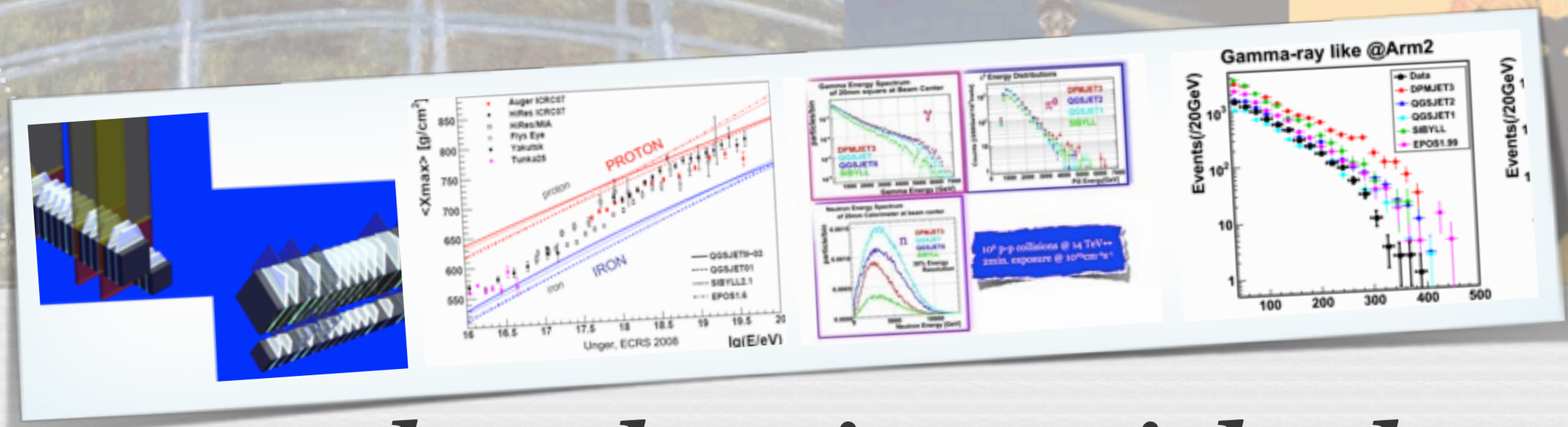
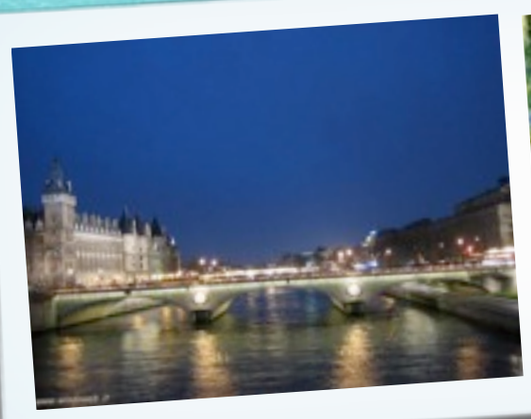


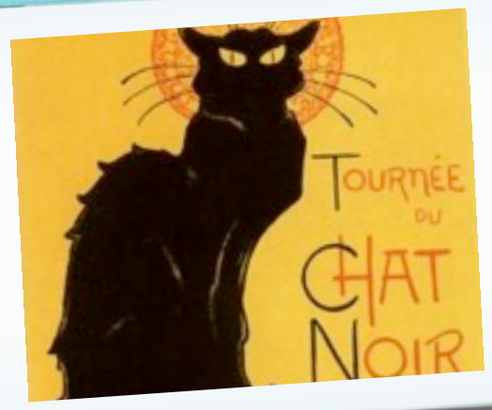
Early Physics with the LHCf Experiment at LHC

ICHEP 2010

Paris 22-28 July 2010

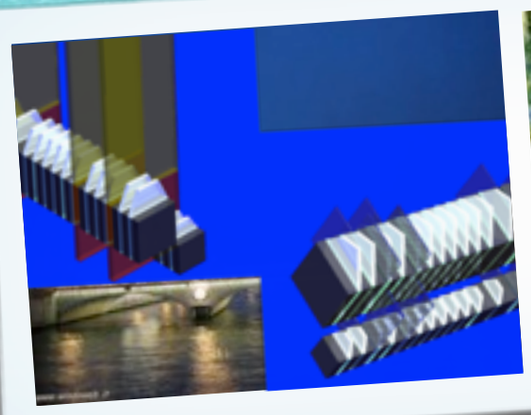
Alessia Tricomi on behalf of the LHCf Collaboration
University and INFN Catania, Italy

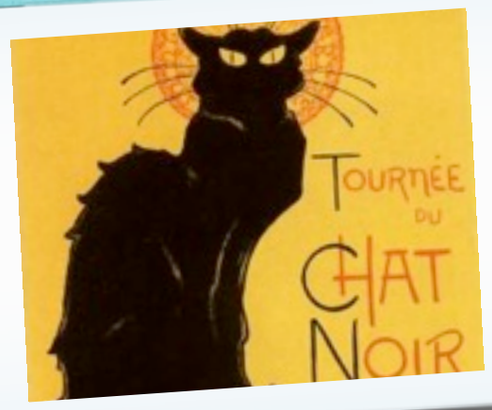




What is LHCf?

Experimental Set-up & Detectors



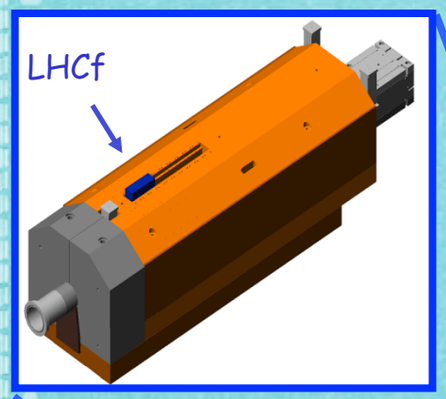


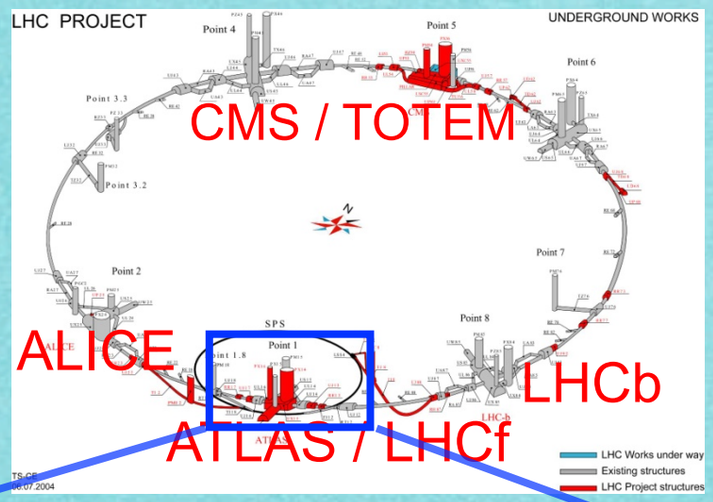
What is LHCf?

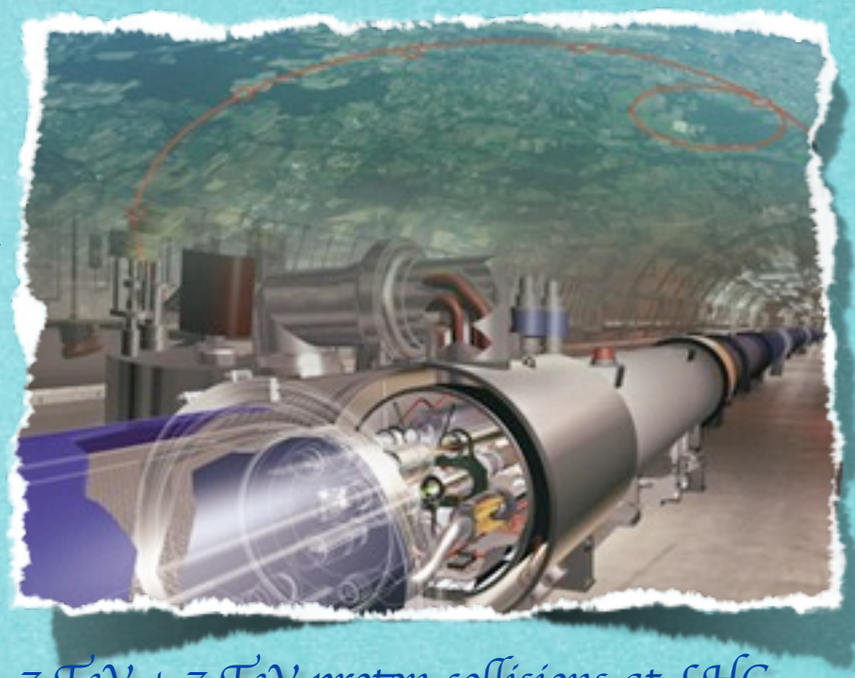
Experimental Set-up & Detectors

The LHCf experiment at LHC

- LHCf, the smallest LHC experiment, is a fully dedicated collider experiment to HECR Physics
- Two independent electromagnetic calorimeters equipped with position sensitive layers, on both sides of IP1





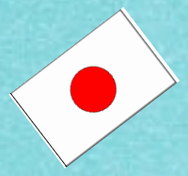


7 TeV + 7 TeV proton collisions at LHC correspond to $E_{LAB} = 10^{17}$ eV

- Measure energy and position for $|\eta| > 8$ of γ from π^0 decays and neutrons produced in pp interaction at LHC
- International Collaboration Japan-Europe-USA (about 30 members)

Alessia Tricomi
University & INFN Catania

The LHCf Collaboration



K.Fukatsu, Y.Itow, K.Kawade, T.Mase, K.Masuda, Y.Matsubara, G.Mitsuka, K.Noda, T.Sako, K.Suzuki, K.Taki

Solar-Terrestrial Environment Laboratory, Nagoya University, Japan

K.Yoshida *Shibaura Institute of Technology, Japan*

K.Kasahara, M.Nakai, Y.Shimizu, T.Suzuki, S.Torii

Waseda University, Japan

T.Tamura *Kanagawa University, Japan*

Y.Muraki *Konan University*

M.Haguenauer *Ecole Polytechnique, France*

W.C.Turner *LBNL, Berkeley, USA*

O.Adriani, L.Bonechi, M.Bongi, R.D'Alessandro, M.Grandi, H.Menjo, P.Papini, S.Ricciarini, G.Castellini

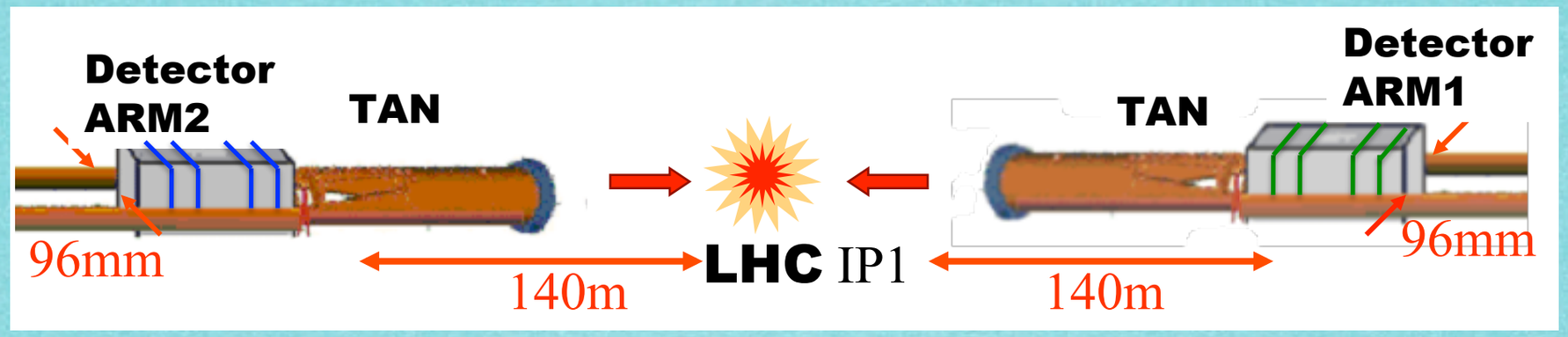
INFN, Univ. di Firenze, Italy

A.Tricomi *INFN, Univ. di Catania, Italy*

J.Velasco, A.Faus *IFIC, Centro Mixto CSIC-UVEG, Spain*

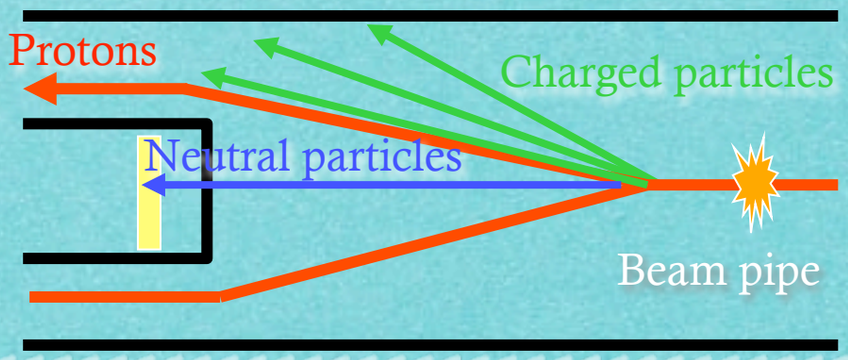
D.Macina, A-L.Perrot *CERN, Switzerland*

Experimental Set-up



Detectors installed in the TAN region, 140 m away from ATLAS Interaction Point (IP1)

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



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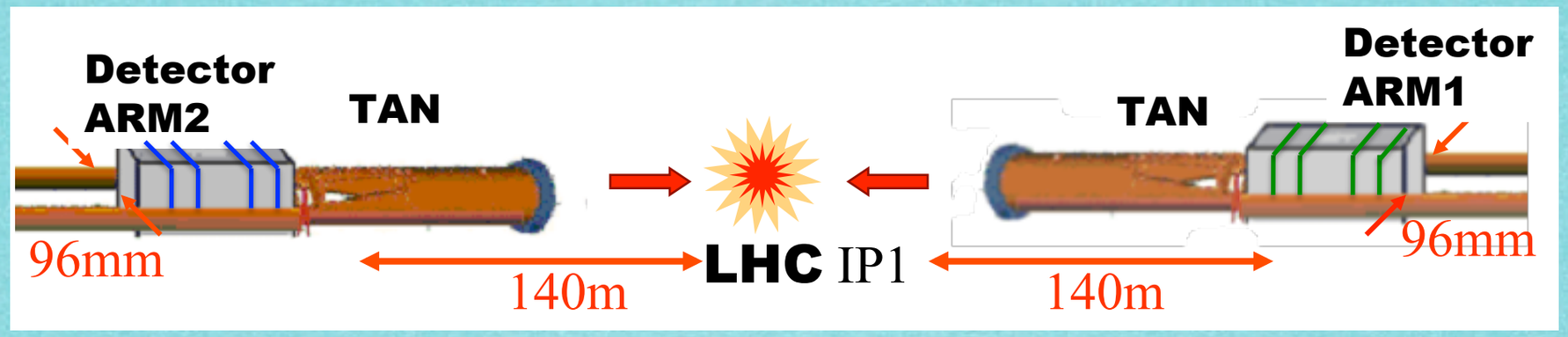

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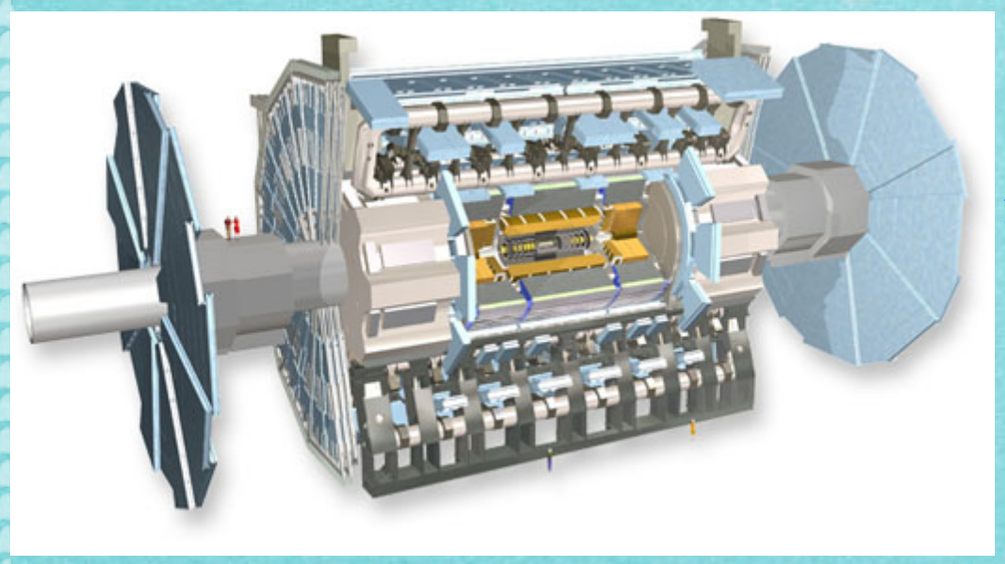

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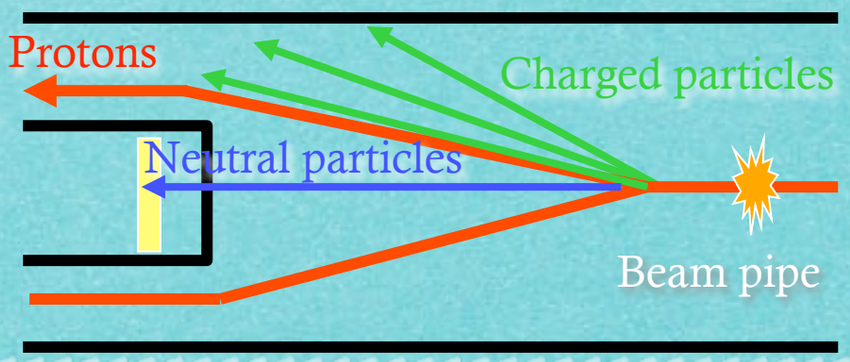
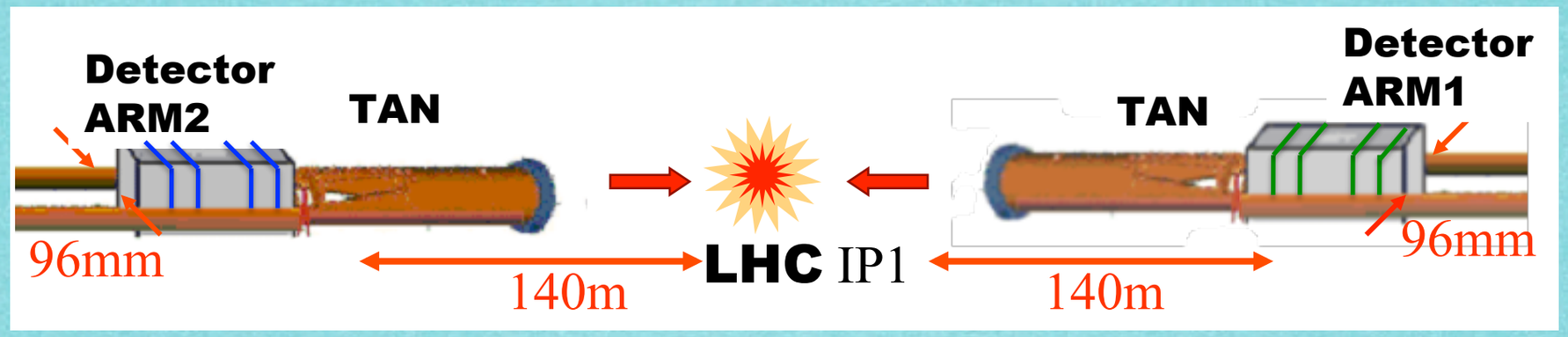


Experimental Set-up



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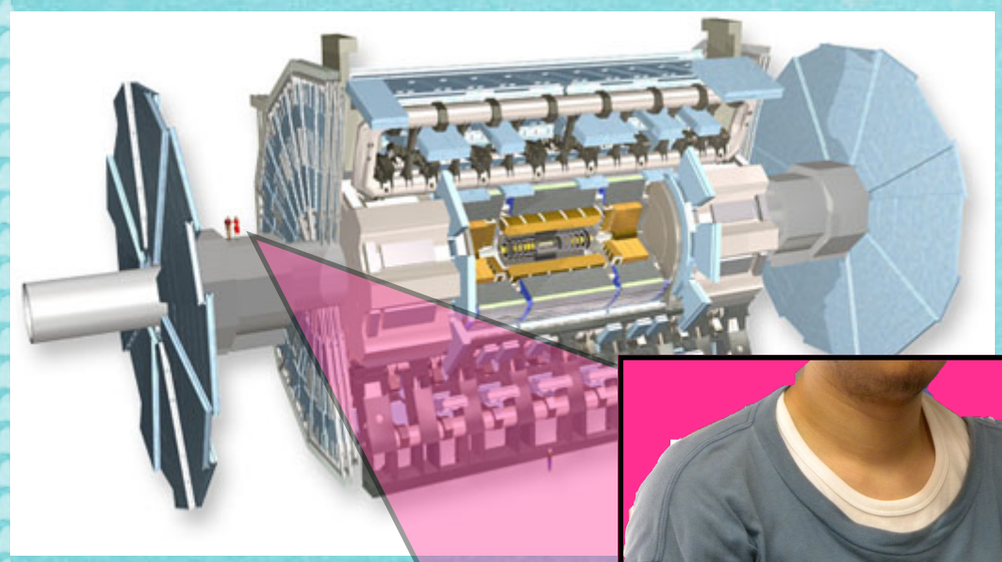

