The first result of the CERN LHCf experiment

K.Kasahara

for the LHCf collaboration.

Waseda Univ.

★ For details: P.L to be published

TeVPA @Stockholm: Aug.1, 2011

Purpose of LHCf (=LHC forward experiment)

- ★ To select better nuclear interaction models

or

- ★ To afford basic information for constructing a better nuclear interaction model

by observing forward energetic neutral particles at LHC for cosmic-ray physics

Excerpt from CERN Courie/Bulletin 2006

LHCf: a tiny new experiment joins the LHC
While most of the LHC experiments are on a grand scale, LHC forward(LHCf) is quite different. Unlike the massive detectors that are used by ATLAS or CMS, LHCf's largest detector is a mere 30 cm.

Most of the LCHf collaborators in one photo!

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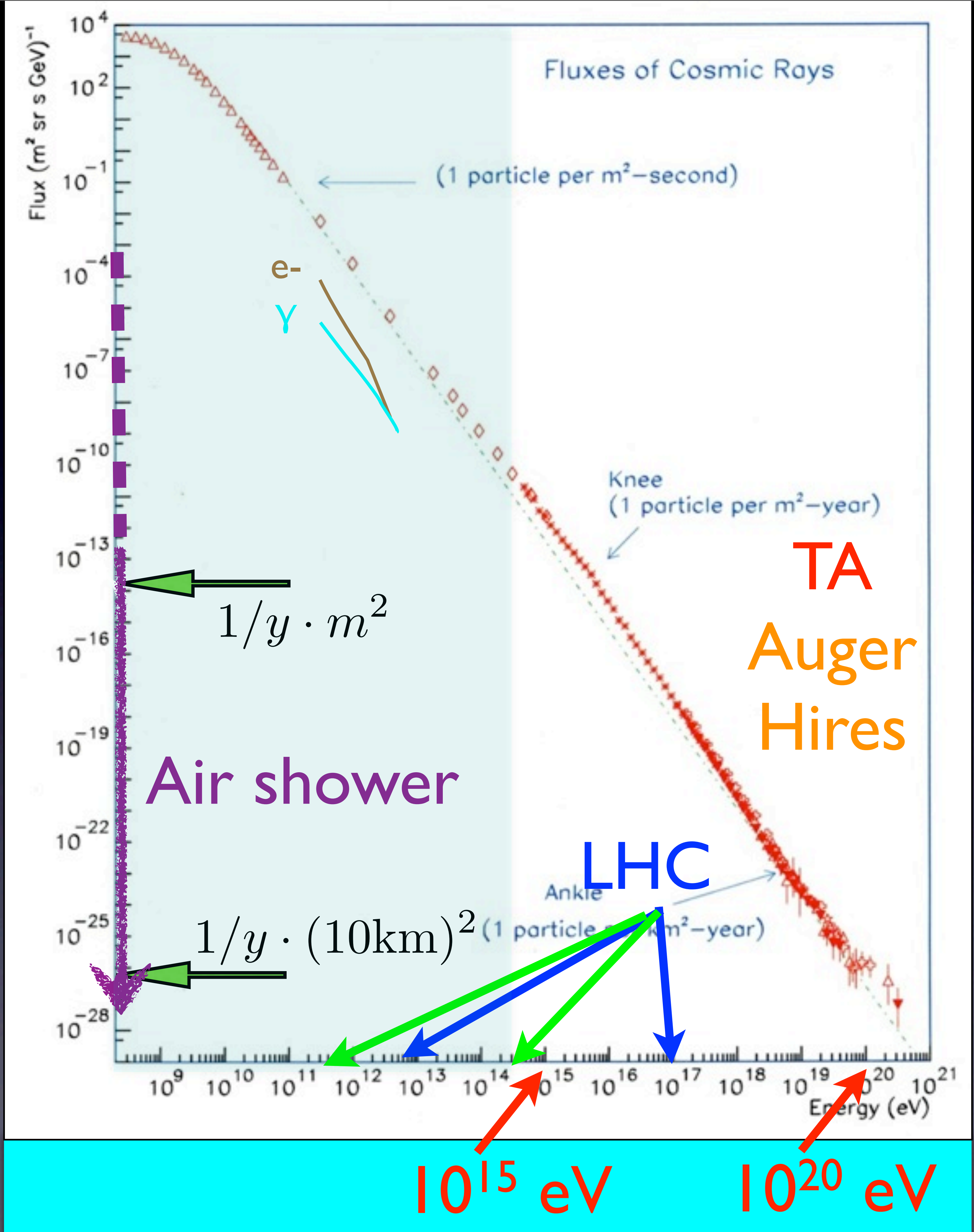
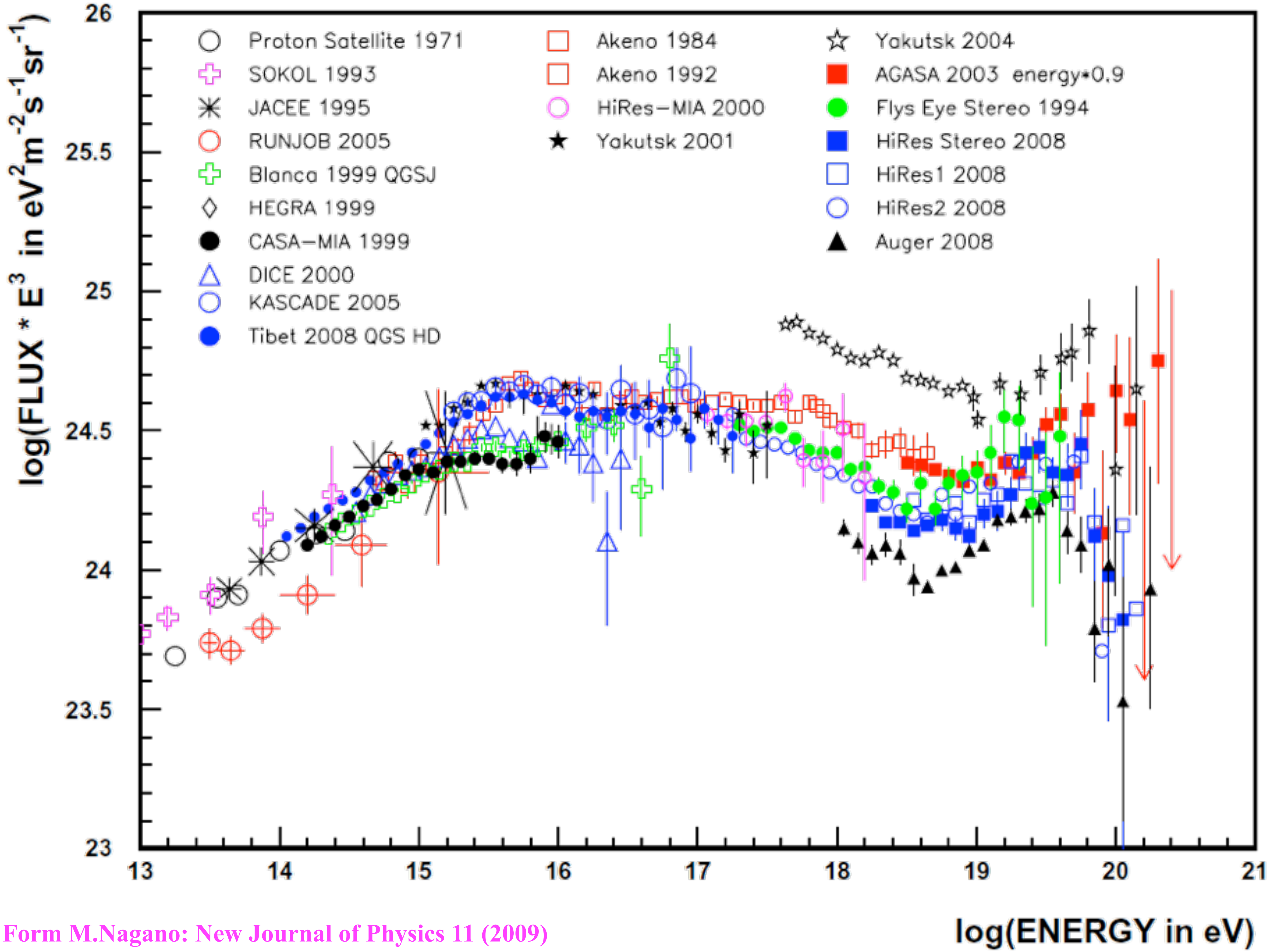
Motivation

