Firenze, 23 Aprile 2010

LHCf: un esperimento per la fisica dei raggi cosmici ad LHC

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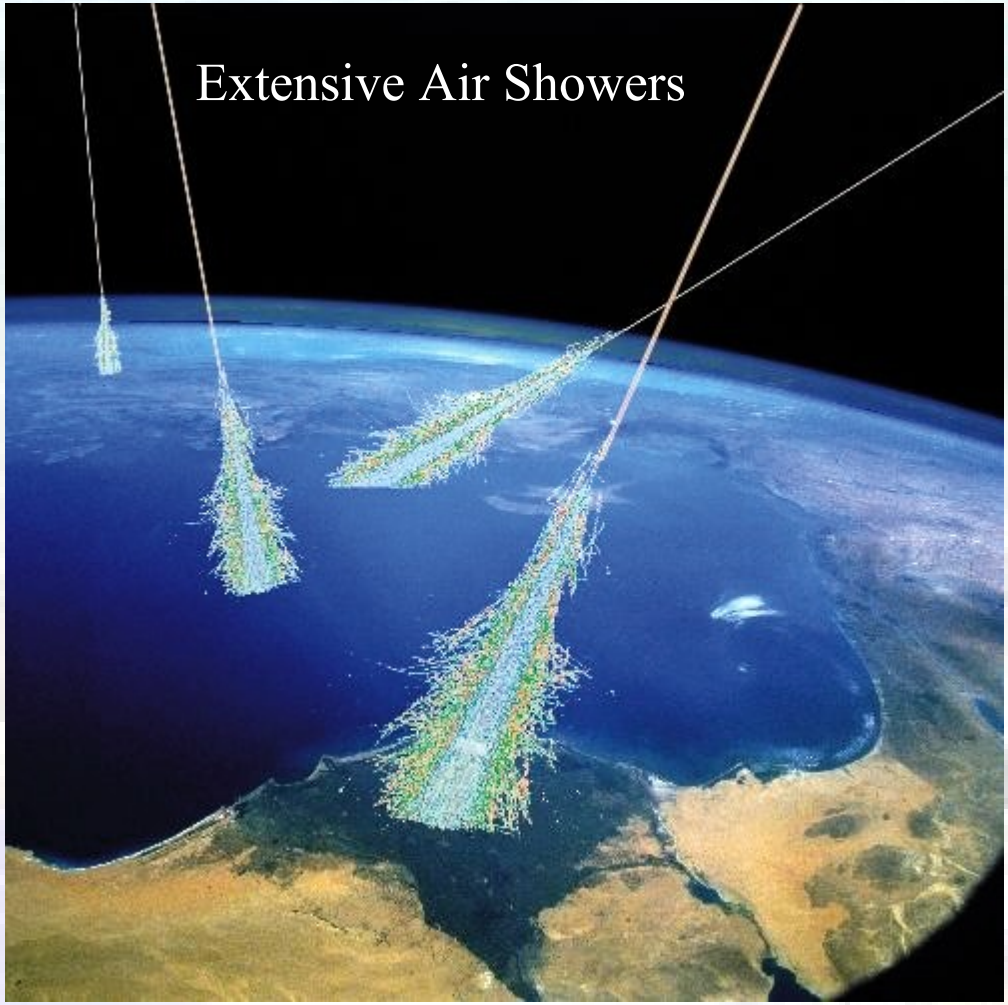
Why LHCf?
Physics Motivations

Ultra High Energy Cosmic Rays

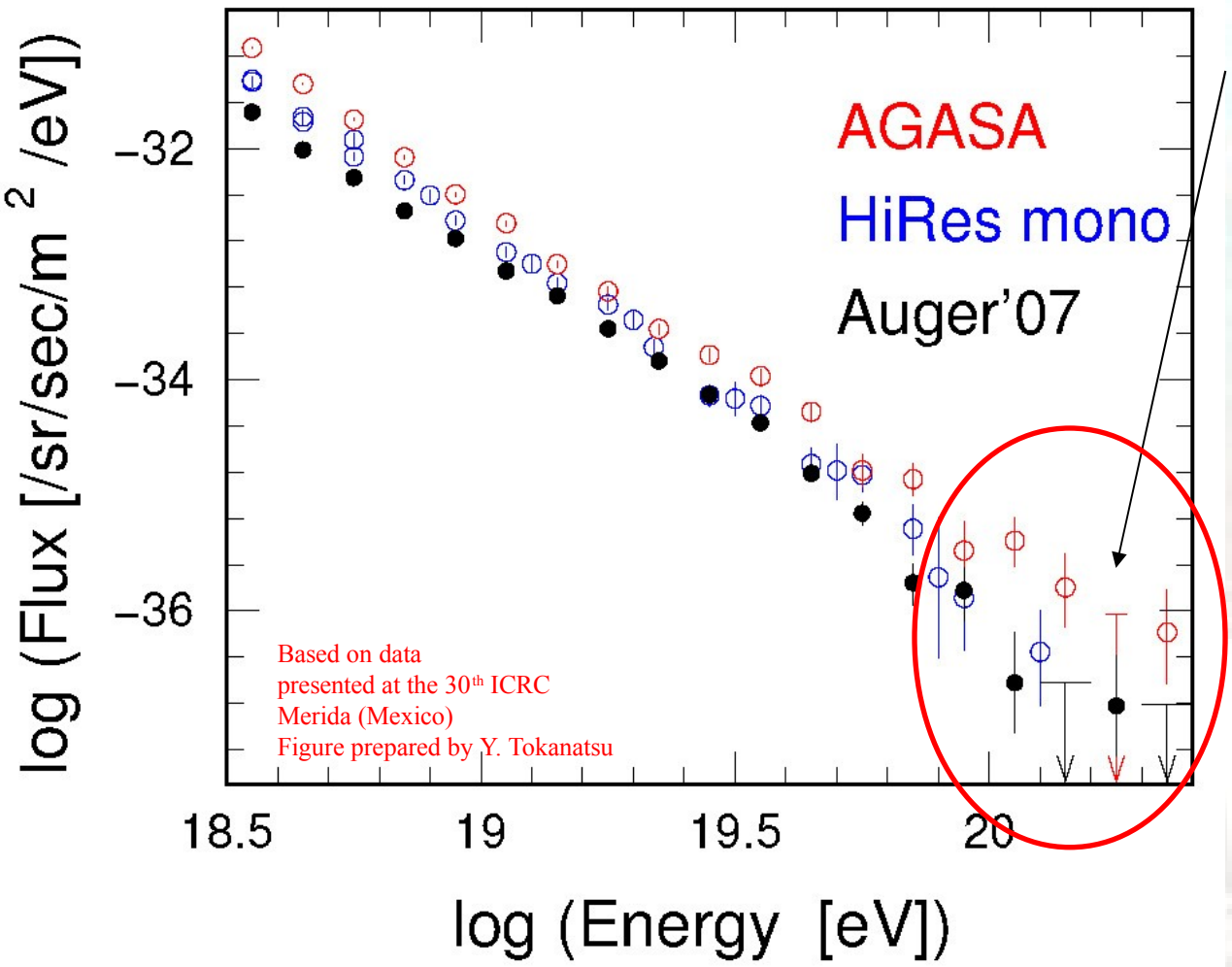


Experimental observations: at E>100 TeV only EAS
(shower of secondary particles)
- **lateral distribution**
- **longitudinal distribution**
- **particle type**
- **arrival direction**

Air shower development (particle interaction in the atmosphere)

Astrophysical parameters:
(primary particles)
- spectrum
- composition
- source distribution
- origin and propagation

The Cosmic Ray Spectra



GZK cutoff: 10^{20}eV

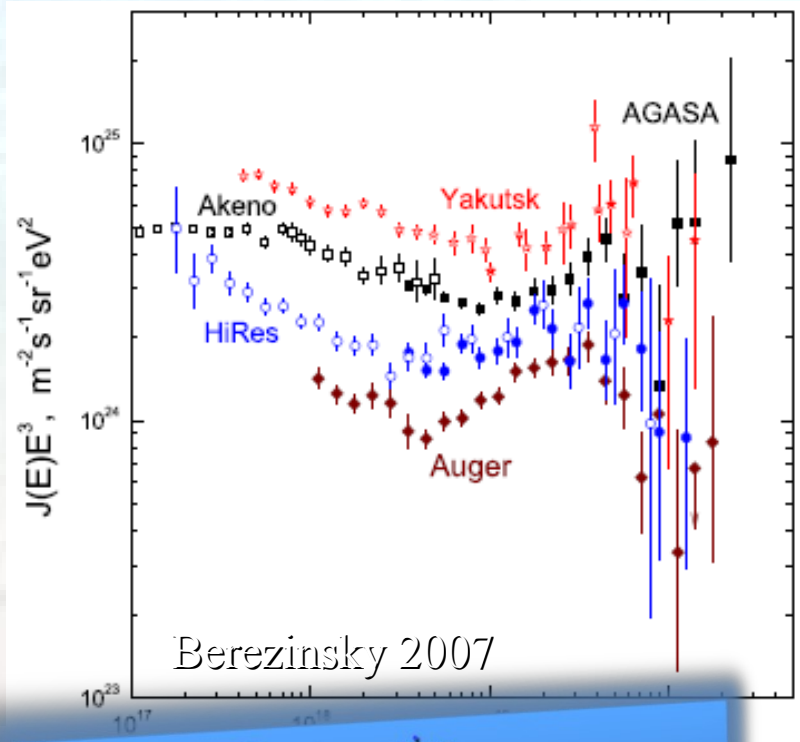
GZK cutoff would limit energy to 10^{20}eV for protons, due to Cosmic Microwave Background

$p\gamma(2.7K) \rightarrow \Delta \rightarrow N\pi$

super GZK events?!?

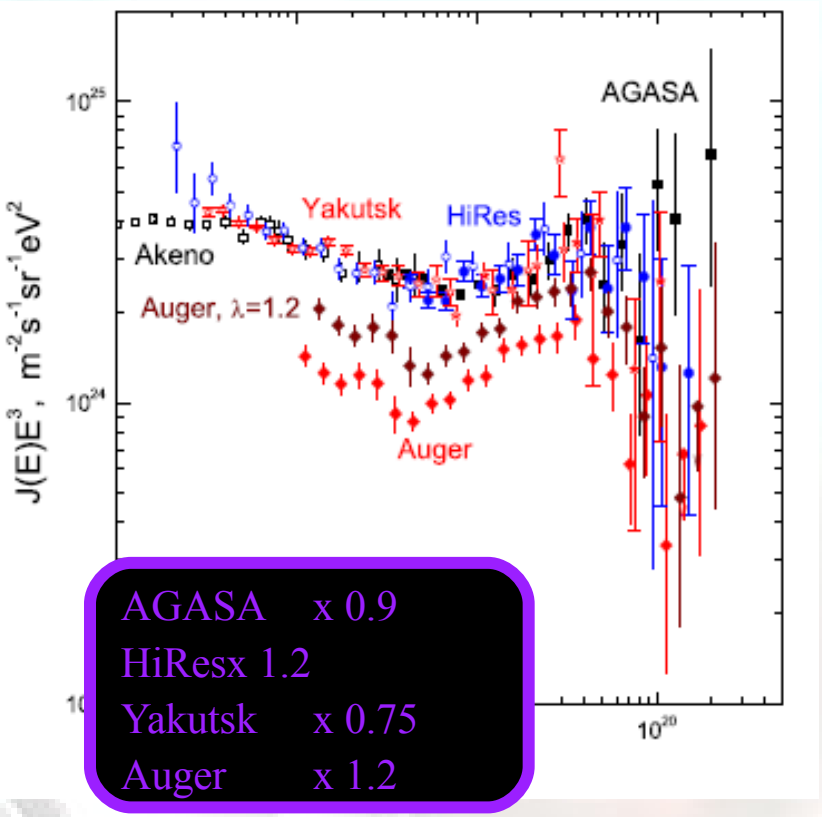
Different results between different experiments

The Cosmic Ray Spectra



Berezinsky 2007

AGASA Systematics
Total
±18%
Hadron interaction
(QGSJET, SIBYLL) ~10%
(Takeda et al., 2003)



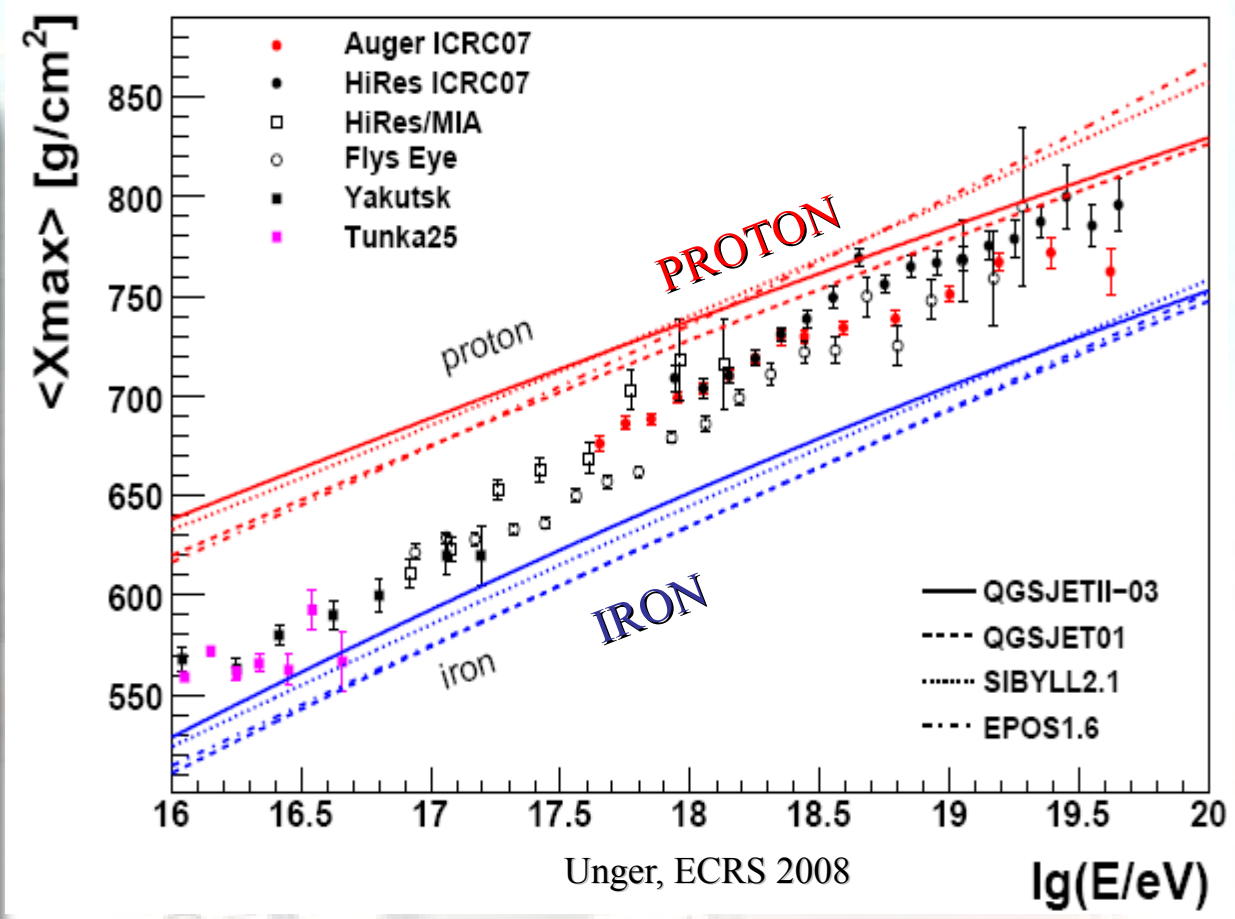
AGASA x 0.9
HiResx 1.2
Yakutsk x 0.75
Auger x 1.2

Difference in the energy scale between different experiments???

