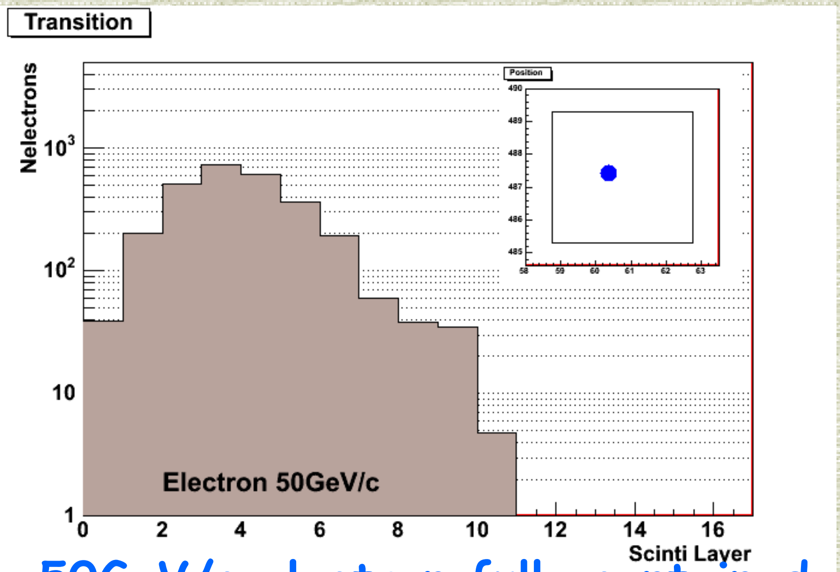
Some results: longitudinal profile of the showers



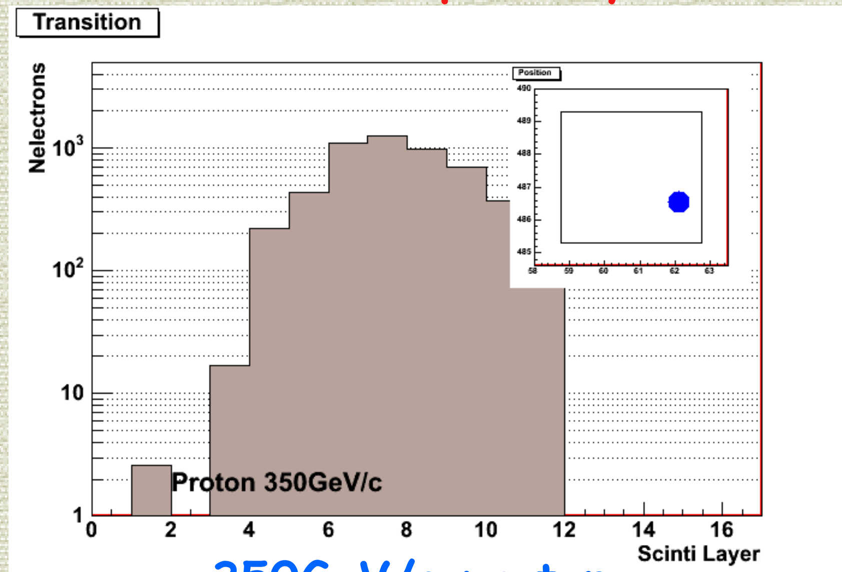
200GeV/c electron fully contained



200GeV/c electron partially contained



50GeV/c electron fully contained

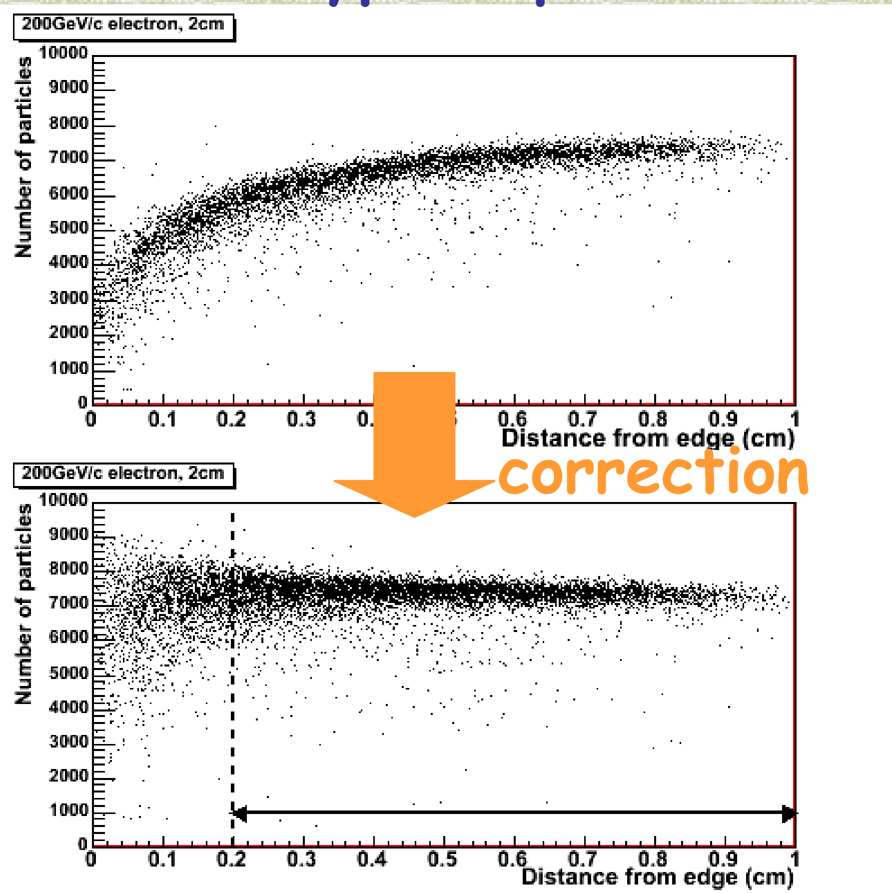


350GeV/c proton

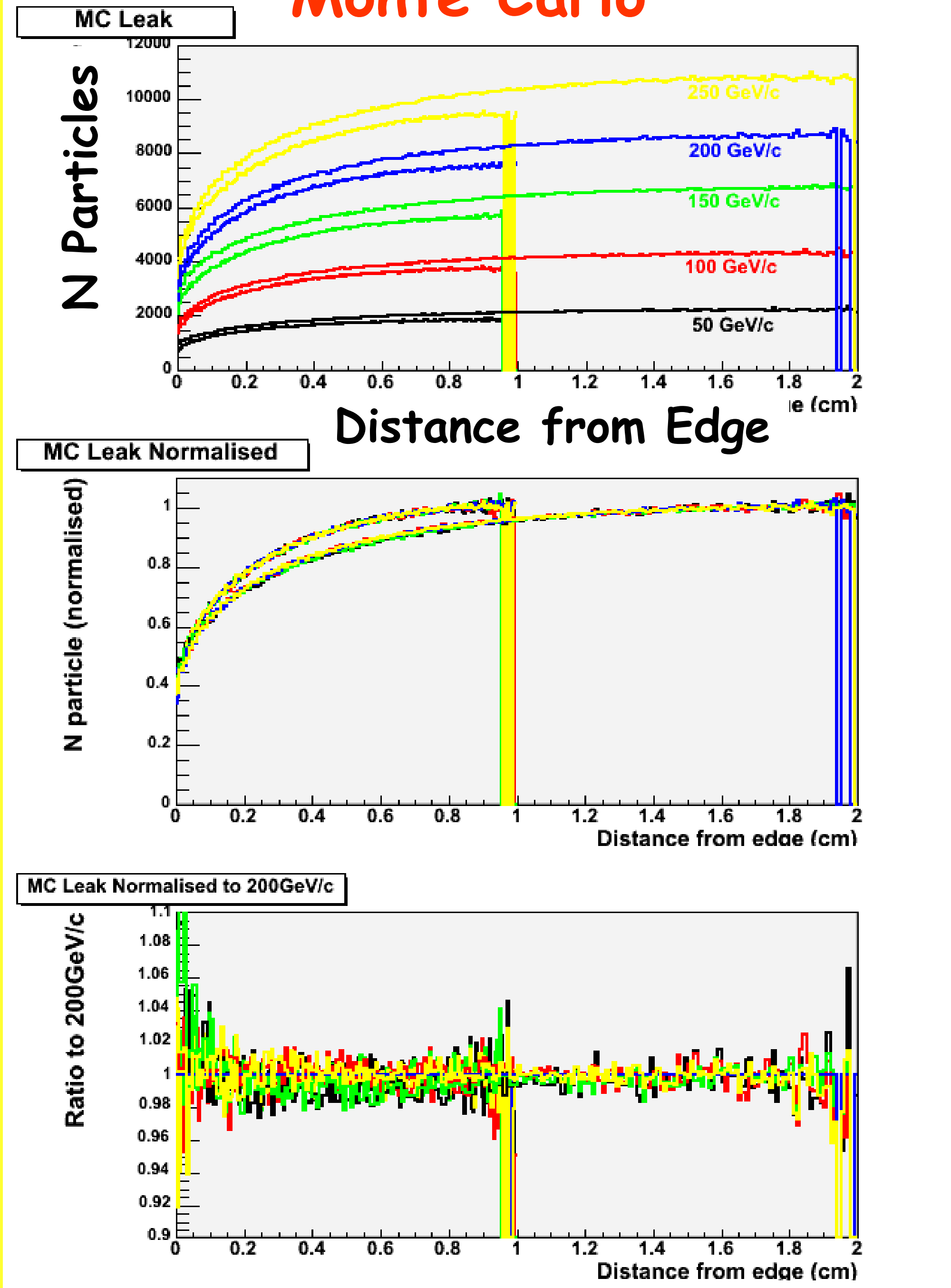
Leakage Correction

MC predicts that the leakage is energy independent!