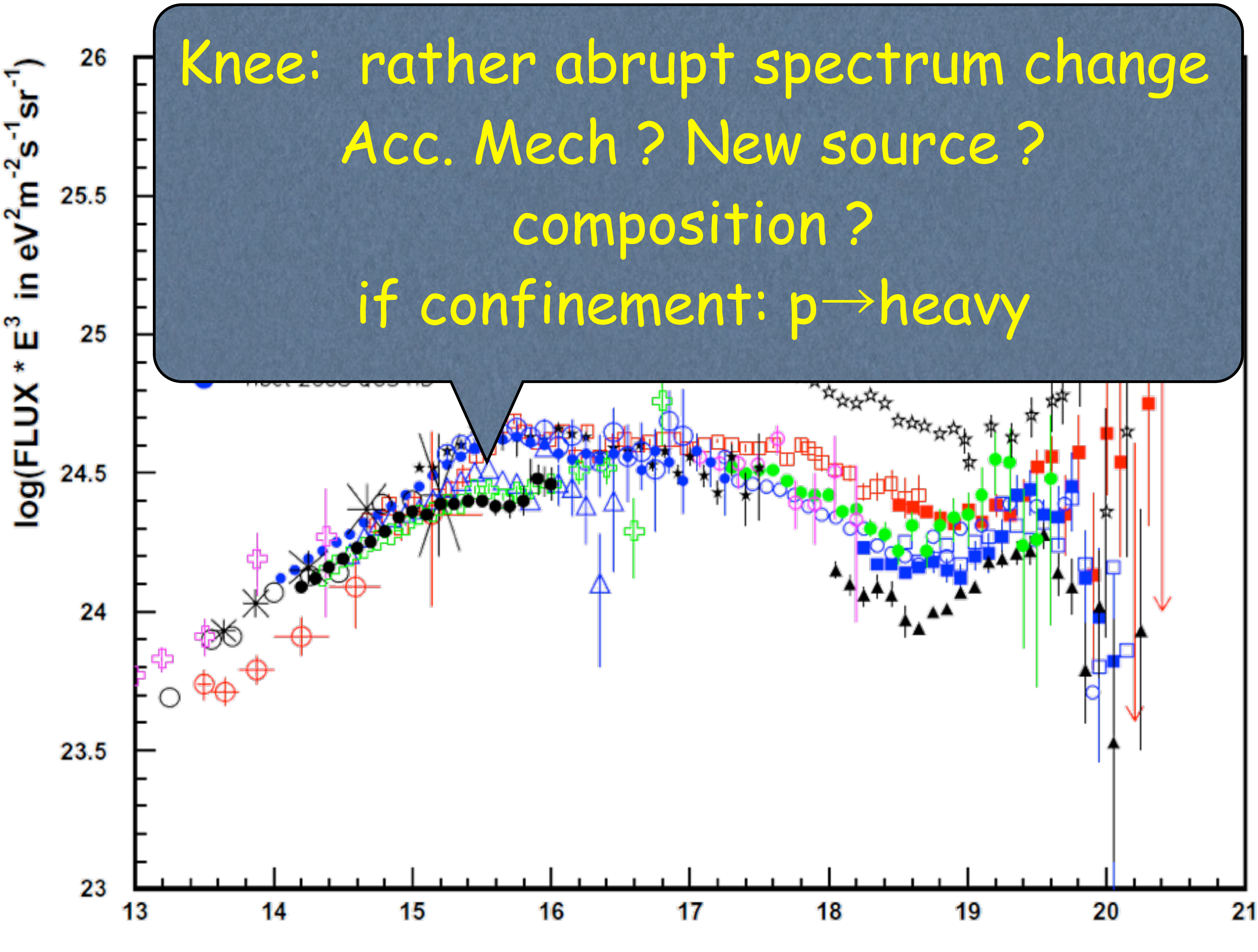
Cosmic-Ray Energy Spectrum

- < *10^{14}eV:accel.SNR
- near-by e- source?
- dark mater ?
- B/C ratio ...





Form M.Nagano: New Journal of Physics 11 (2009)