HECR composition

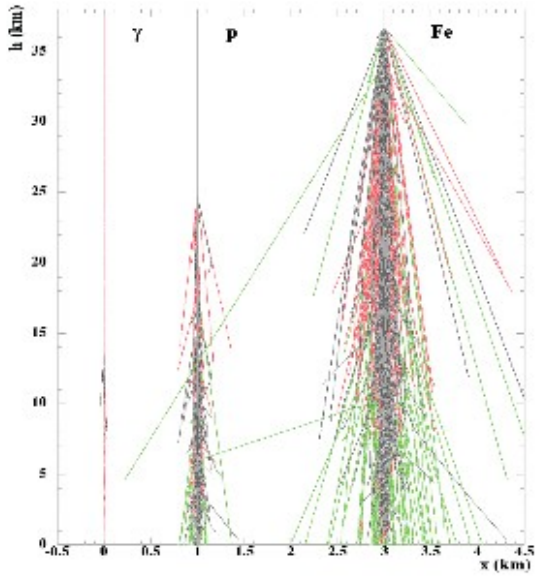
The depth of the maximum of the shower X_{max} in the atmosphere depends on energy and type of the primary particle

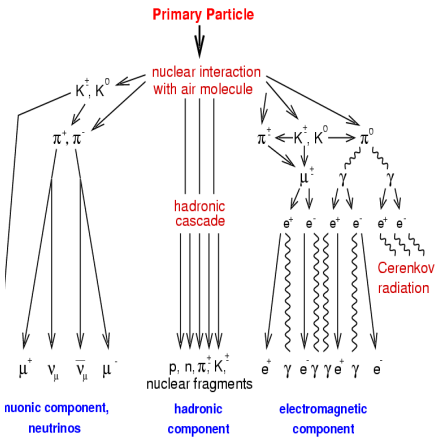
Different hadronic interaction models give different answers about the composition of HECR

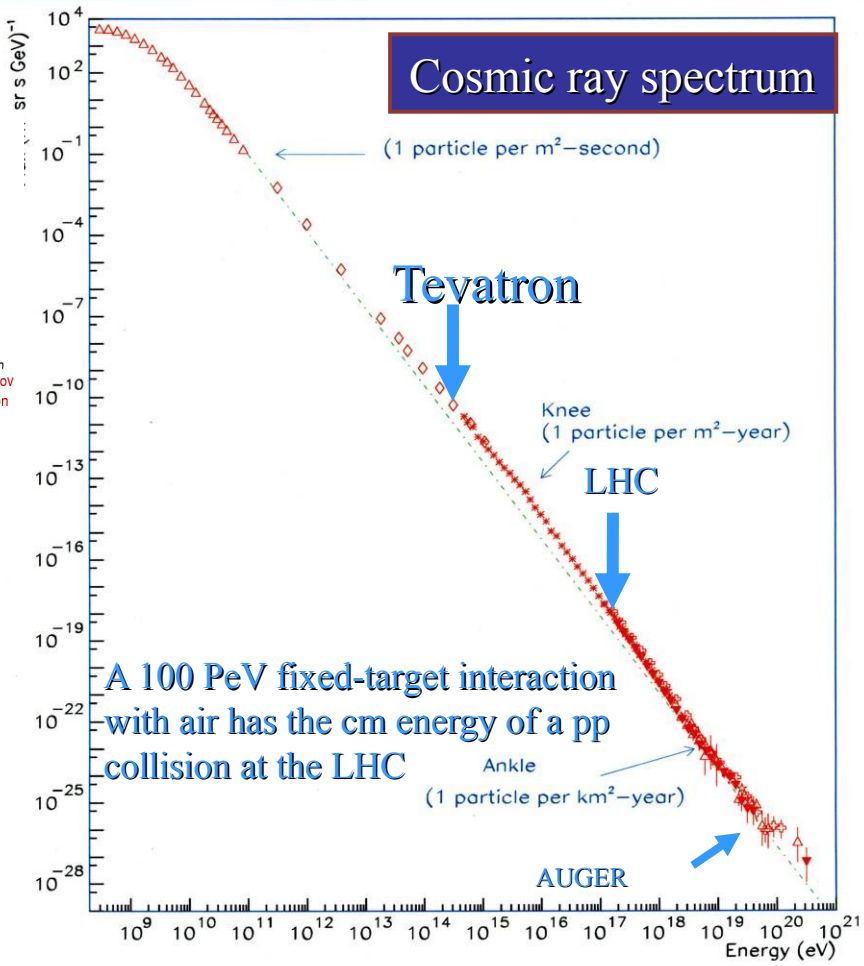


Unger, ECRS 2008

Development of atmospheric showers







Determination of E and mass of cosmic rays depends on description of primary UHE interaction

Hadronic MC's need tuning with data

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 done by UA7 ($E \sim 10^{13}$ eV, $\gamma \sim 3 \cdot 10^7$)

LHCf: use LHC

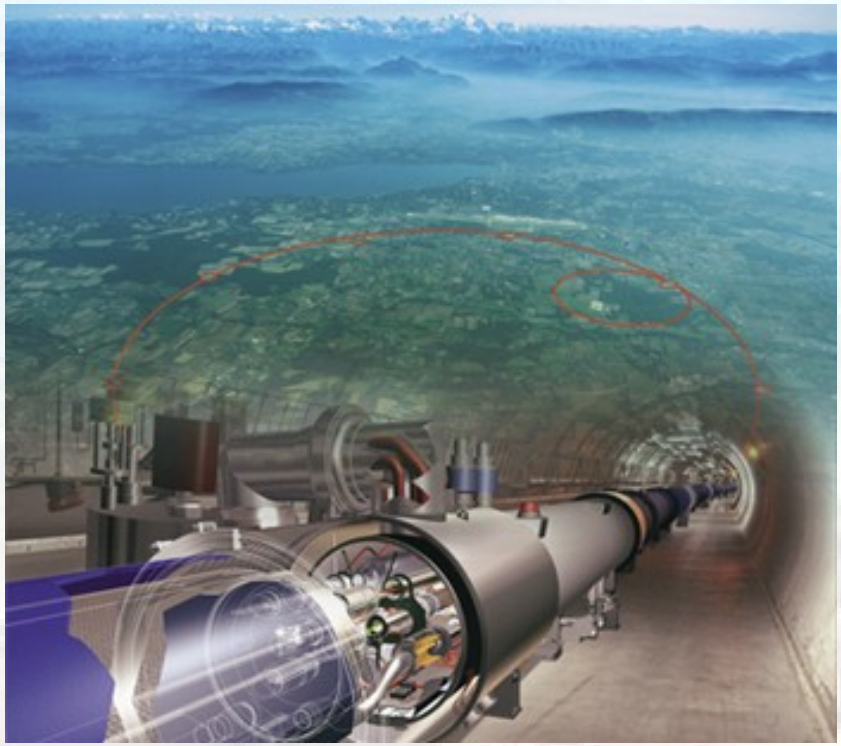
$\sqrt{s} = 14$ TeV $\Rightarrow E_{lab} = 10^{17}$ eV

to calibrate MCs

What is LHCf?

The Detectors

LHCf: an Astroparticle Experiment at LHC



7TeV+ 7 TeV proton collisions at LHC

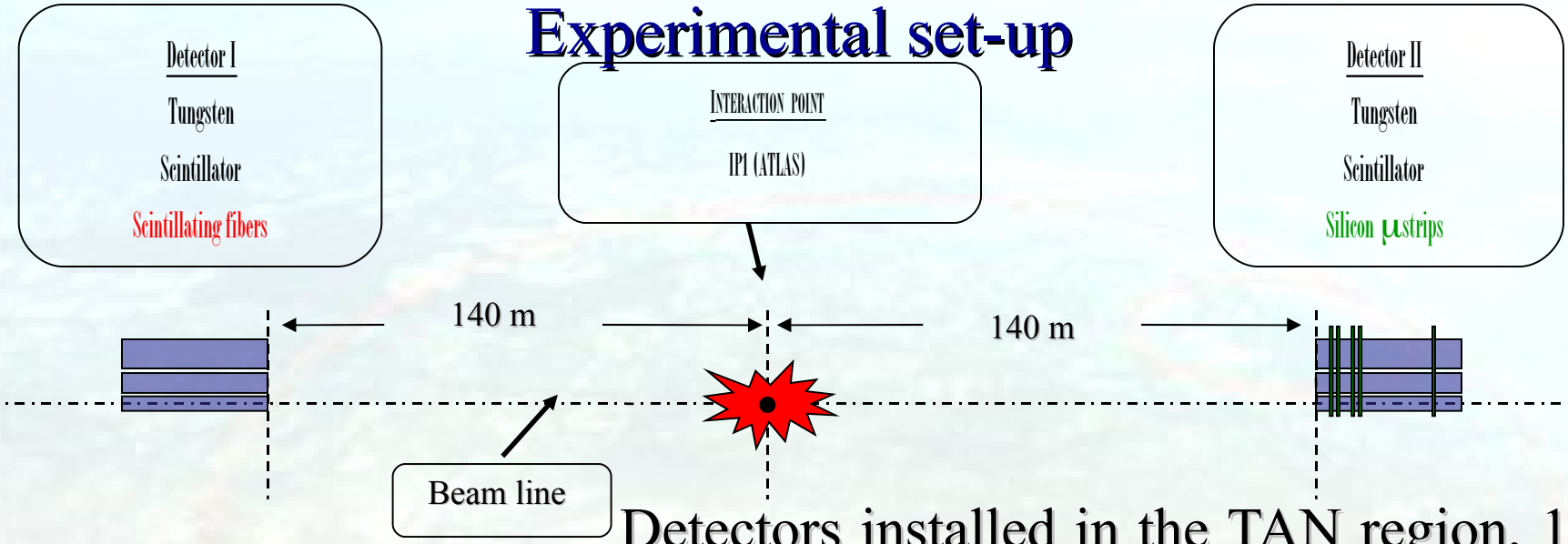
corresponds to $E_{lab} = 10^{17}$ eV

- LHCf is the smallest of the six LHC experiments and is a fully dedicated collider experiment for HECR Physics

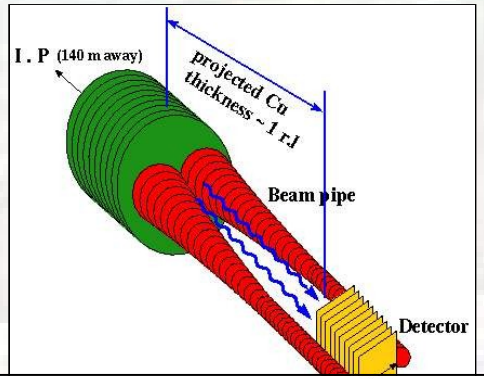
- LHCf will use the highest energy particle accelerator to provide useful data to calibrate the hadronic interaction models used in Monte Carlo simulations of atmospheric showers

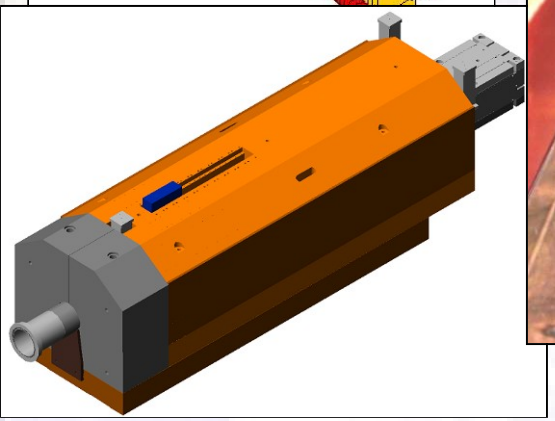
- Two independent electromagnetic calorimeters equipped with position sensitive layers, on both sides of IP1 will measure energy and position of γ from π^0 decays and neutrons produced in pp interaction at LHC

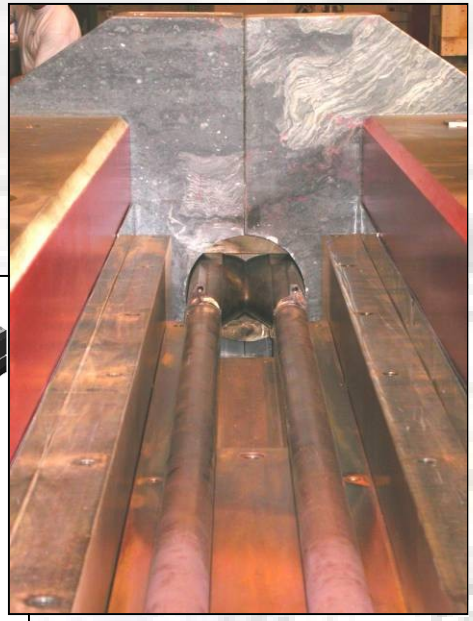
Experimental set-up



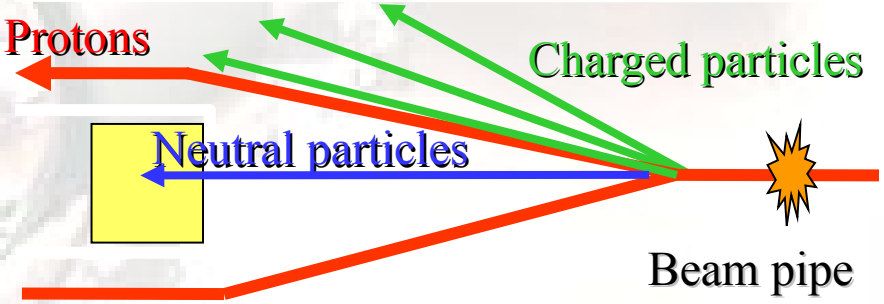
Detectors installed in the TAN region, 140 m away from the Interaction Point 1







- Here the beam pipe splits in 2 separate tubes.
- Charged particle are swept away by magnets
- We cover up to $y \rightarrow \infty$



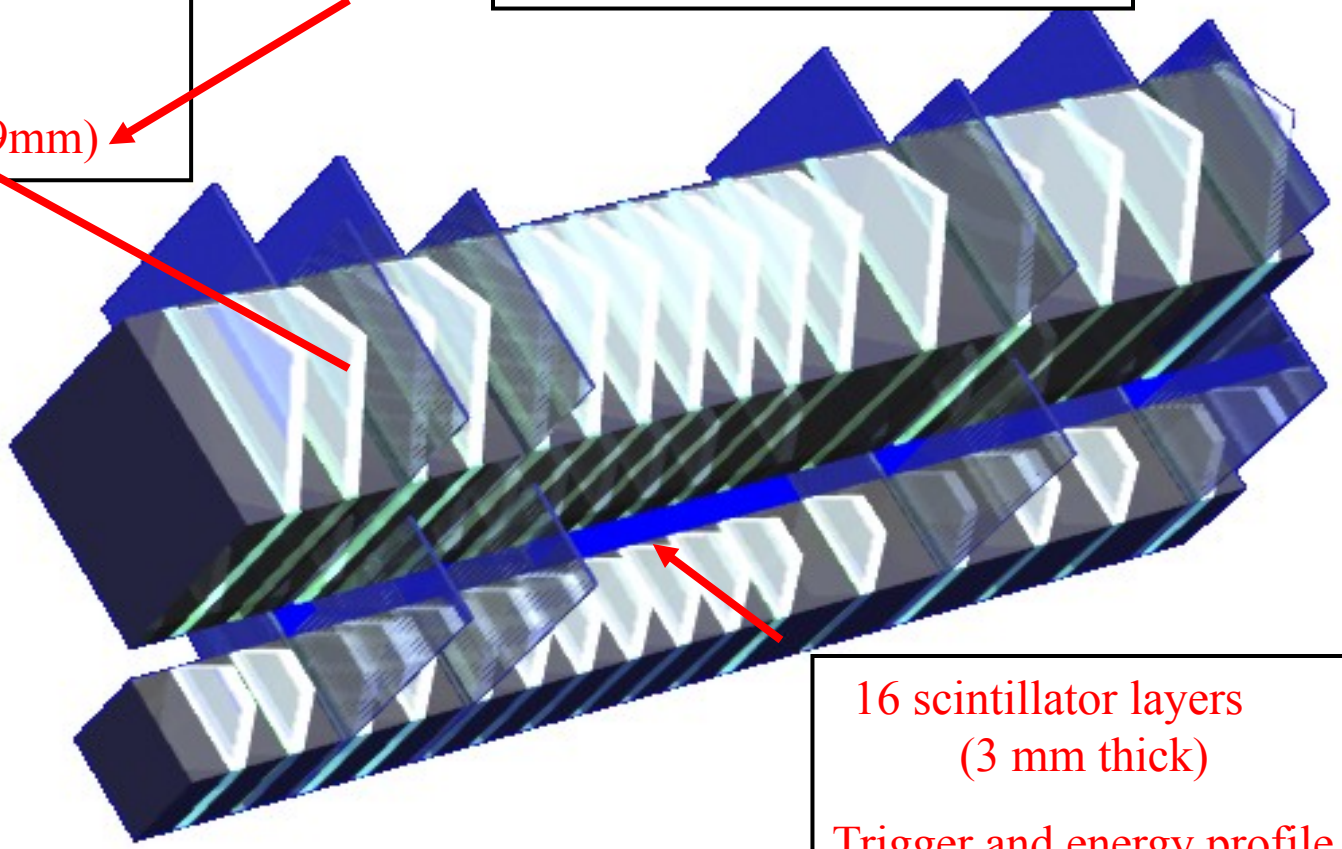
Arm1

Absorber

22 tungsten layers
7mm – 14 mm thick

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

4 pairs of scintillating fiber layers for tracking purpose (6, 10, 32, 38 X_0.)