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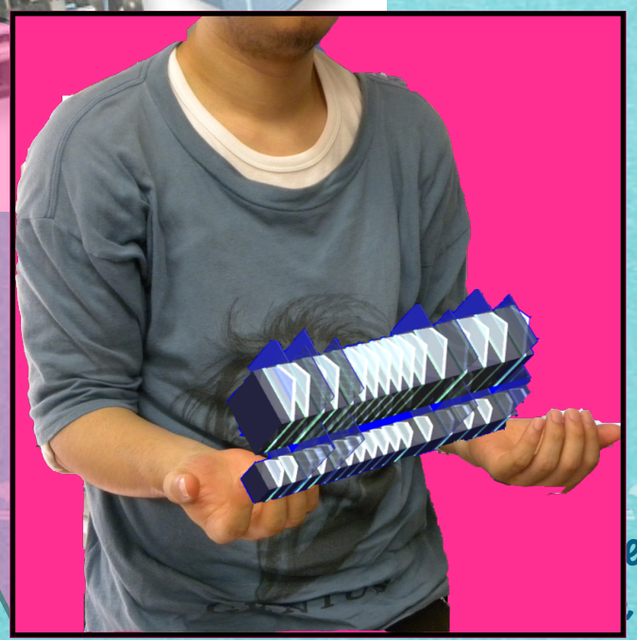
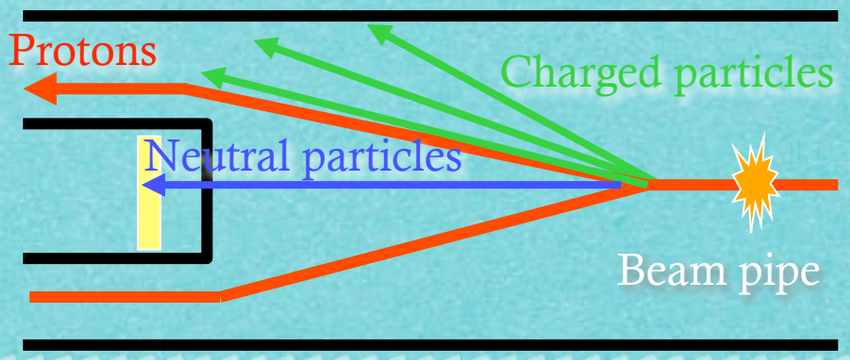




ARM1 & ARM2 detectors

ARM1

2 towers 24 cm long stacked vertically with 5 mm gap

Lower: 2 cm x 2 cm area

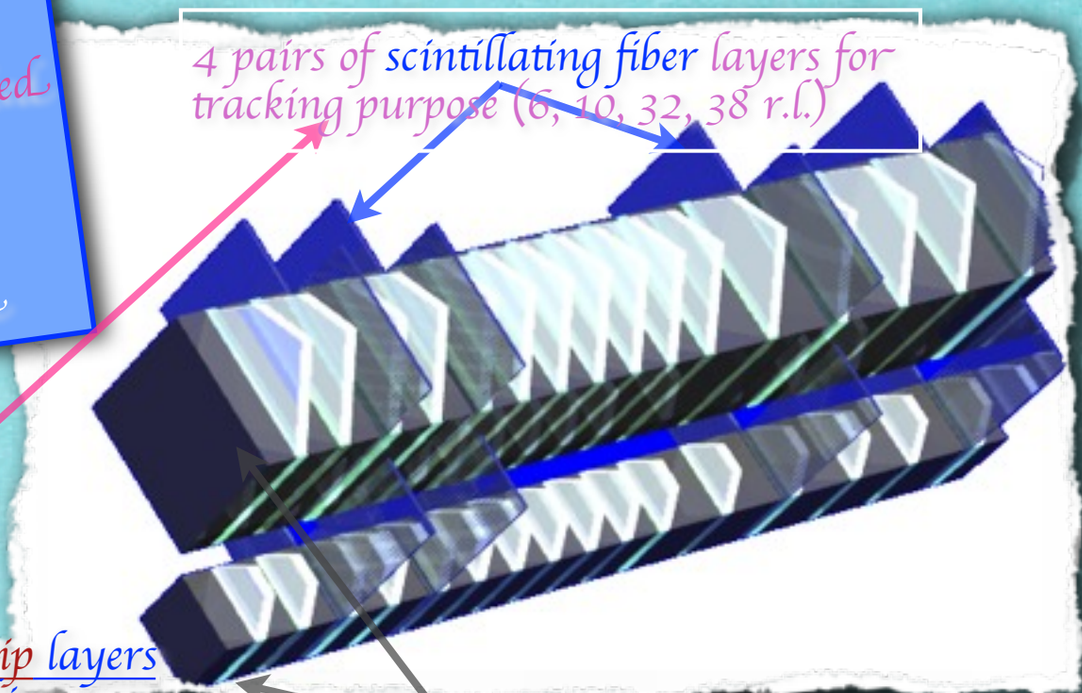
Upper: 4 cm x 4 cm area

ARM2

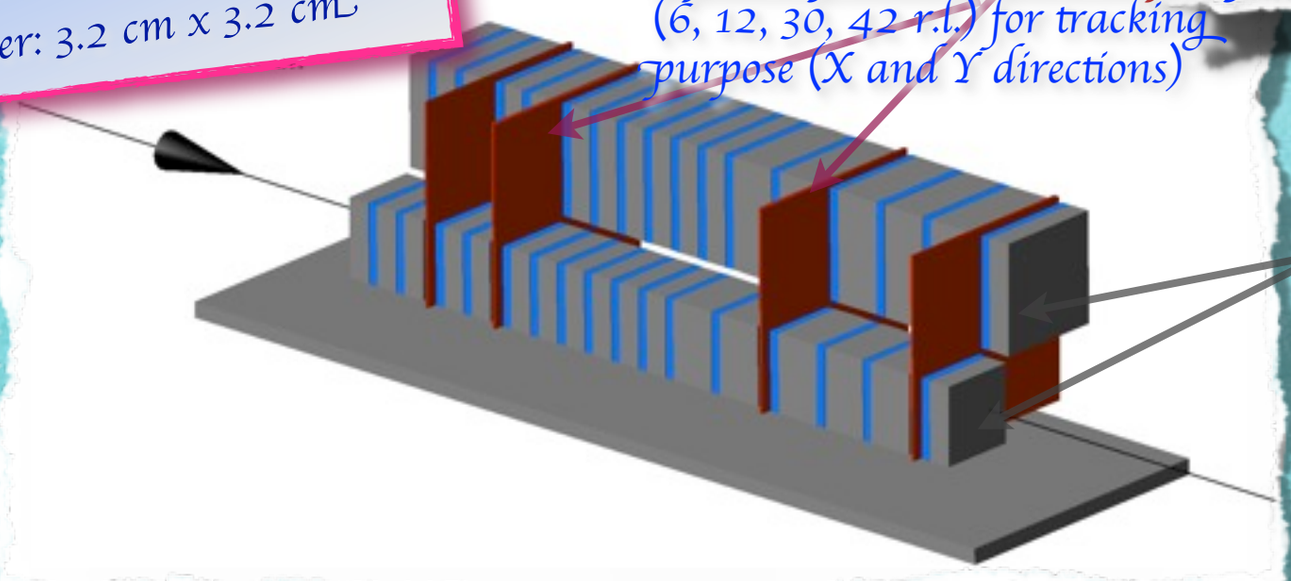
2 towers 24 cm long stacked on their edges and offset from one another

Lower: 2.5 cm x 2.5 cm

Upper: 3.2 cm x 3.2 cm



Impact point (η)



Absorber

22 tungsten layers

7mm – 14 mm thick (2-4 r.l.)

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

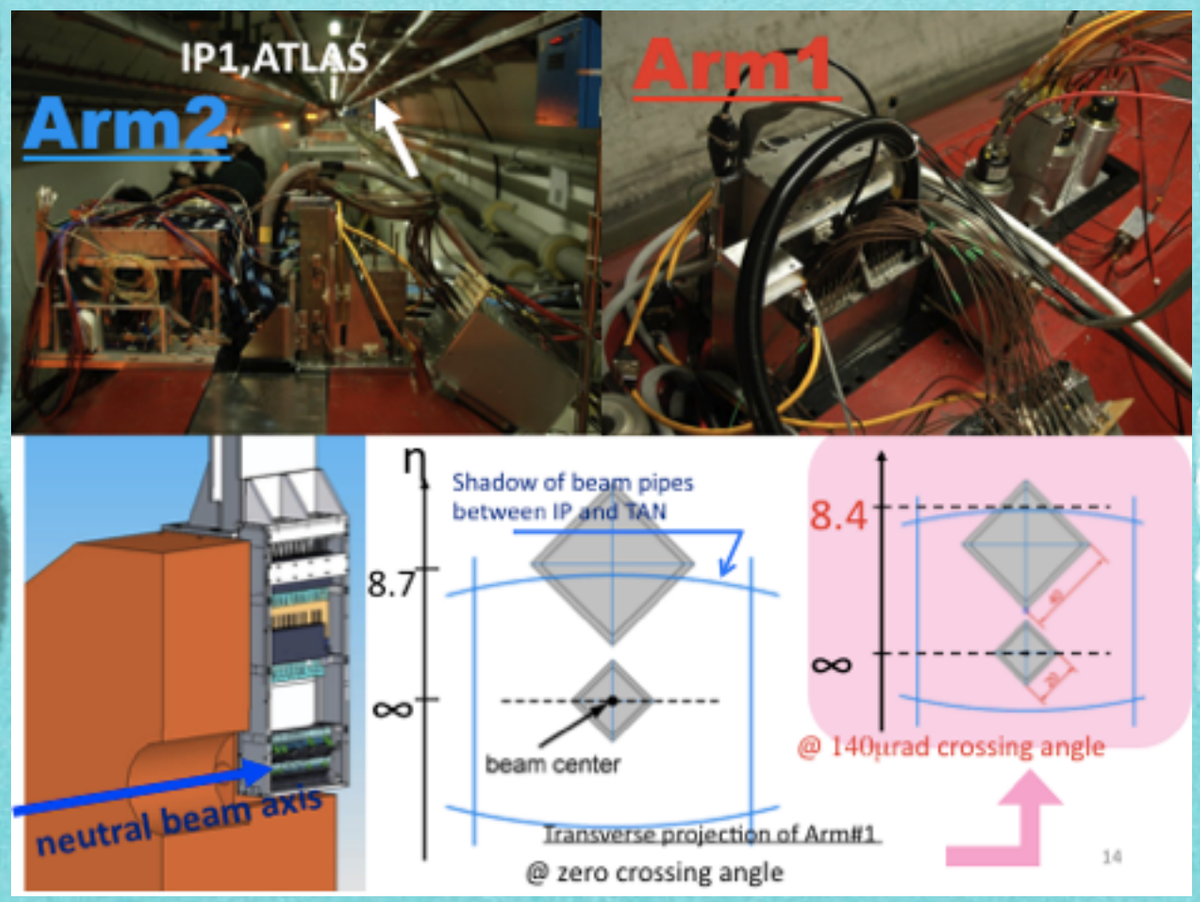
Energy

16 scintillator layers (3 mm thick)

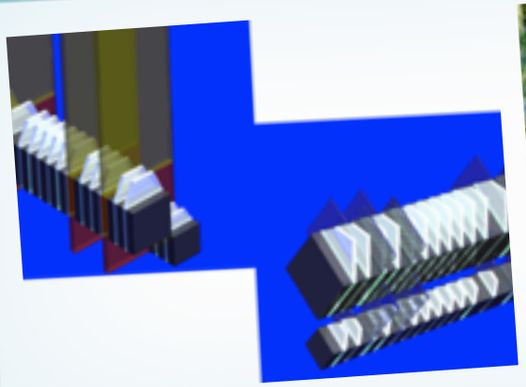
Trigger and energy profile measurements

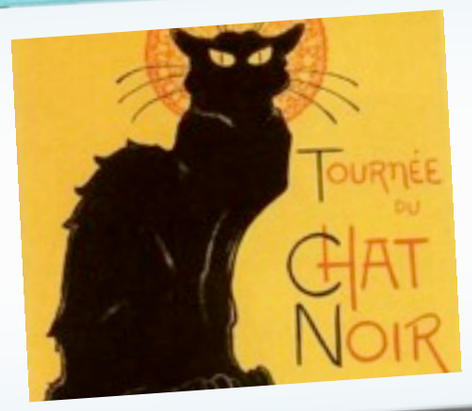
Alessia Tricomi
University & INFN Catania

Double ARM detector



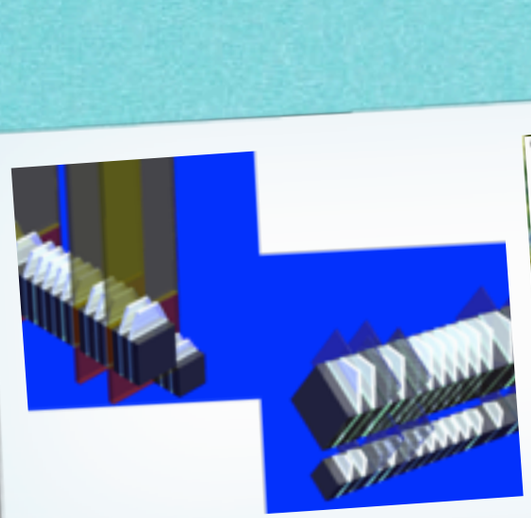
Alessia Tricomi
University & INFN Catania

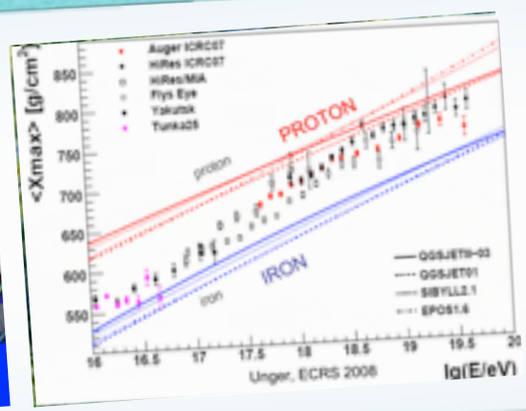


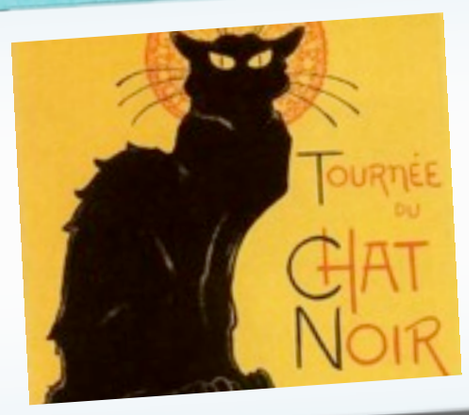


Why LHCf?

Physics goals & motivations



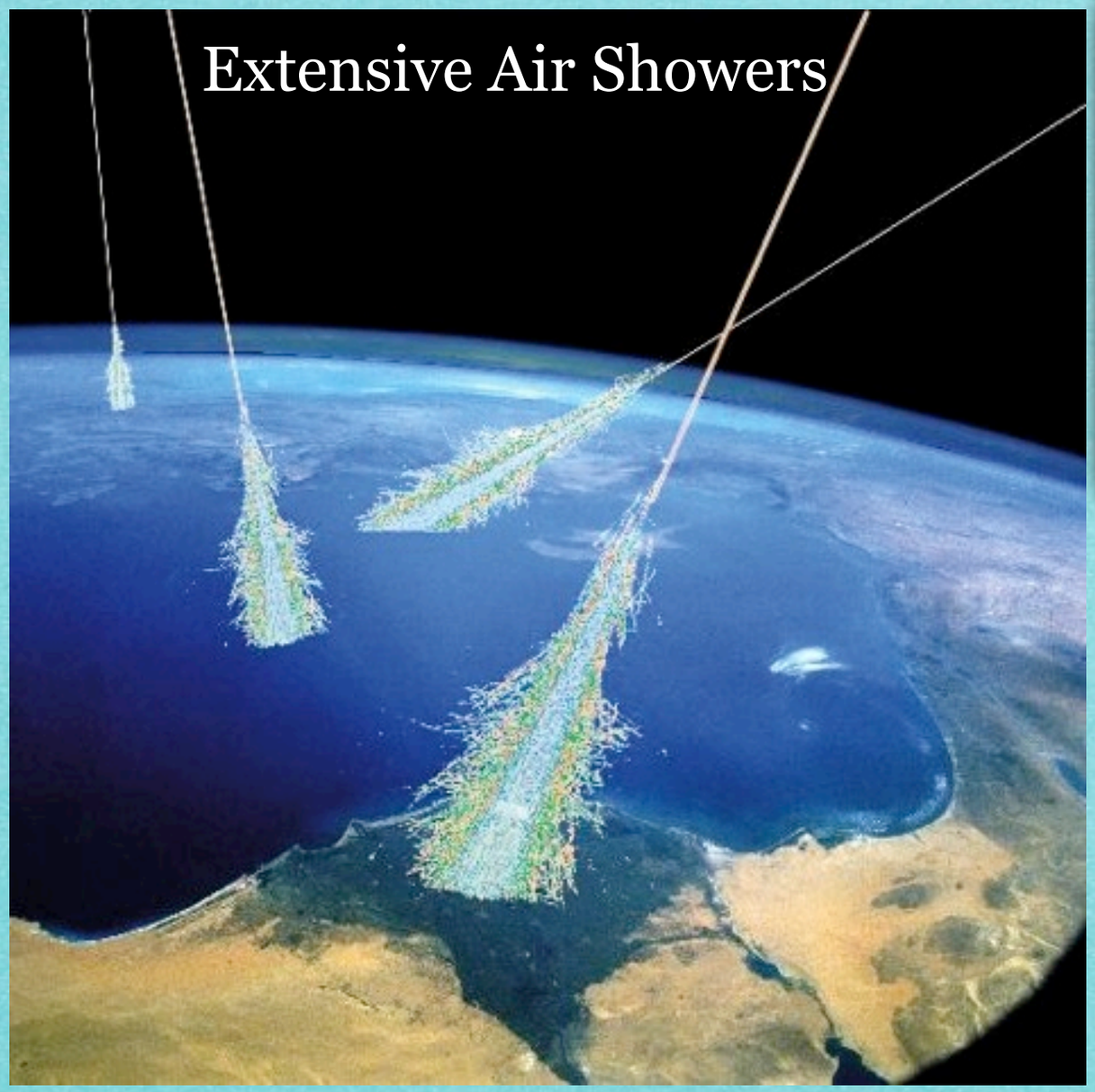




Why LHCf?