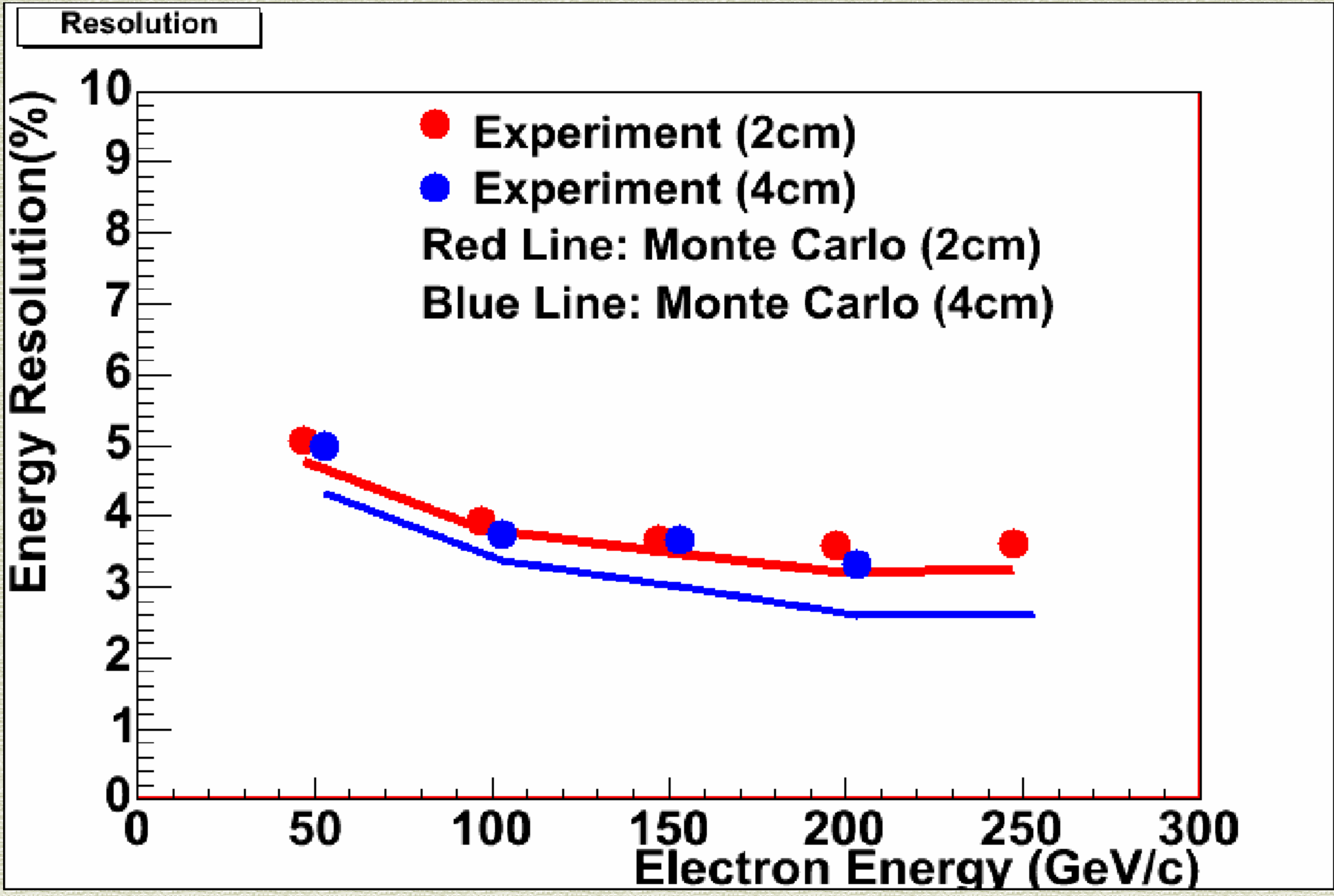
Prototype Experiment



Monte Carlo



Energy Resolution



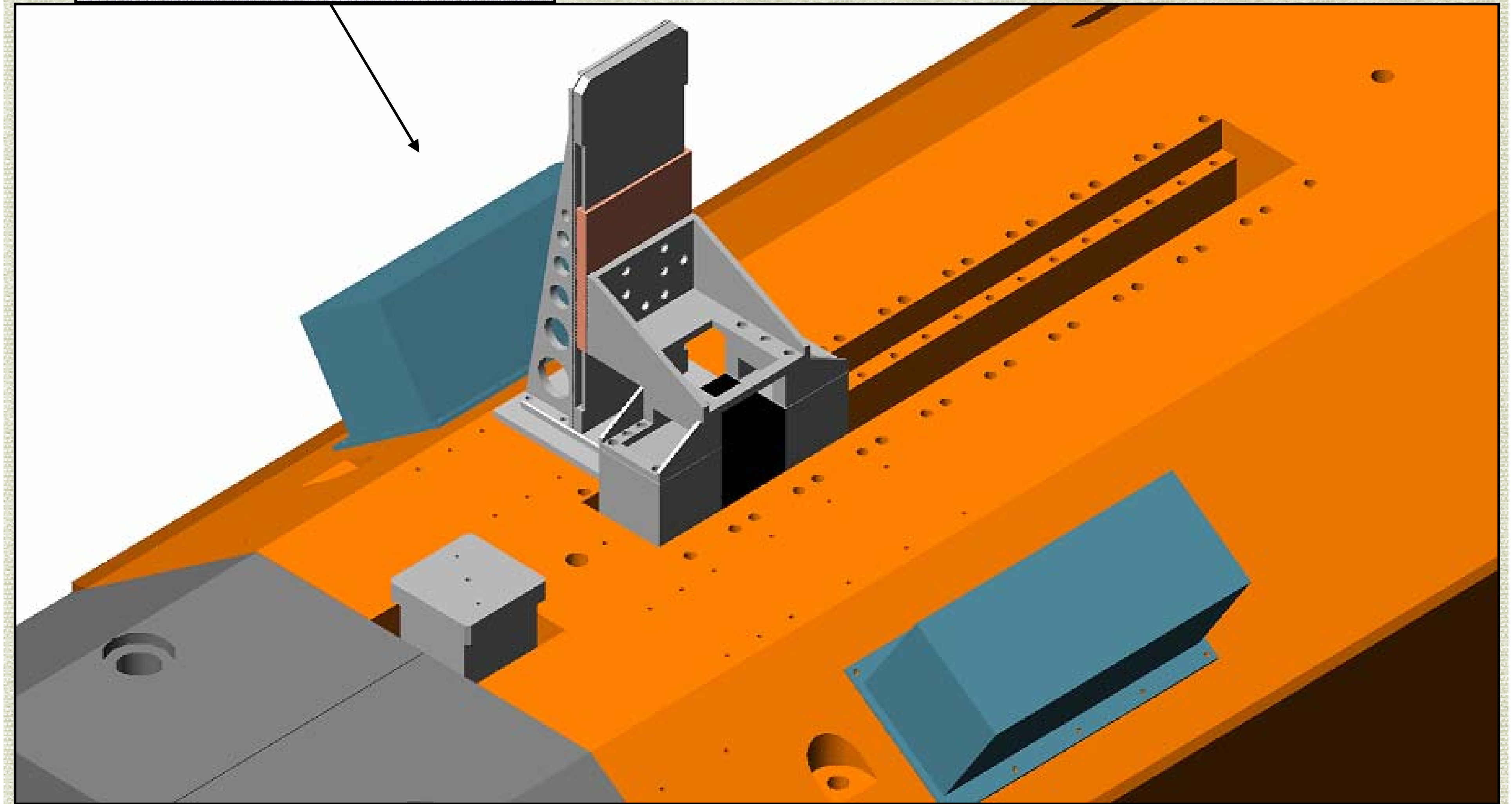
LHCf: summary and schedule

- LHCf just approved: LHCC 16 May
- Physics performance:
  - able to measure π^0 mass with $\pm$5% resolution.
  - able to distinguish the models by measurements of π^0 and γ
  - able to distinguish the models by measurements of n
  - Beam crossing angle $\neq$0 and/or vertical shifts of LHCf by few cm will allow more complete physics measurements
- Running conditions:
  - Three forseen phases
    - Phase I: parasitic mode during LHC commisioning
    - Phase II: parasitic mode during TOTEM low luminosity run
    - Phase III: Heavy Ion runs ?
- Beam Test in August 2006:
  - Full detector #1 will be tested
  - Part of detector #2 will be tested
- Installation starting from end of 2006