16 scintillator layers (3 mm thick)

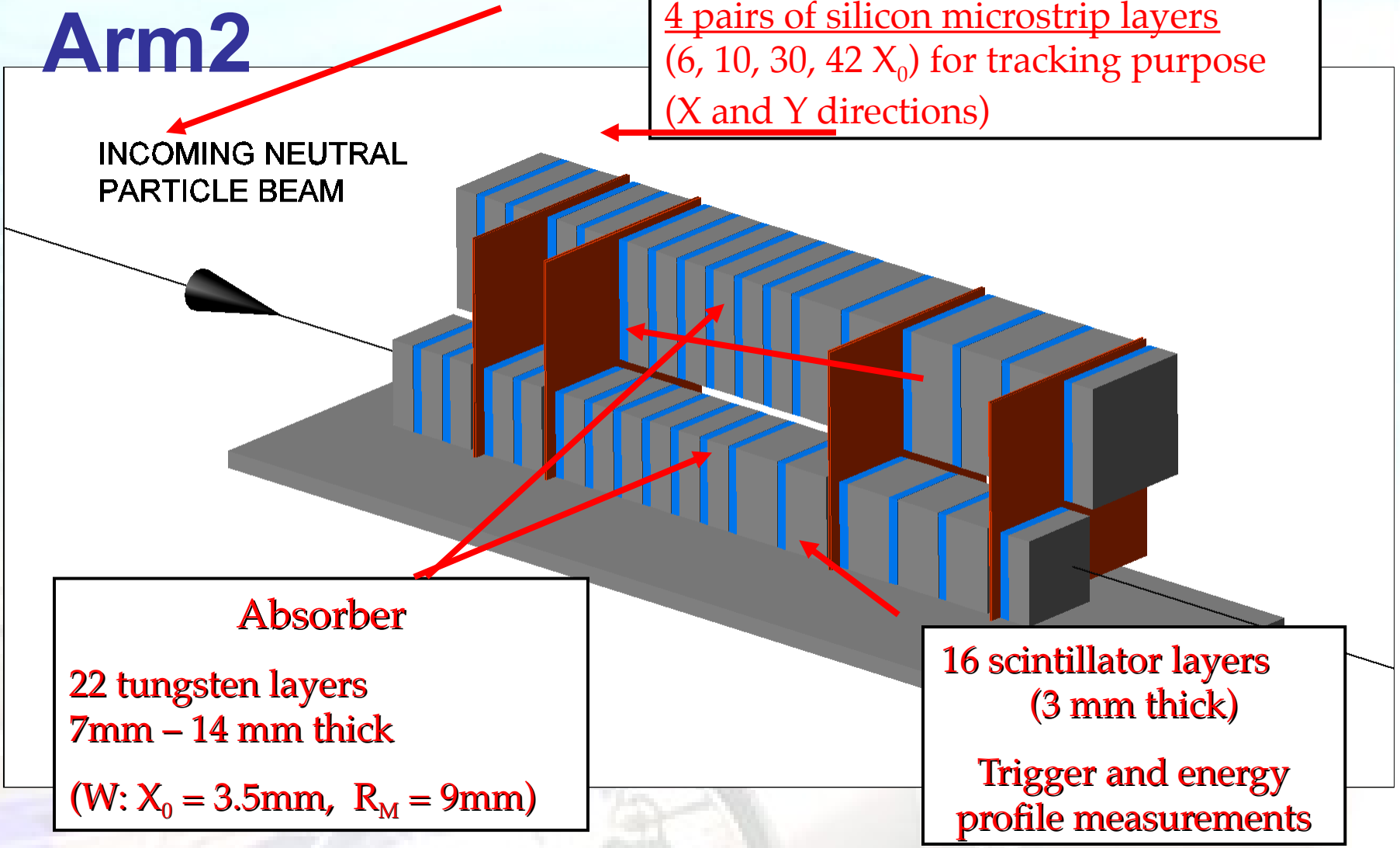
Trigger and energy profile measurements

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

Lower: 2 cm x 2 cm area

Upper: 4 cm x 4 cm area

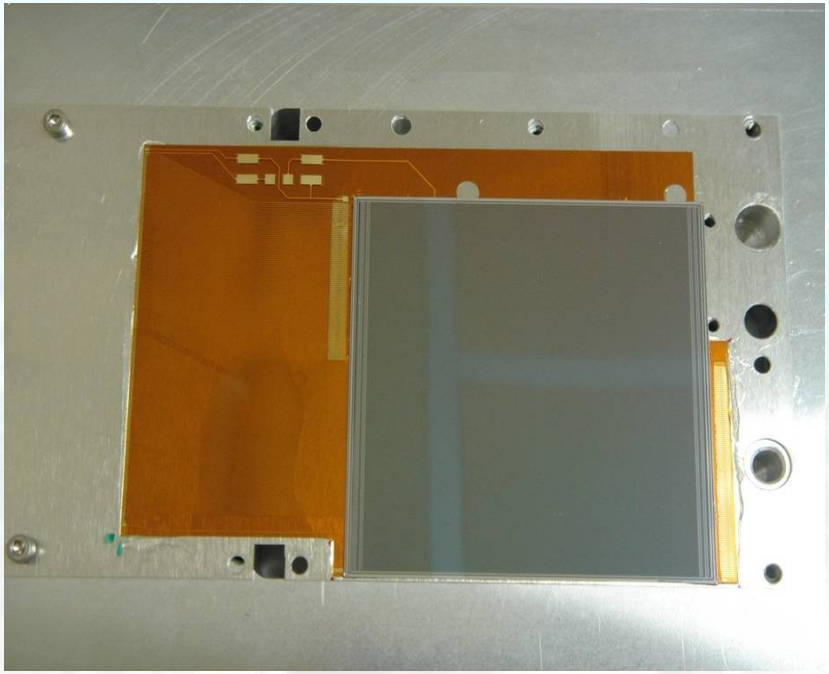
Arm2

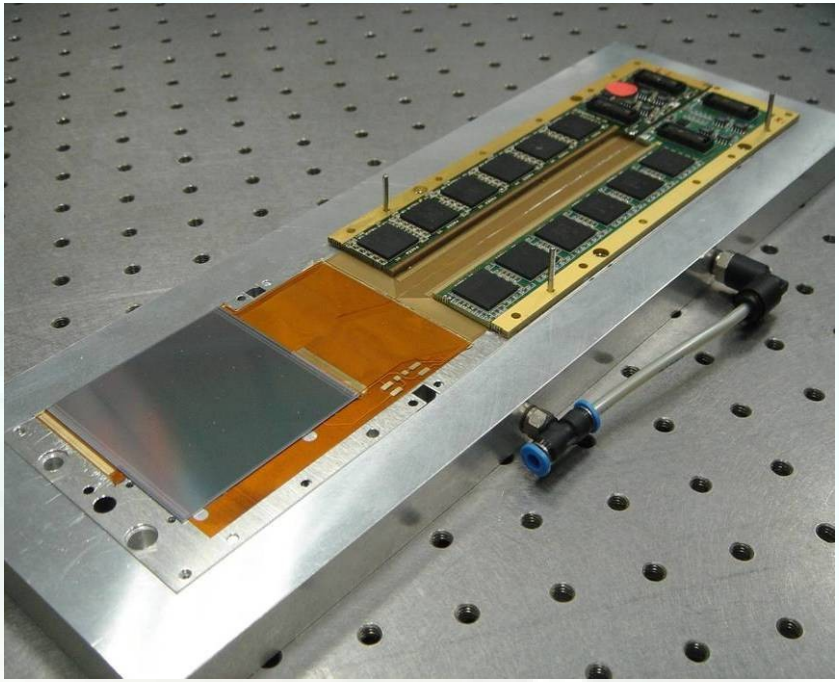


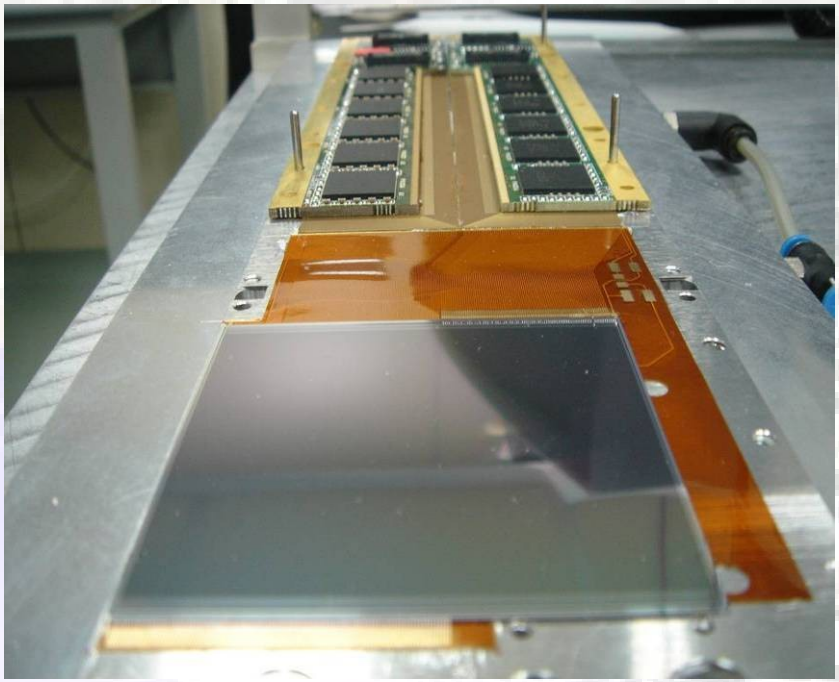
2 towers 24 cm long stacked on their edges and offset from one another

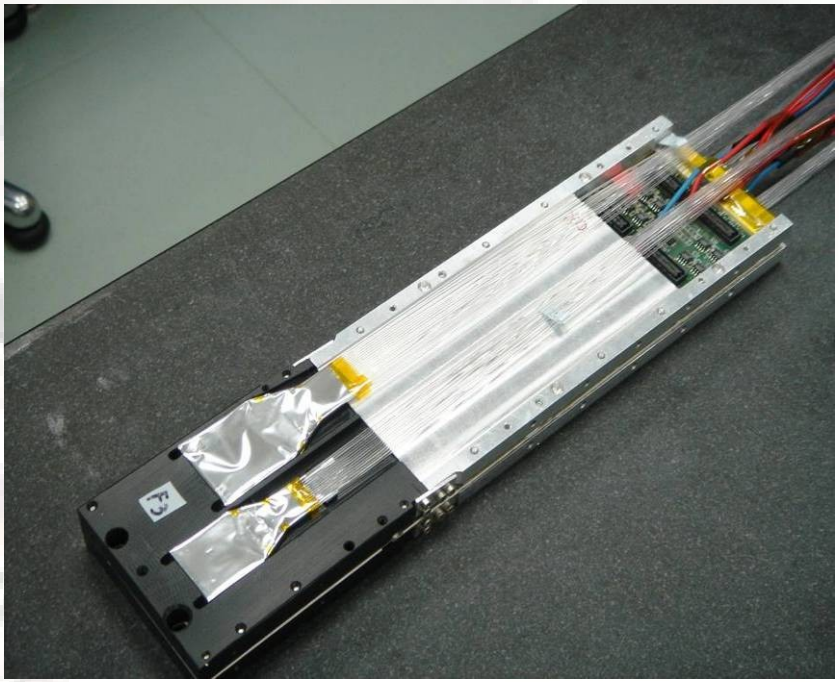
Lower: 2.5 cm x 2.5 cm

Upper: 3.2 cm x 3.2 cm









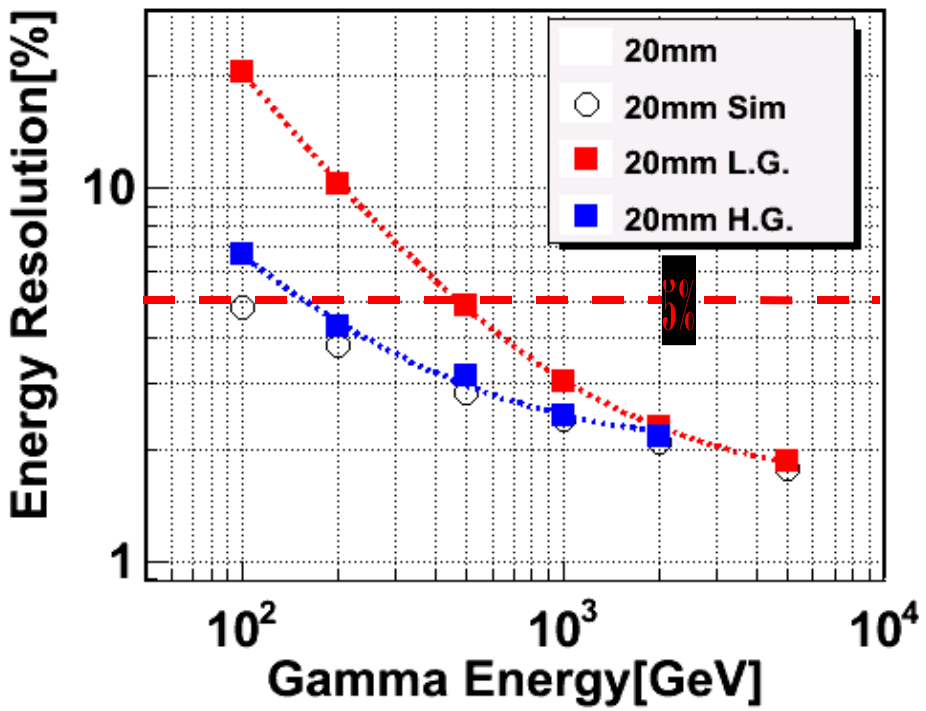
Double ARM Detectors

LHCf detectors in the LHC tunnel

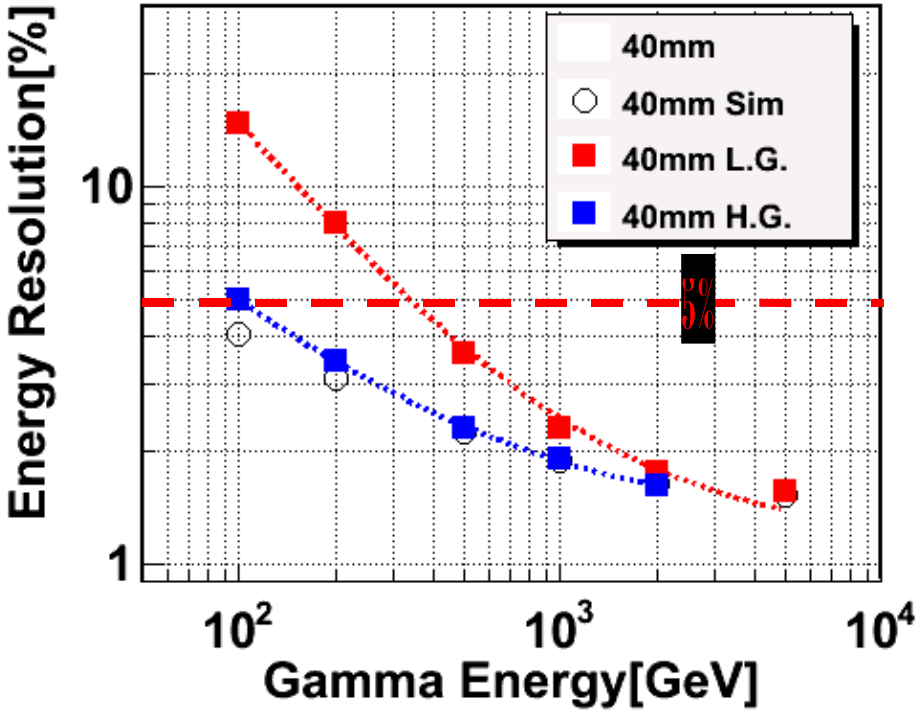
How can LHCf calibrate MCs?
Physics Perfomance