Physics goals & motivations

Ultra High Energy Cosmic Rays



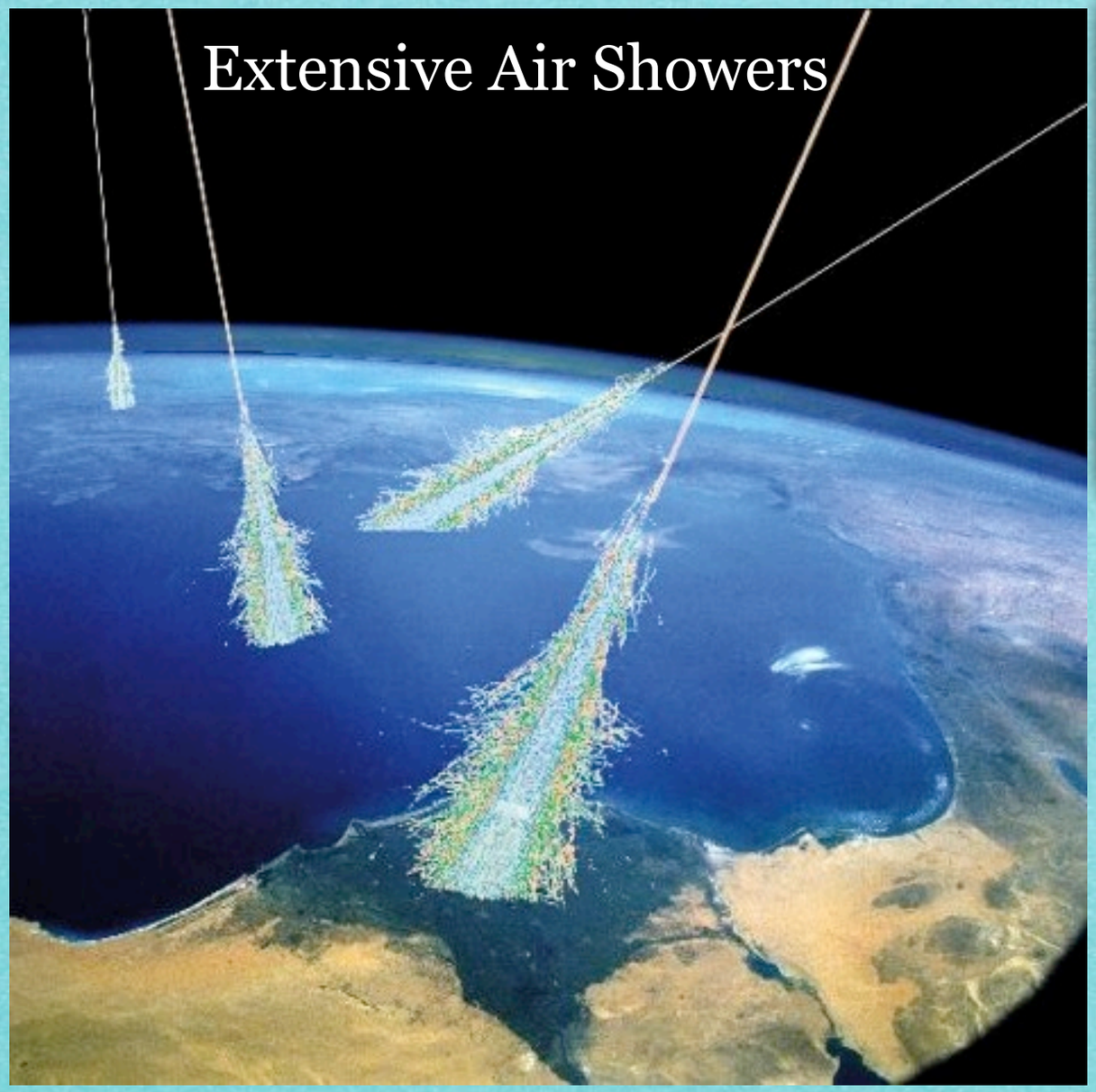
Experimental observations:
at E>100 TeV only EAS
(shower of secondary particles)

- lateral distribution
- longitudinal distribution
- particle type
- arrival direction

Astrophysical parameters:
(primary particles)

- spectrum
- composition
- source distribution
- origin and propagation

Ultra High Energy Cosmic Rays



Experimental observations:
at E>100 TeV only EAS
(shower of secondary particles)

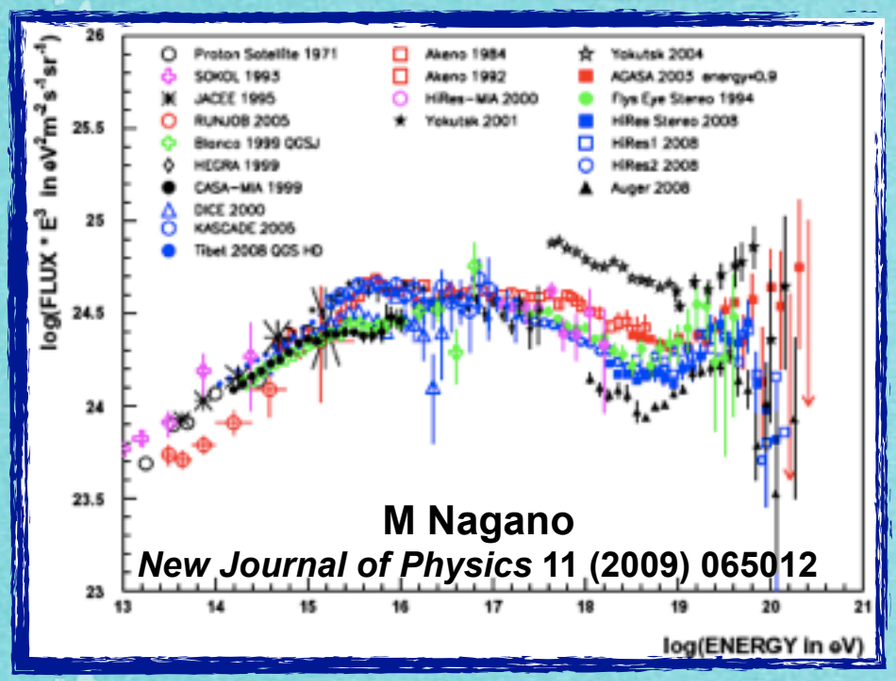
- lateral distribution
- longitudinal distribution
- particle type
- arrival direction

Air shower development (particle interaction in the atmosphere)

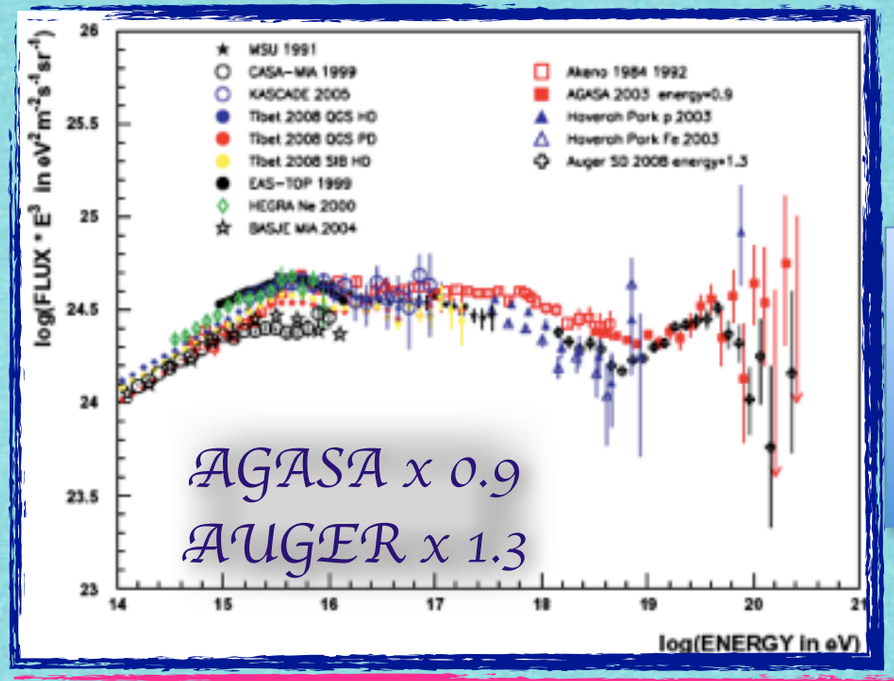
Astrophysical parameters:
(primary particles)

- spectrum
- composition
- source distribution
- origin and propagation

HECR Open Issues



M Nagano
***New Journal of Physics* 11 (2009) 065012**

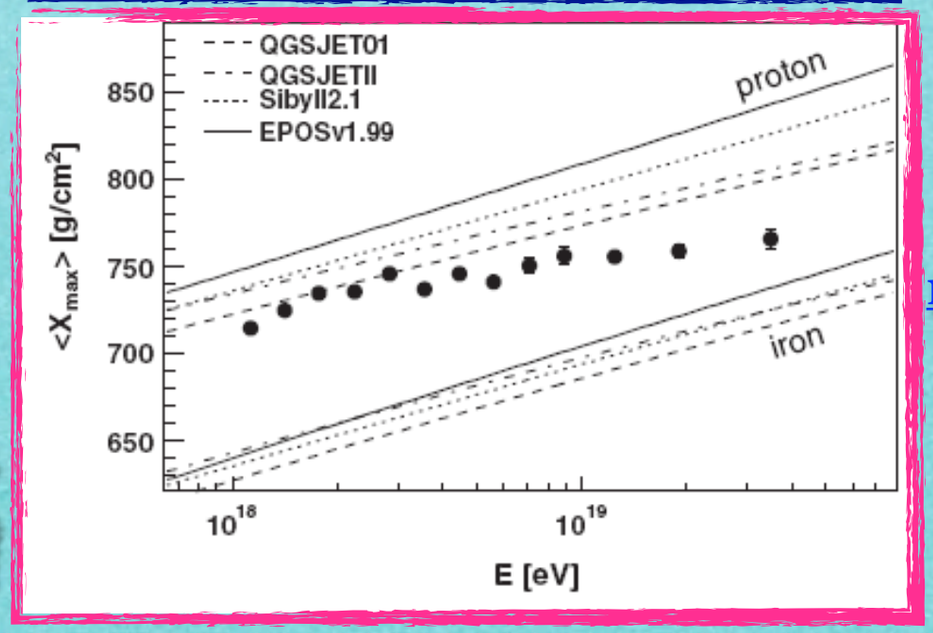


AGASA x 0.9
AUGER x 1.3

AGASA Systematics
Total ±18%
Hadr Model ~10%
(Takeda et al., 2003)

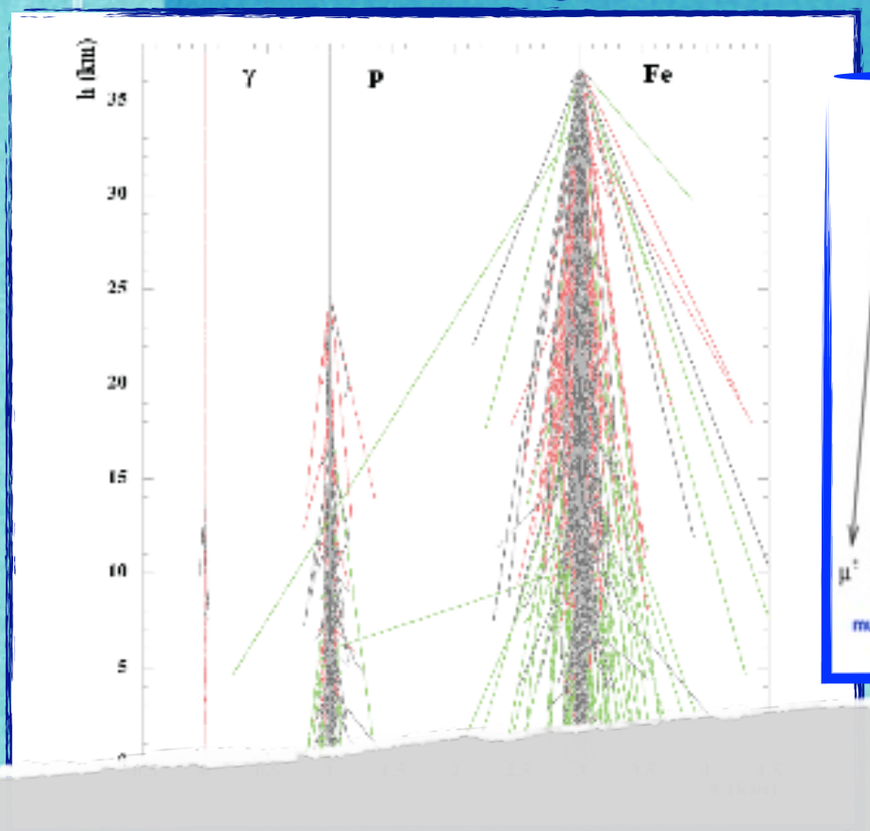
Difference in the energy scale between different experiments???

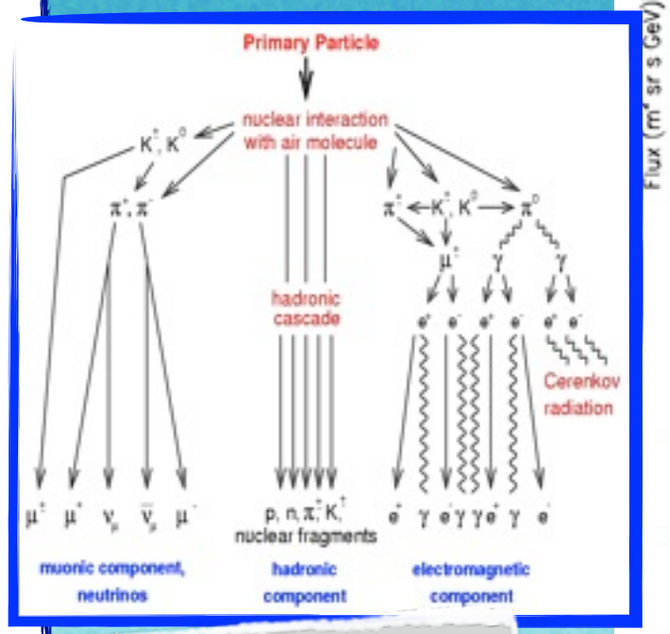
Different hadronic interaction models give different answers about the composition of HECR

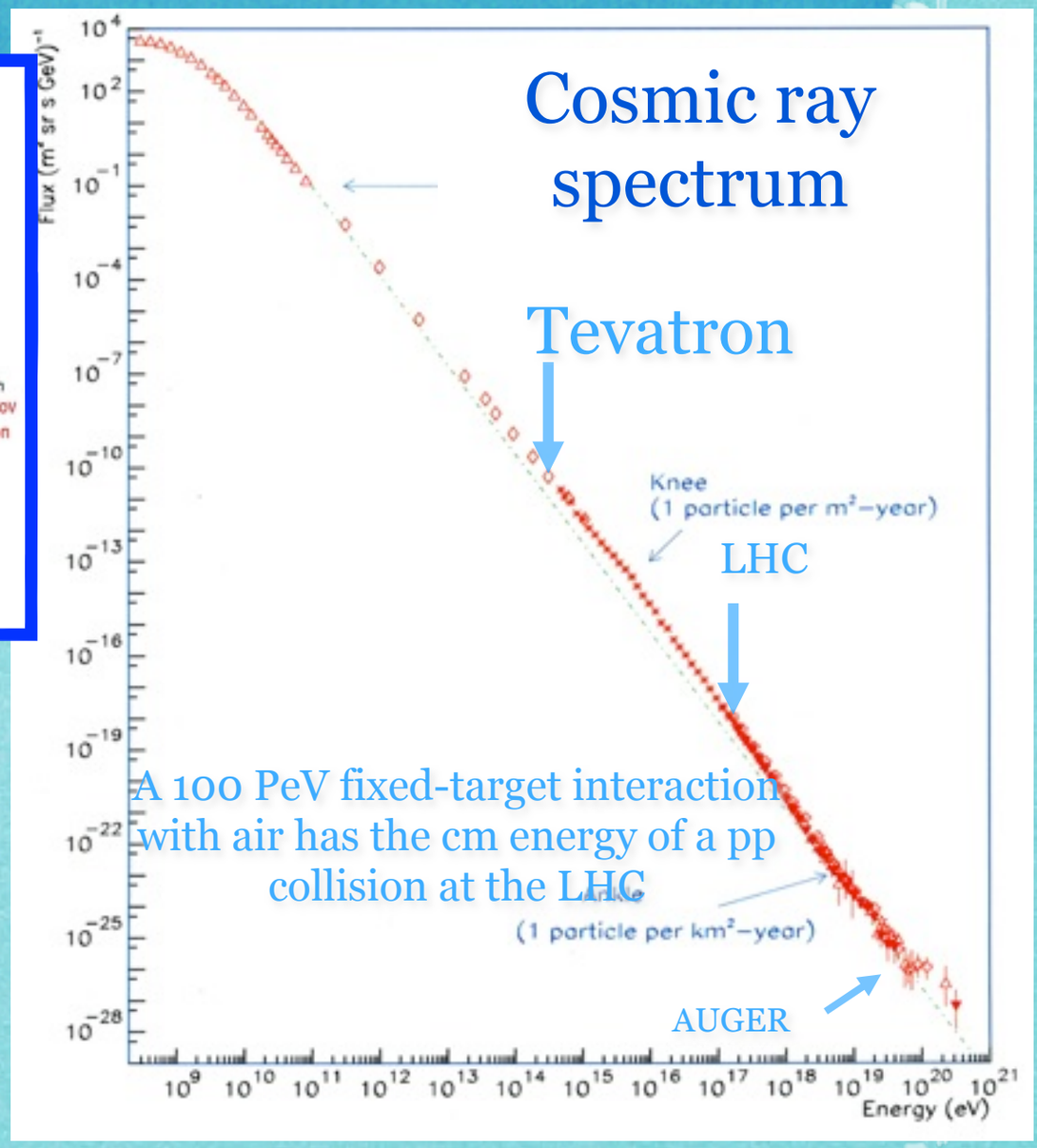


The depth of the maximum of the shower X_{max} in the atmosphere depends on energy and type of the primary particle

Development of atmospheric showers







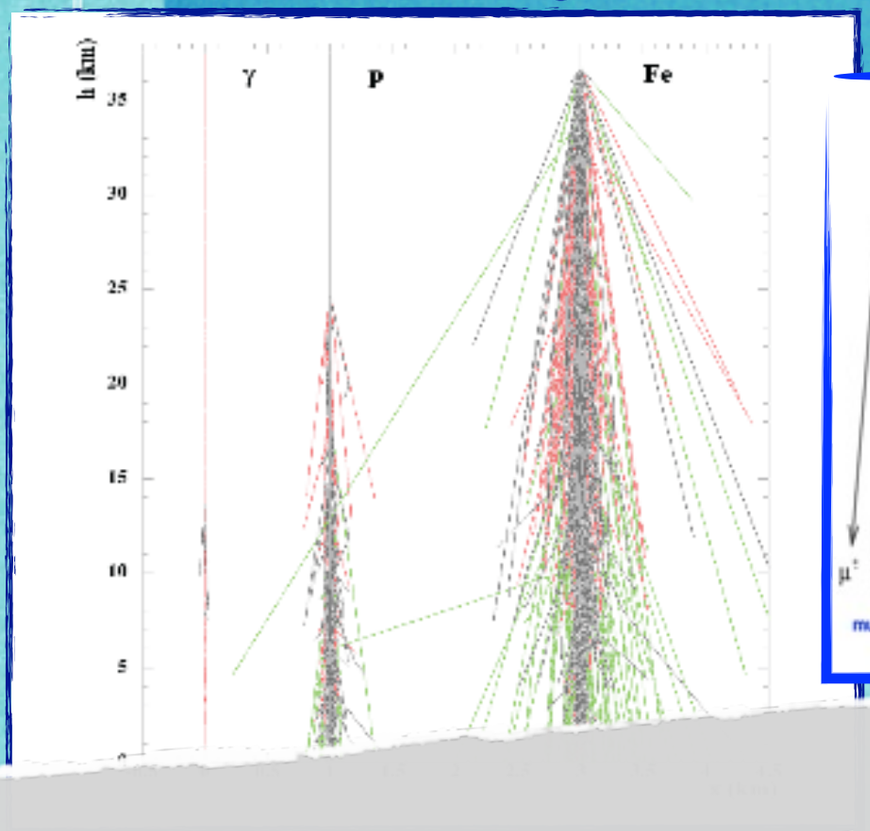
Determination of E and mass of CRs depends on description of primary UHE QCD (p+N,O-Fe+N,O) interaction

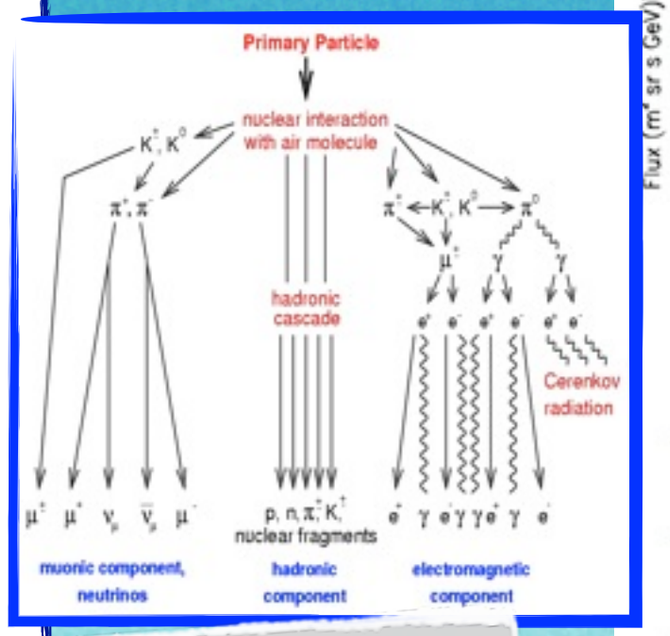
Hadronic MC's need tuning with data

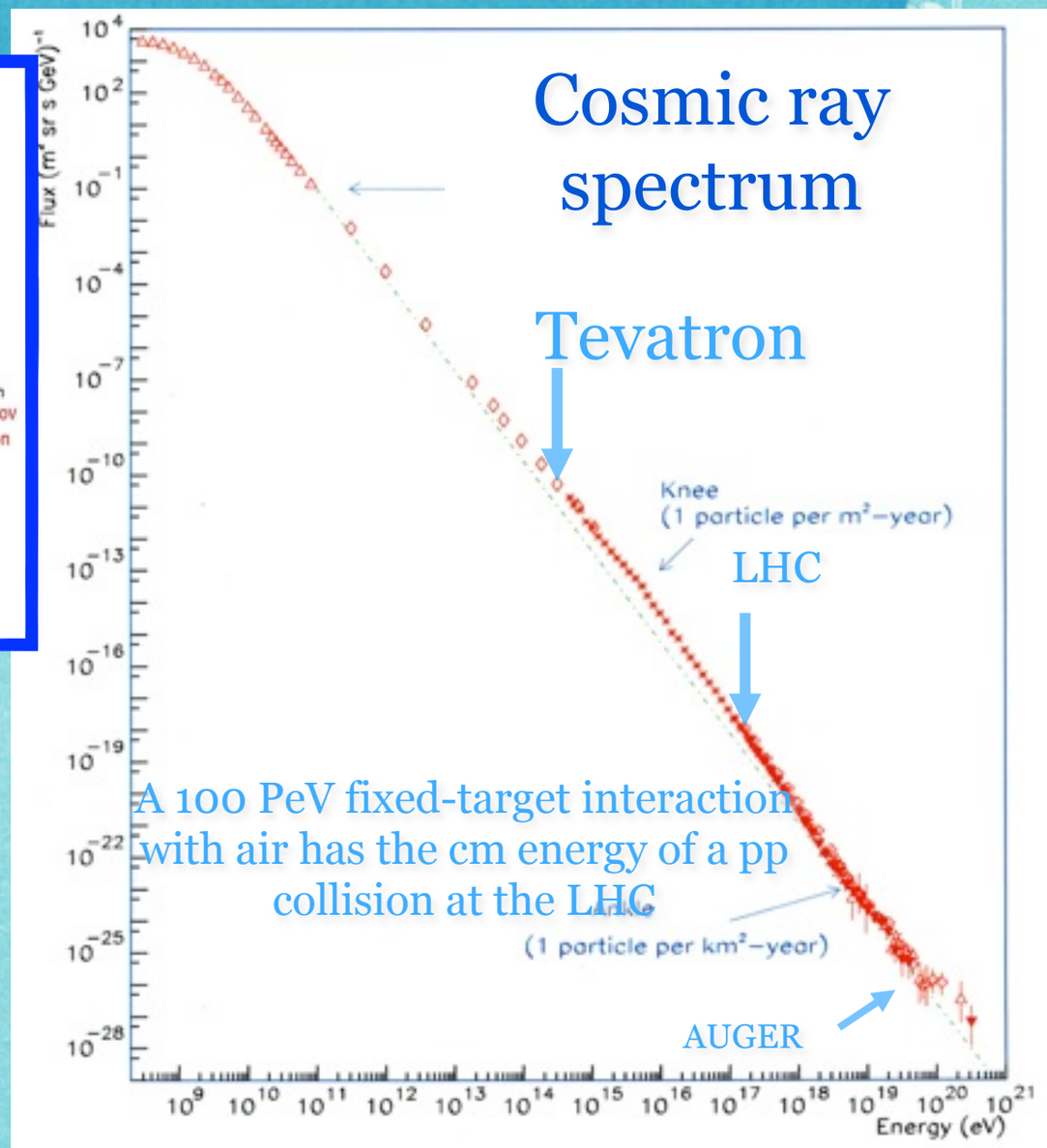
The dominant contribution to the energy flux is in the very forward region ($\theta \approx 0$)