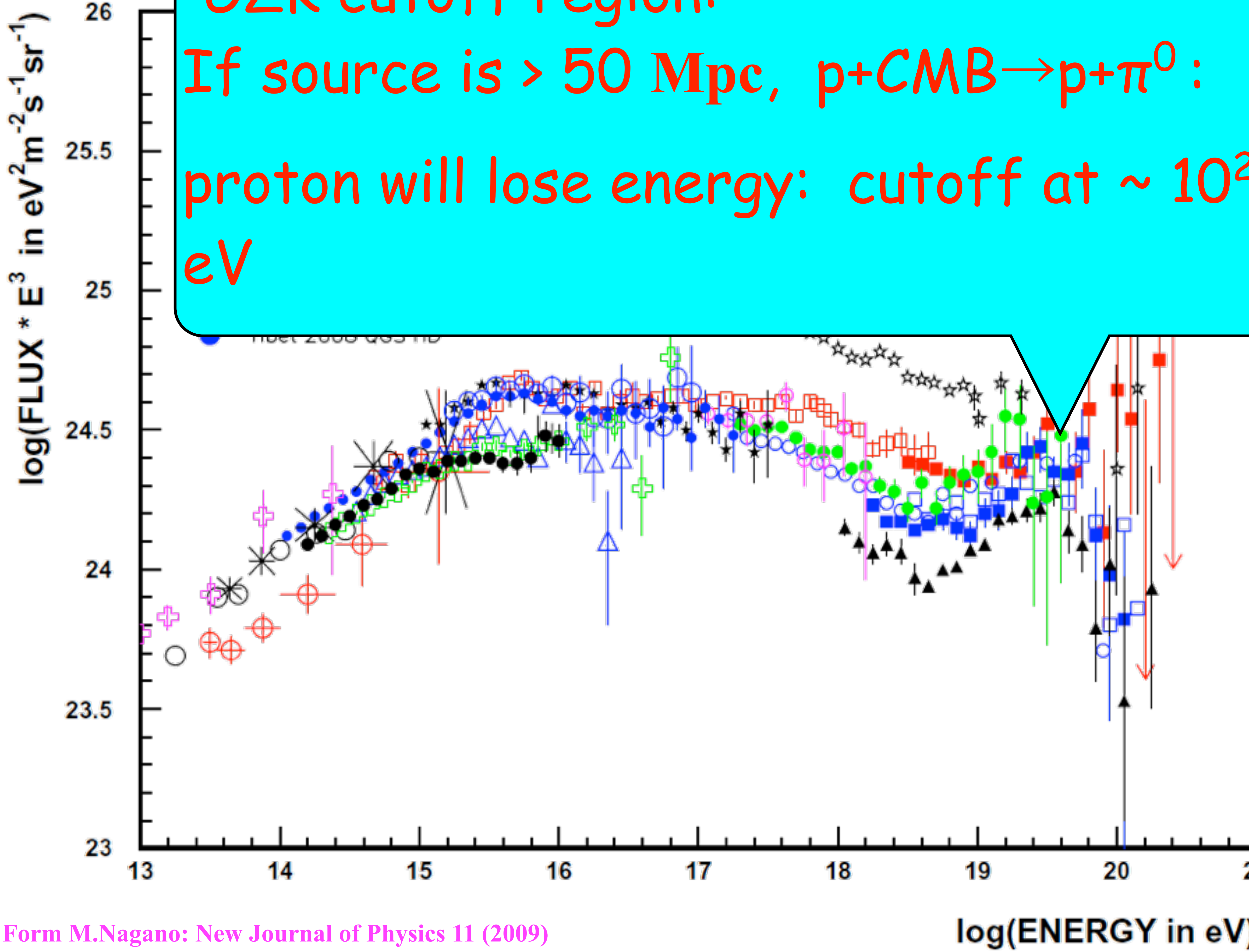


Form M.Nagano: New Journal of Physics 11 (2009)

GZK cutoff region:

If source is > 50 Mpc, $p+CMB \rightarrow p+\pi^0$:

proton will lose energy: cutoff at ~ 10^{20} eV

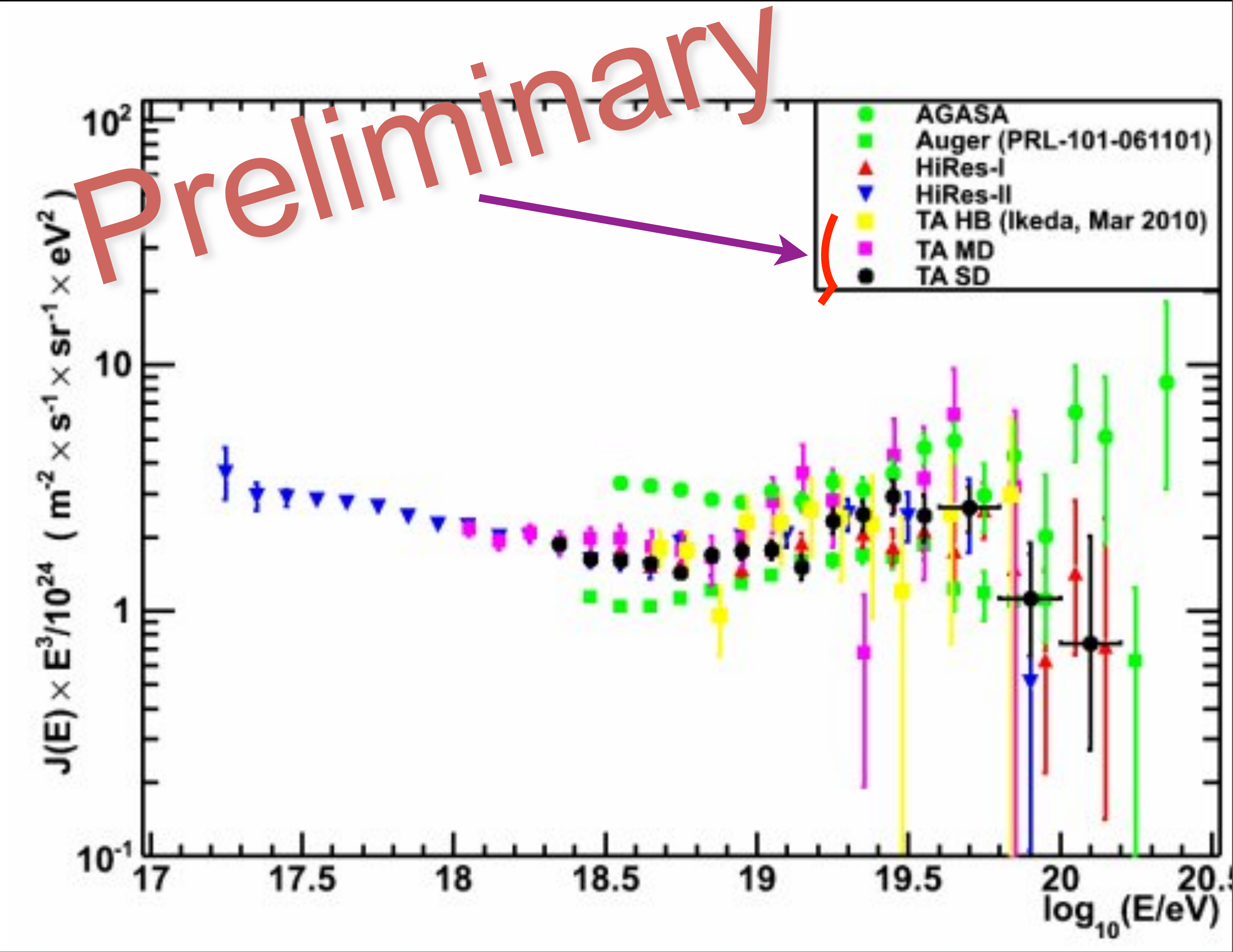


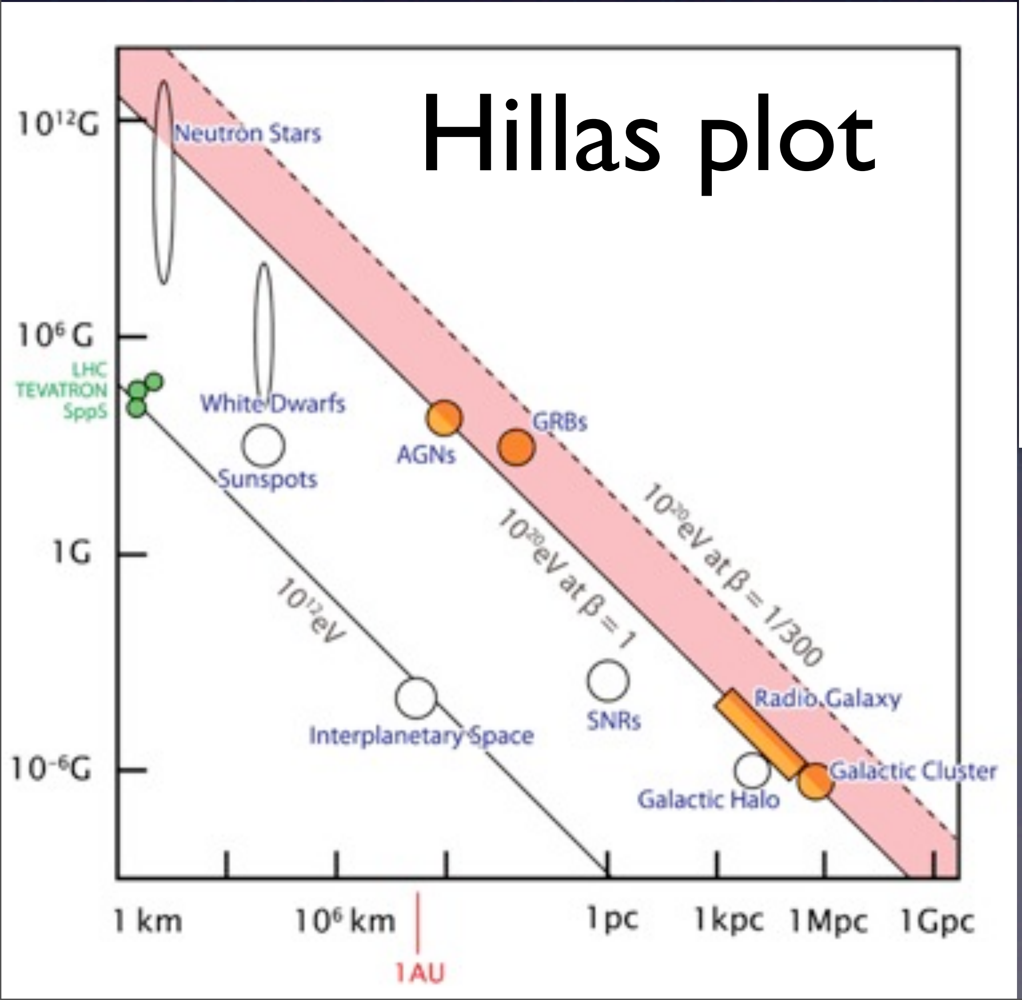
Form M.Nagano: New Journal of Physics 11 (2009)

Recent TA result

If Super GZK: various interesting scenarios:

New results: GZK cutoff

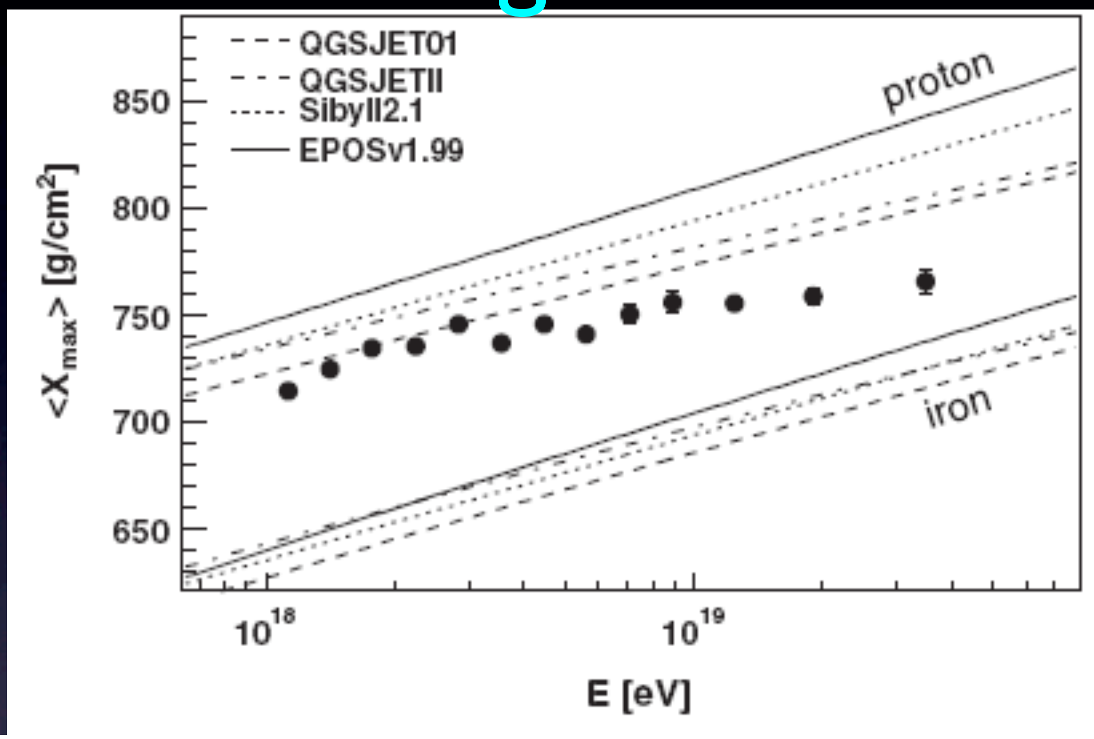




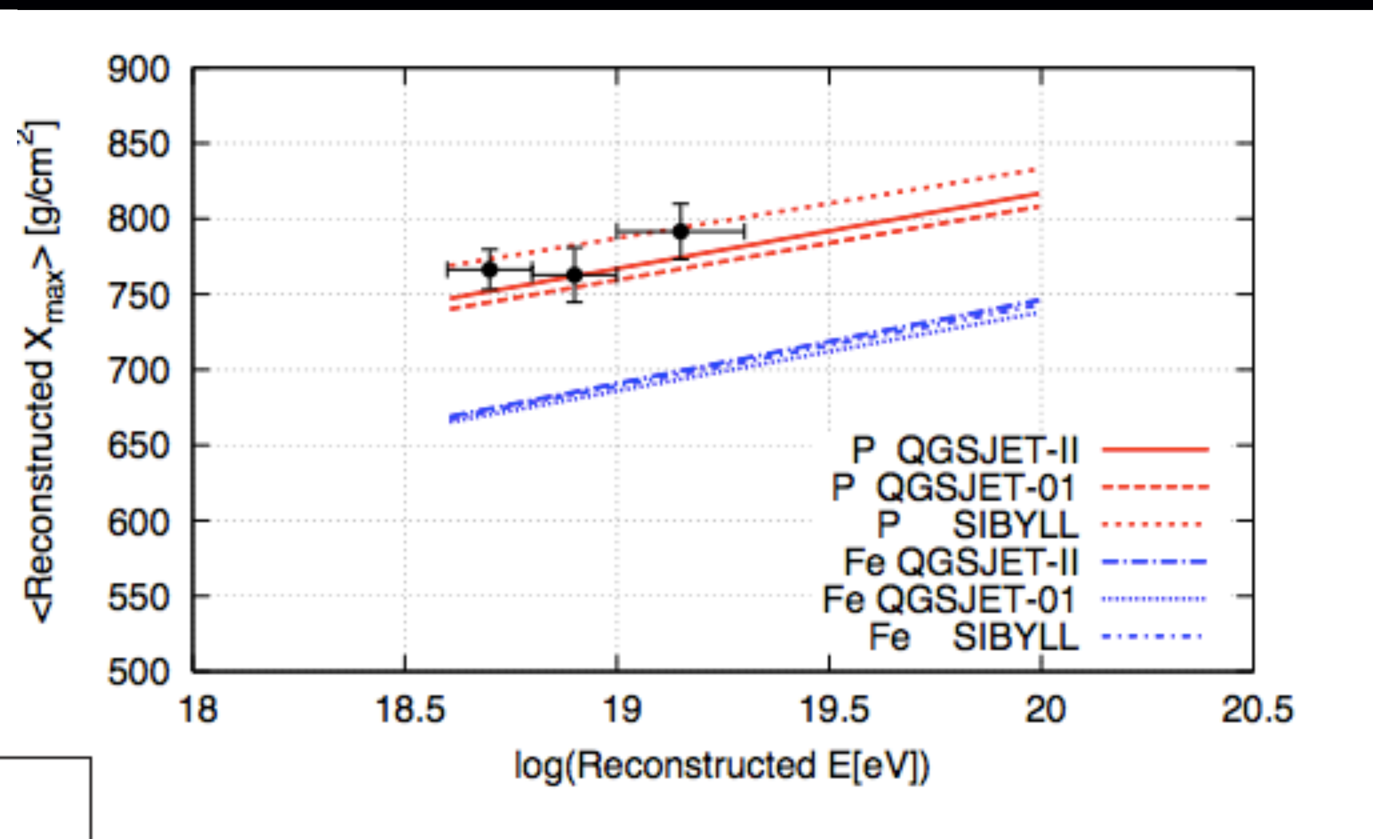
There still remain lots of problems:
source: AGN ? GRB ? .Composition ?
near-by source→super GZK recovery