Energy resolution for γ

For 20mm

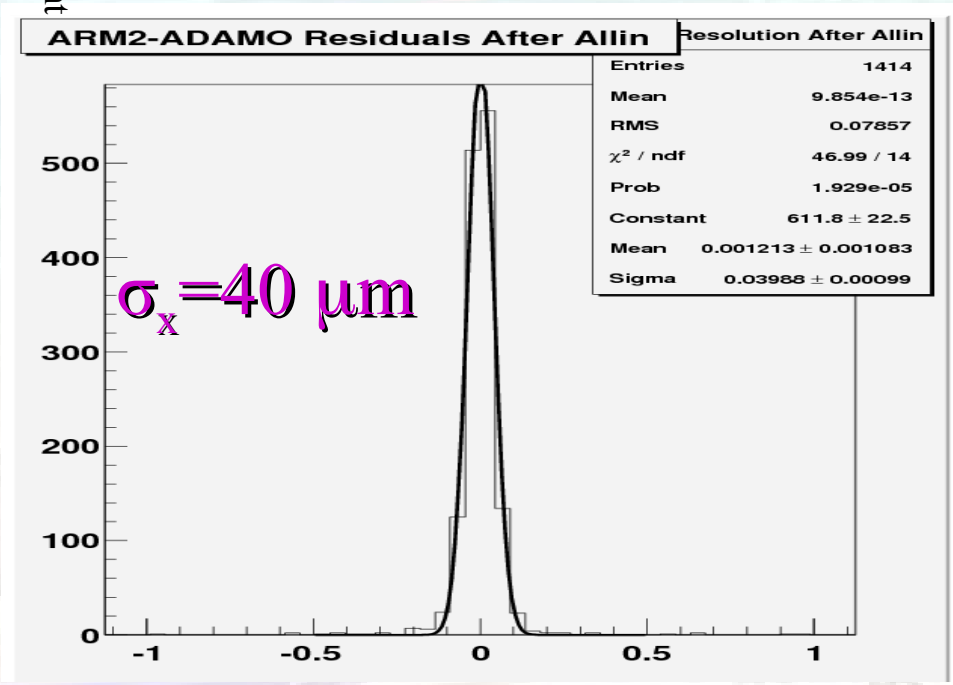


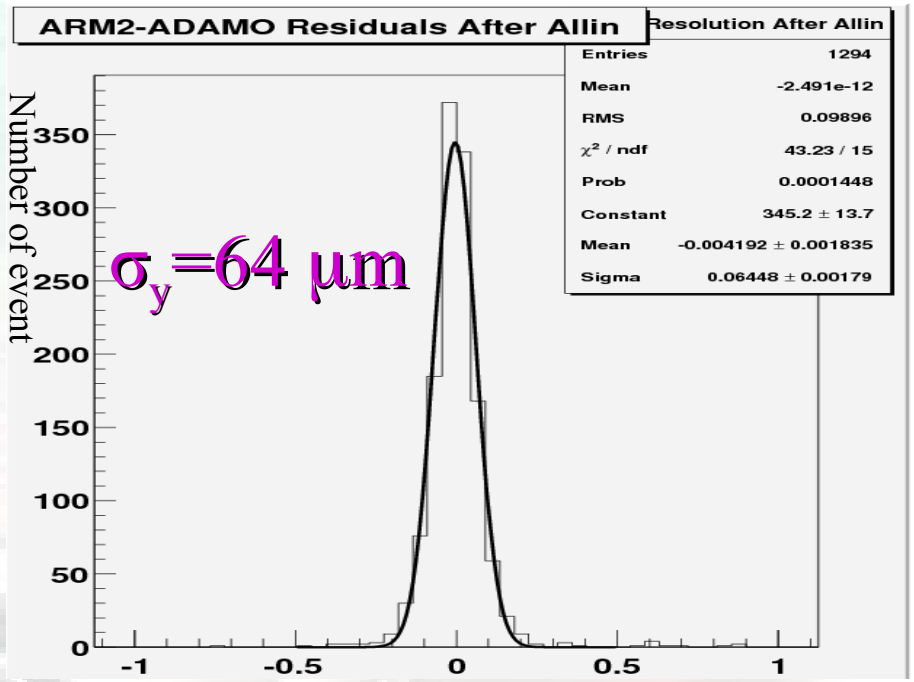
For 40mm



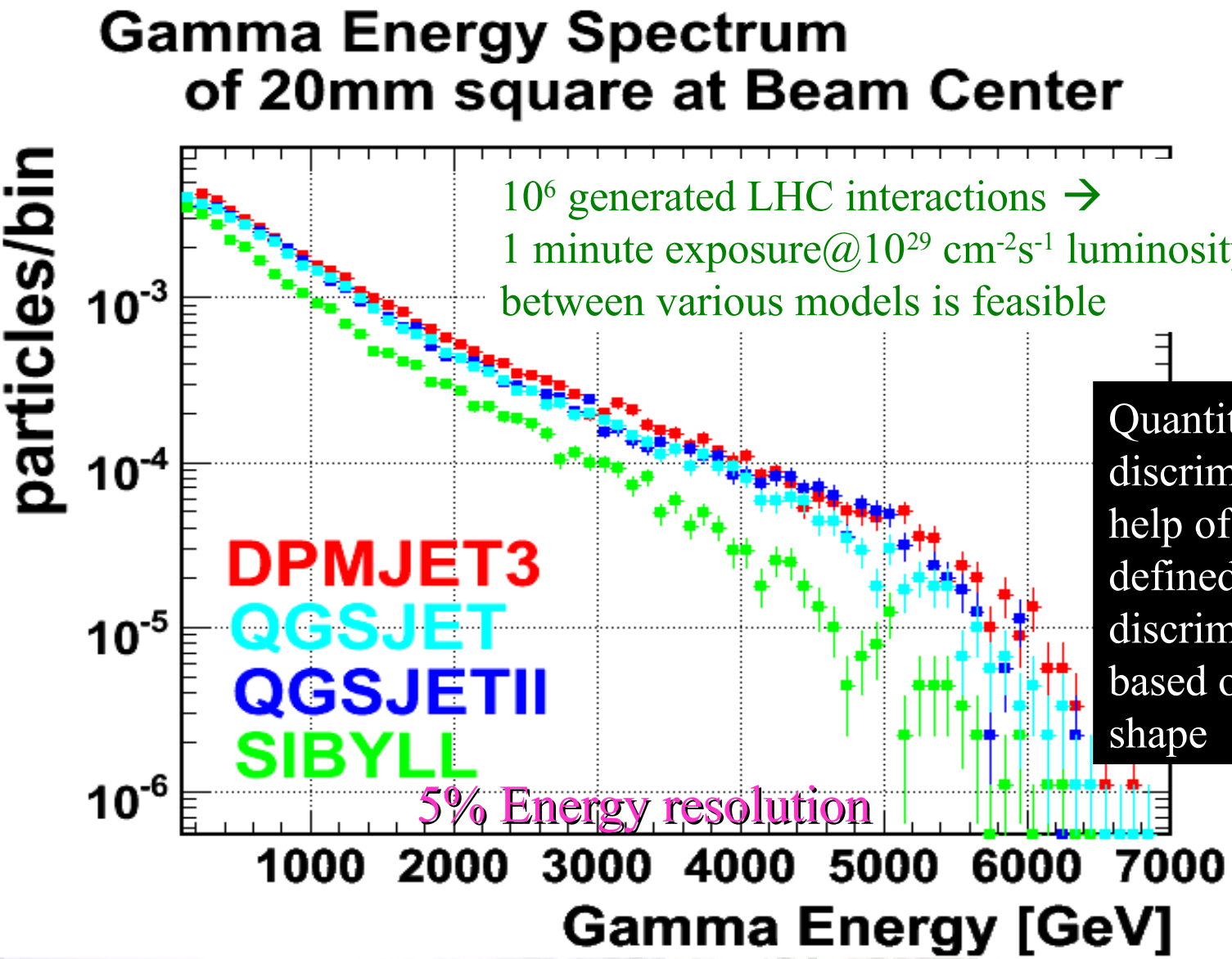
ARM2 Position Resolution

200 GeV electrons





LHCf : Monte Carlo discrimination

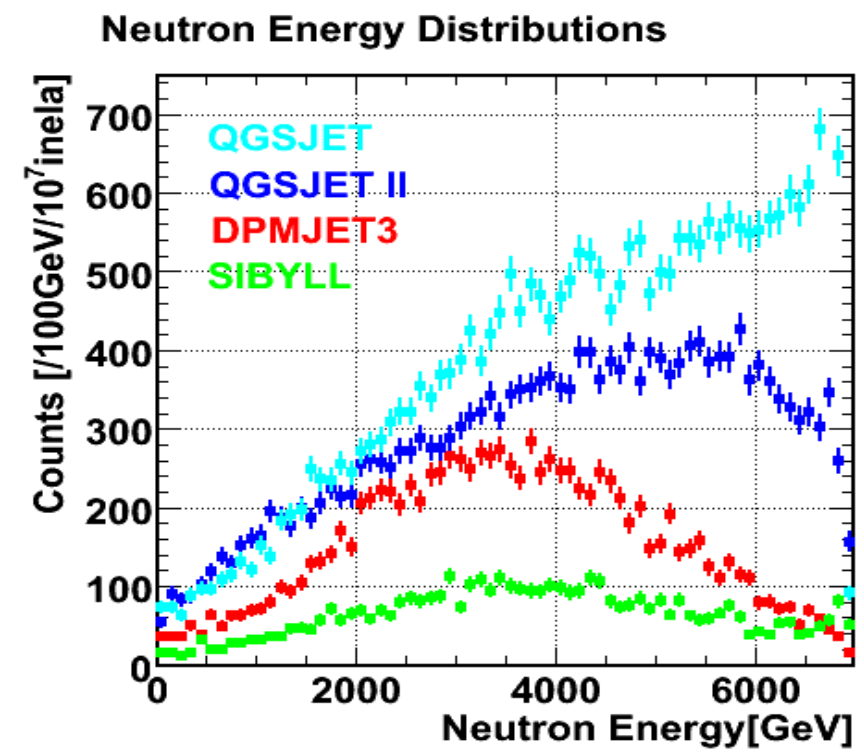


10^6 generated LHC interactions →
1 minute exposure@10^{29} $cm^{-2}s^{-1}$ luminosity Discrimination between various models is feasible

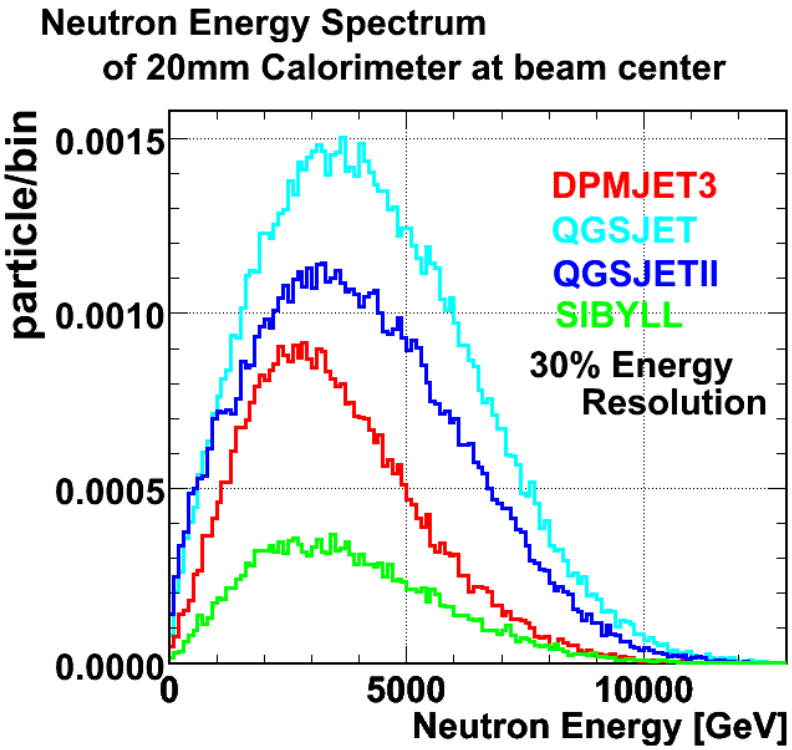
Quantitative discrimination with the help of a properly defined χ^2 discriminating variable based on the spectrum shape

LHCf: model dependence of neutron energy distribution

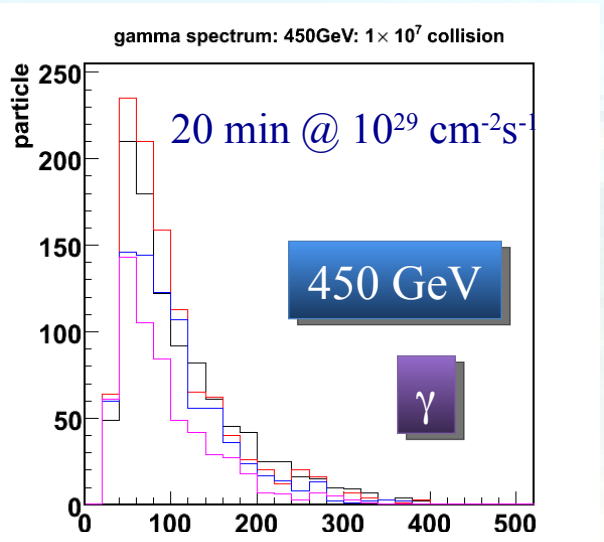
Original n energy

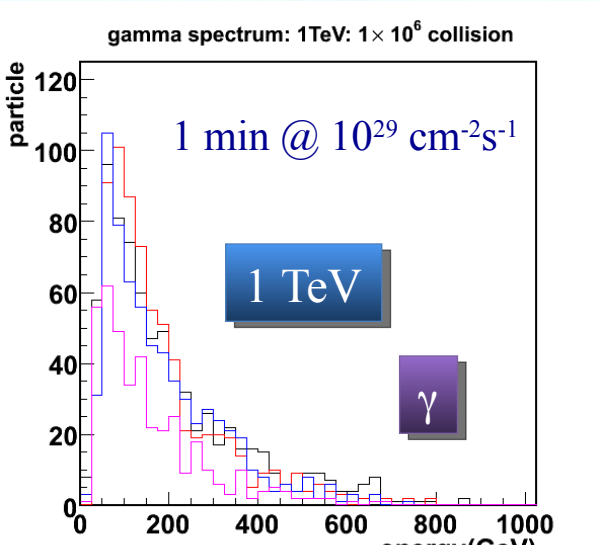


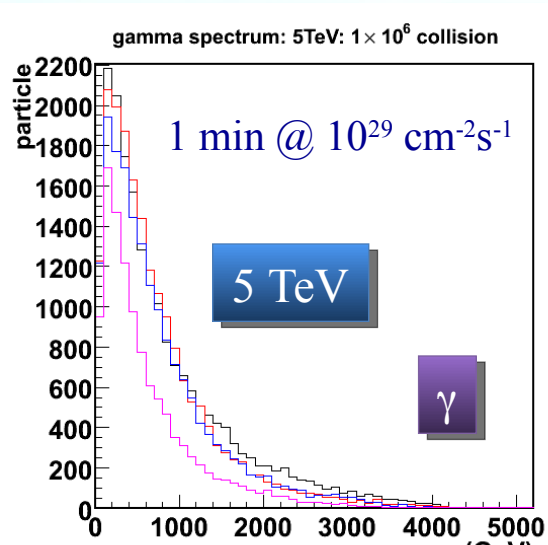
30% energy resolution

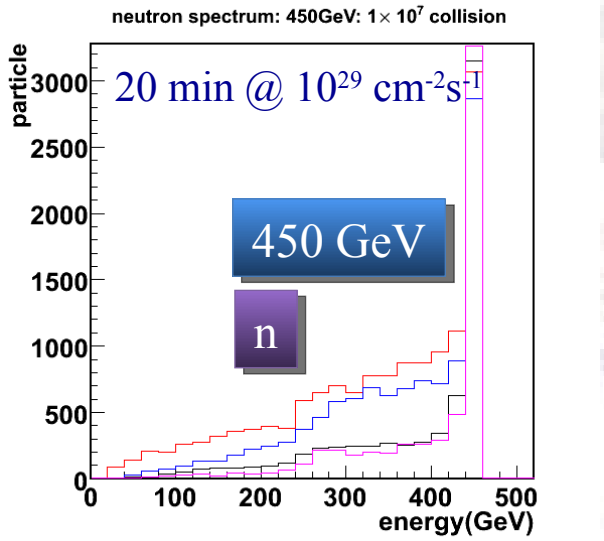


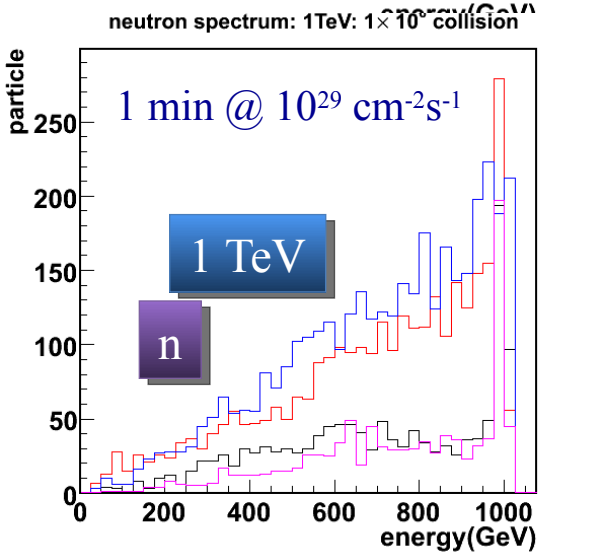
γ and n spectra at different energies

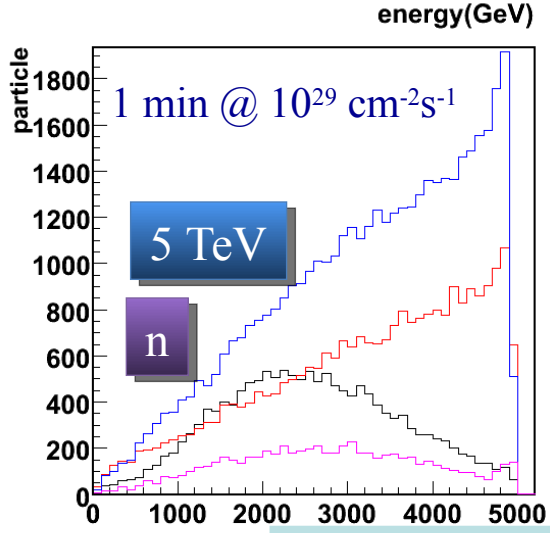












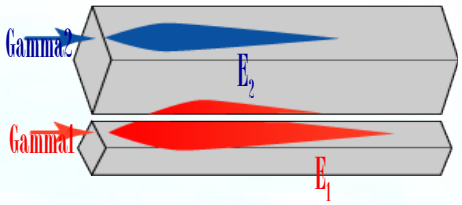
No detector resolution taken into account