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

Development of atmospheric showers







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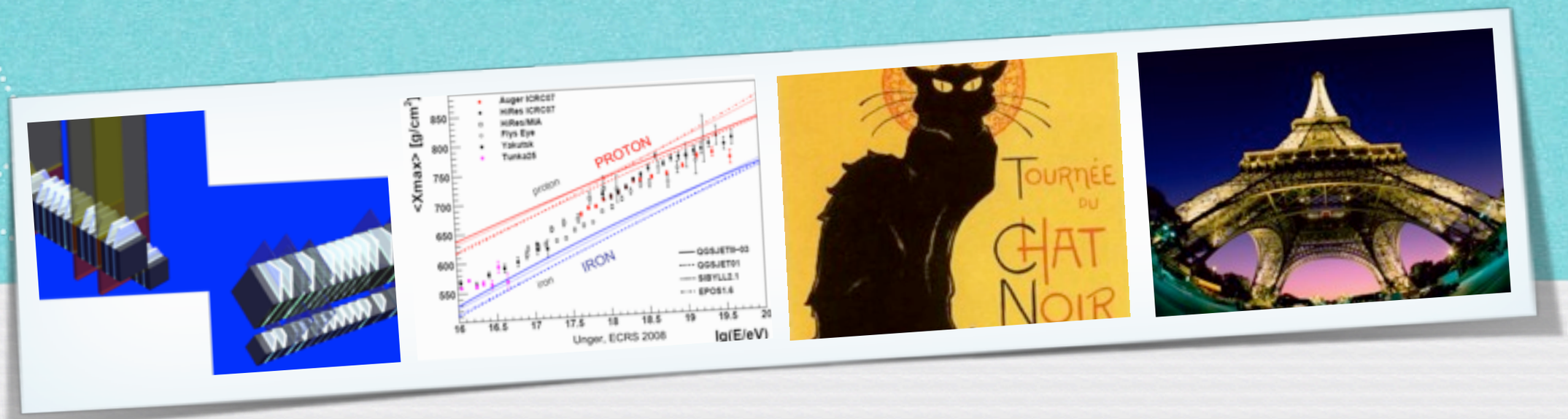
In this forward region the highe… available measurements of π… section done by UA7 ($E=10^{14}$ eV…

LHCf: use LHC

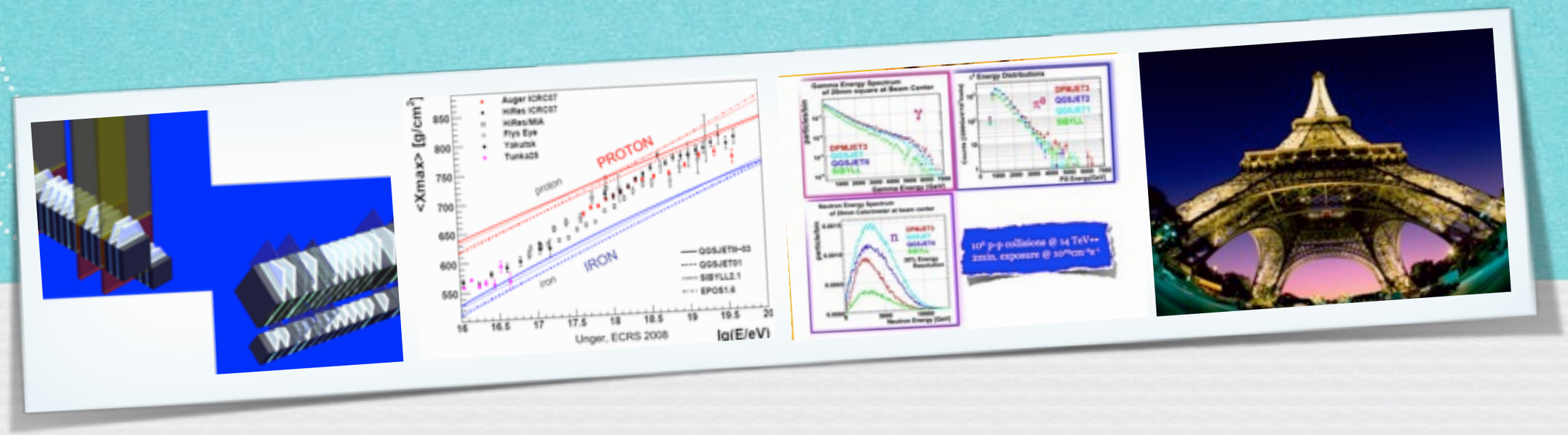
$\sqrt{s}$ = 14 TeV ⇒ $E_{lab}=10^{17}$ eV

to calibrate MCs



How LHCf can calibrate MC?

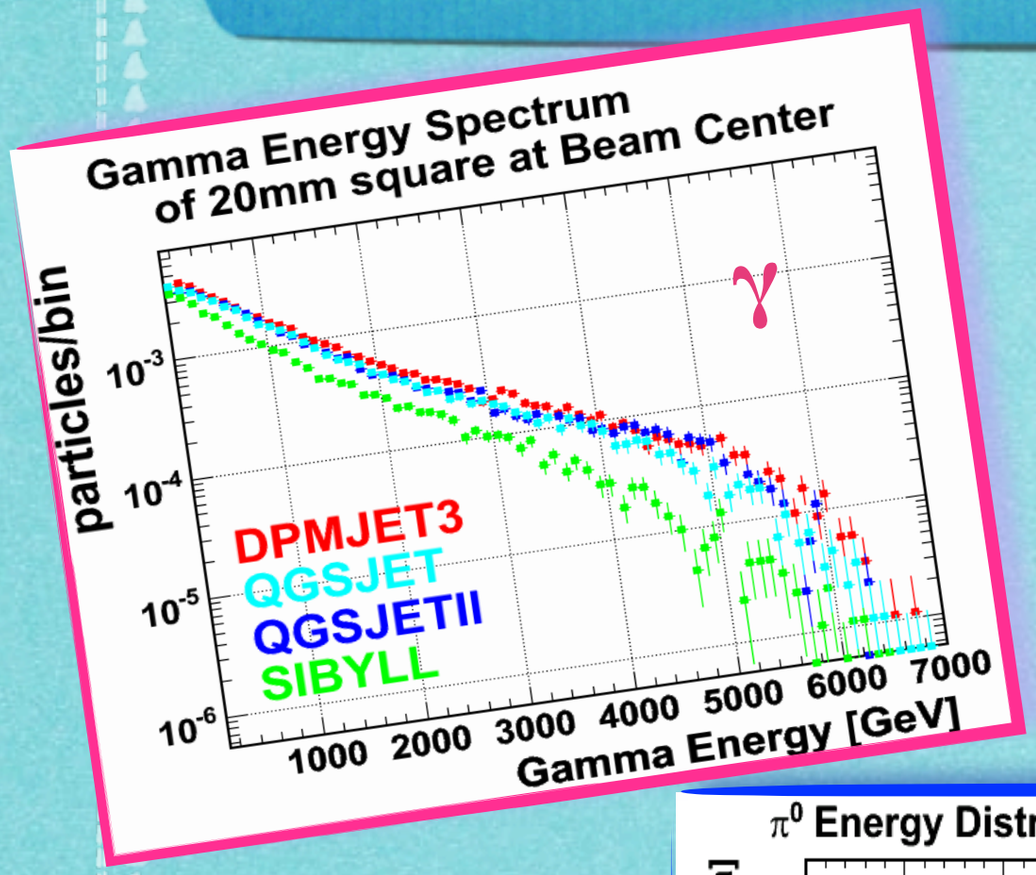
Physics Performances



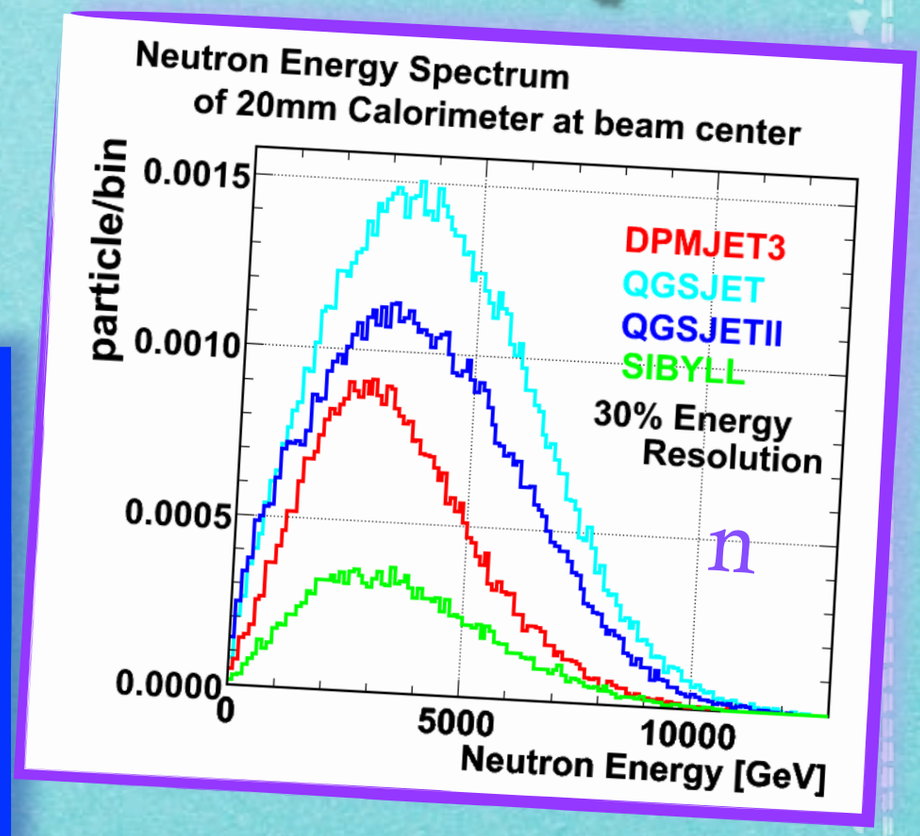
How LHCf can calibrate MC?

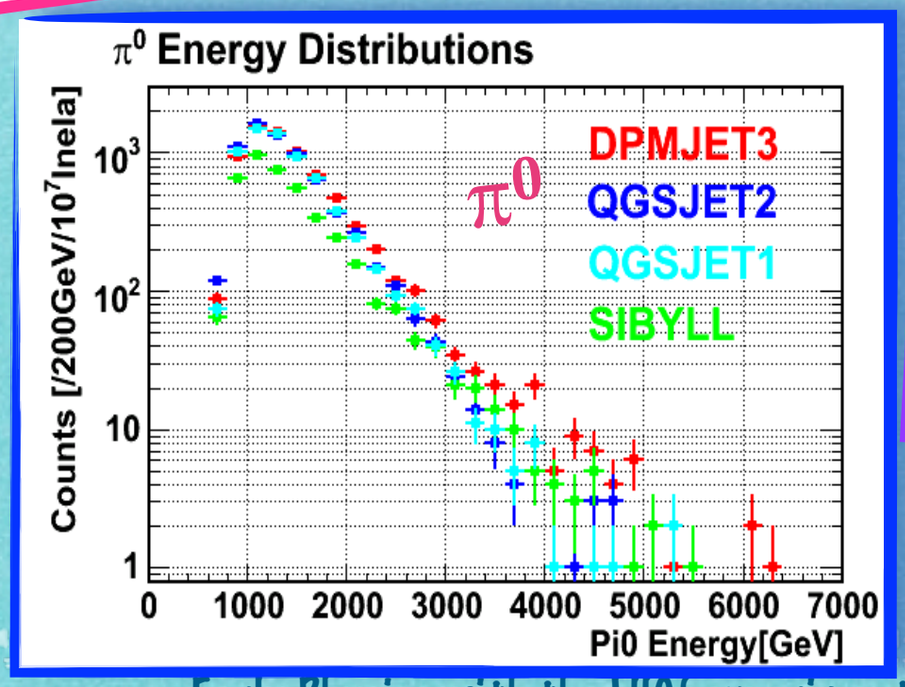
Physics Performances

LHCf : Monte Carlo discrimination @ 14 TeV



10^6 collisions
↔ 2min. exposure @ $10^{29}cm^{-2}s^{-1}$

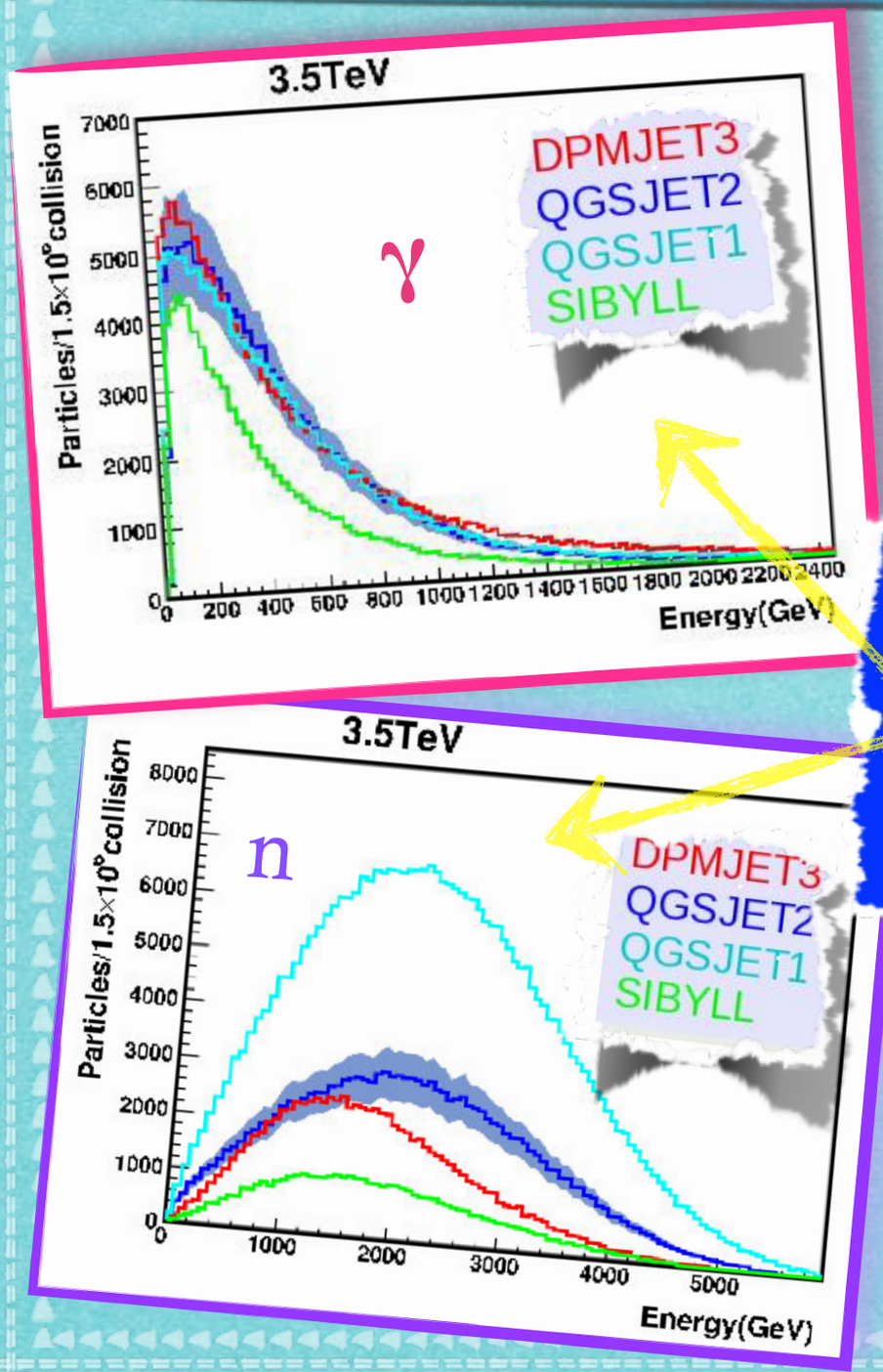


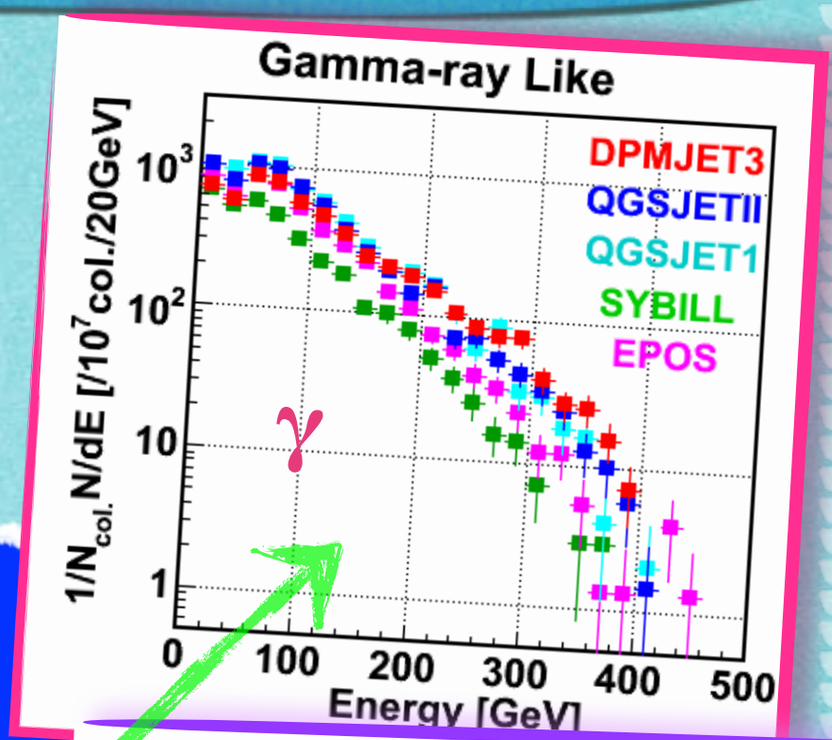


Alessia Tricomi
University & INFN Catania

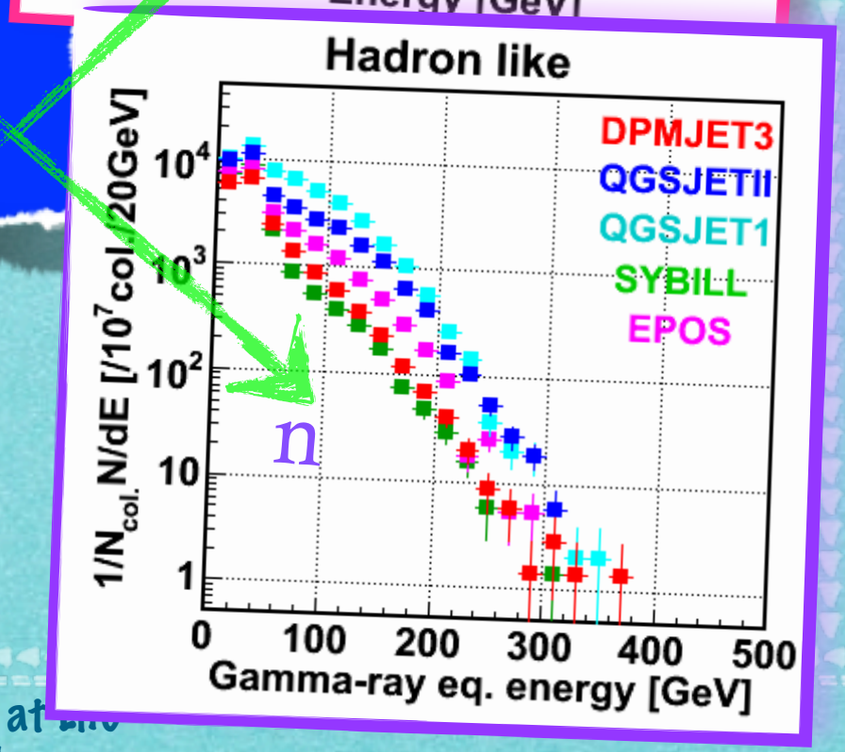
Early Physics with the LHCf experiment at LHC
ICHEP 2010, July 22-28, 2010, Paris