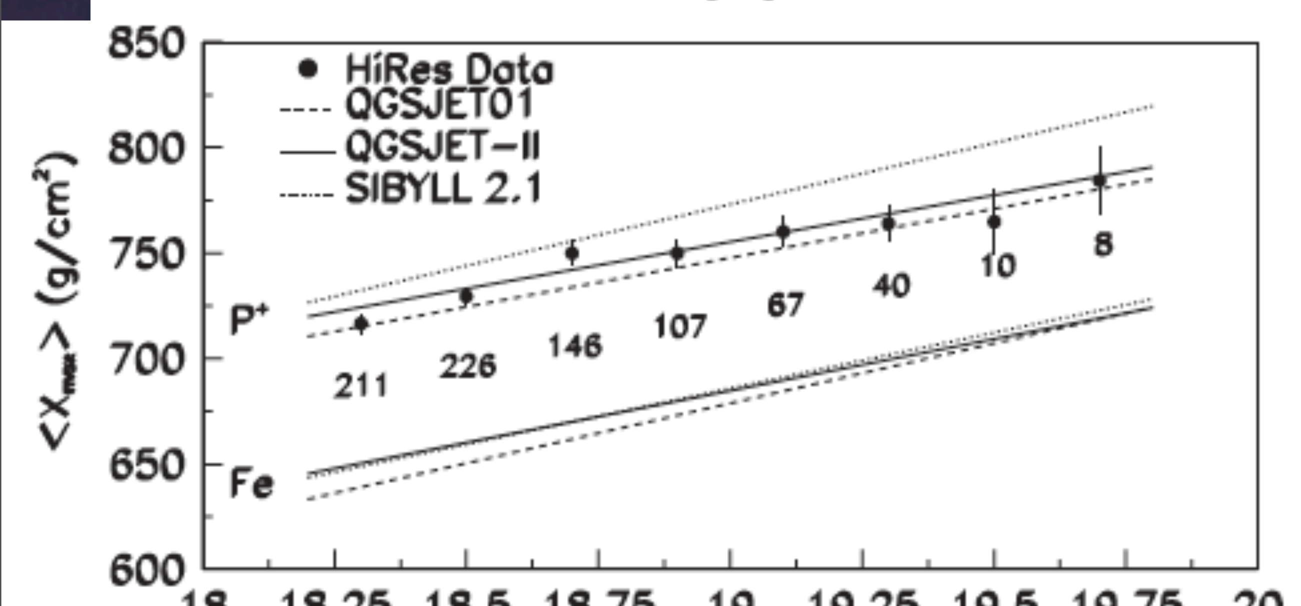
Composition

Auger



TA

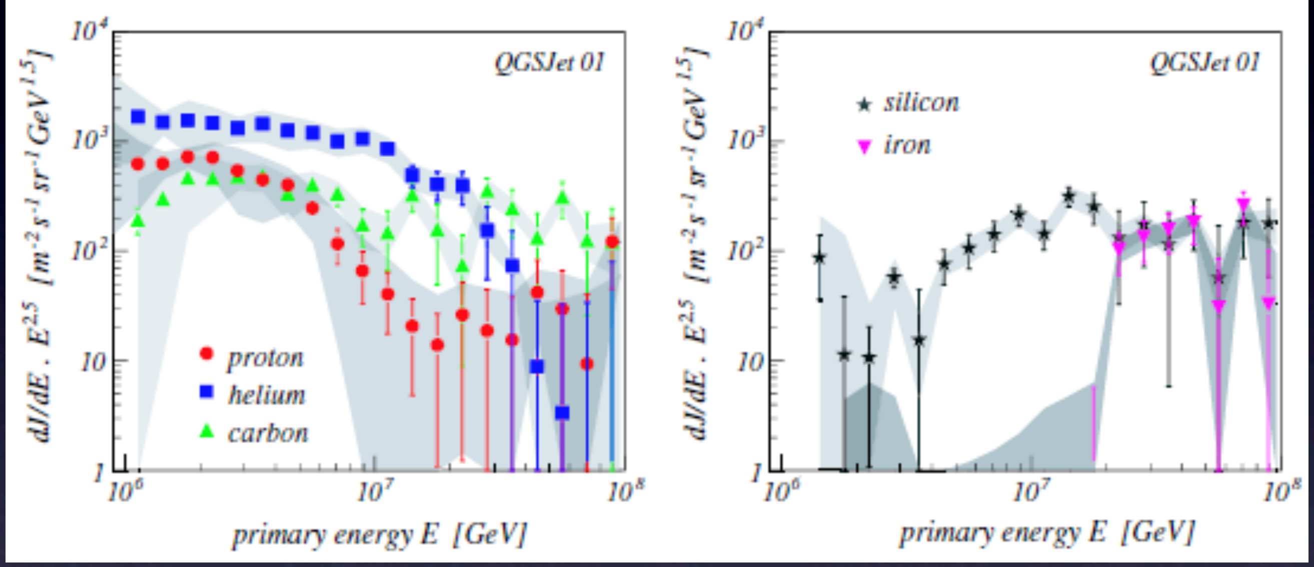




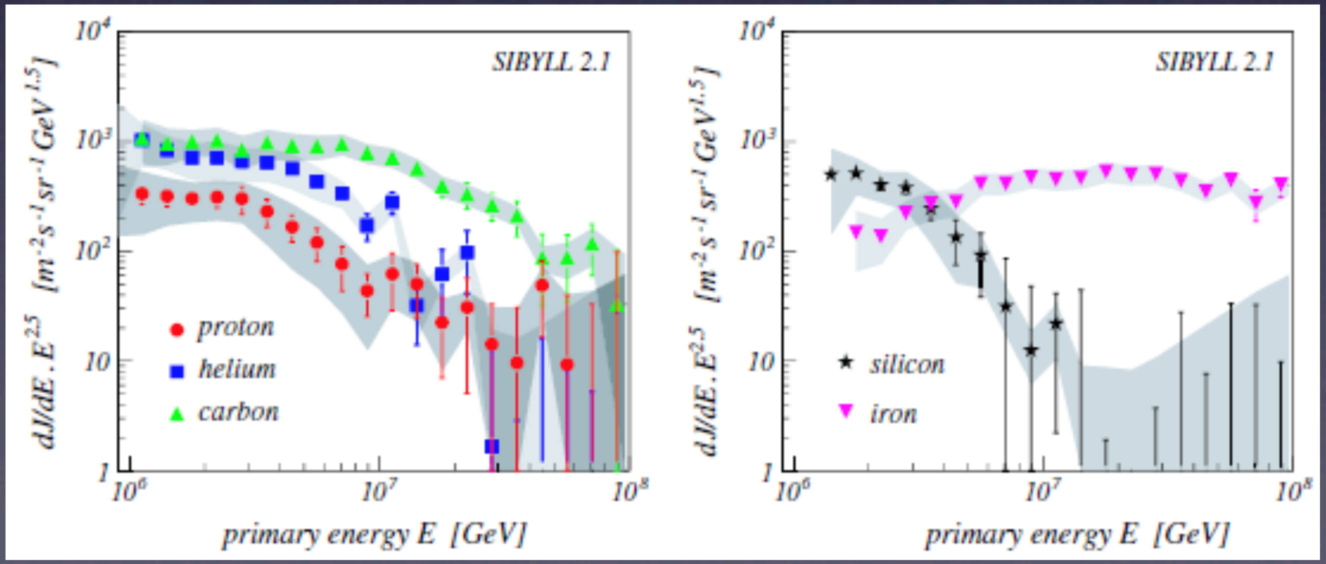
HiRes

Not only UHECRs

composition (@ ~10^{16} eV) by KASCADE



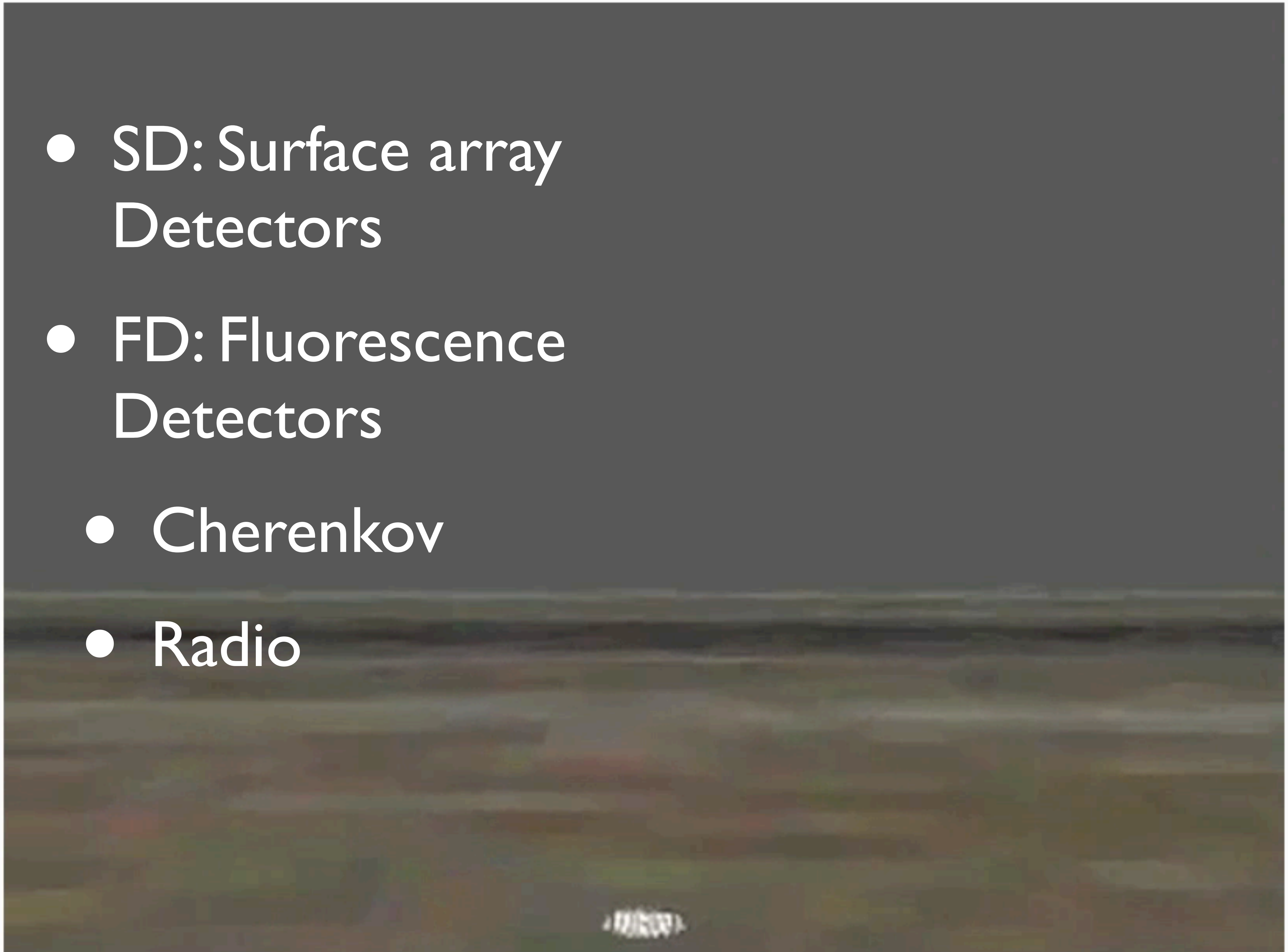
qgsjet1



Sibyll2.1

Air shower observation

Air shower observation



- SD: Surface array Detectors
- FD: Fluorescence Detectors
- Cherenkov
- Radio

M.C: Indispensable tool

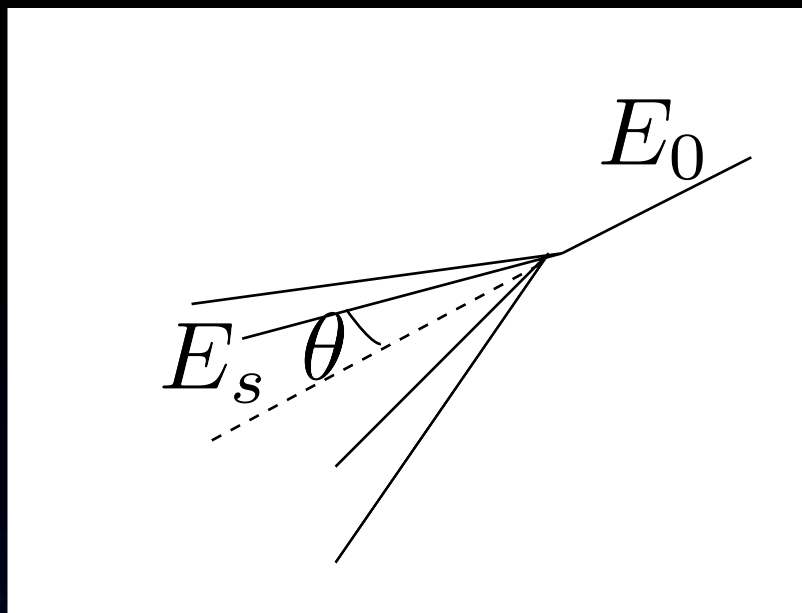
- Energy scale