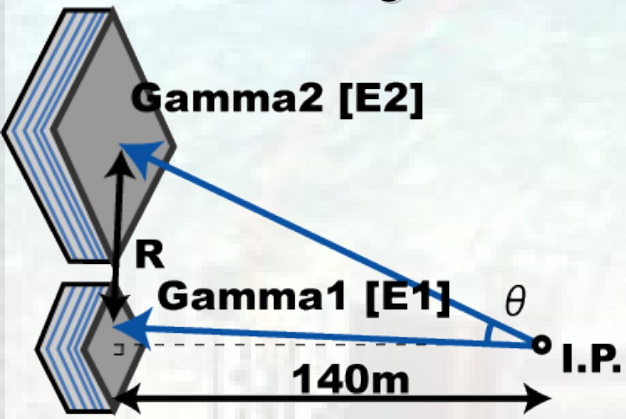
DPMJET3
QGSJET2
QGSJET1
SIBYLL

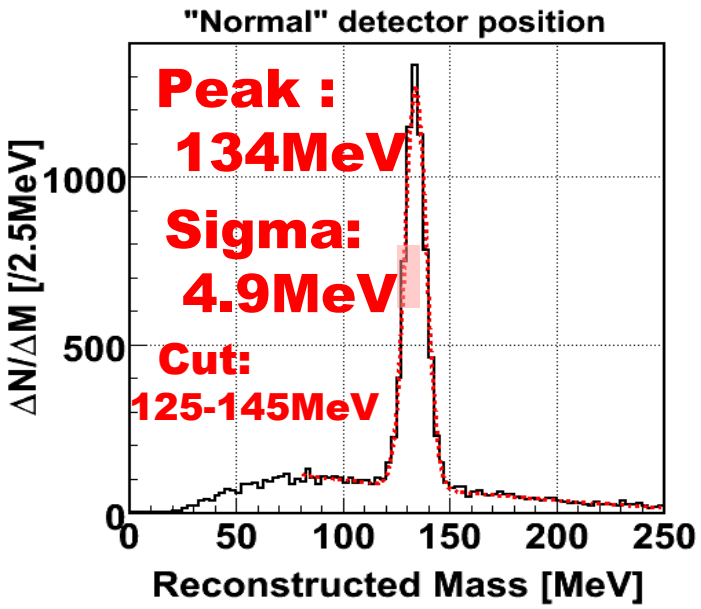
π^0 spectra

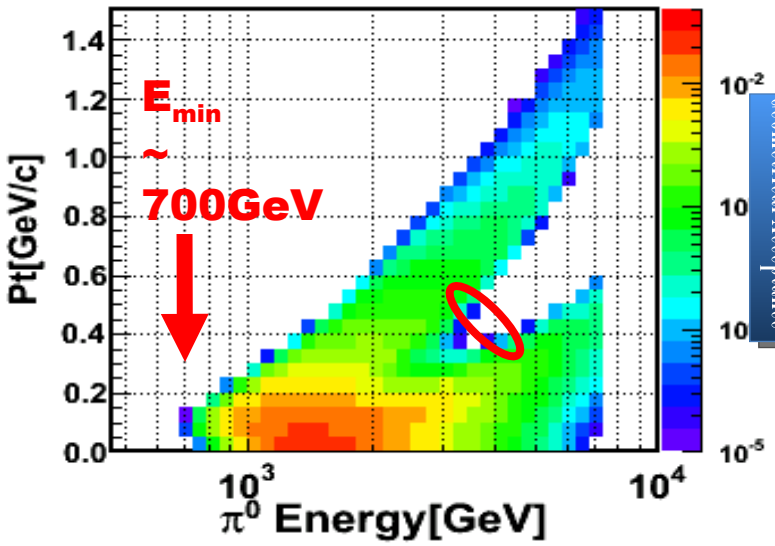
π^0 produced at collision can be extracted by using gamma pair events

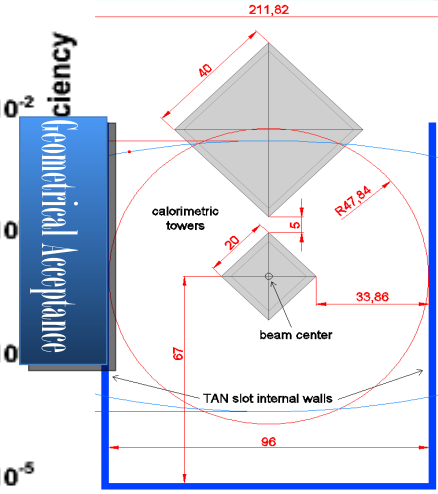
Powerful tool to calibrate the energy scale and also to eliminate beam-gas BG

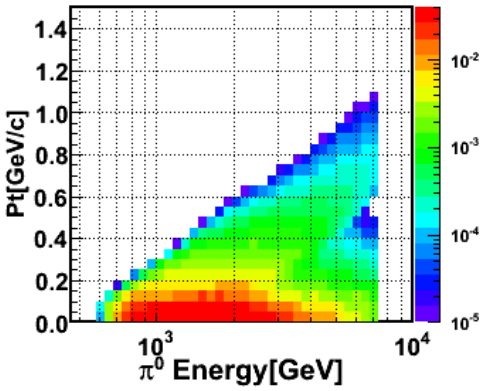


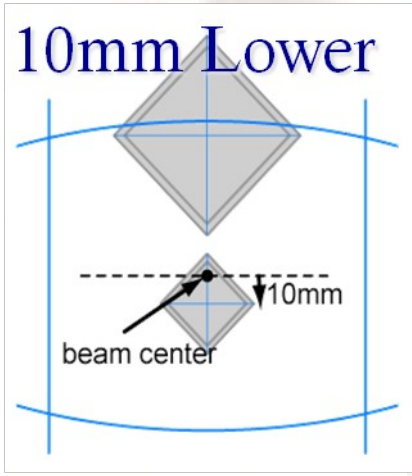




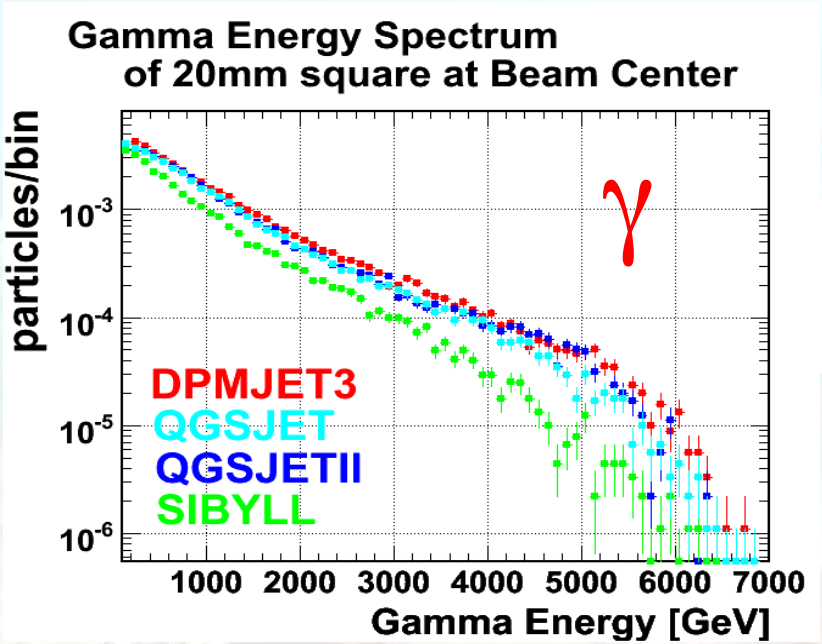






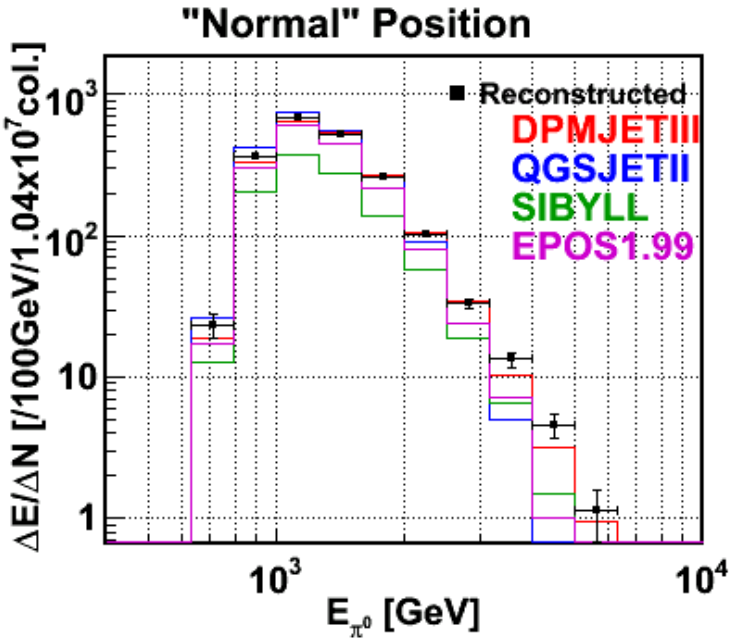


LHCf : Monte Carlo discrimination

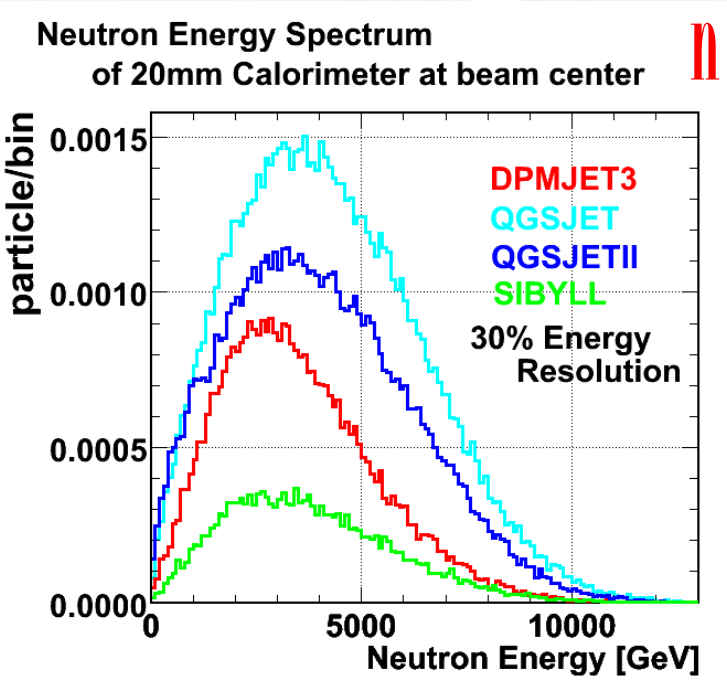


γ

10^6/10^7 generated LHC interactions
at 7□7 TeV →
1 minute exposure□10^{29} $cm^{-2}s^{-1}$ luminosity



π^0



n

When LHCf?

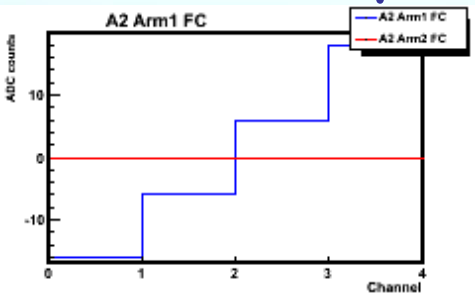
NOW!!!!!!!!!!!

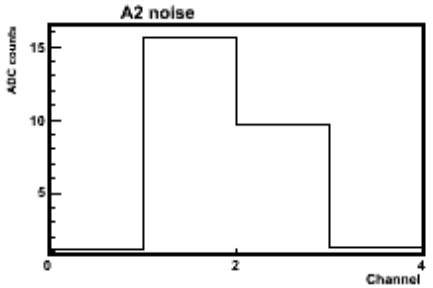
2009 LHC Operation

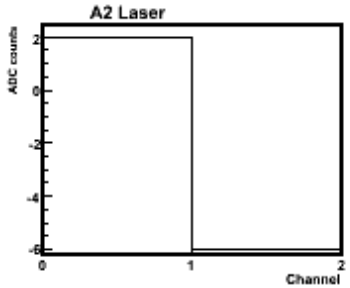
- From End of October 2009 LHC restarted operation
- 450 GeV + 450 GeV → 1.2 TeV + 1.2 TeV
- Exceptional effort and success from LHC!!!
- Few weeks of 'smooth' running allowed LHCf to collect some statistics at 450+450 GeV in stable beam conditions (Moving from garage to running position) ☺ ☺ ☺ ☺
- No stable beam at 1.2+1.2 TeV → No data at this energy for this year ☹

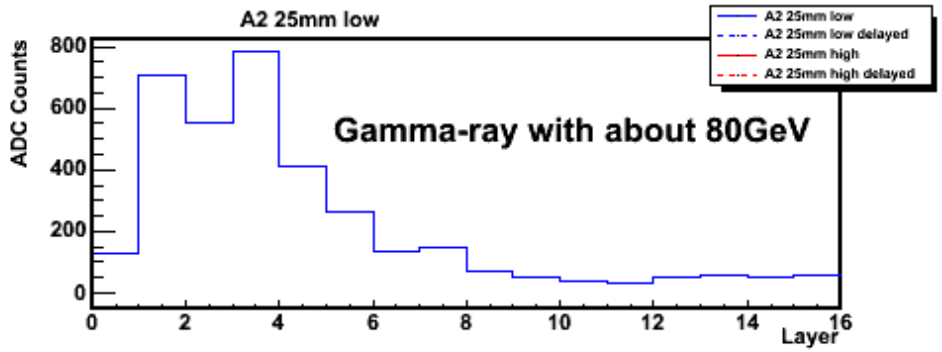
Arm2 γ event

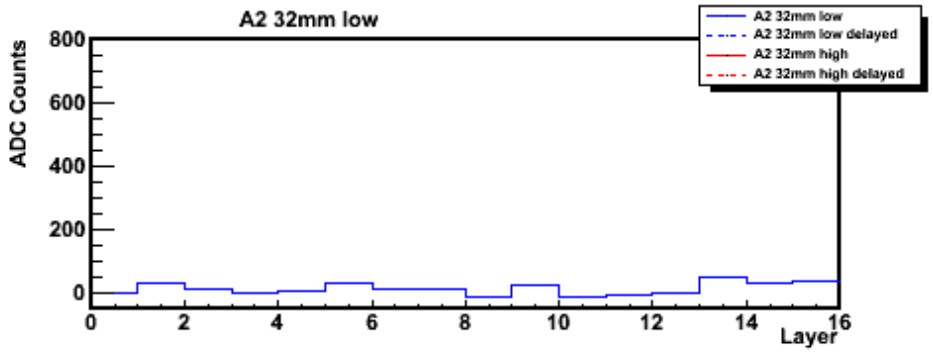
RUN:	2342
NUMBER:	506
GNUMBER:	1154
TIME:	1260085179
FLAG0:	00009557
FLAG1:	000009ff
FLAG2:	00a02371