LHCf : Monte Carlo discrimination @ <14 TeV





10^7 p-p collisions
3.5 TeV + 3.5 TeV
450 GeV + 450 GeV



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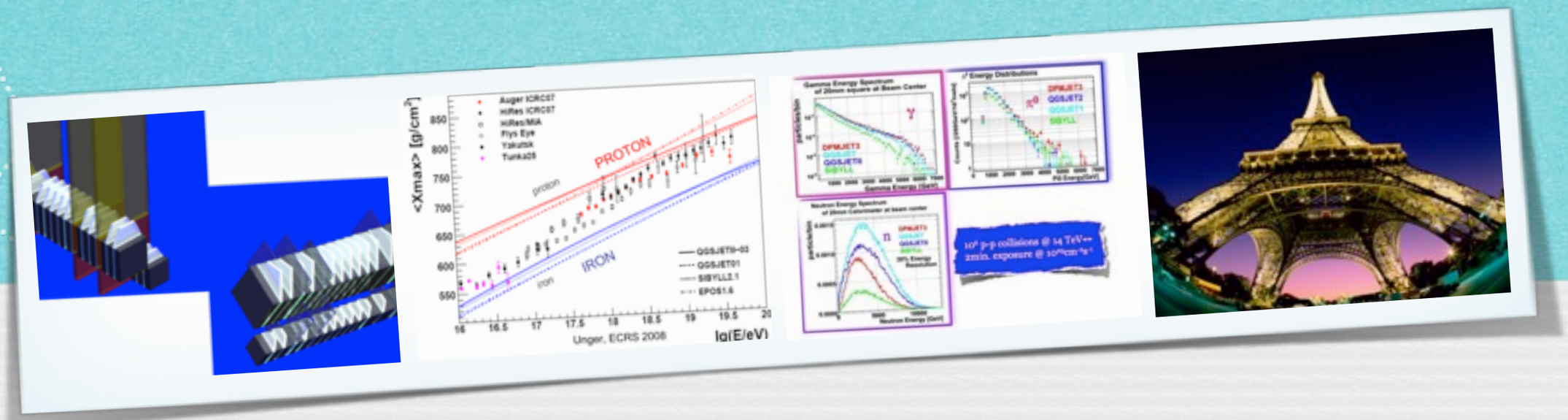
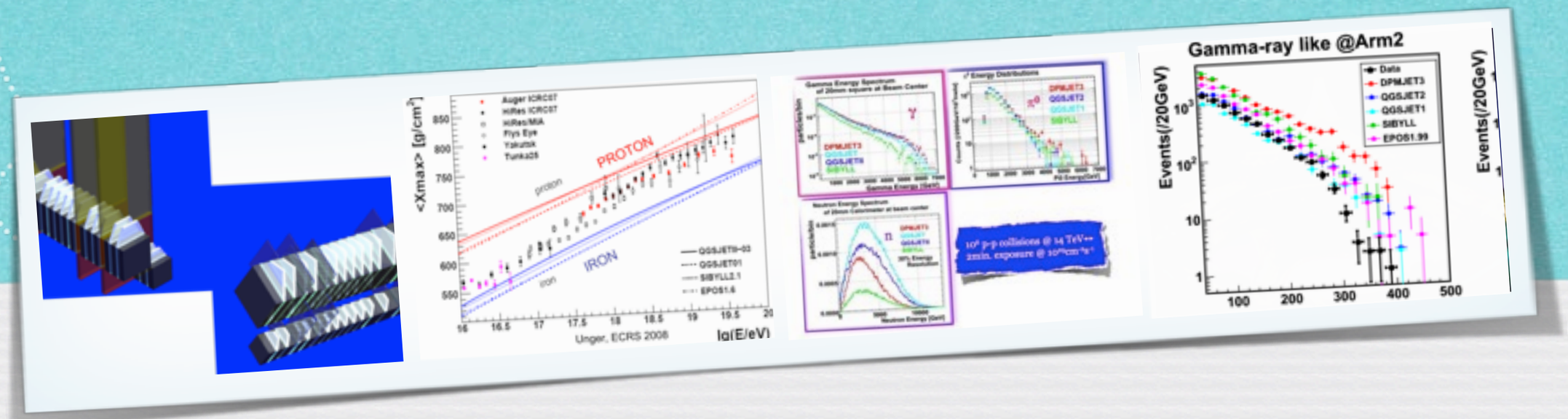


LHCf at work!!!

Data taking & Analysis

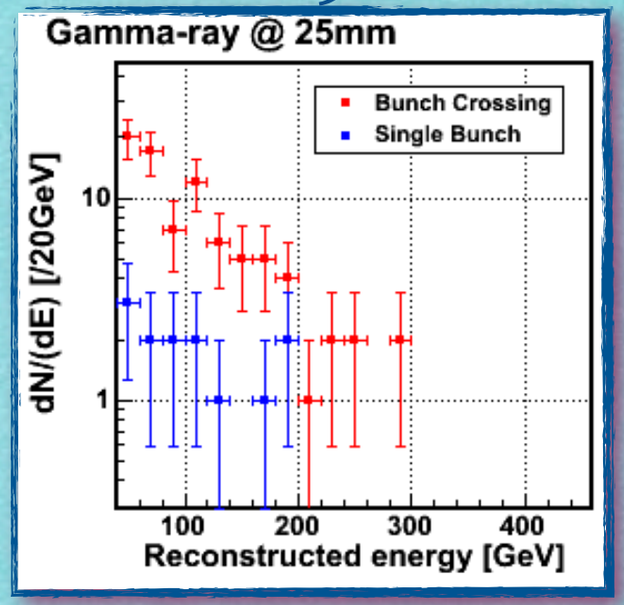


LHCf at work!!!

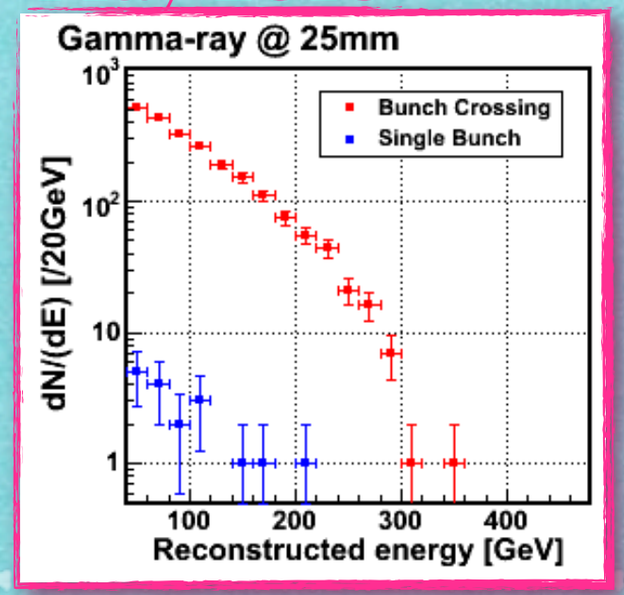
Data taking & Analysis

LHCf operation @ 900 GeV

- With Stable Beam at 900 GeV 06 Dec – 15 Dec 2009
  - 2.6 h for commissioning
  - 27.7 hours for physics
  - ~5x10^5 collisions at IP1
  - ~2,800 shower events in Arm1
  - ~3,700 shower events in Arm2

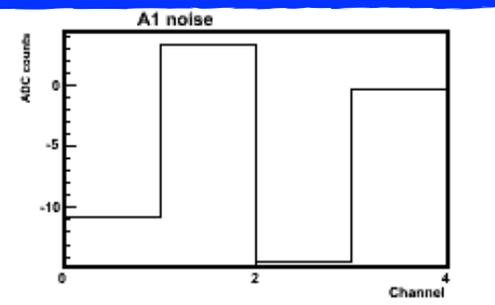


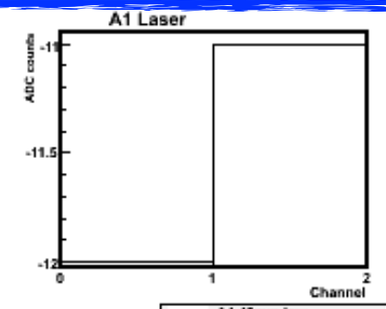
- With Stable Beam at 900 GeV 02 May – 27 May 2010
  - 15 hours for physics
  - ~5.5x10^6 collisions at IP1 (Statistics x 11 wrt 2009)
  - ~44,000 shower events in Arm1
  - ~63,000 shower events in Arm2
  - Beam Gas significantly reduced wrt 2009

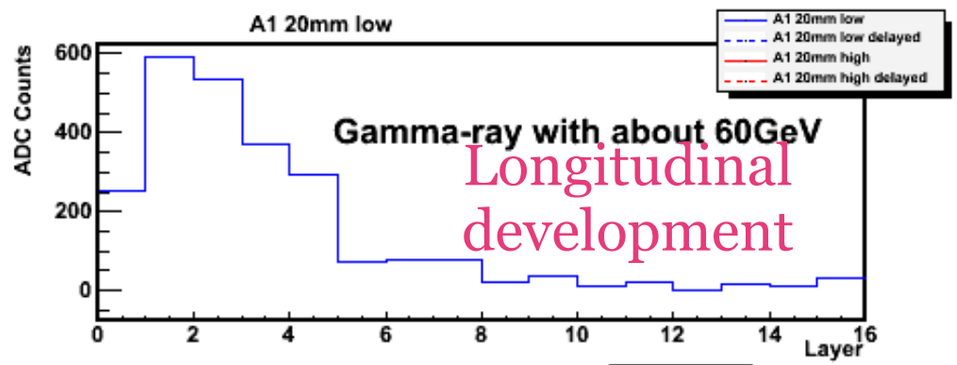


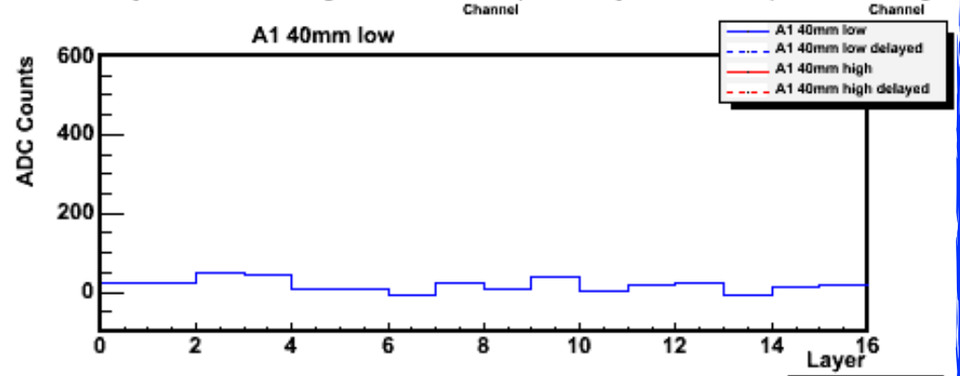
ARM1: γ event at 900 GeV

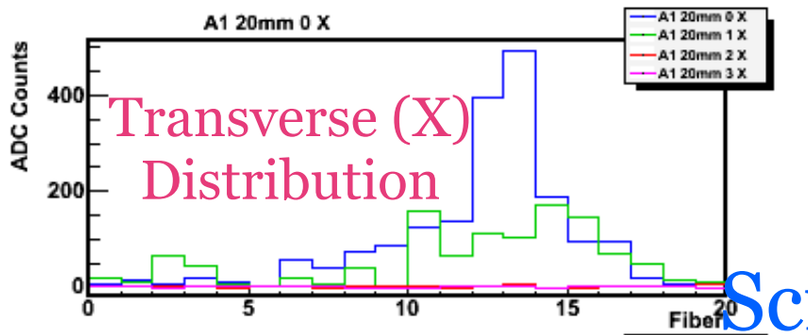
RUN: 2342
NUMBER: 223
GNUMBER: 423
TIME: 1260084266
FLAG0: 00009557
FLAG1: 0000007f
FLAG2: 000f1317

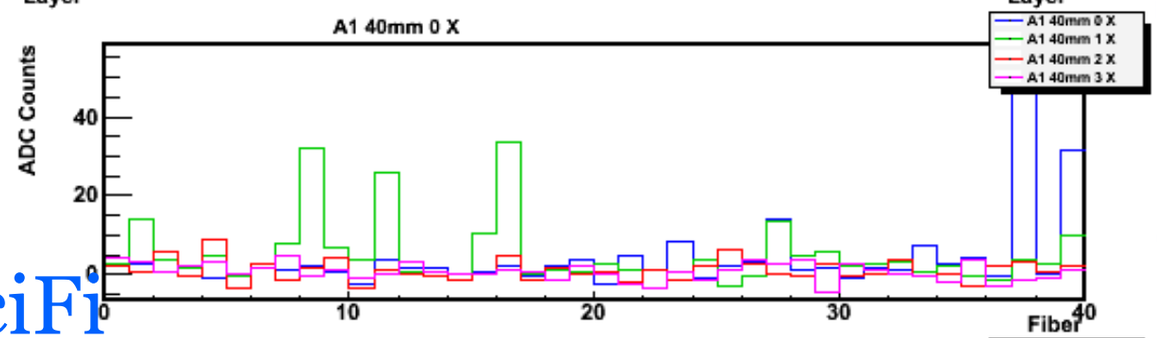




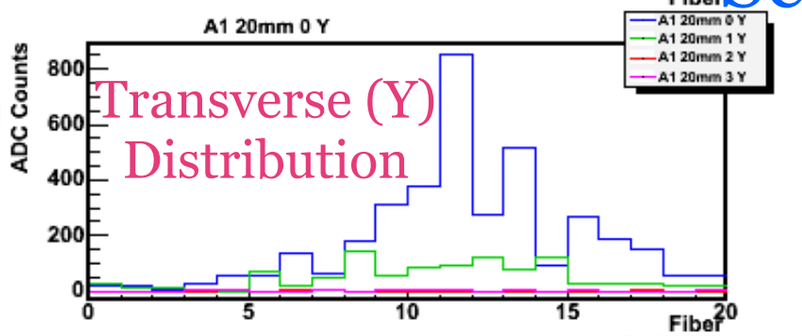


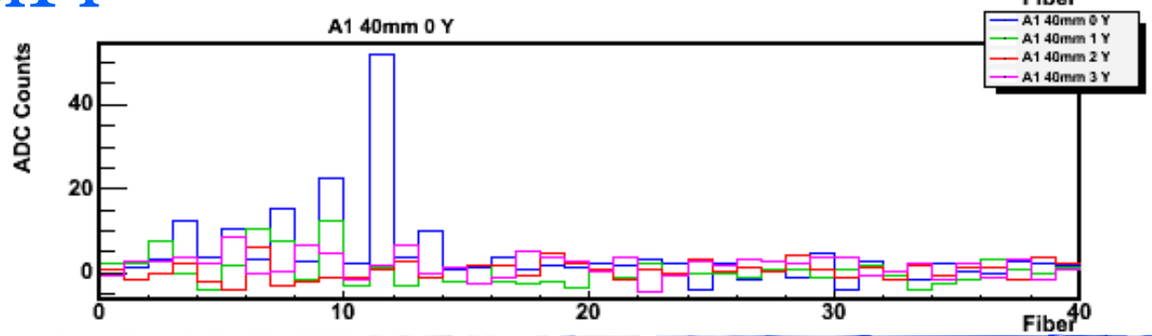






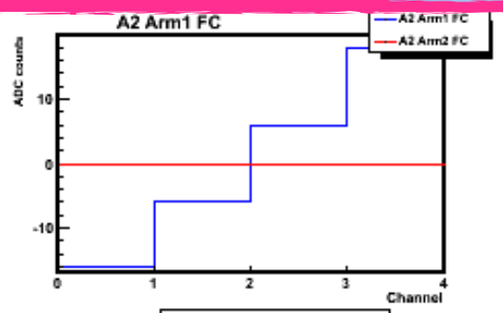
SciFi

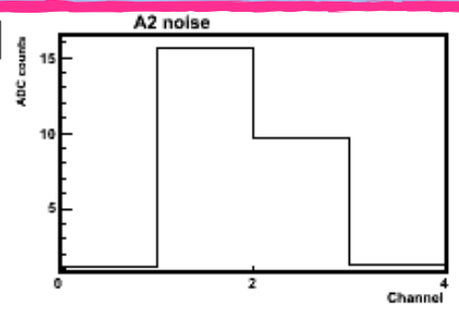


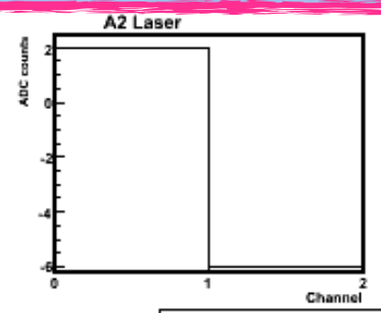


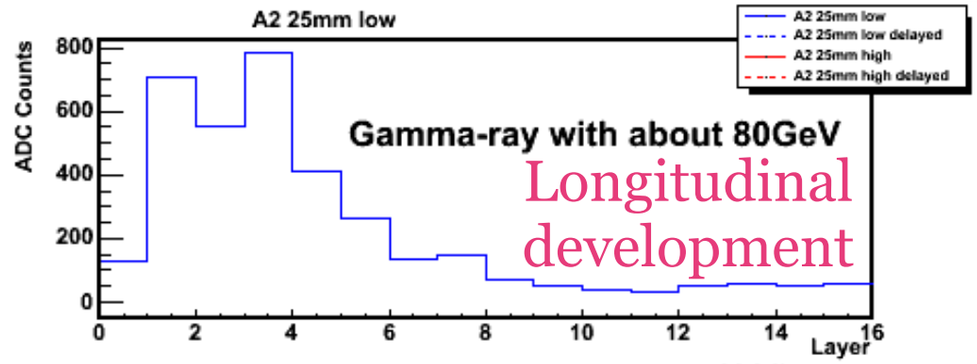
ARM2: γ event at 900 GeV

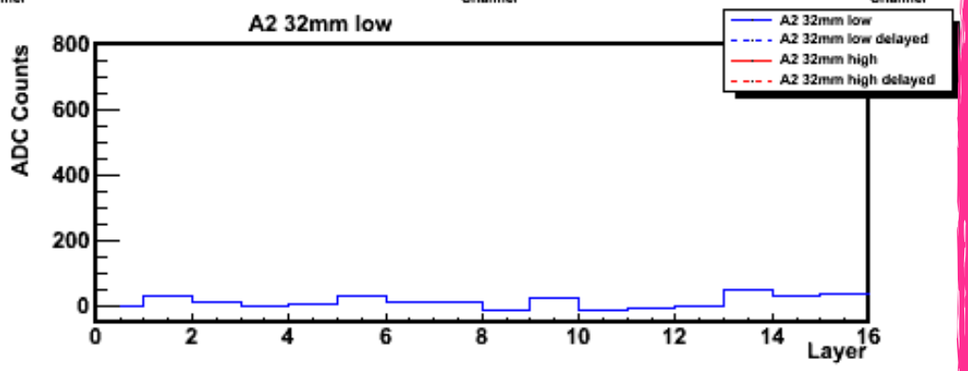
RUN: 2342
NUMBER: 506
GNUMBER: 1154
TIME: 1260085179
FLAG0: 00009557
FLAG1: 000009ff
FLAG2: 00a02371

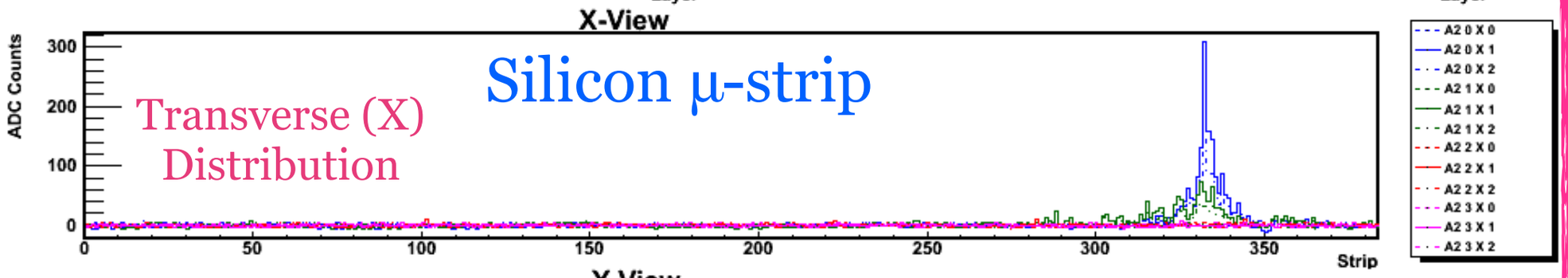


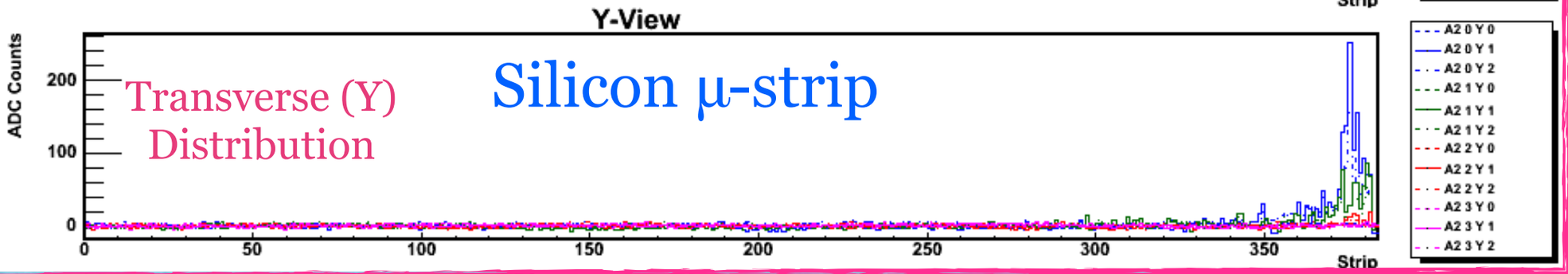






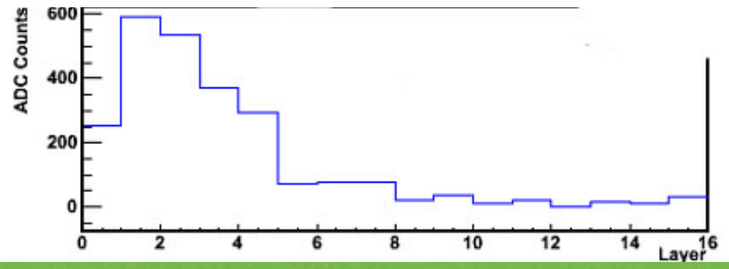






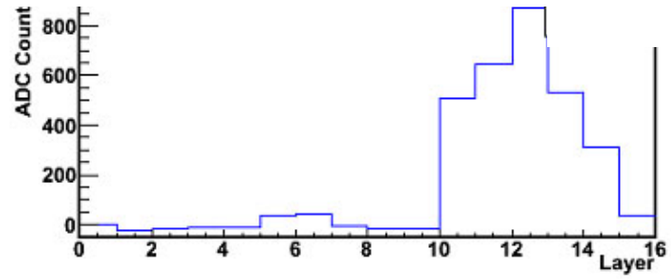
Particle Identification

Longitudinal development of γ shower

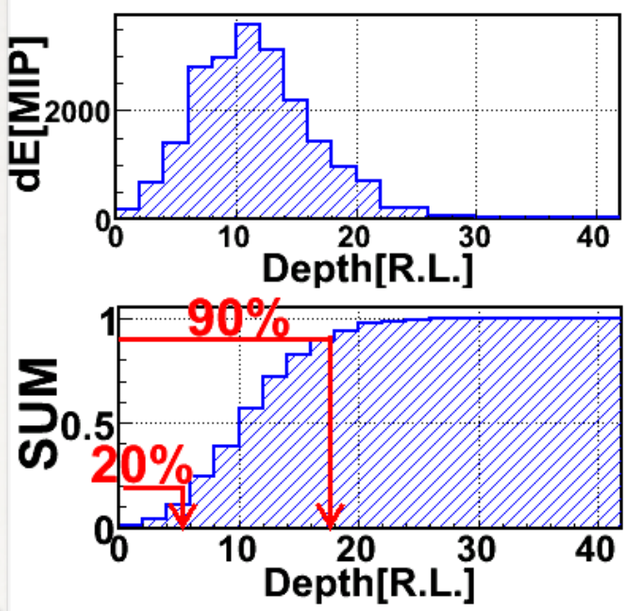


Thick for E.M. interaction ($44X_0$)