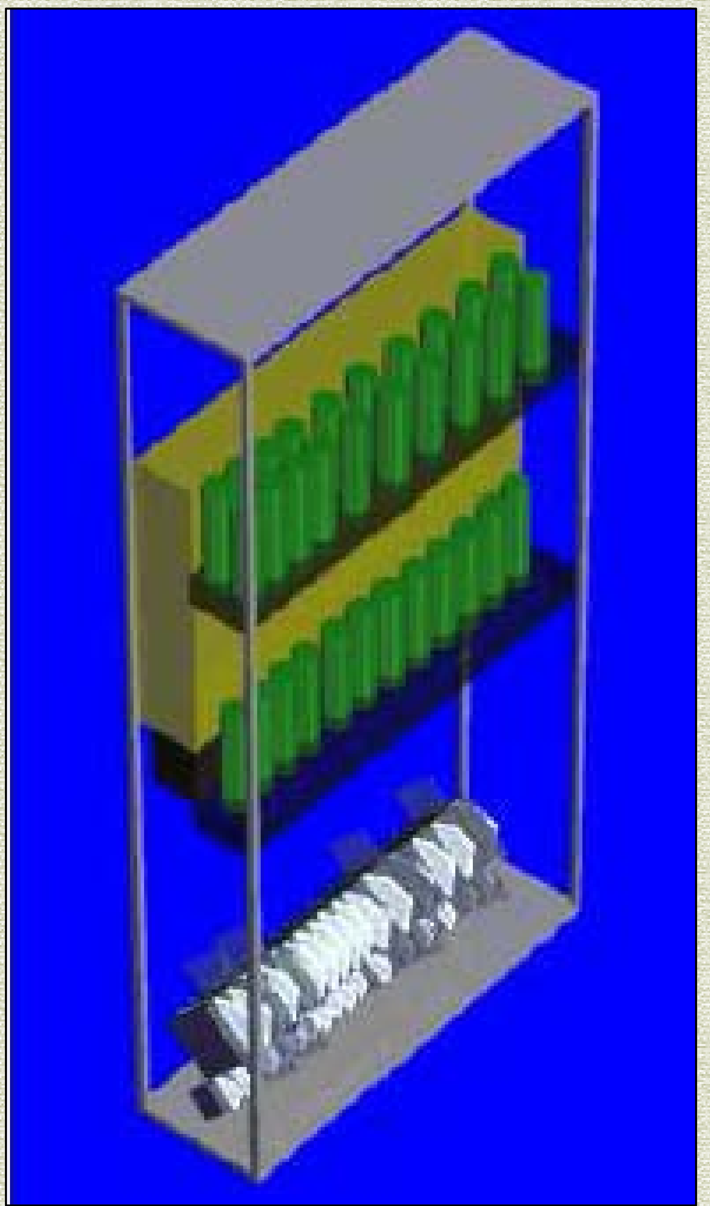
More slides

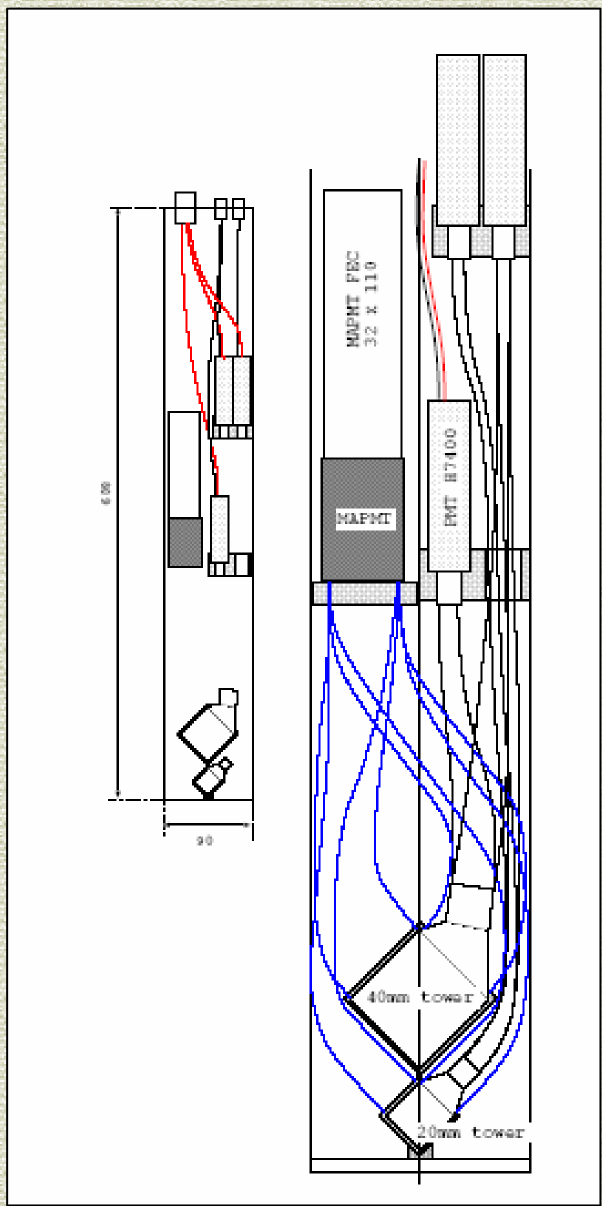
TAN and LHCf

box ~ (15×15×40) cm³

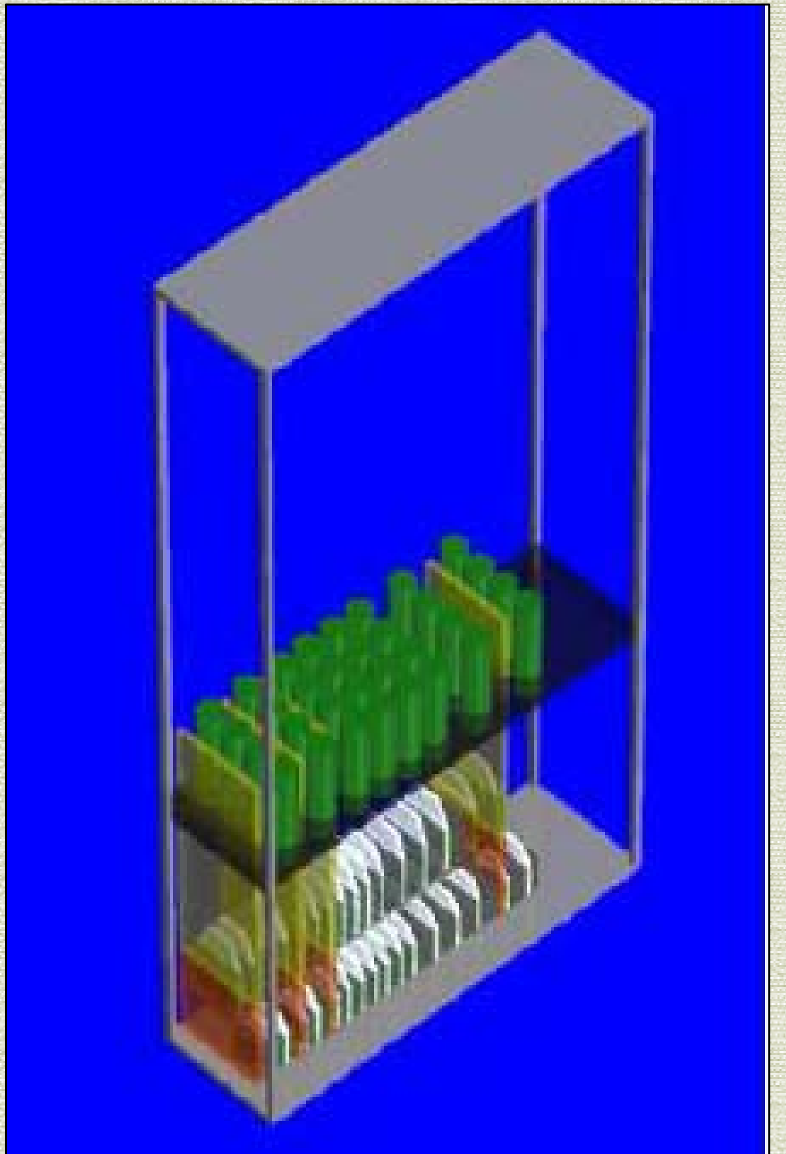


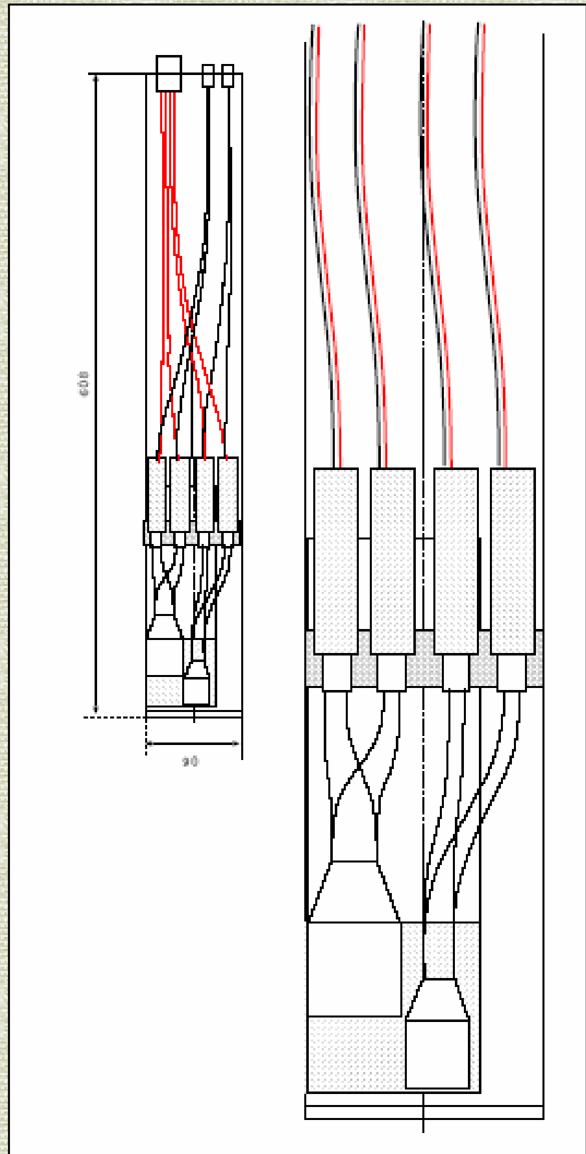