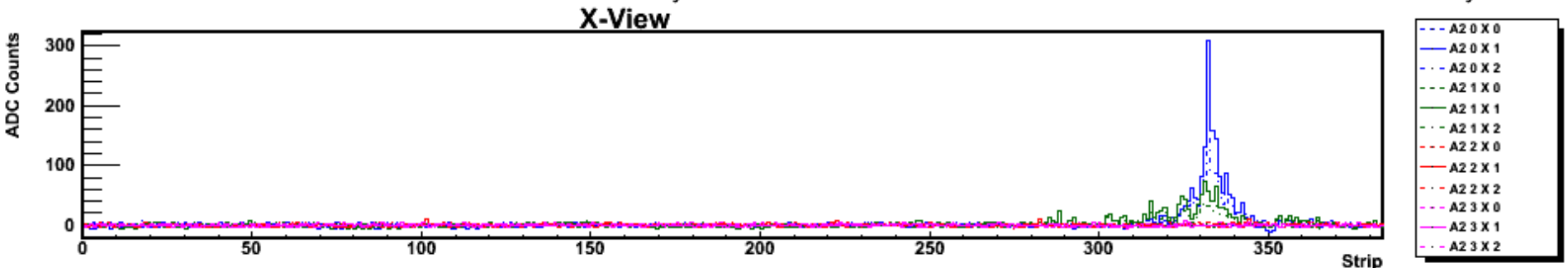


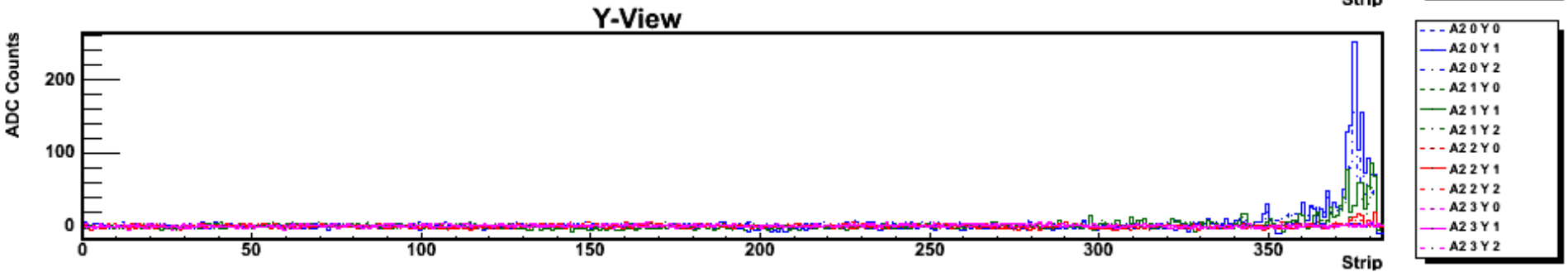




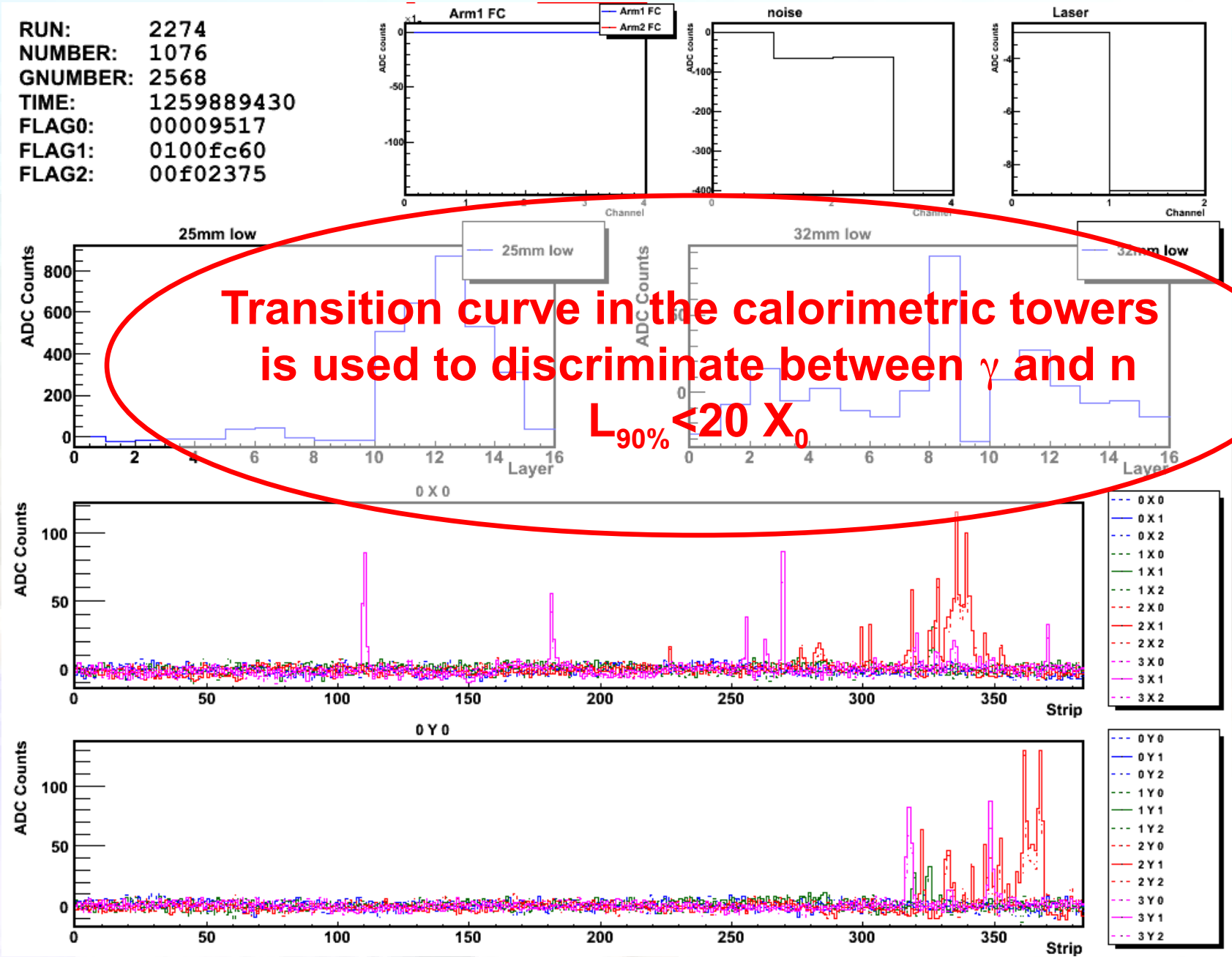




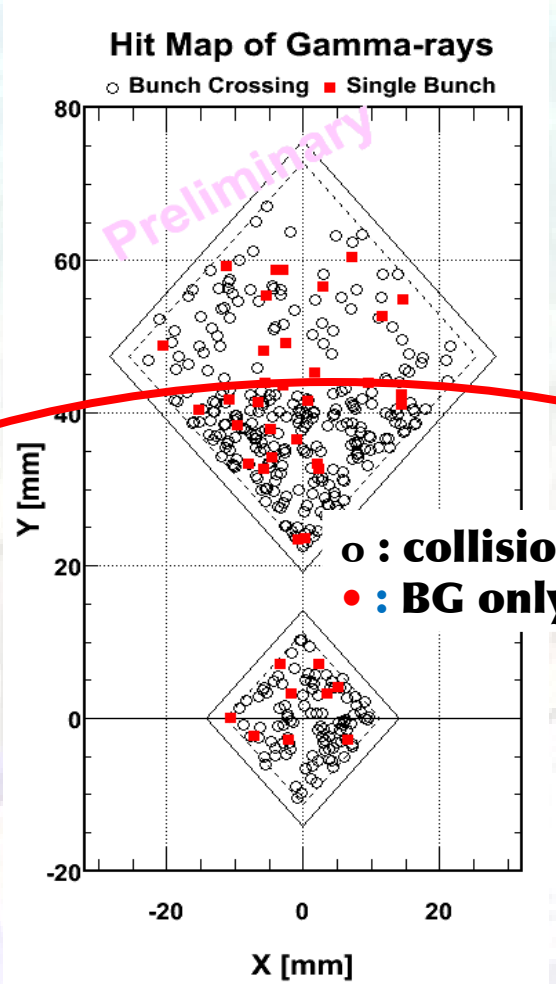




Arm2 neutron event

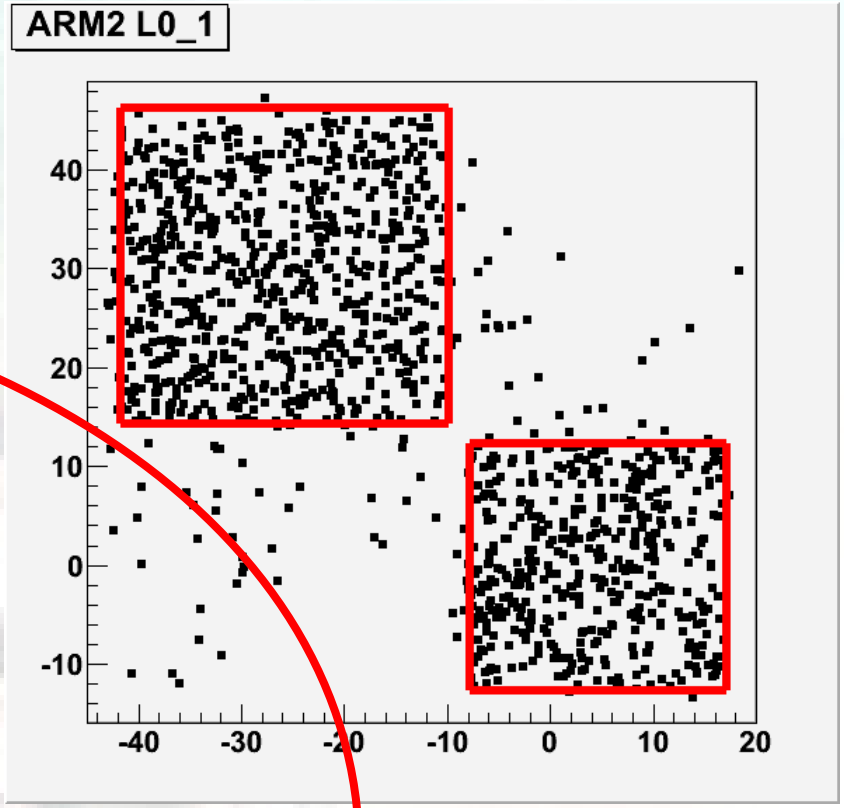


Hit map on ARM1 and ARM2



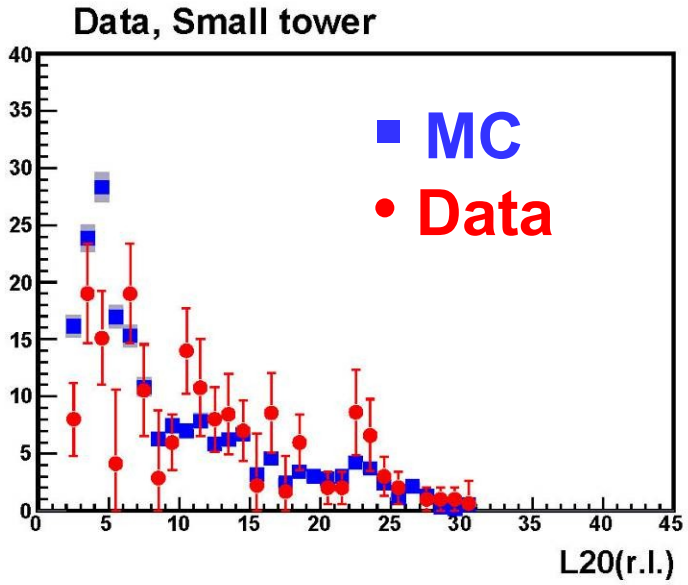
o : collision + BG

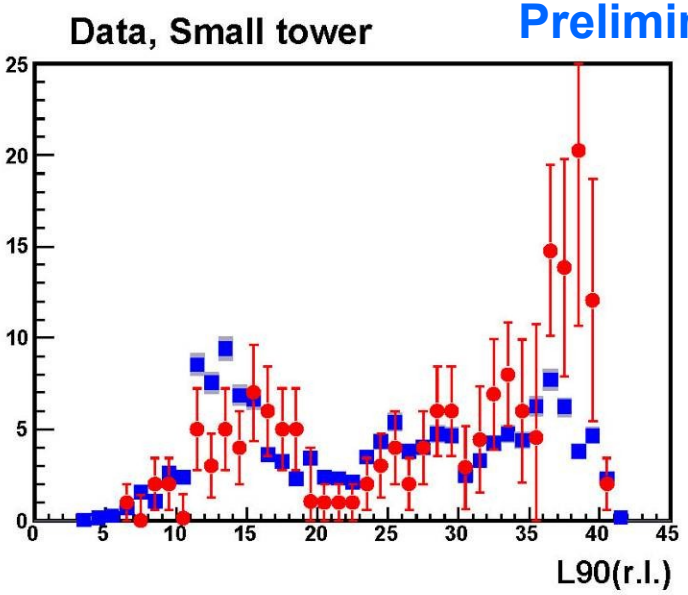
• : BG only

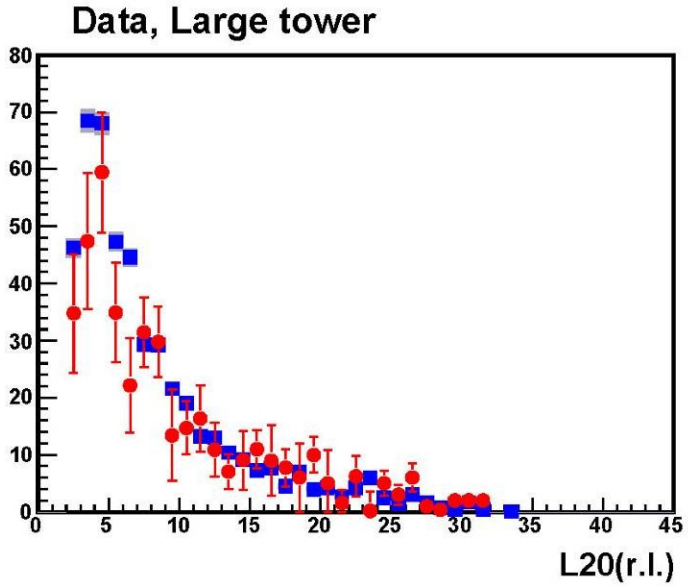


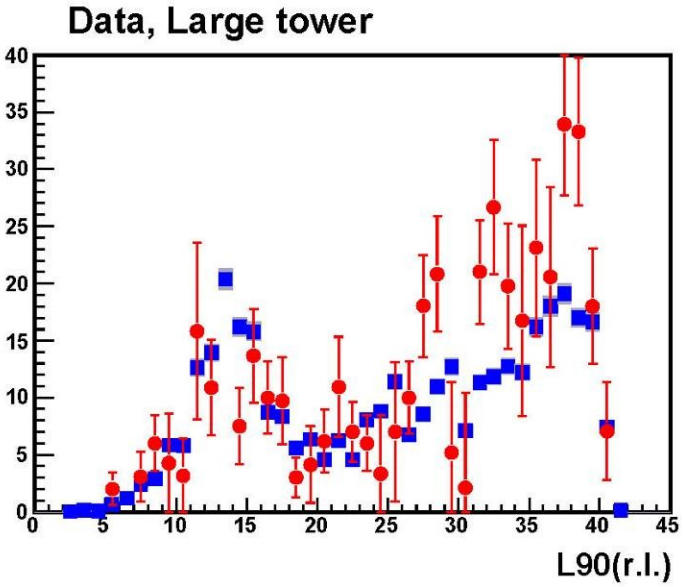
Arm1 Results: L20 and L90

Preliminary



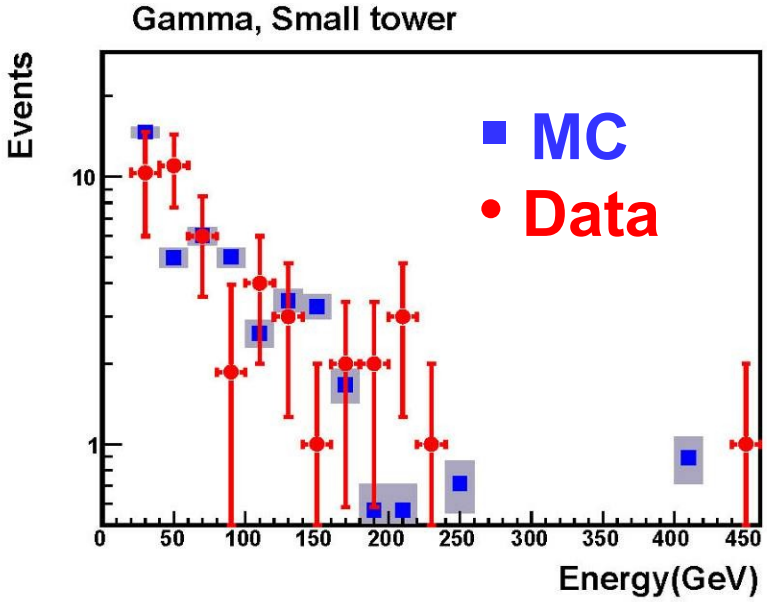


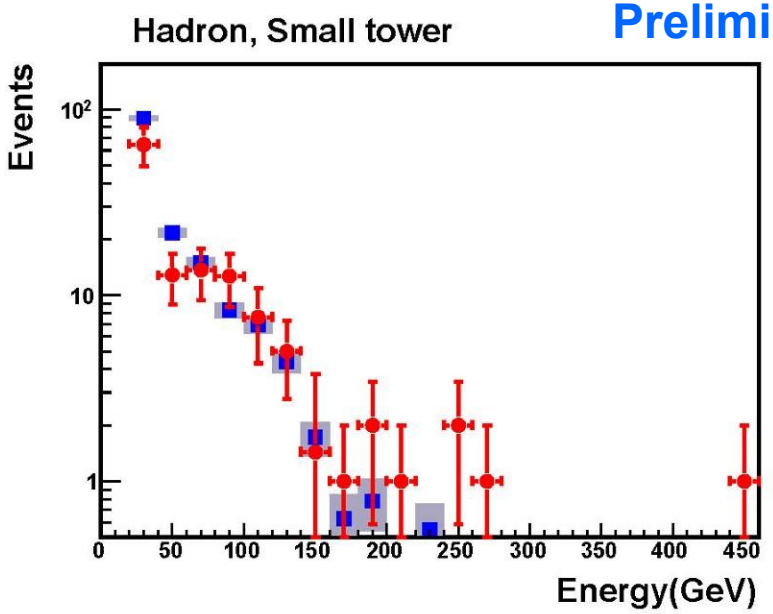