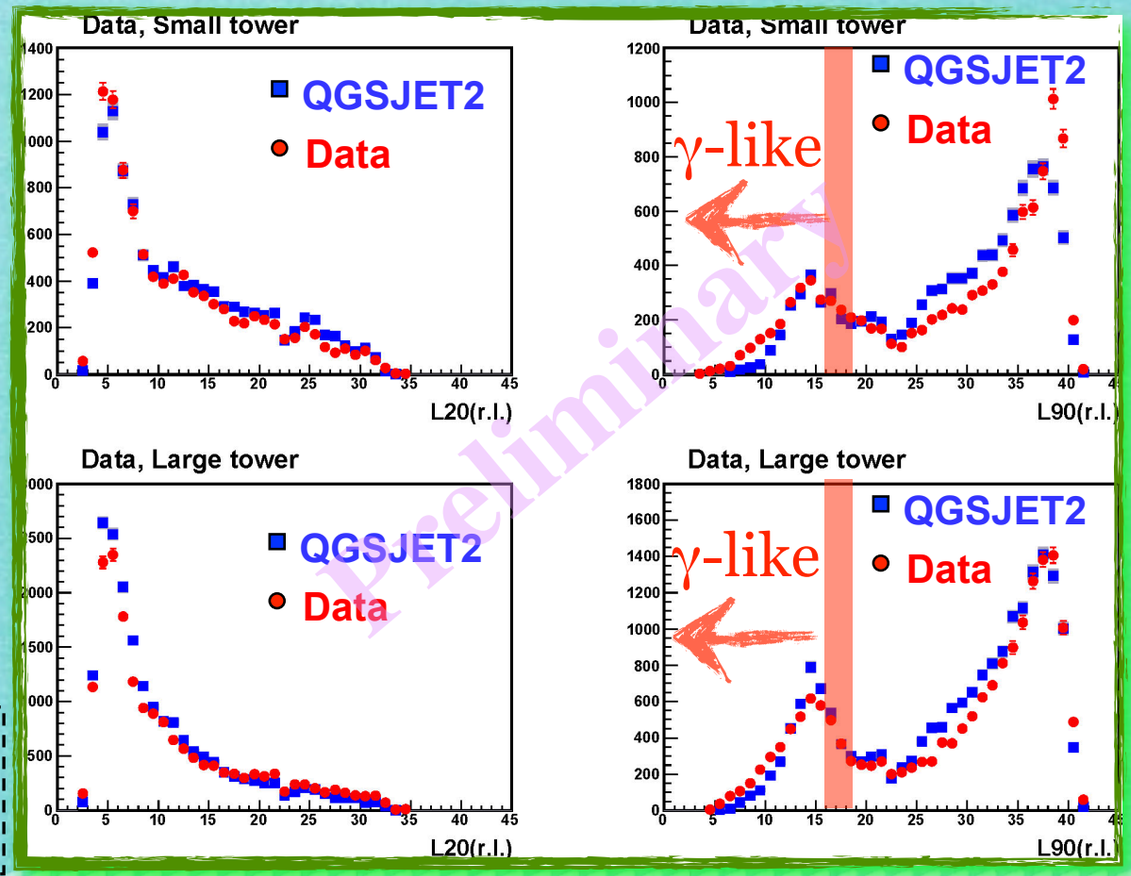
Longitudinal development of Hadron shower



Thin for hadronic interaction(1.7λ)



Criteria
for gamma-rays
16 r.l. + 0.002 x ΣdE



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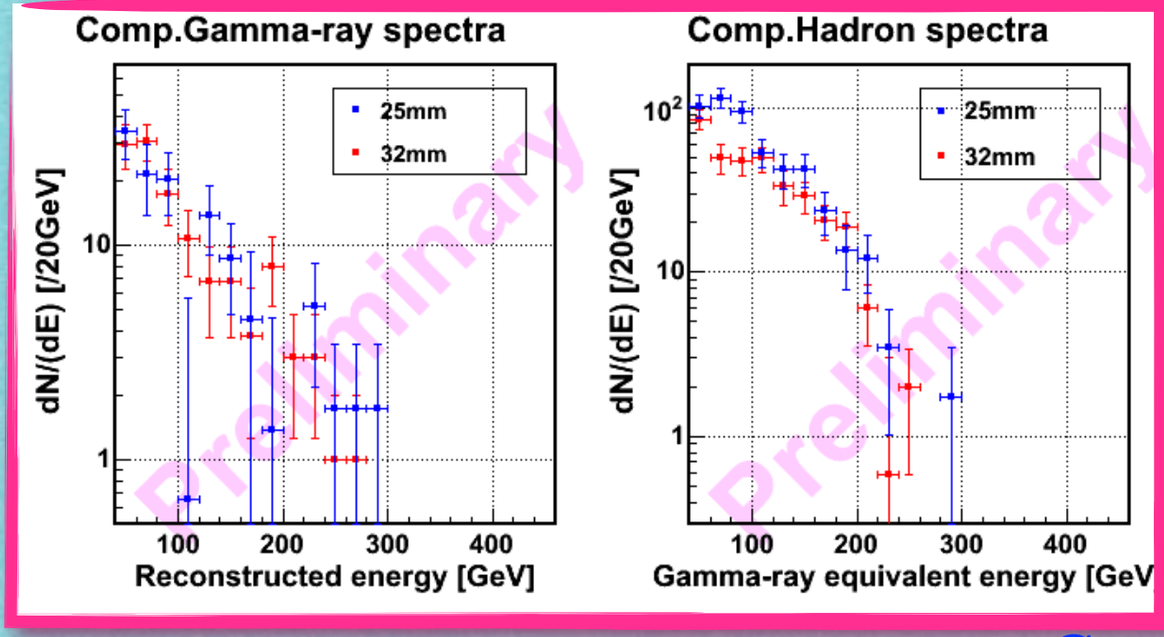
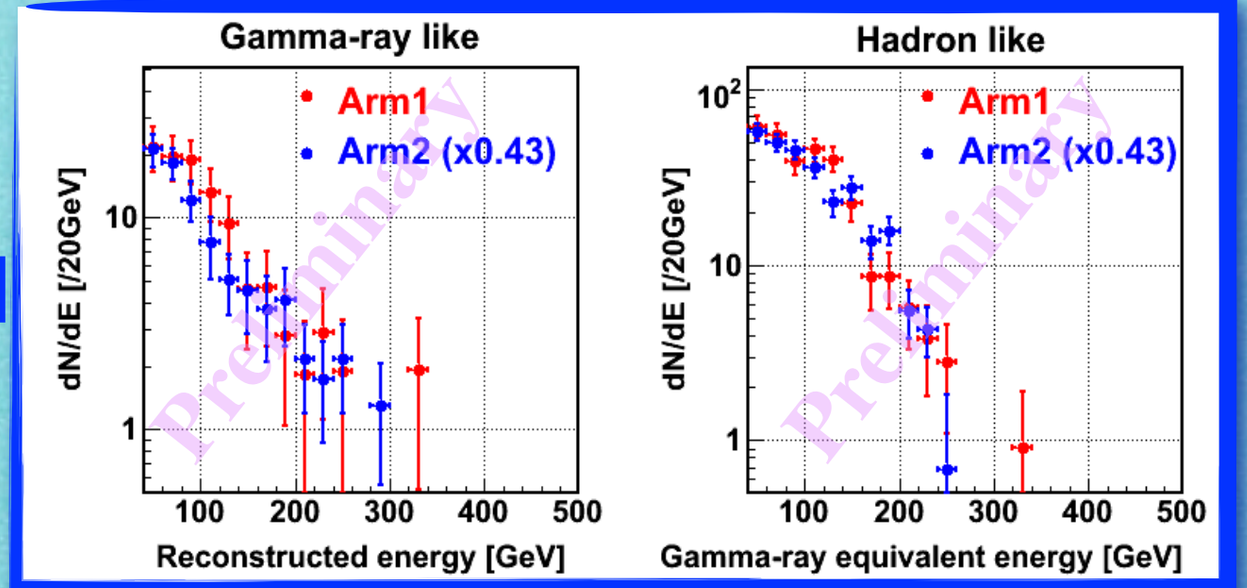
900 GeV analysis: consistency check

Comparison between ARM2 towers



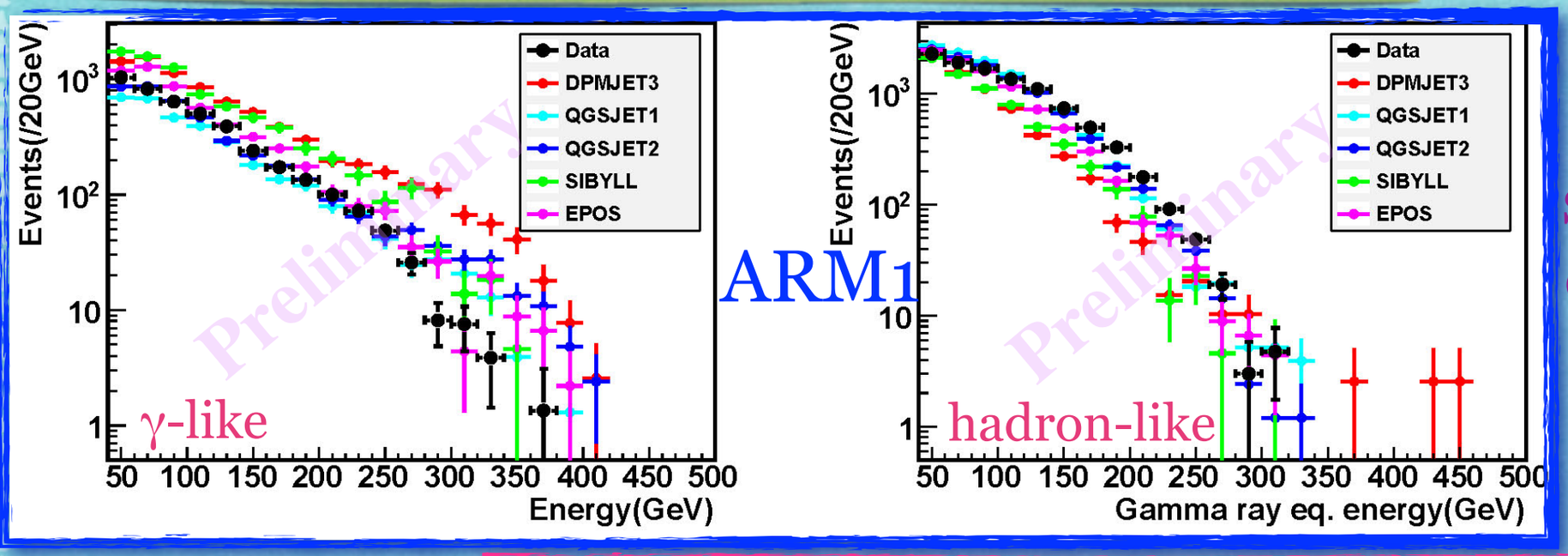
No angular dependance

Comparison between two ARMs



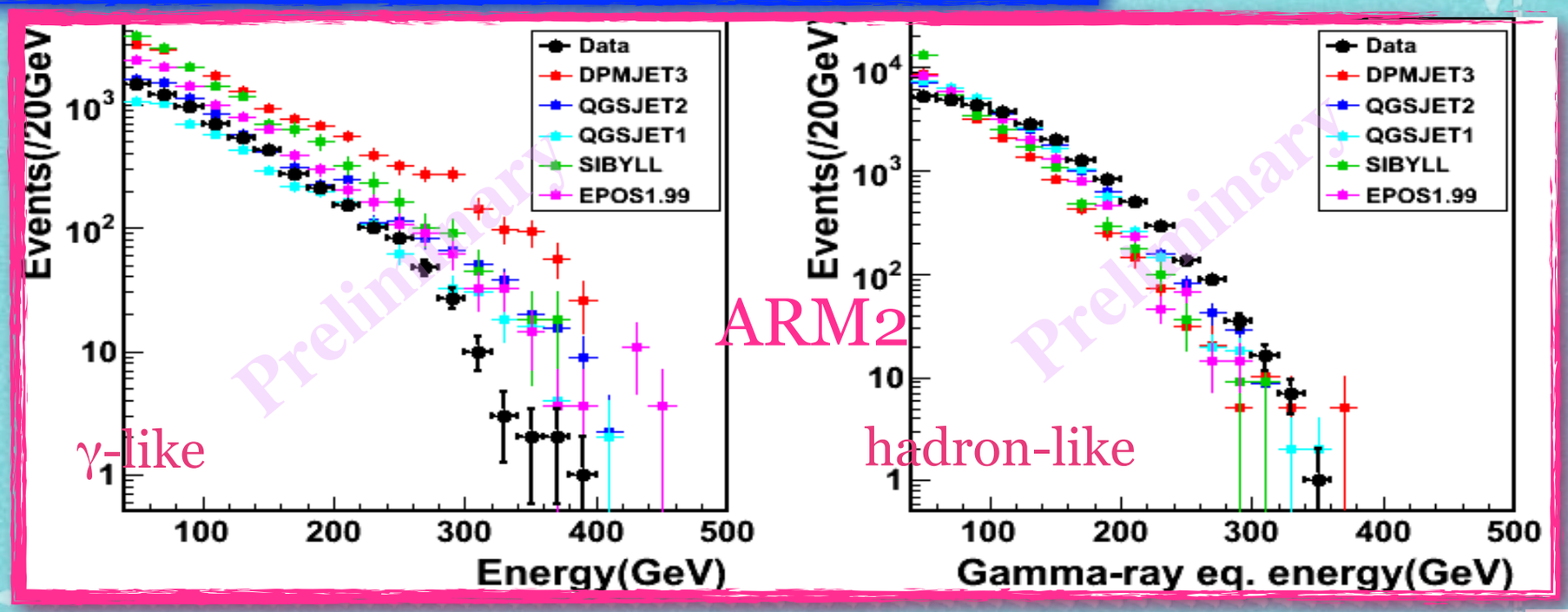
ARM1 vs ARM2
Spectra consistent

LHCf spectra at 900 GeV



Enough sensitivity to discriminate between models!!!

Statistical error only

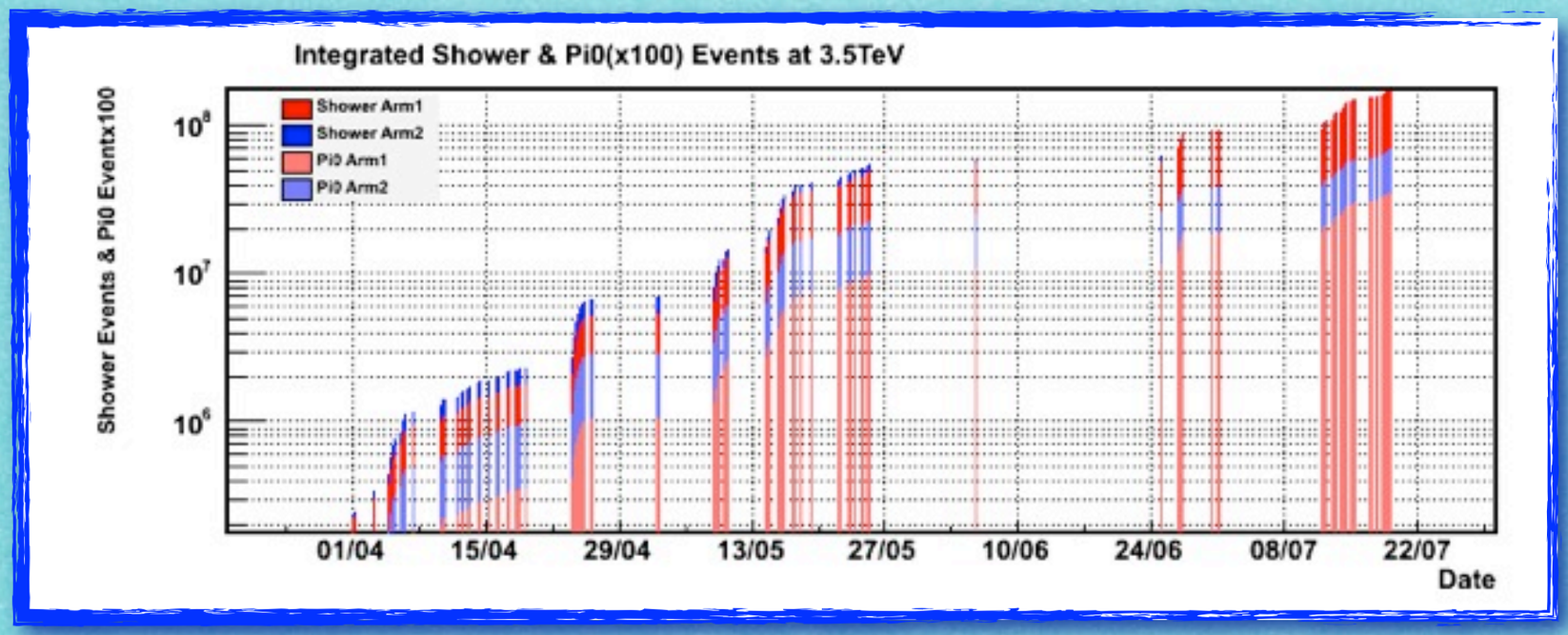


MC normalised to the total number of events in the 2 towers,without PID. Only one normalisation factor common to all models

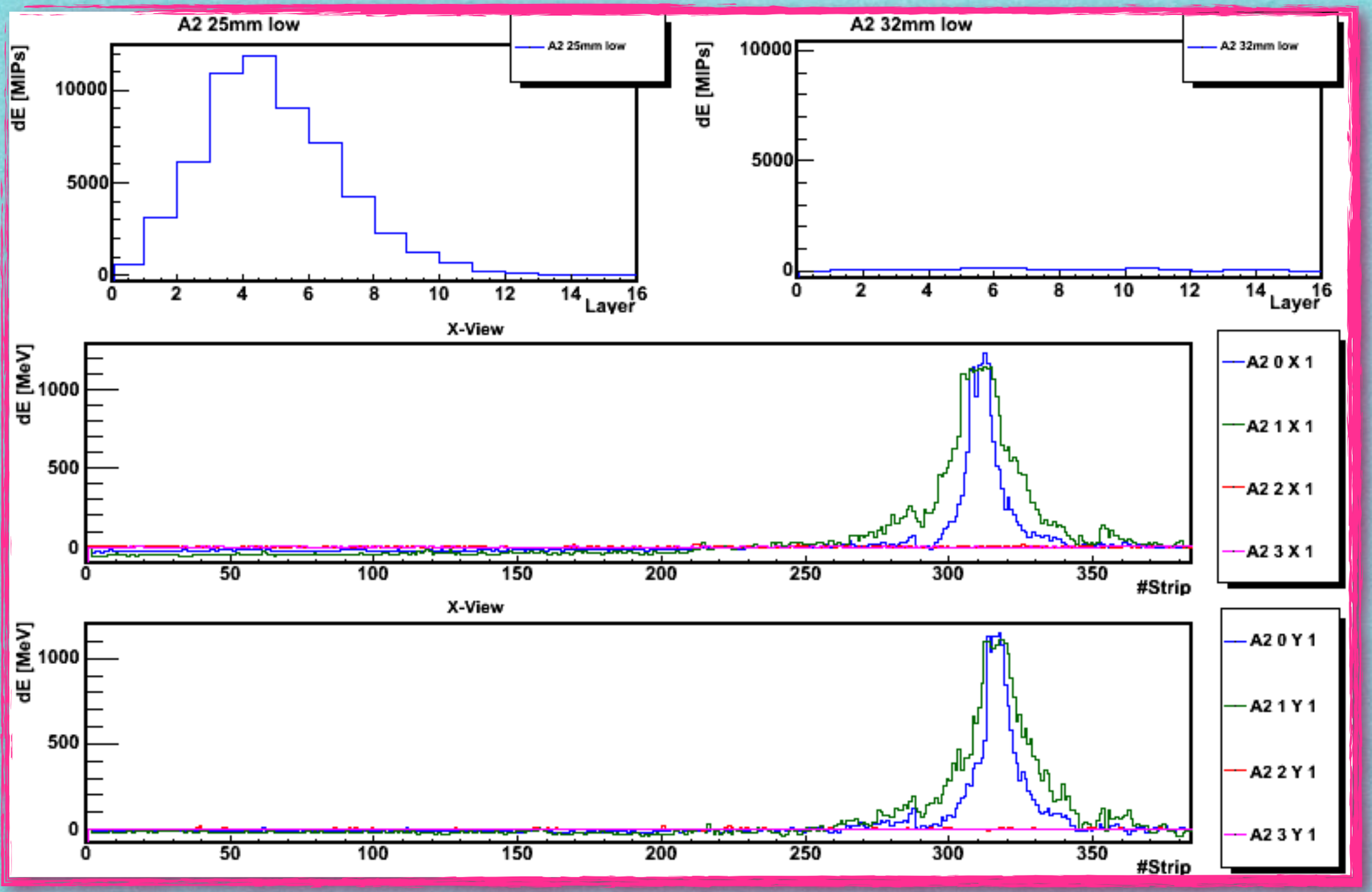
LHCf operation @ 7 TeV

From 30/3 till 19/7 we took data with and without 100 μrad crossing angle for different vertical detector positions