Detector # 1: layout



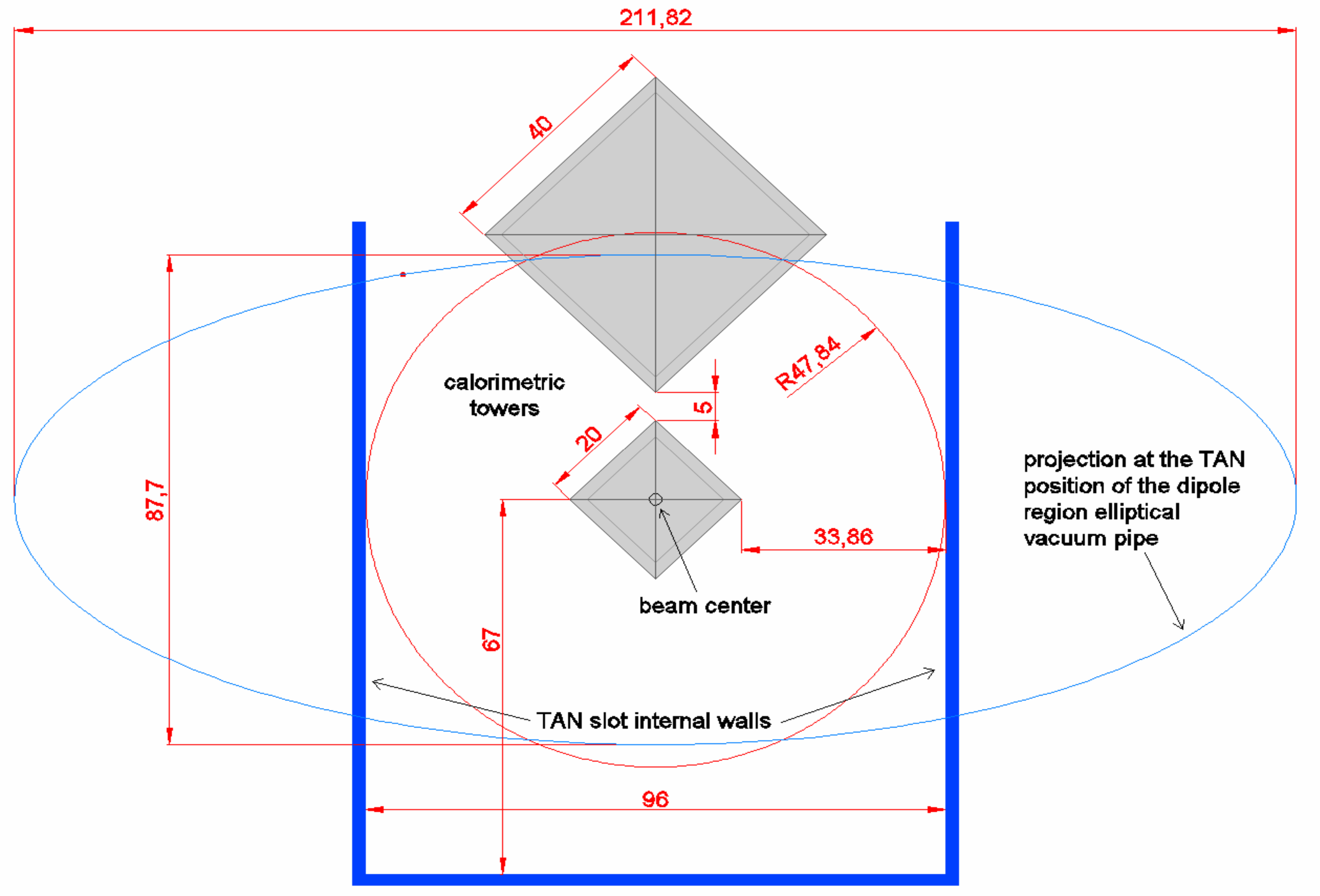


Detector # 2: layout

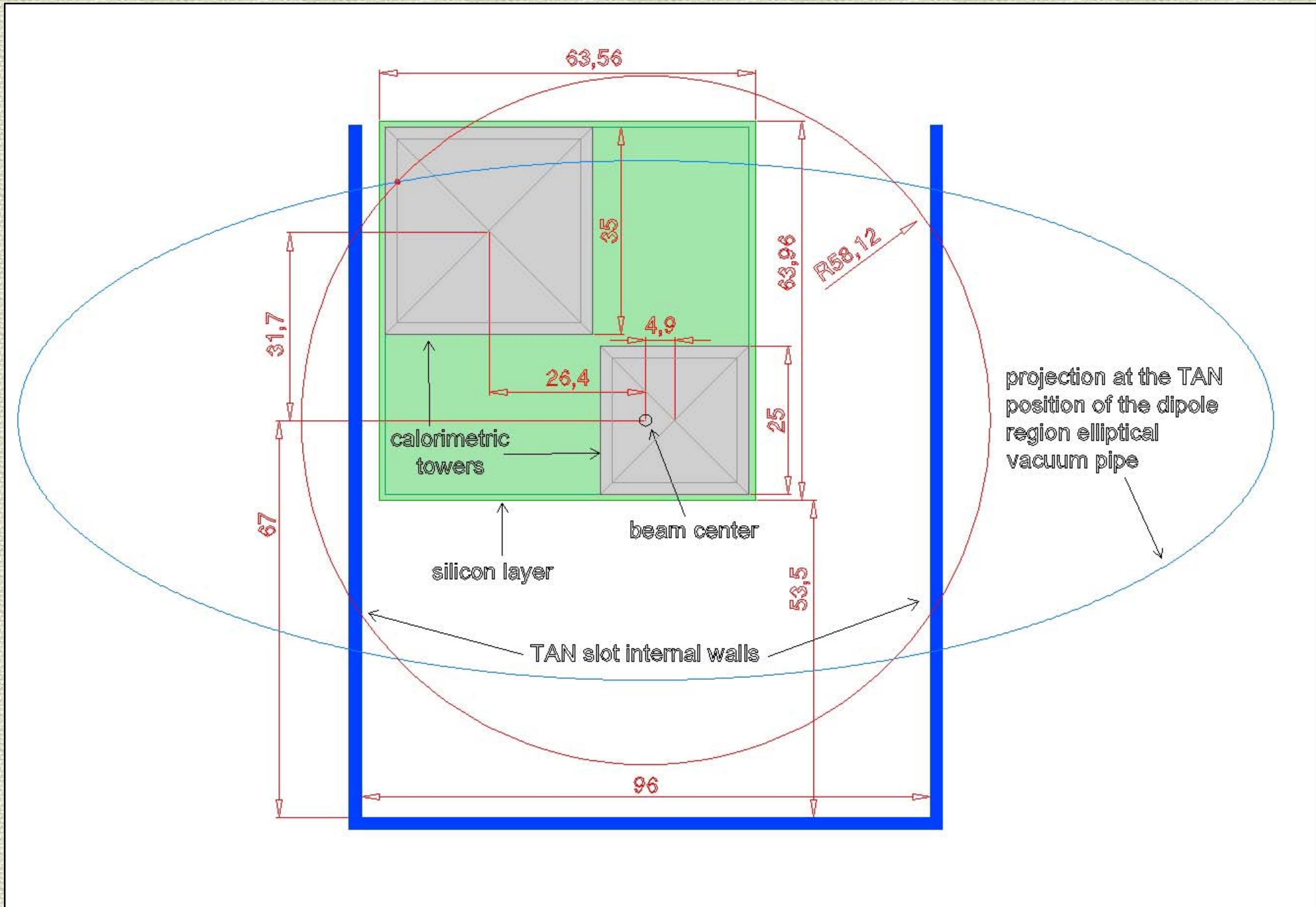




Transverse projection of detector #1 in the TAN slot