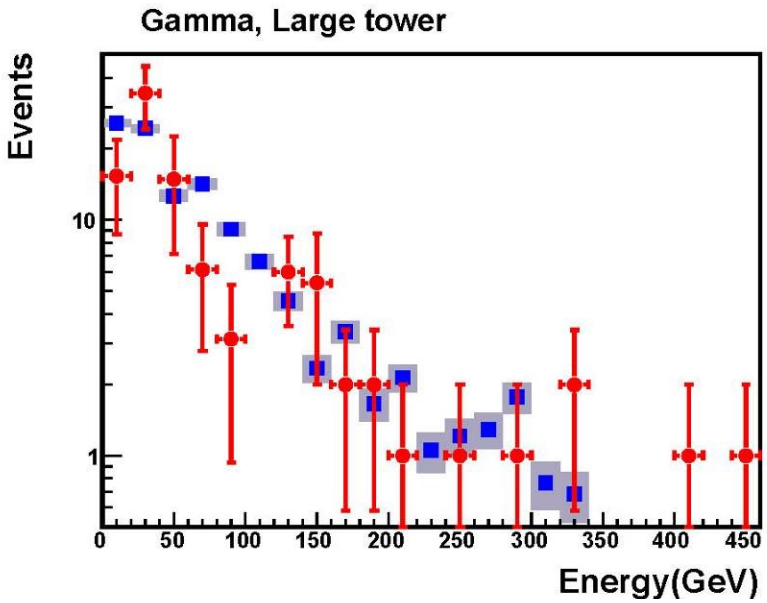


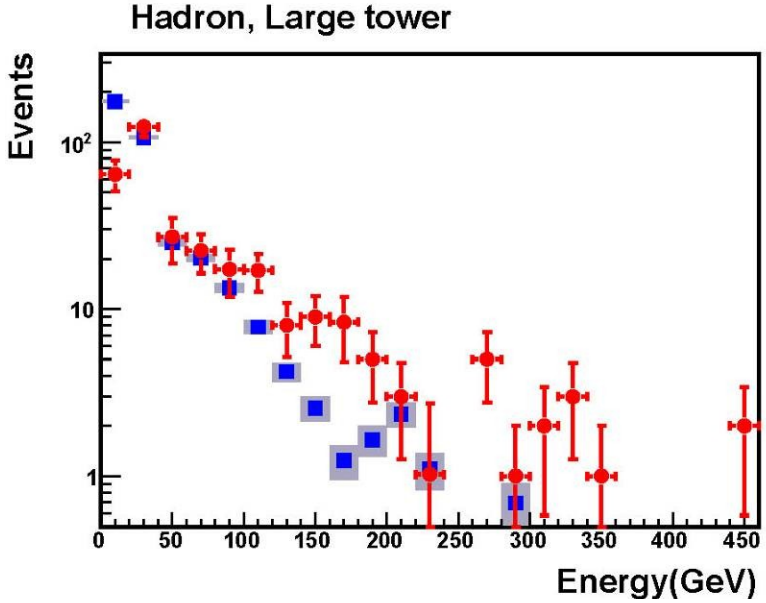
Arm1 Results: γ and n spectra on the 2 towers

Preliminary



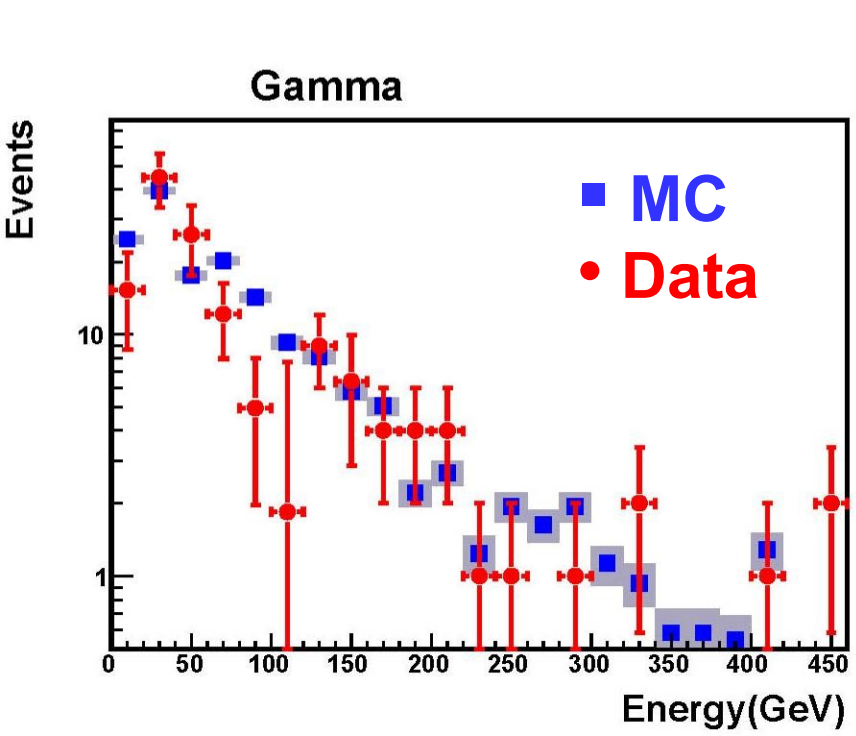




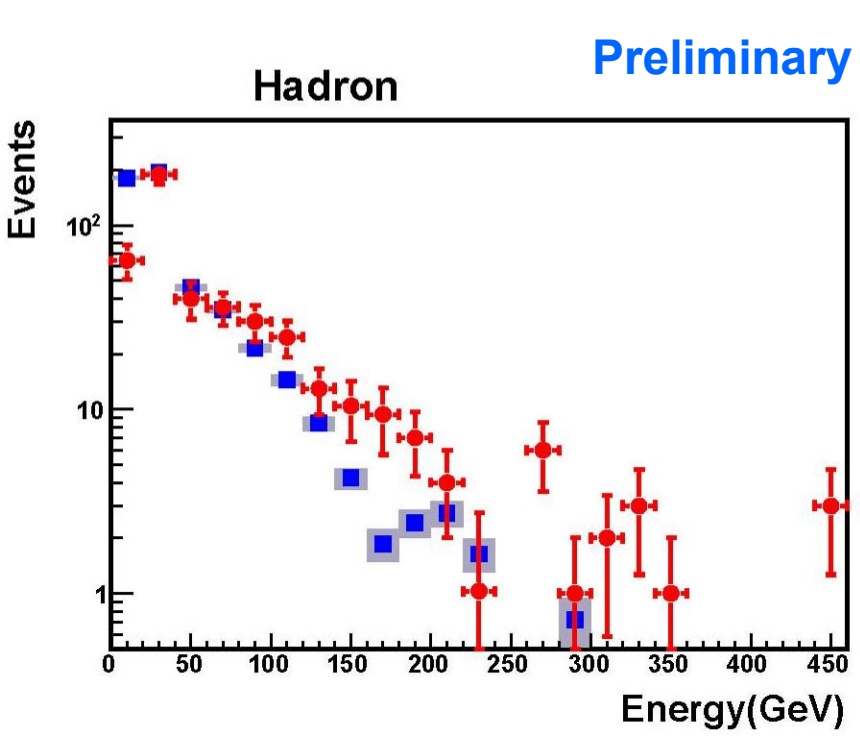


After the subtraction of the Not Colliding Bunches properly normalized

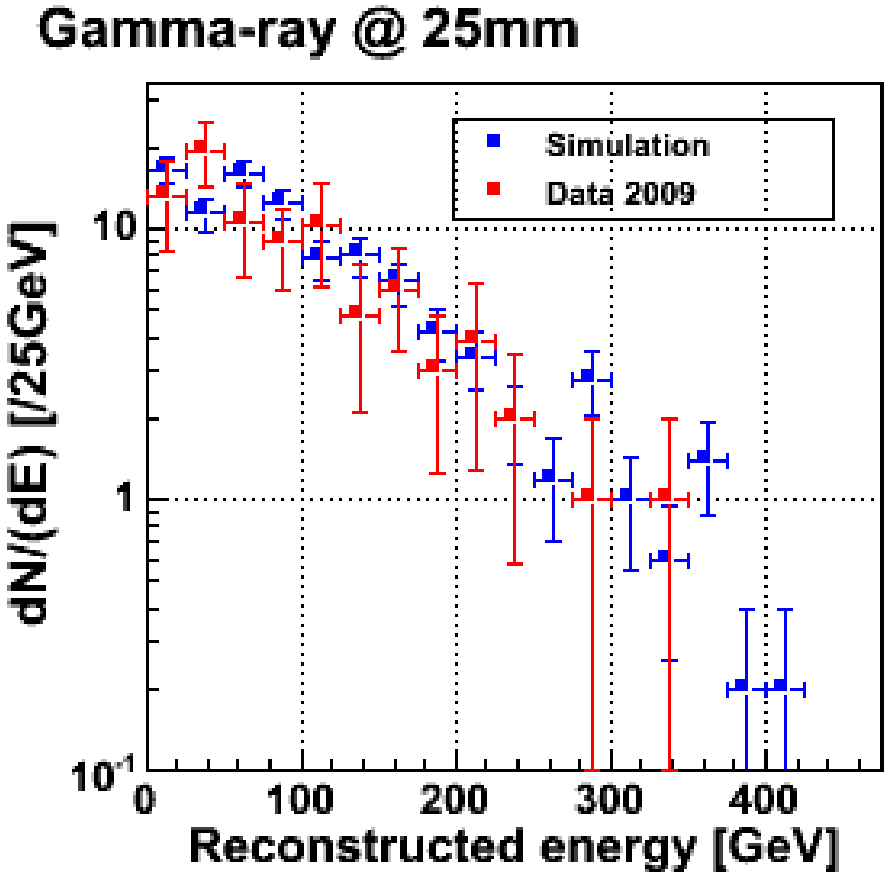
Arm1 Results: combined γ and n spectra

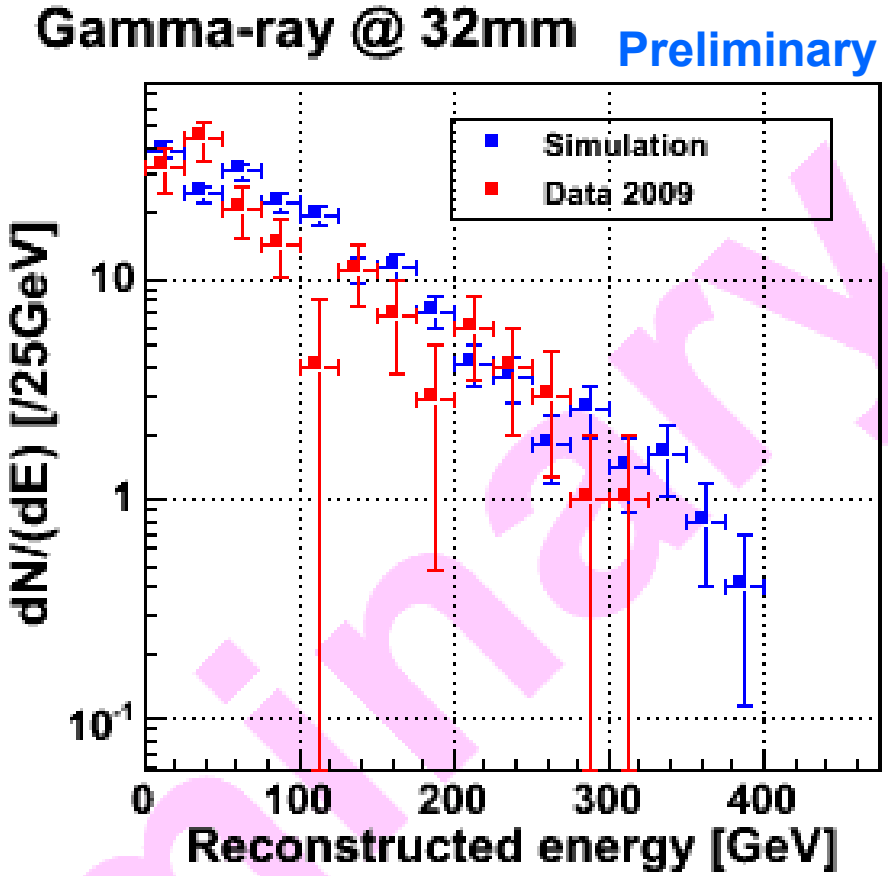


Preliminary

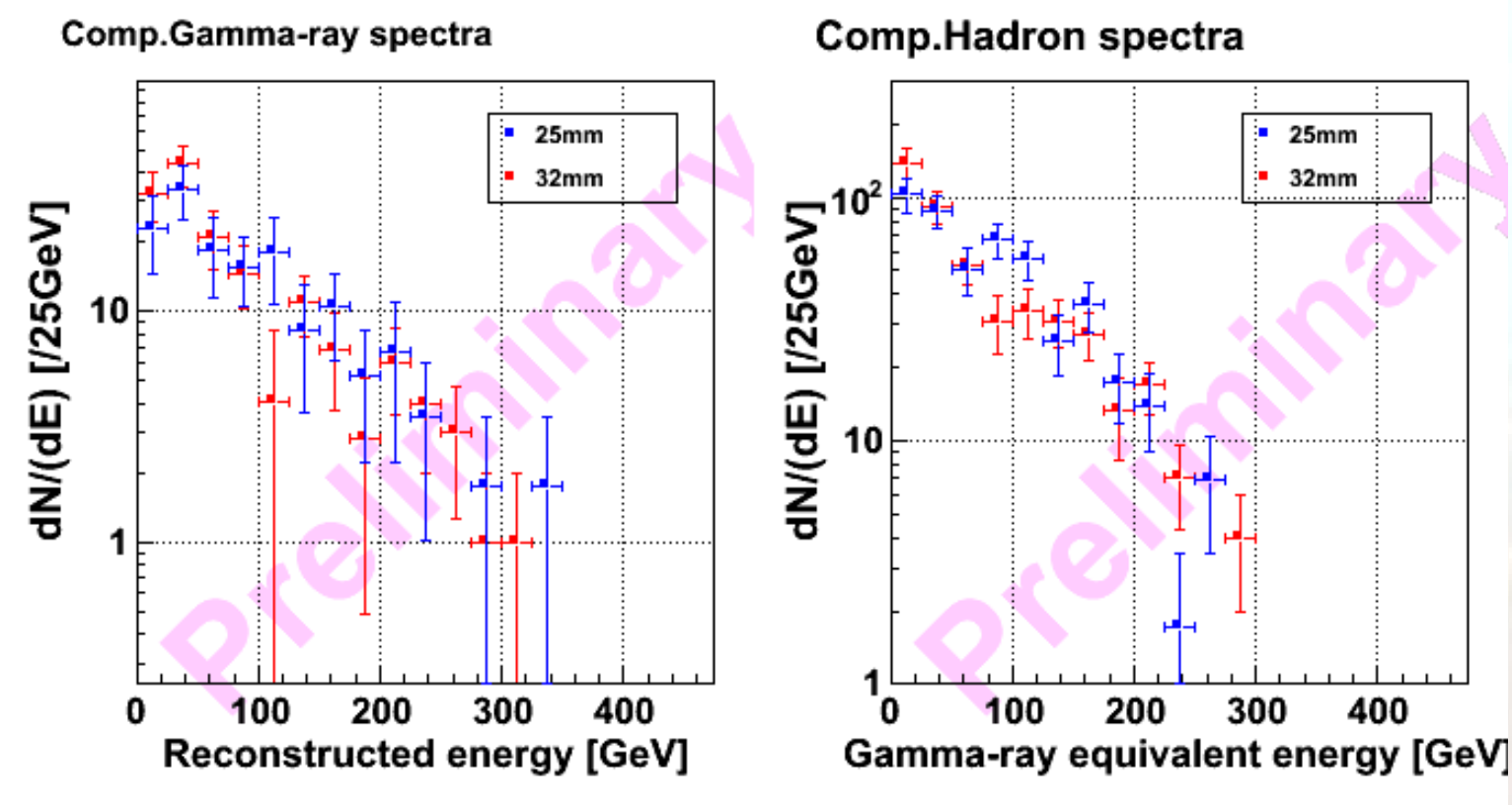


Arm2 Results: γ spectra on the 2 towers





Arm2 Results: Comparison of 25mm and 32mm



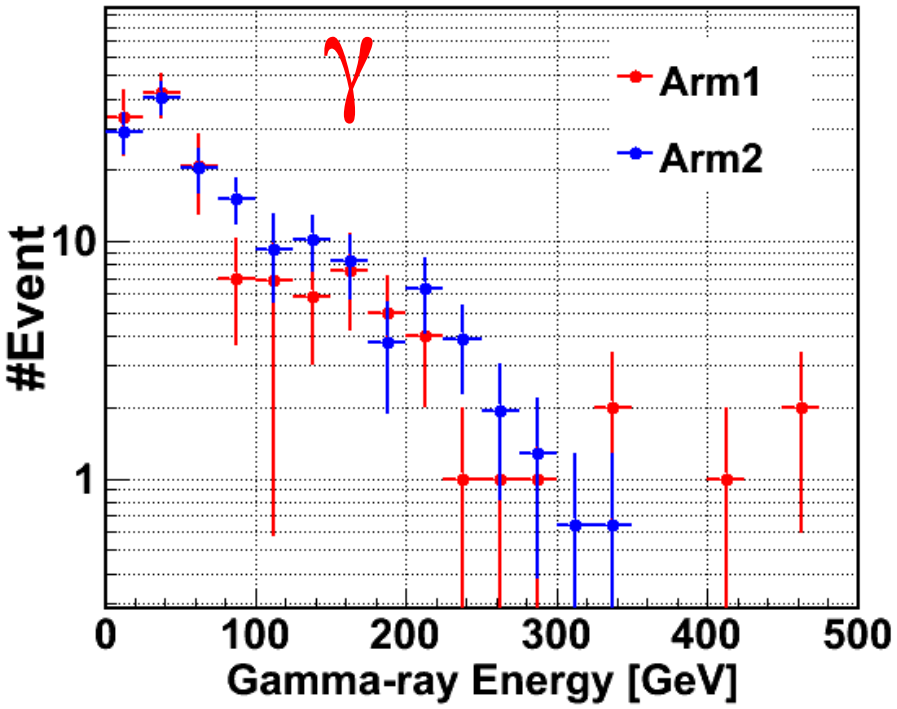
Chi2 : 13.3 (DOF=10)