	Shower	Gamma	Hadron	π^0
Arm1	172,263,255	56,846,874	111,971,115	344,526
Arm2	160,587,306	52,993,810	104,381,748	676,157



Impressive TeV Showers



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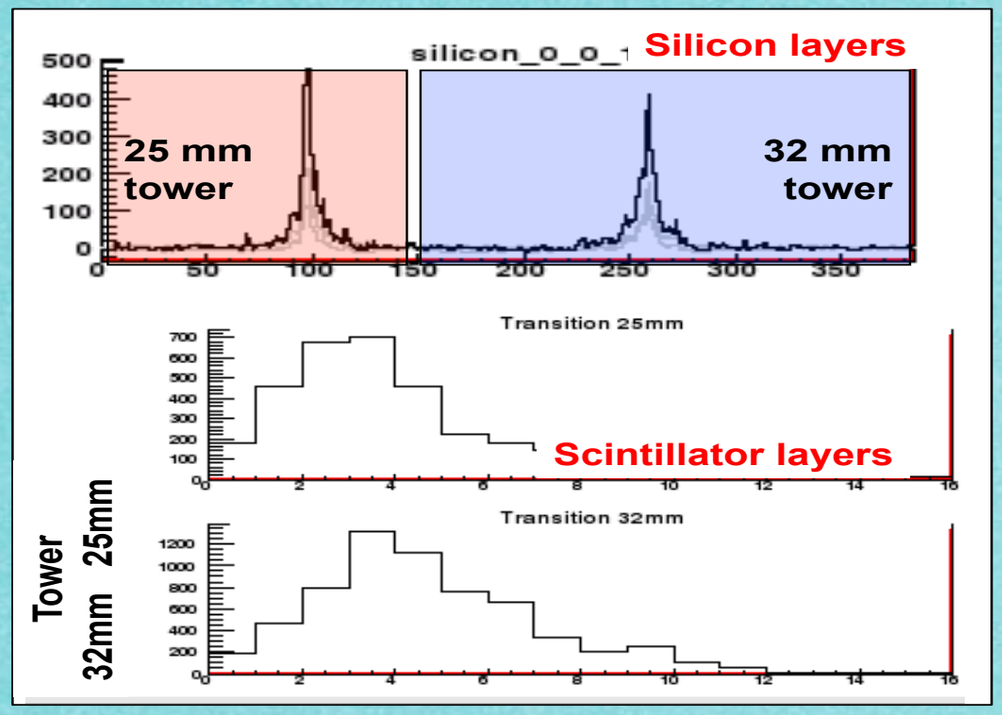
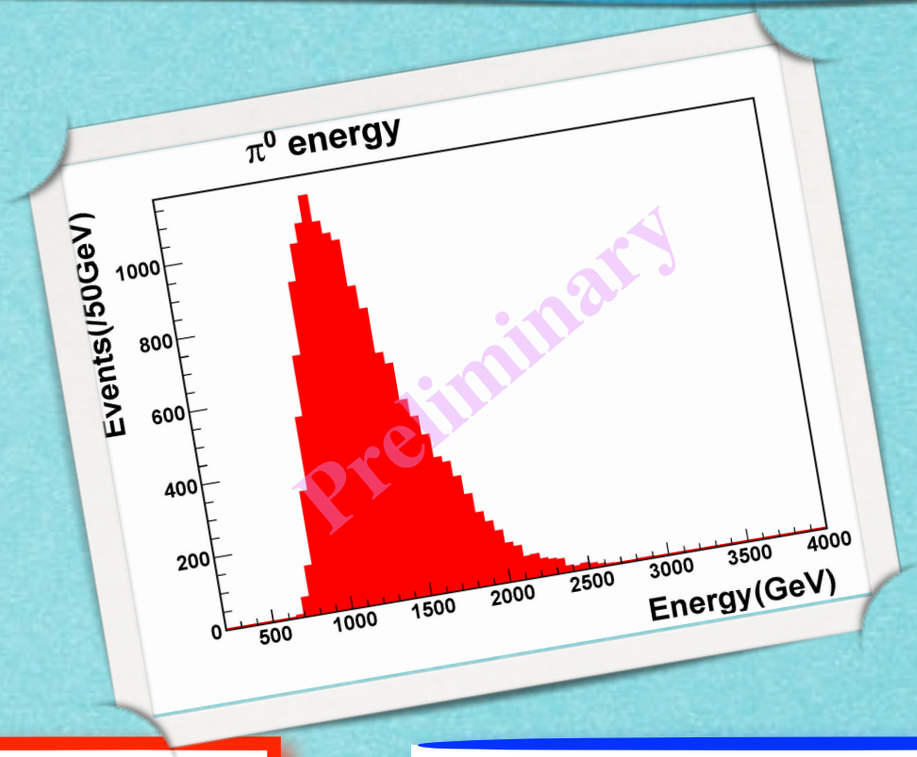
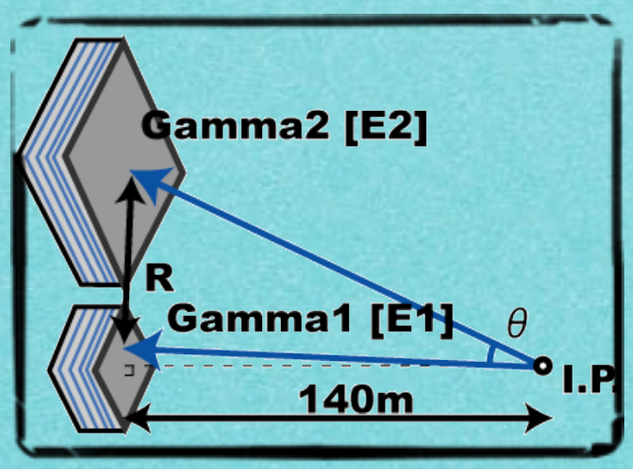
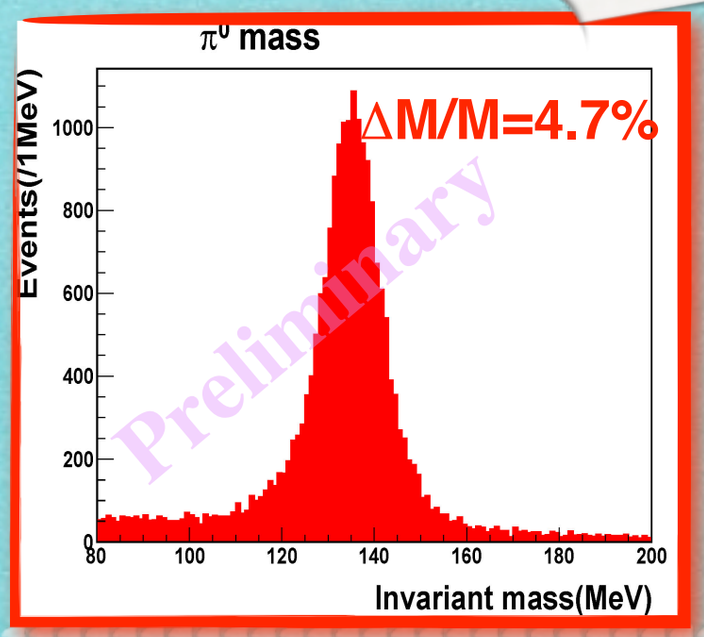
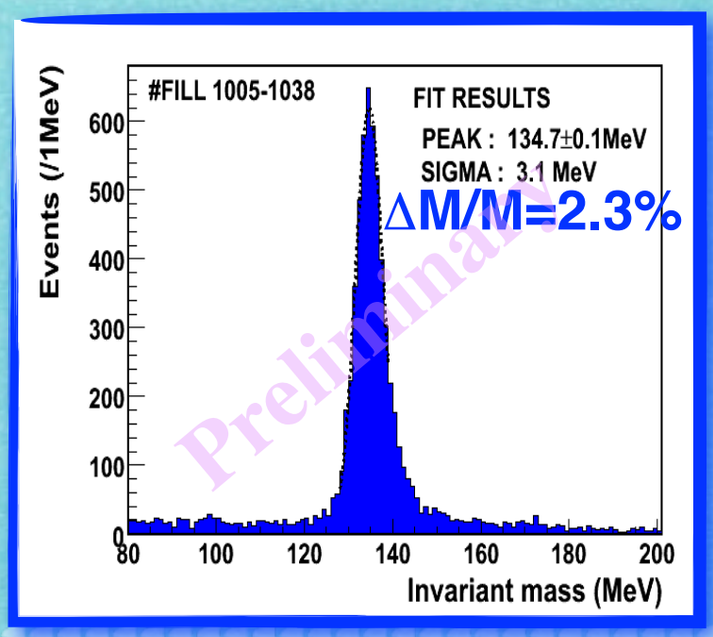
π^0 reconstruction:
the mandatory tool for energy scale calibration











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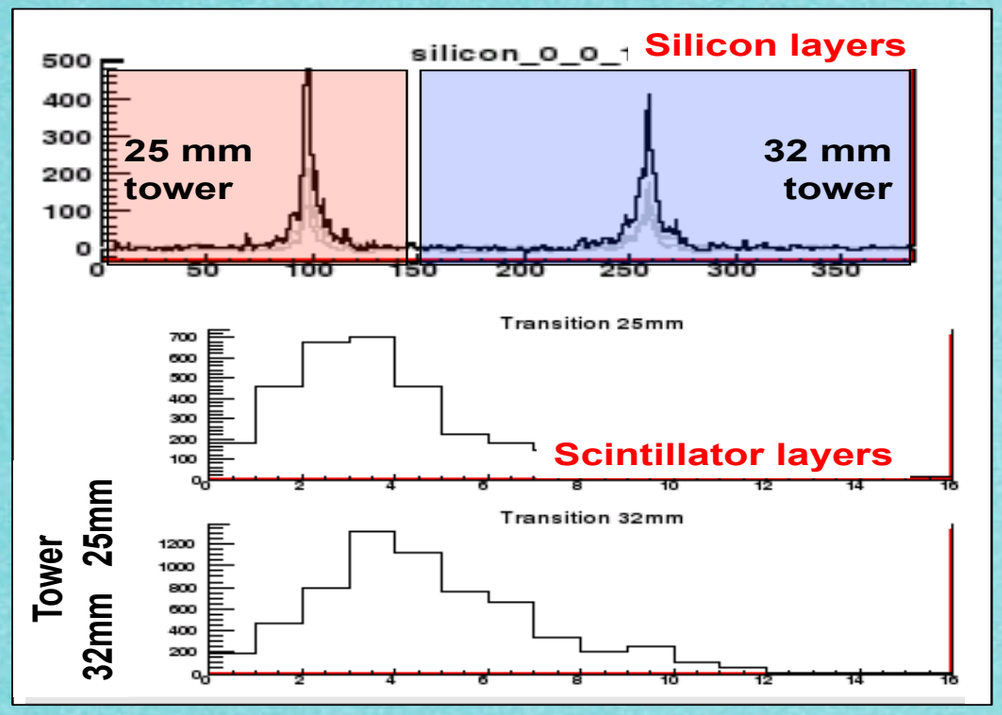
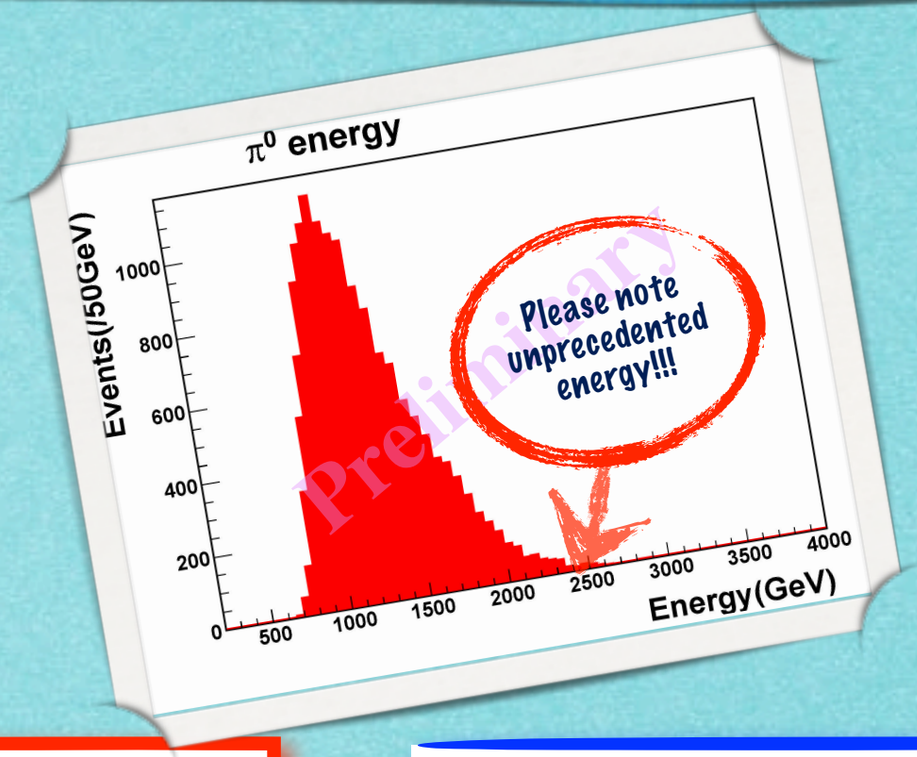
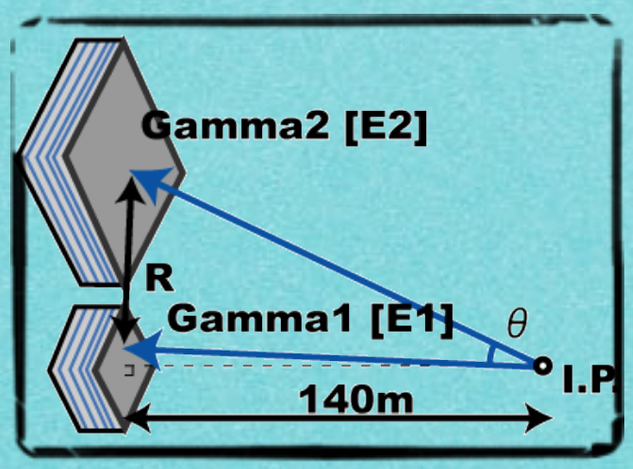
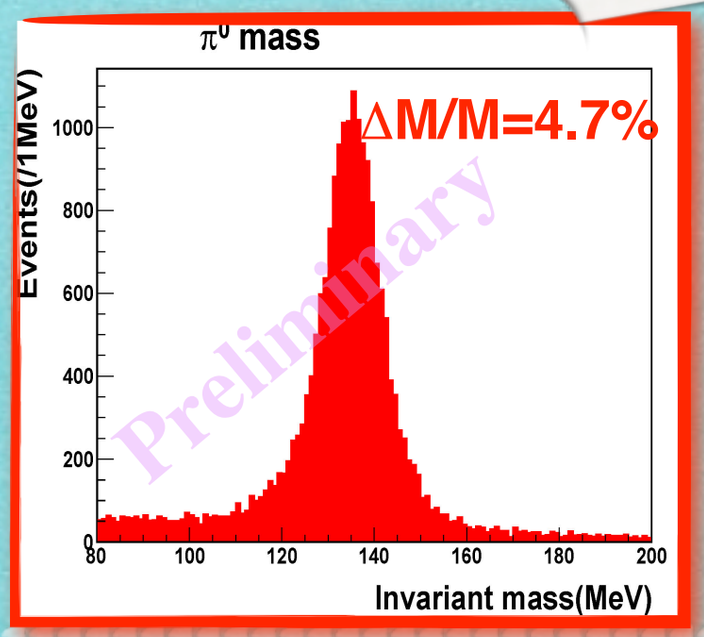
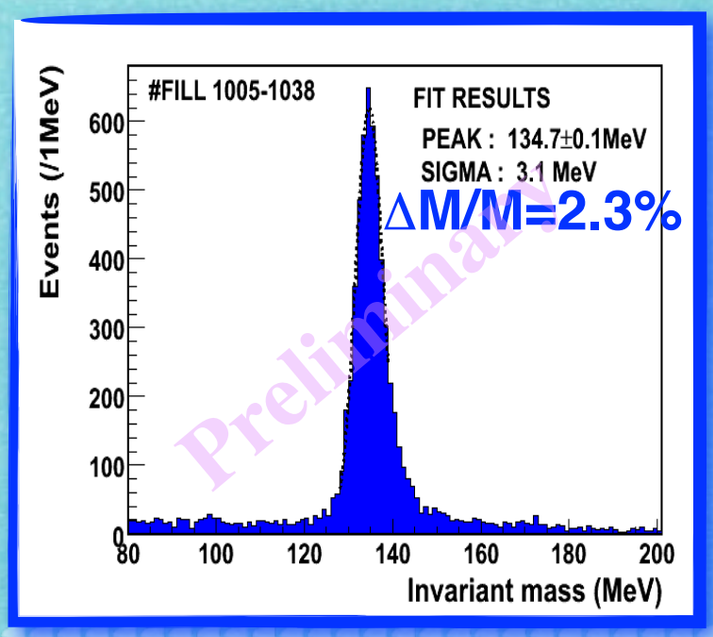
π^0 reconstruction:
the mandatory tool for energy scale calibration











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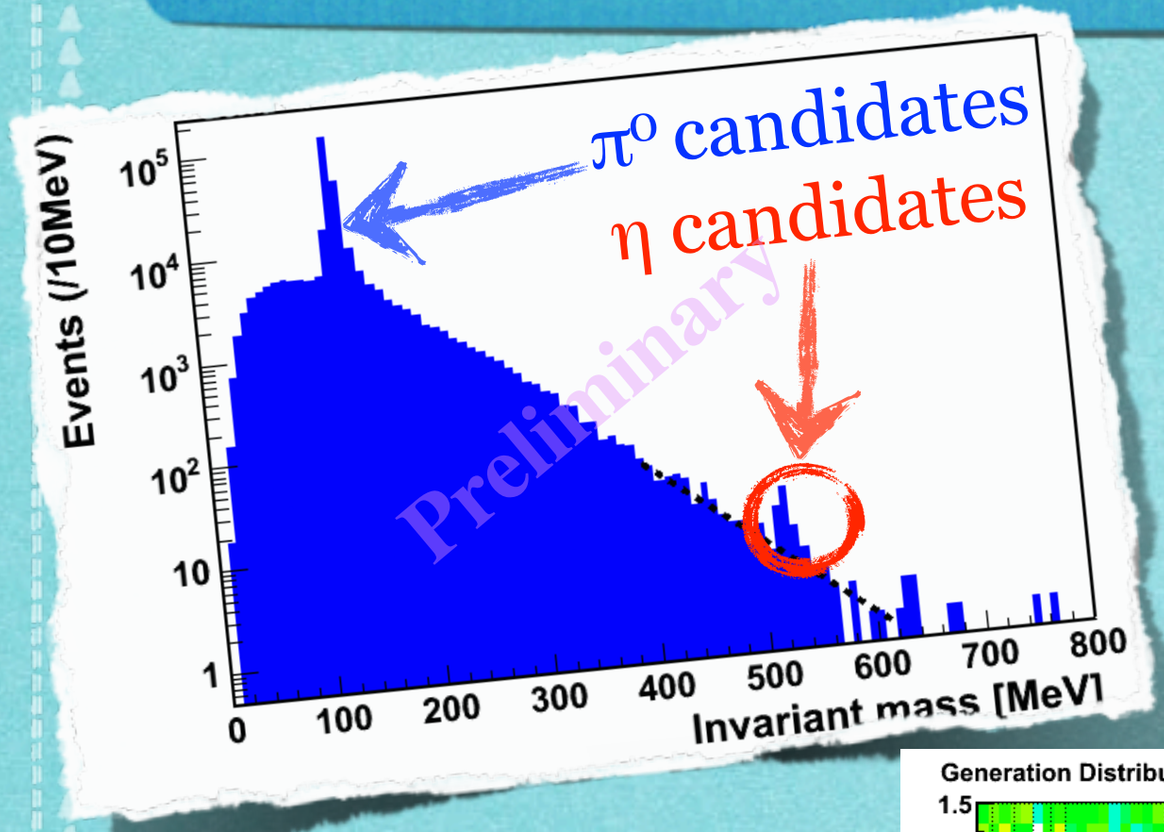
Early Physics with the LHCf experiment at LHC
ICHEP 2010, July 22-28, 2010, Paris