- Composition
- Trigger efficiency, $S\Omega$

* Problems:
  * Hadronic interaction model
  * Computation time at $>10^{16}$eV

- Hadronic Interaction model

- Several interaction models in cosmic ray field
  - qgsjet1
  - qgsjet2
  - dpmjet3
  - sibyll
  - EPOS

Imortant variables for AS development



$$\frac{1}{\sigma}\frac{d\sigma}{dx} \qquad x = \frac{E_s}{E_0}$$

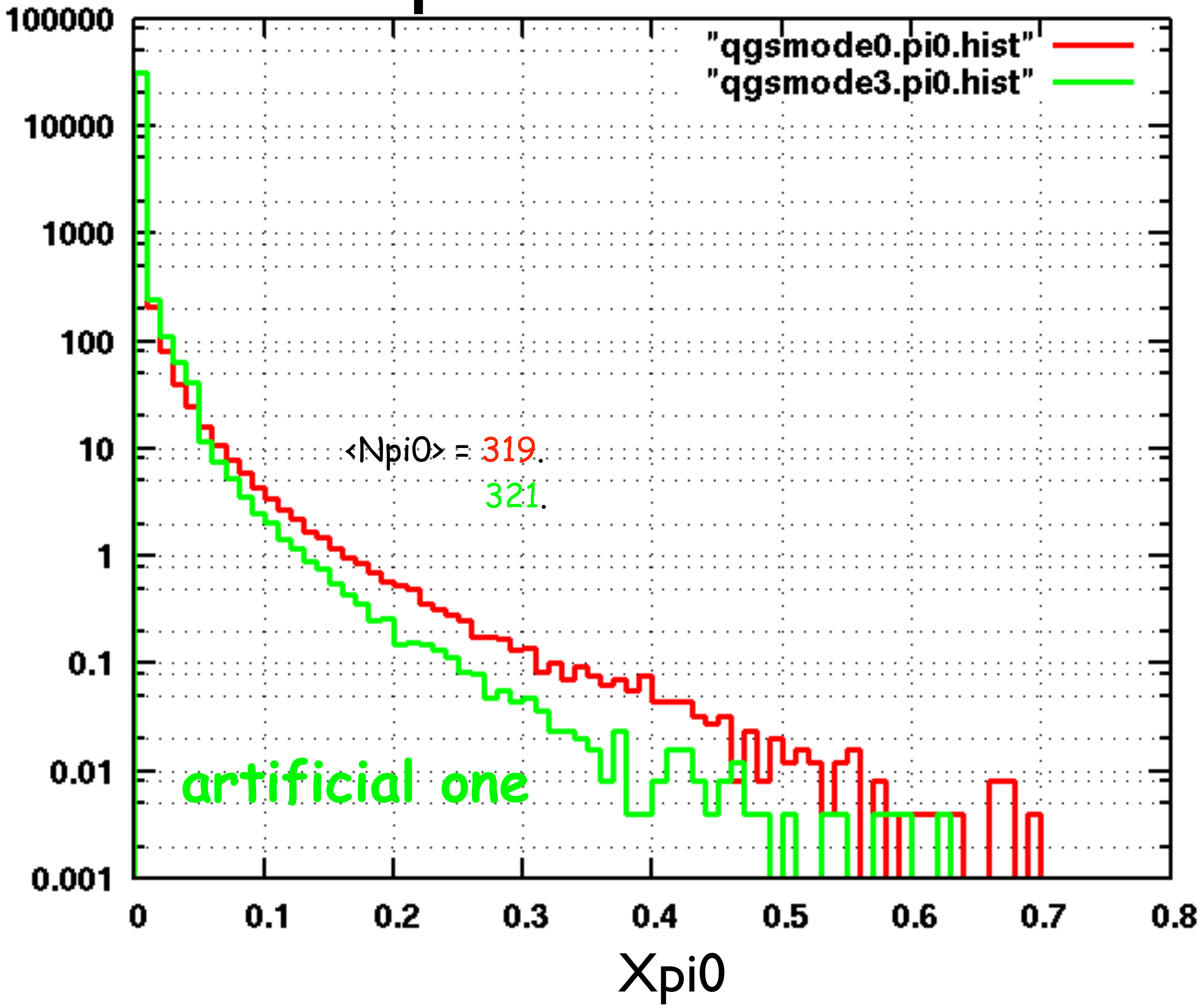
$$\frac{1}{\sigma}\frac{d\sigma}{d\eta} \qquad \eta = -\log(\tan(\frac{\theta}{2}))$$