Chi2 : 7.7 (DOF=10)

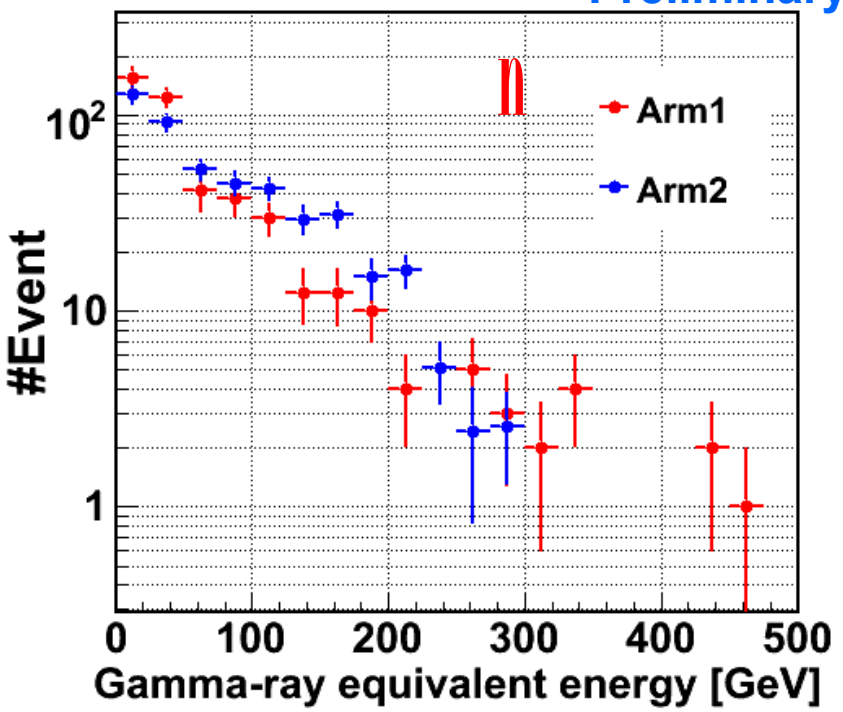
The spectra of 32 mm are normalized by the relative acceptance (factor 1.77)
No significant difference between 25mm and 32mm spectra.
It is consistent with the expectation by simulation:

Flat distributions at 450 GeV

Arm1 & Arm2 comparison



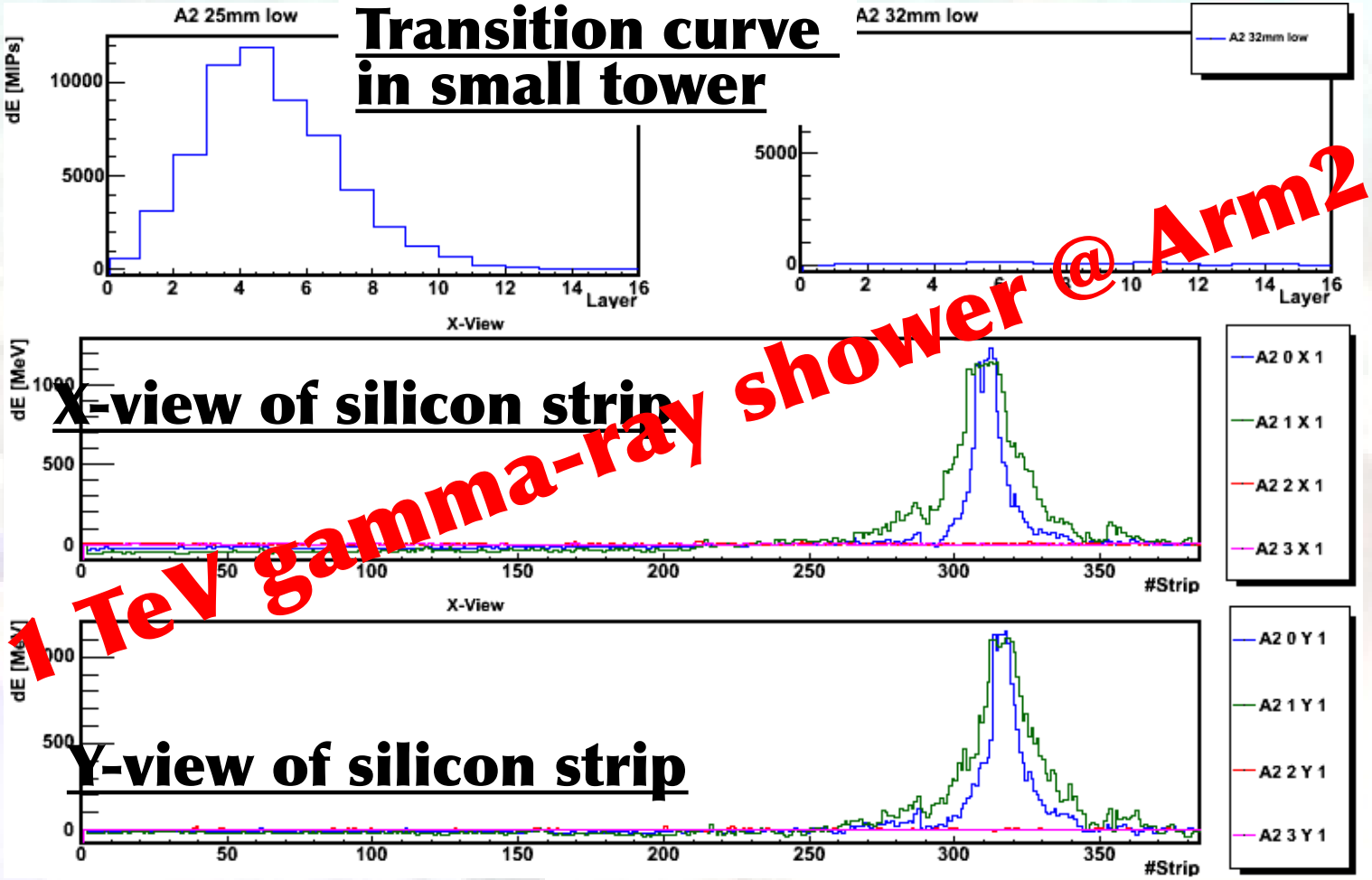
Preliminary



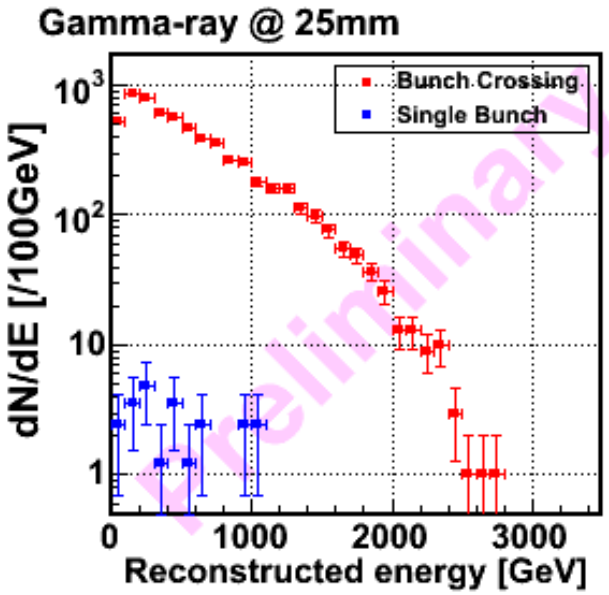
Arm1 and Arm2 γ spectra are normalized to the ratio of the fiducial volumes surfaces

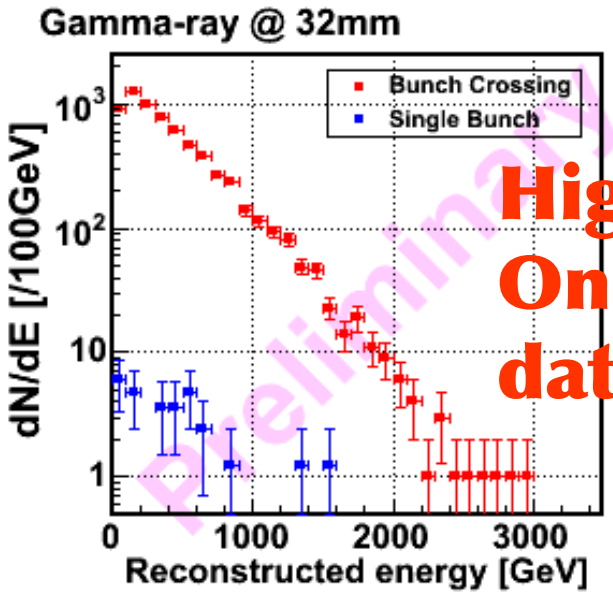
= Operations in 2010 =

Data taking at 7TeV collisions is ongoing !!!
Already 7×10^6 shower events in Arm1 and Arm2 have been collected (30th Mar. - 19th Apr. 2010)

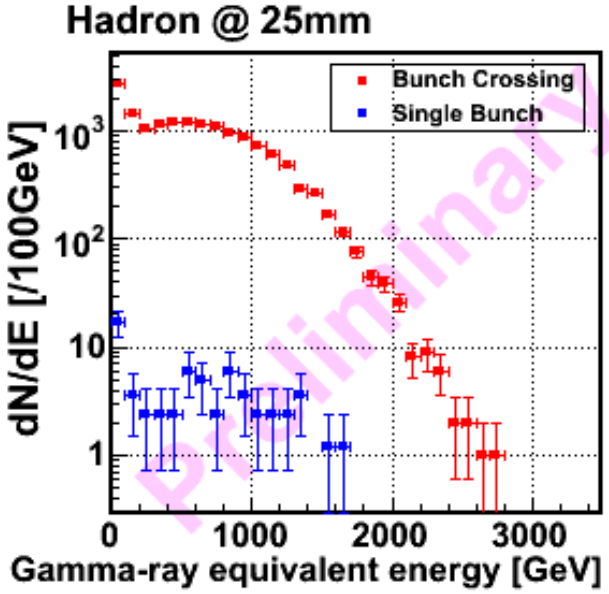


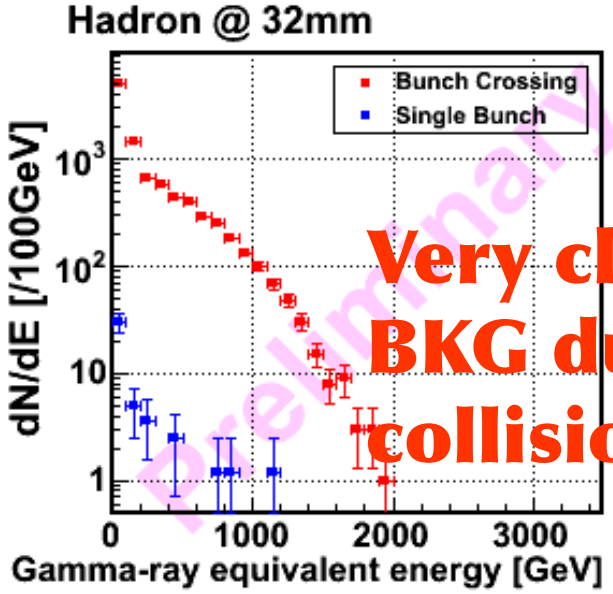
Very preliminary results





High statistics !!
Only 1.5% of total data are used





Very clean data!!
BKG due to beam-gas collisions is ~ 1%

Which is the future of LHCf?

Present running and Plans for the future

- Now we are taking data at 3.5+3.5 TeV

- When luminosity will become too high (>10^{31} $cm^{-2}s^{-1}$, 2 pb^{-1}) we will go out from the TAN (Radiation damage of the plastic scintillator is significant, LHCf has been designed to run at low luminosity/high energy!)

Improve the radiation resistance of LHCf

Basic idea:

- Replace the plastic scintillator with more RadHard scintillators
  - GSO
- Rearrange the order of silicon sensors to improve the silicon energy measurement
  - Cross check for scintillator measurement
- Go back in the TAN for 7+7 TeV run when it will be done
  - Removal when Luminosity will be too high

- This work will be done in the Florence INFN clean room in Summer 2010

Chi

- Dipendenti Università
  - Oscar Adriani
  - Raffaello D'Alessandro
- Dipendenti INFN
  - Paolo Papini
- Dipendenti CNR
  - Guido Castellini
- Assegnisti/Borsisti
  - Lorenzo Bonechi
  - Massimo Bongi
  - Menjo Hiroaki
  - Sergio Ricciarini

Dove

- Laboratori nell'edificio di Fisica Sperimentale
- Camera Pulita nell'edificio di Fisica Sperimentale

Quando

- Attività prevista per i prossimi 3-4 anni
  - Modifiche hardware
  - Presa dati
  - Analisi dati

Pubblicazioni

1) Astroparticle physics at LHC: The LHCf experiment ready for data taking. By M. Bongi, et al., Nucl.Instrum.Meth.A612:451-454,2010,.
2) The construction and testing of the silicon position sensitive modules for the LHCf experiment at CERN. By O. Adriani, et al., JINST 5:P01012,2010,.
3) The LHCf experiment at the LHC: Physics goals and status. By A. Tricomi, et al., Nucl.Phys.Proc.Suppl.196:30-35,2009,.
4) The LHCf experiment at CERN: Motivations and current status. By R. D'Alessandro, et al., Nucl.Phys.Proc.Suppl.190:52-58,2009,.
5) Production and test of the LHCf microstrip silicon system. By L. Bonechi, et al.,Nucl.Instrum.Meth.A596:85-87,2008,.
6) Current status of the LHCf experiment. By LHCf Collaboration [arXiv:0811.4019] (Nov 2008) 6p.
7) The LHCf experiment: Modelling cosmic rays at LHC. By LHCf Collaboration J.Phys.Conf.Ser.110:072044,2008,.
8) The LHCf detector at the CERN Large Hadron Collider. By LHCf Collaboration JINST 3:S08006,2008,.
9) LHCf: A LHC detector for astroparticle physics. By R. D'Alessandro, et al., Acta Phys.Polon.B38:829-838,2007,.
10) The LHCf experiment at the LHC accelerator. By L. Bonechi, et al., AIP Conf.Proc.867:266-273,2006,.
11) The LHCf experiment at LHC. By O. Adriani, et al., Czech.J.Phys.56:A107-A116,2006,.
12) Technical design report of the LHCf experiment: Measurement of photons and neutral pions in the very forward region of LHC. By LHCf Collaboration CERN-LHCC-2006-004 (Feb 2006) 104p.
13) Technnical proposal for the CERN LHCf experiment: Measurement of photons and neutral pions in the very forward region of LHC. By LHCf Collaboration CERN-LHCC-2005-032 (Oct 2005) 49p.