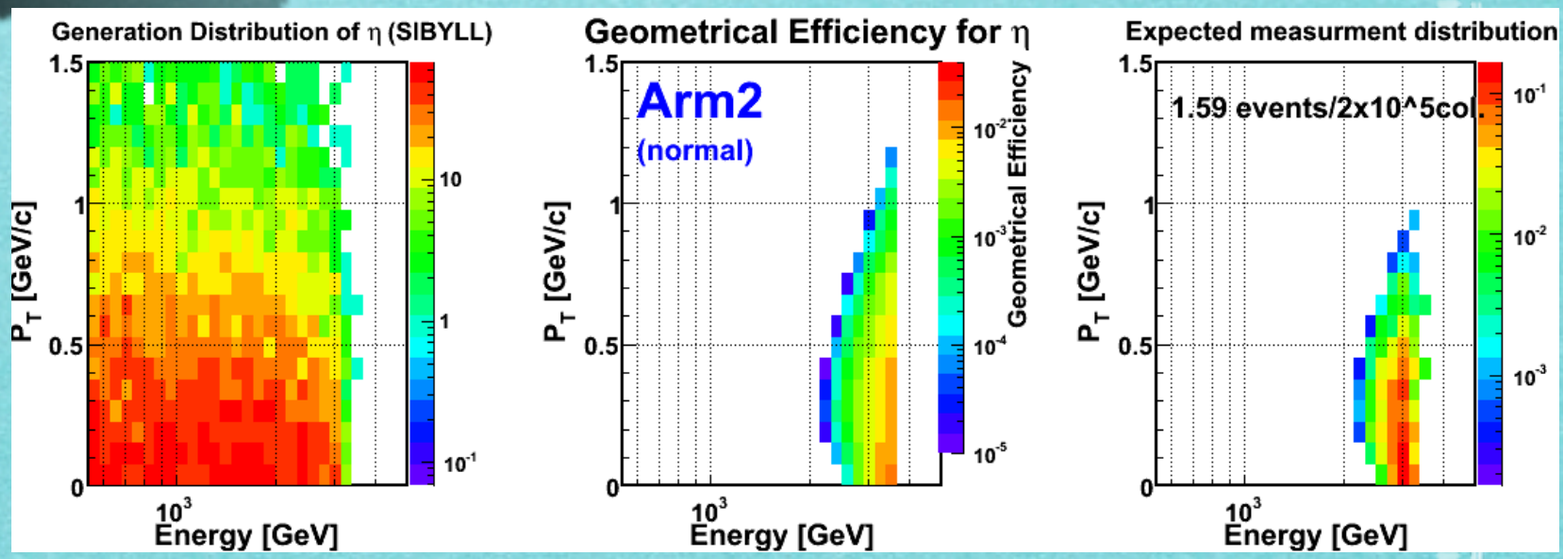
η reconstruction:
an additional tool for calibration and model discrimination



	QGSJET2			SIBYLL			DPMJET3			Pythia		
	η	π^0	η/π^0	η	π^0	η/π^0	η	π^0	η/π^0	η	π^0	η/π^0
Arm1 (Normal)	0.08	46.9	0.002	0.01	46.7	0.0002	0.01	75.5	0.0001			
Arm1 (-20mm)	7.35	238.4	0.031	0.21	191.9	0.0011	1.05	310.7	0.0034			
Arm2 (Normal)	1.6	123.7	0.012	0.10	110.8	0.0009	0.24	177.5	0.0014	0.15	150	0.0010
Arm2 (-10mm)	3.36	191.3	0.018	0.21	165.1	0.0013	0.47	268.5	0.0016	0.1	169	0.00059

- ✓ η/π^0 ratio or η production spectra vary a lot among different interaction models. A good handle to probe the models
- ✓ Another calibration point for more robust energy scale

Typical $\eta/\pi^0 = 10^{-3} \sim 10^{-4}$ at 7TeV.



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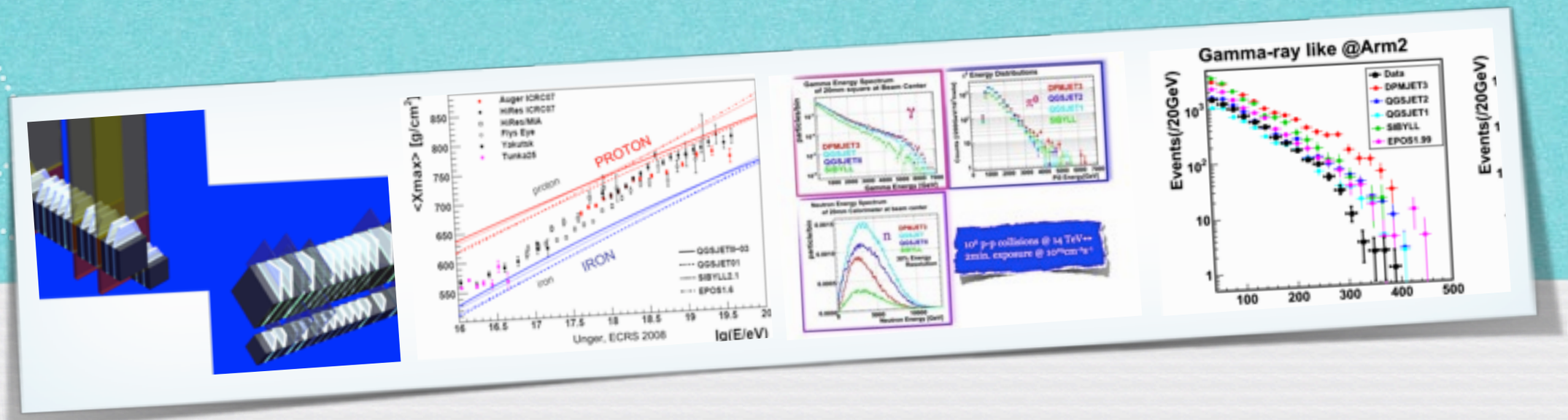
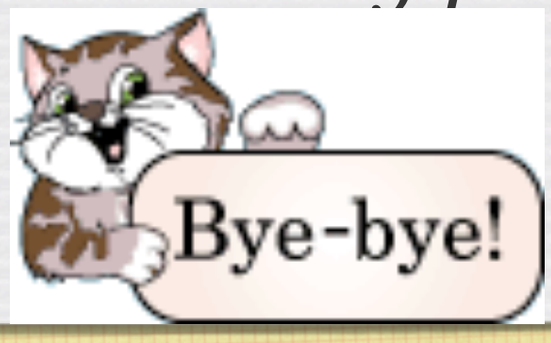
Summary

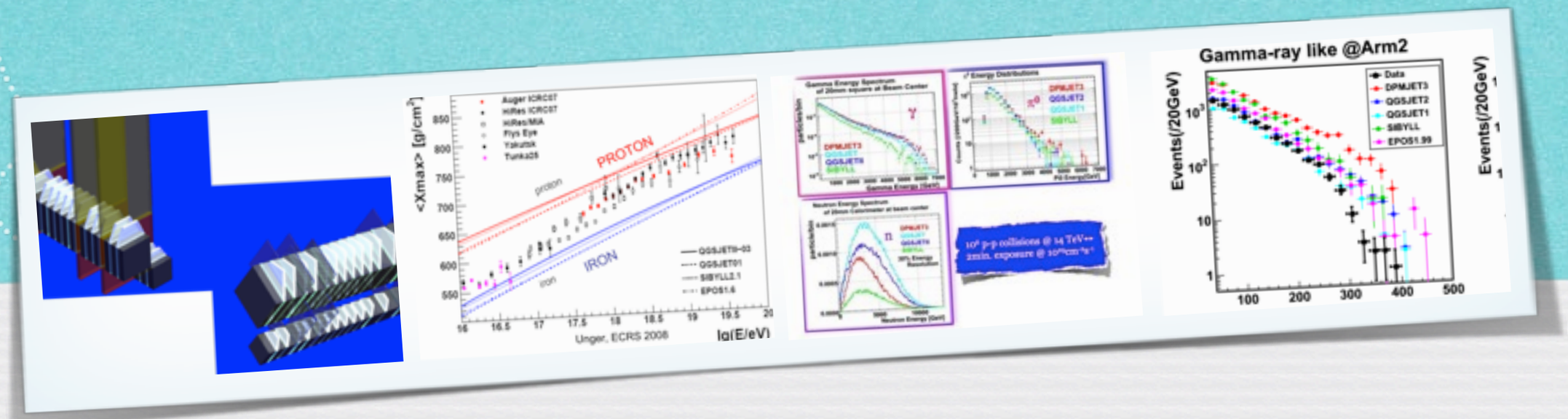
- LHCf is a dedicated astroparticle experiment to measure neutral particle produced in the very forward region at LHC
- LHCf successfully completed data taking at 900 GeV and 7 TeV. The detector has been removed from the TAN on July 20
- 900 GeV analysis is almost final and ready to be submitted for publication while 7 TeV analysis is progressing quickly
- The detector will be upgraded during 2011 to improve radiation hardness
- LHCf will provide crucial calibration of hadron interaction for CR study with the actual and forthcoming data



We wish to thanks all the people who contributed to this successful first data taking period and say…



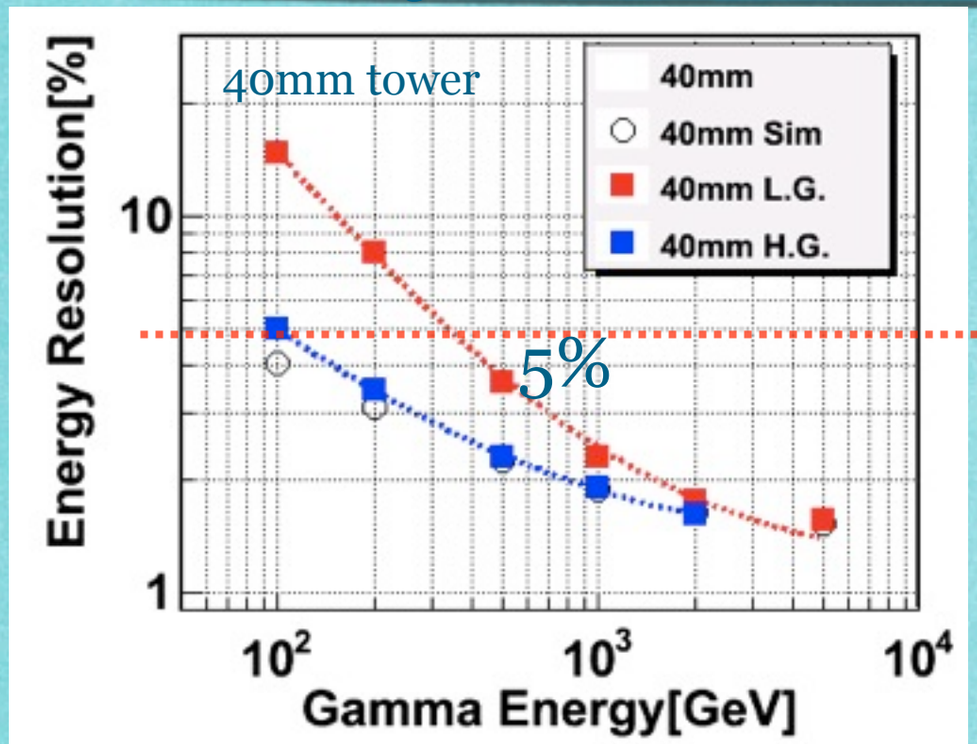
Looking forward to come back very soon for 14 TeV data taking!!!

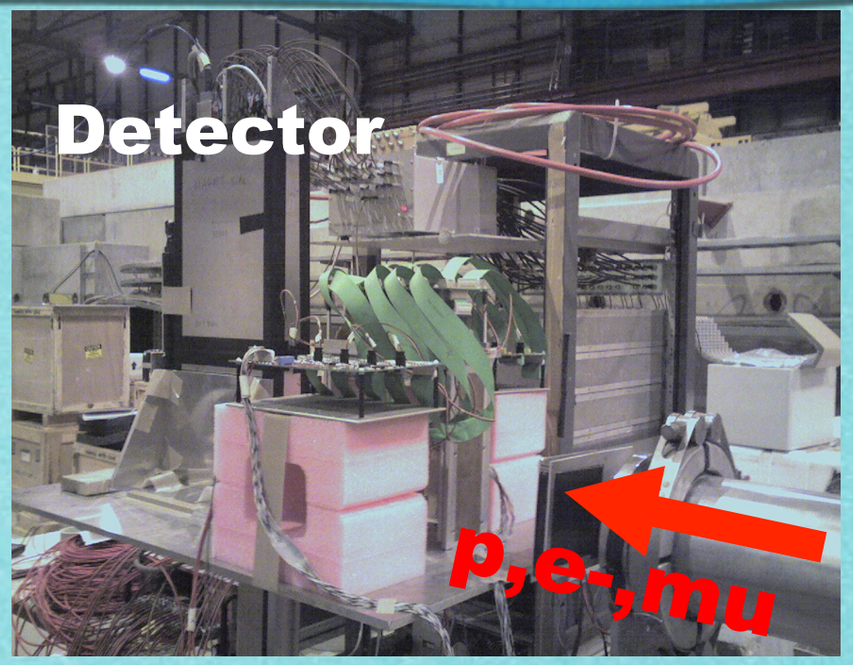


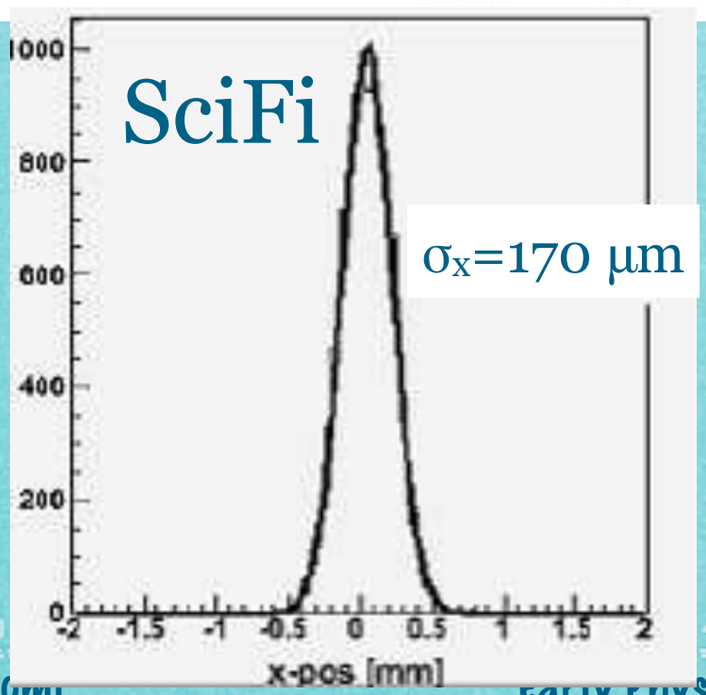
LHCf Backup

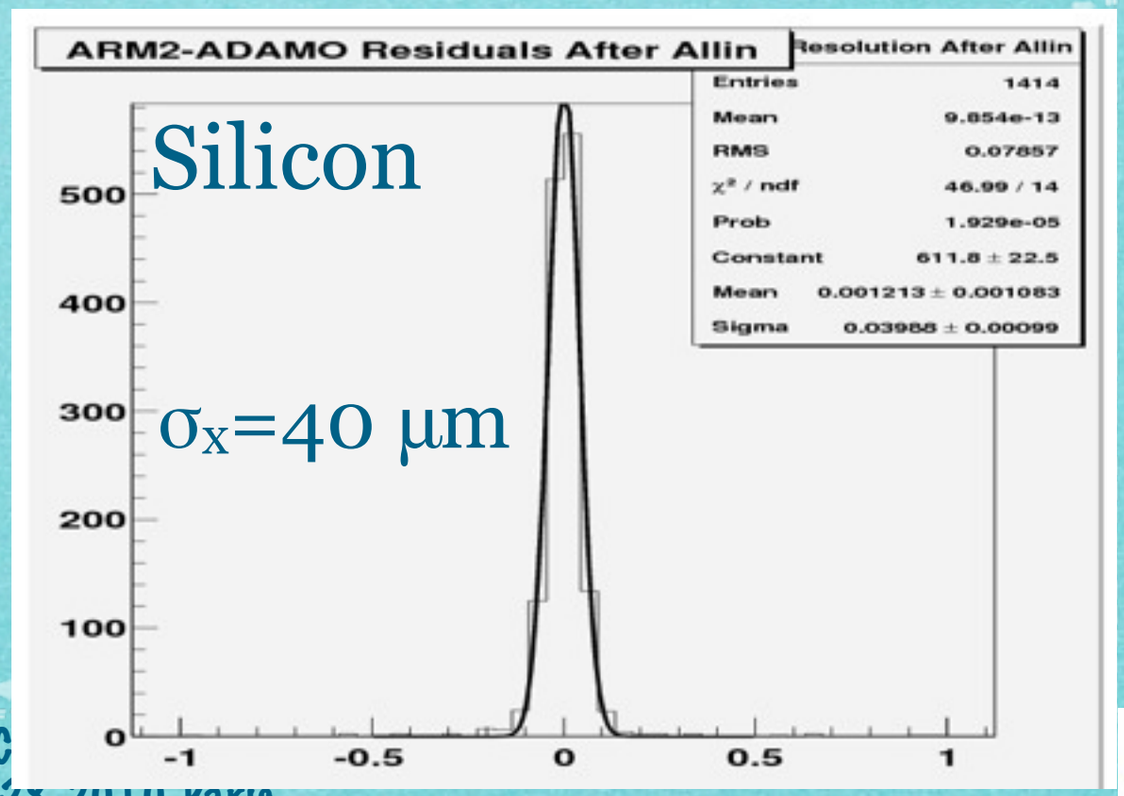
Some additional infos...

Physics Performances: Energy and position resolution for γ





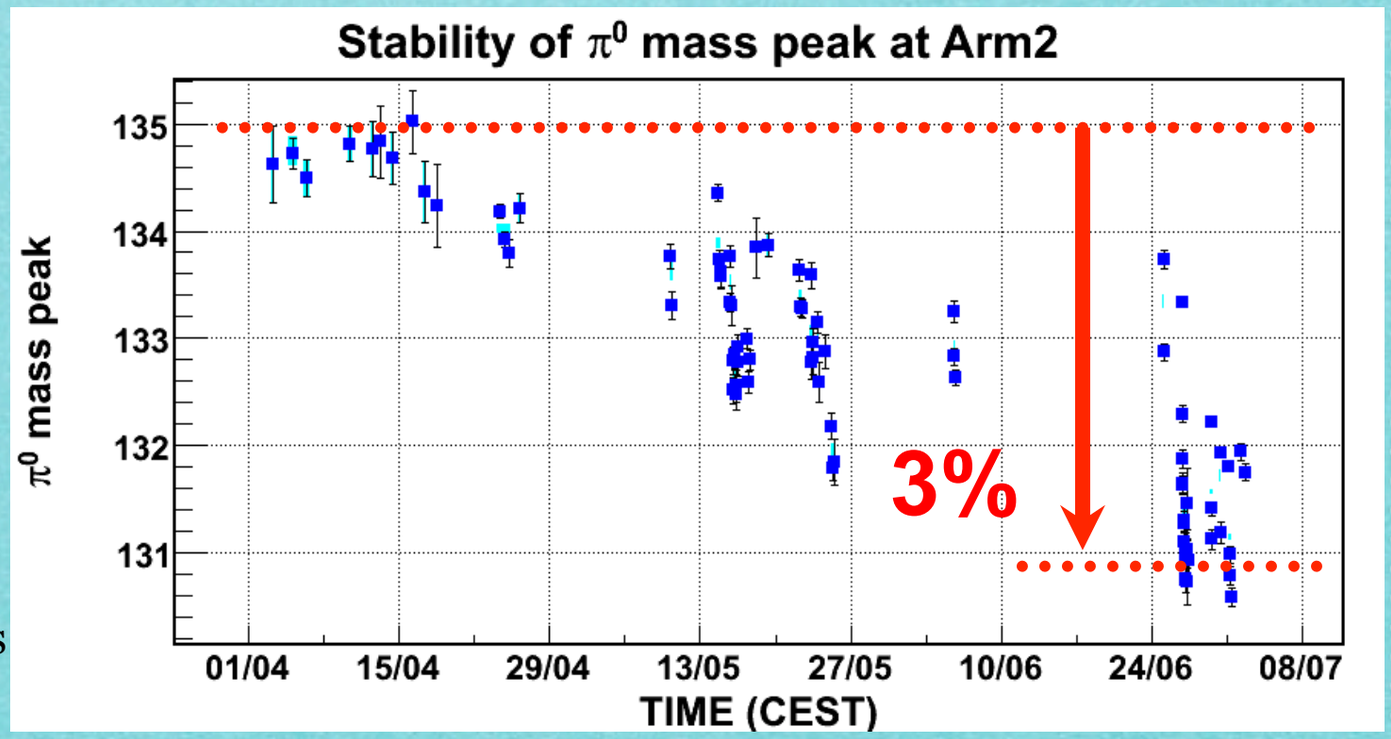




Radiation Damage

- Light yield of plastic scintillators inserted in calorimeters is decreasing due to the radiation damage, in agreement with what we expect from our irradiation measurements
- We are monitoring light yield by nitrogen laser and πo invariant mass.

Slow recovery of
light yield with time
When irradiation stops
(Annealing effect)



Integrated dose

In agreement with our expectations for the Integrated Luminosity

Radiation Damage studies