Transverse projection of detector #2 in the TAN slot

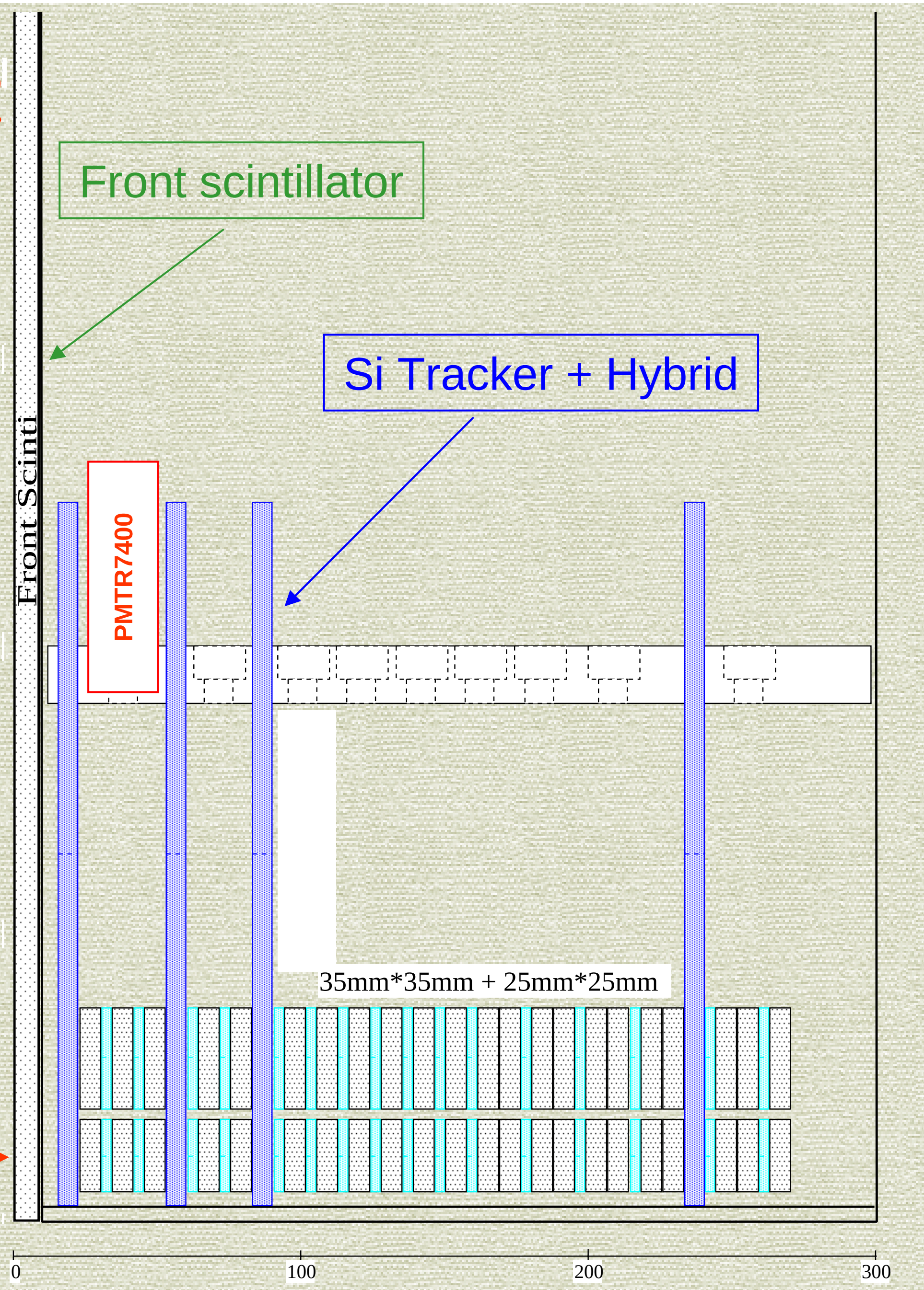


Lateral view of ARM #2

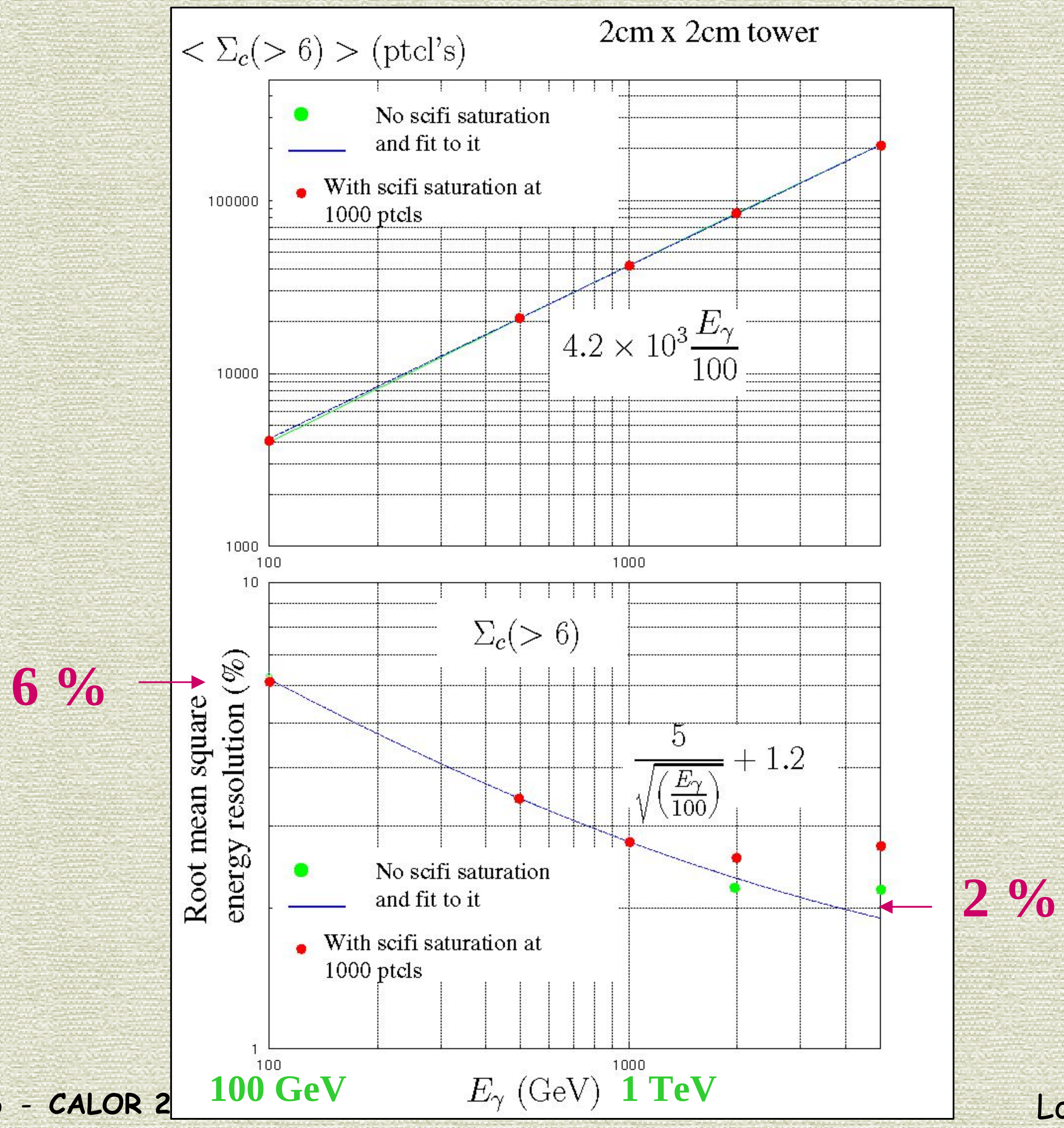
Front scintillator:
Fixed position wrt to TAN

Silicon + Tungsten + Scintillator:
+/- 5 cm vertical excursion

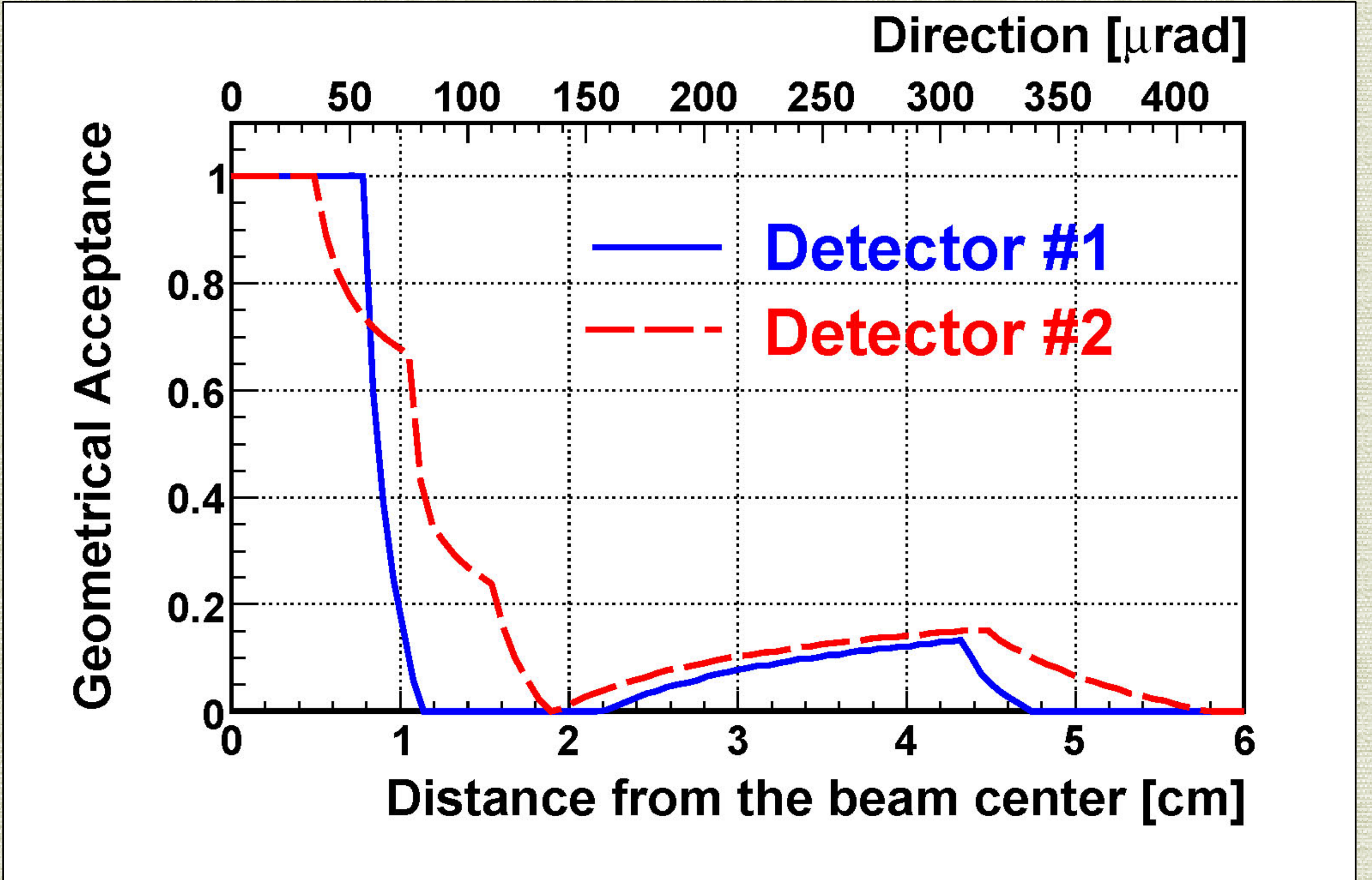
Beam axis



Energy resolution

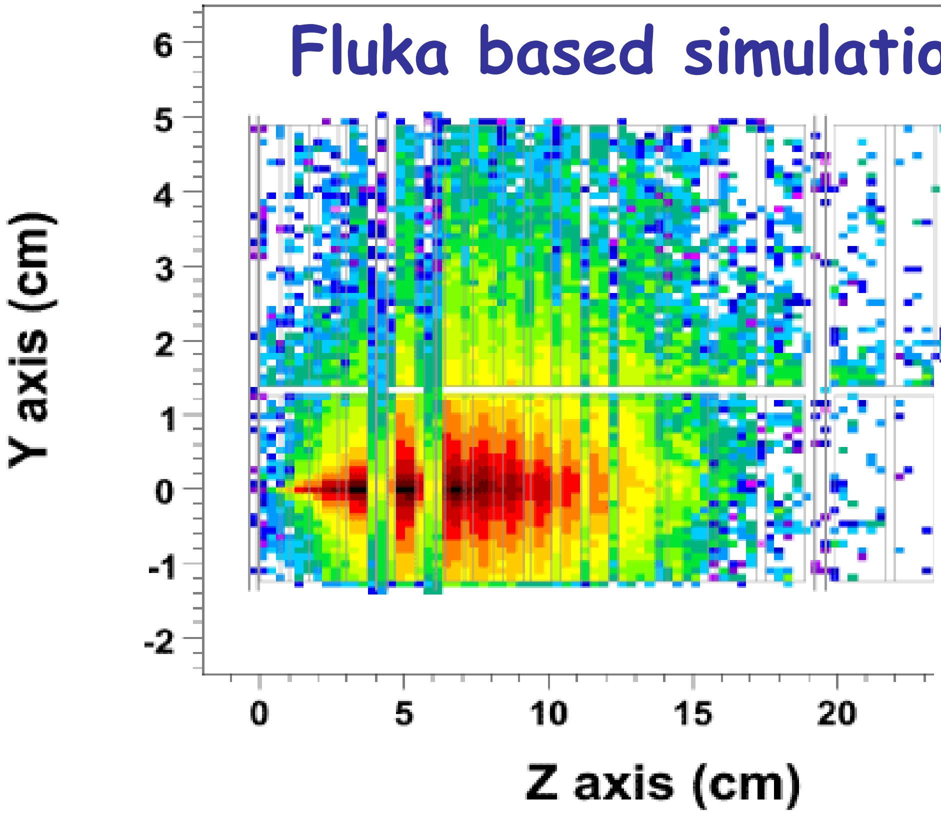


LHCf performances: single γ geometrical acceptance

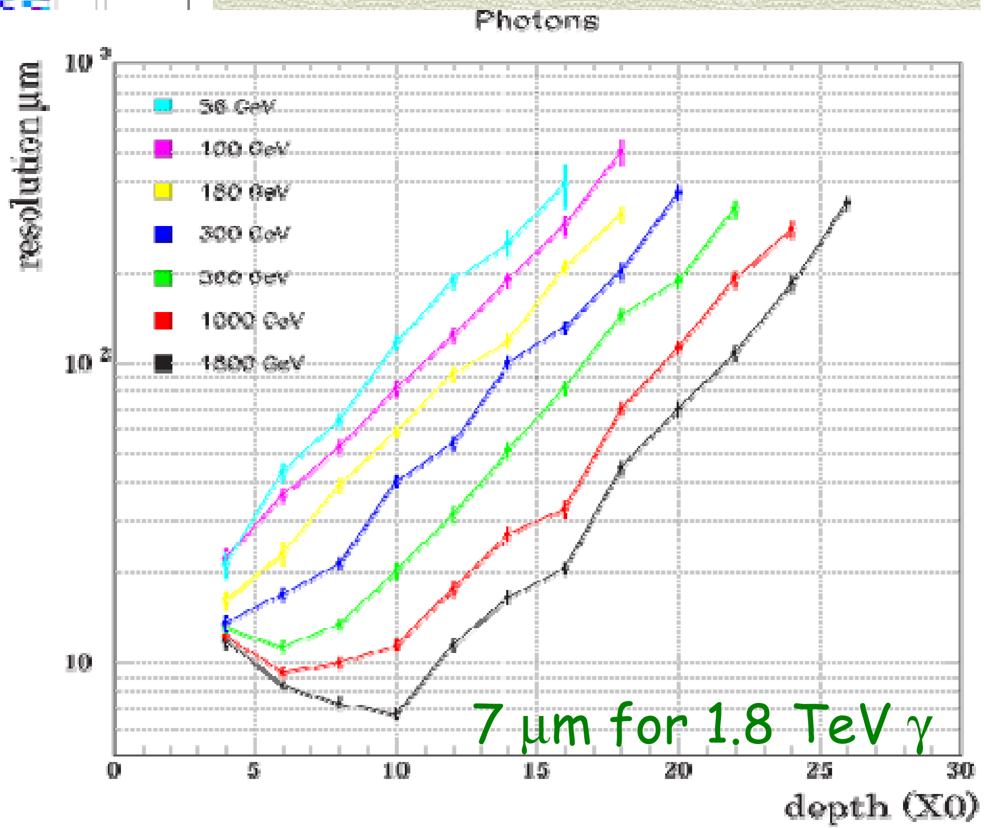


LHCf performance: γ shower in Arm #2

500 GeV γ shower

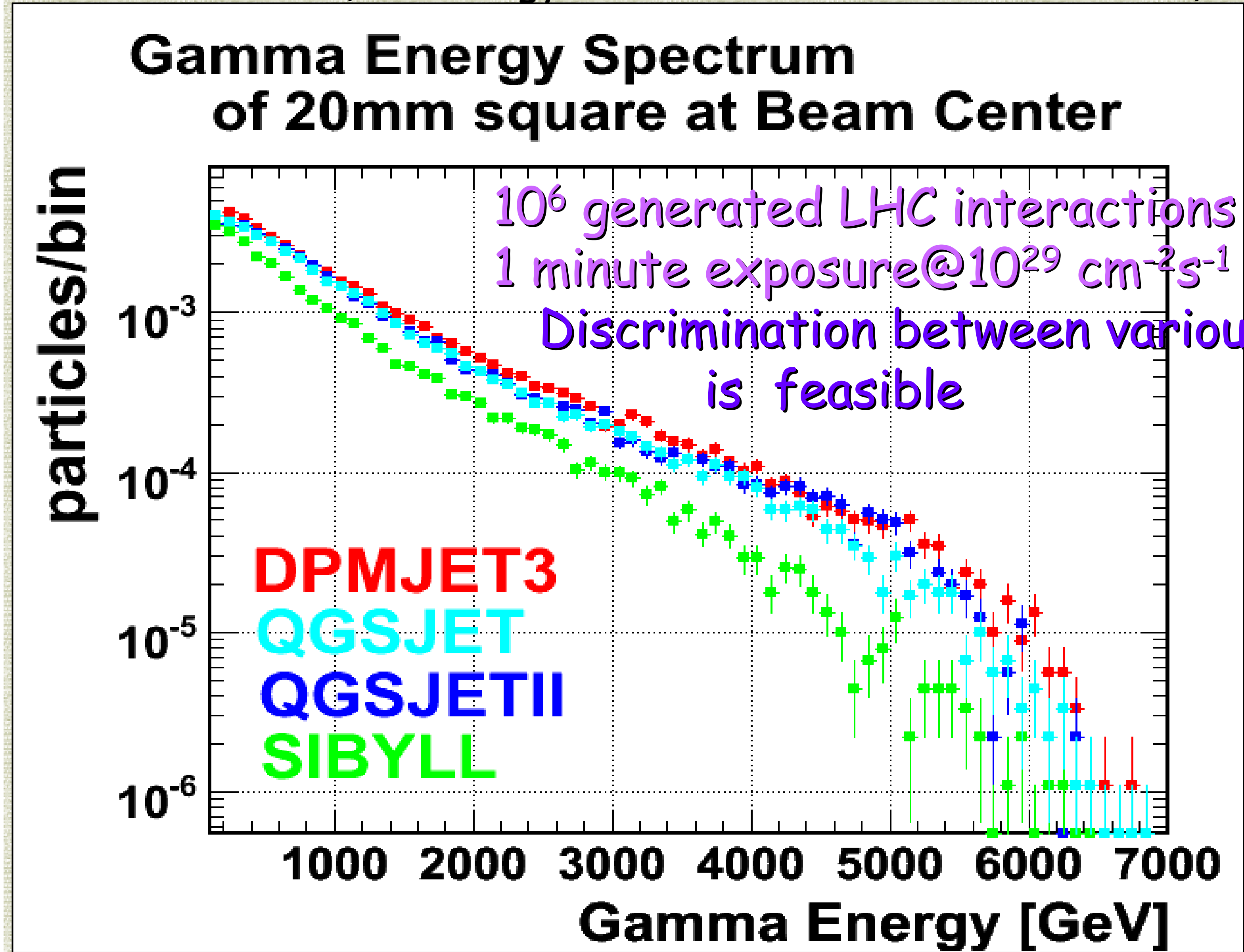


Position resolution of detector # 2



LHCf performance: Monte Carlo γ-ray energy spectrum

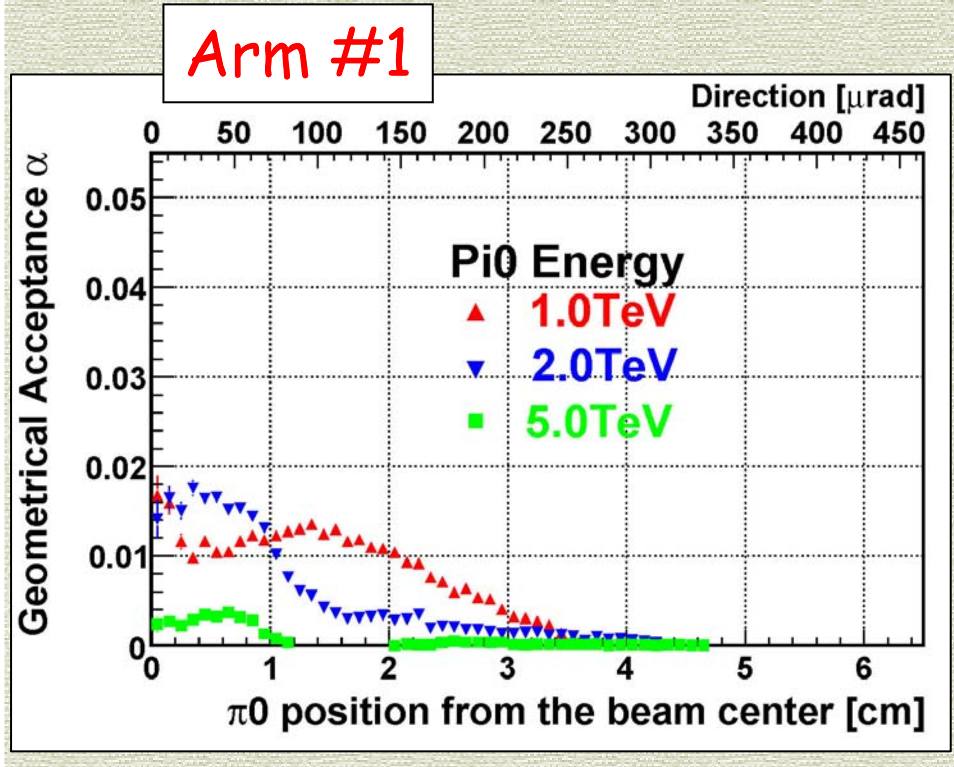
(5% Energy resolution is taken into account)

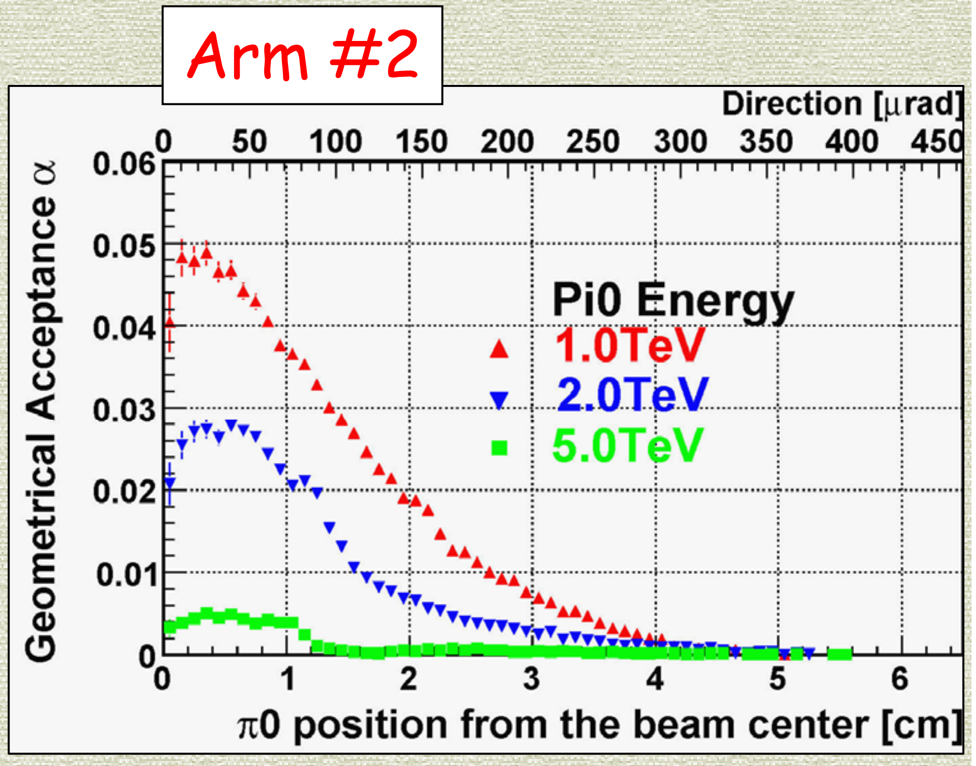


10^6 generated LHC interactions →
1 minute exposure@10^{29} $cm^{-2}s^{-1}$ luminosity

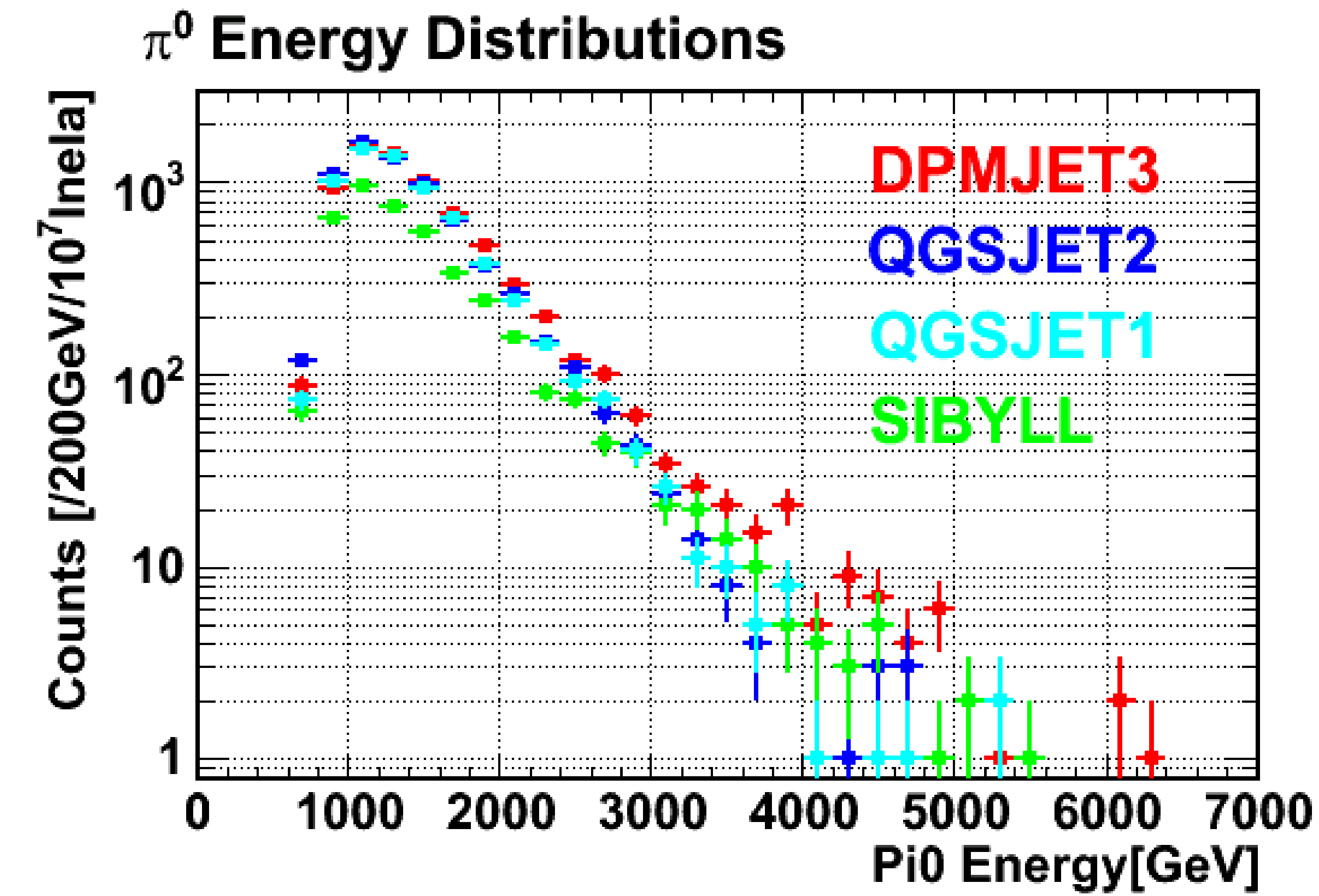
Discrimination between various models is feasible

LHCf performance: π^0 geometrical acceptance



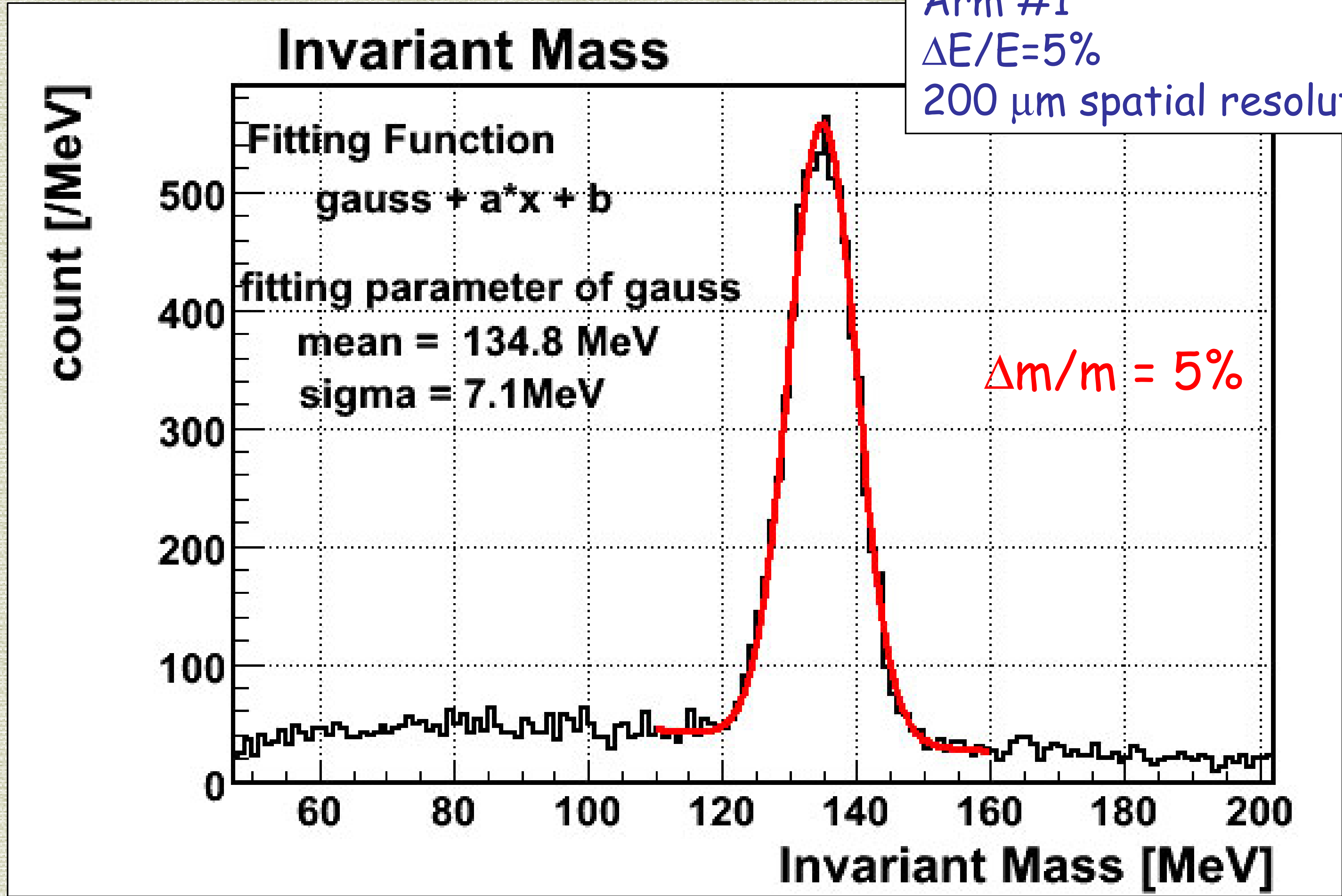


LHCf performance: energy spectrum of π^0



Typical energy resolution of γ is 3 % at 1TeV

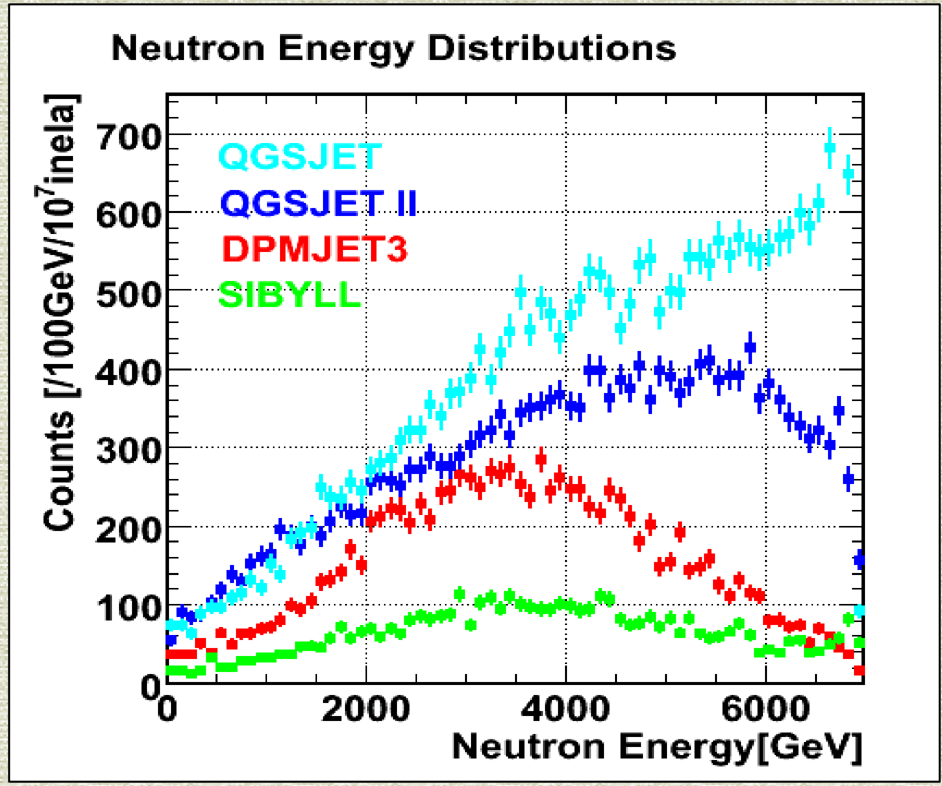
LHCf performance: π^0 mass resolution



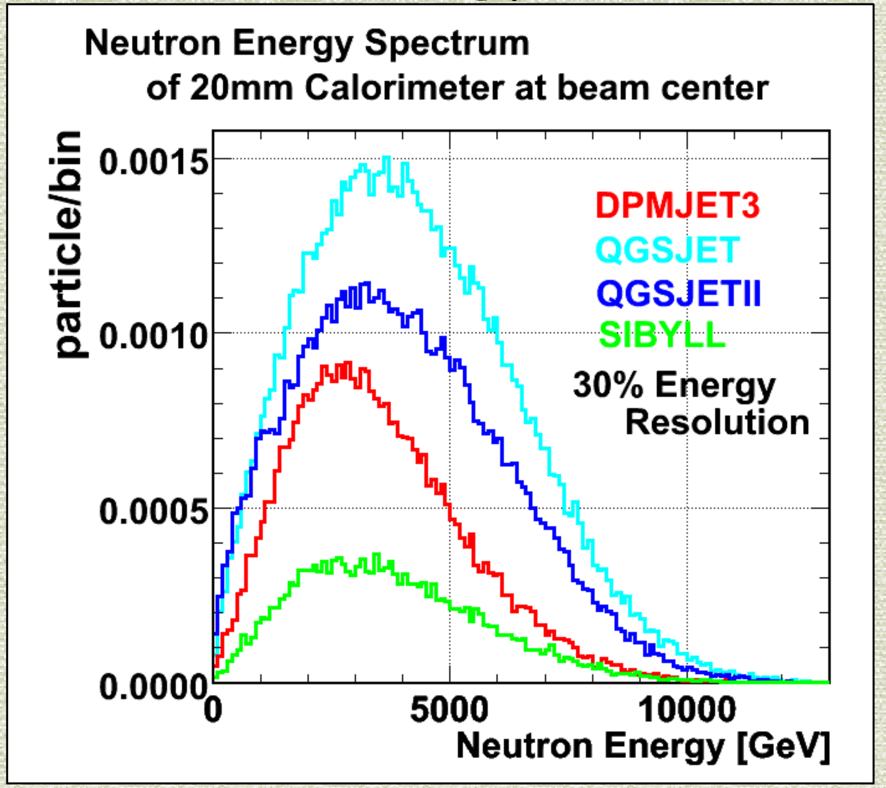
Arm #1
$\Delta E/E = 5\%$
200 μm spatial resolution

LHCf performance: model dependence of neutron energy distribution

Original n energy

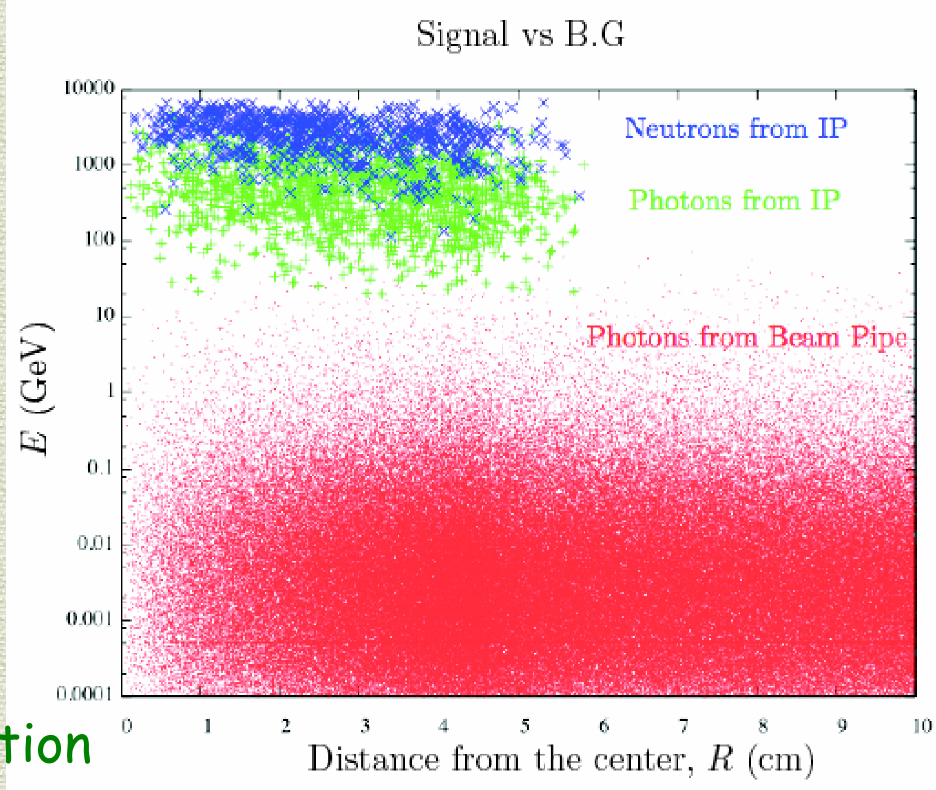


30% energy resolution



Estimate of the background

- beam-beam pipe
  → E_γ(signal) > 200 GeV, OK
  background < 1%



- beam-gas
  → It depends on the beam condition
  background < 1% (under 10^{-10} Torr)

- beam halo-beam pipe
  → It has been newly estimated from the beam loss rate

  Background < 10% (conservative value)

Particles from the beam pipe: background vs signal