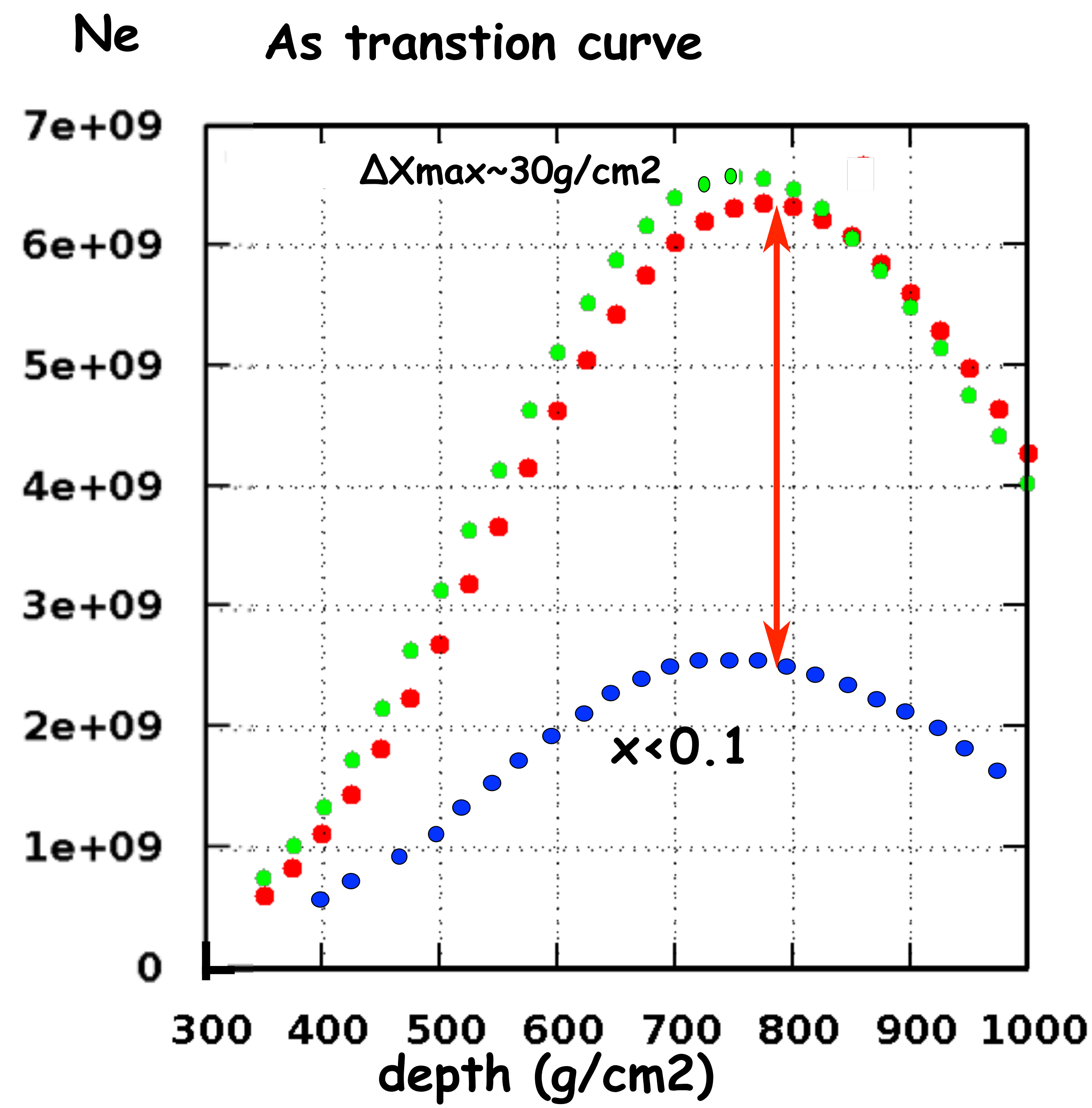
- For Ne and Nγ
  - large x is important
- For Nμ
  - large x is important at high energies but
  - small x (or η_{cms} ~0) becomes important at lower energies

electron/gamma in AS
50~60 % are from pi, K with x>0.1
(~40 % from γ with x>0.05)

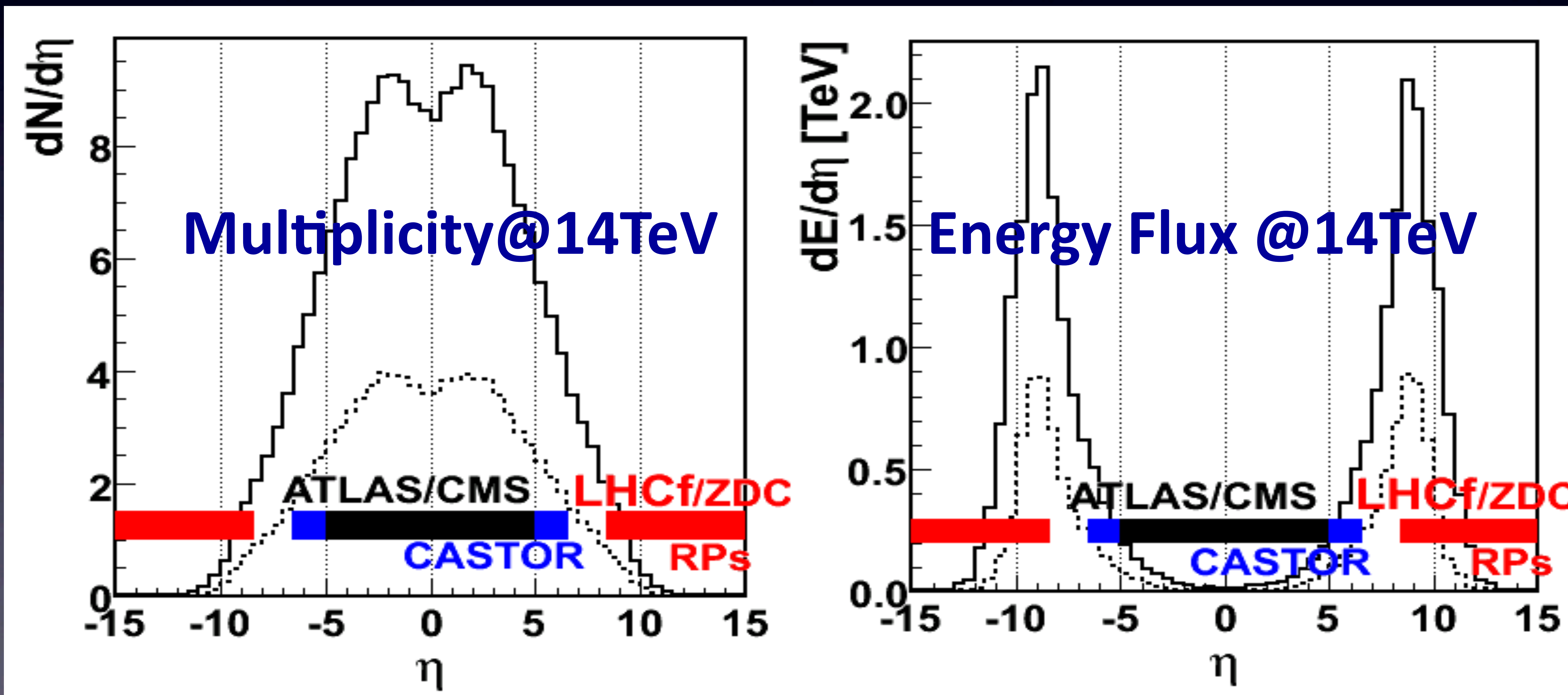
p 10^{19}eV

dn/dx/ev: pi0

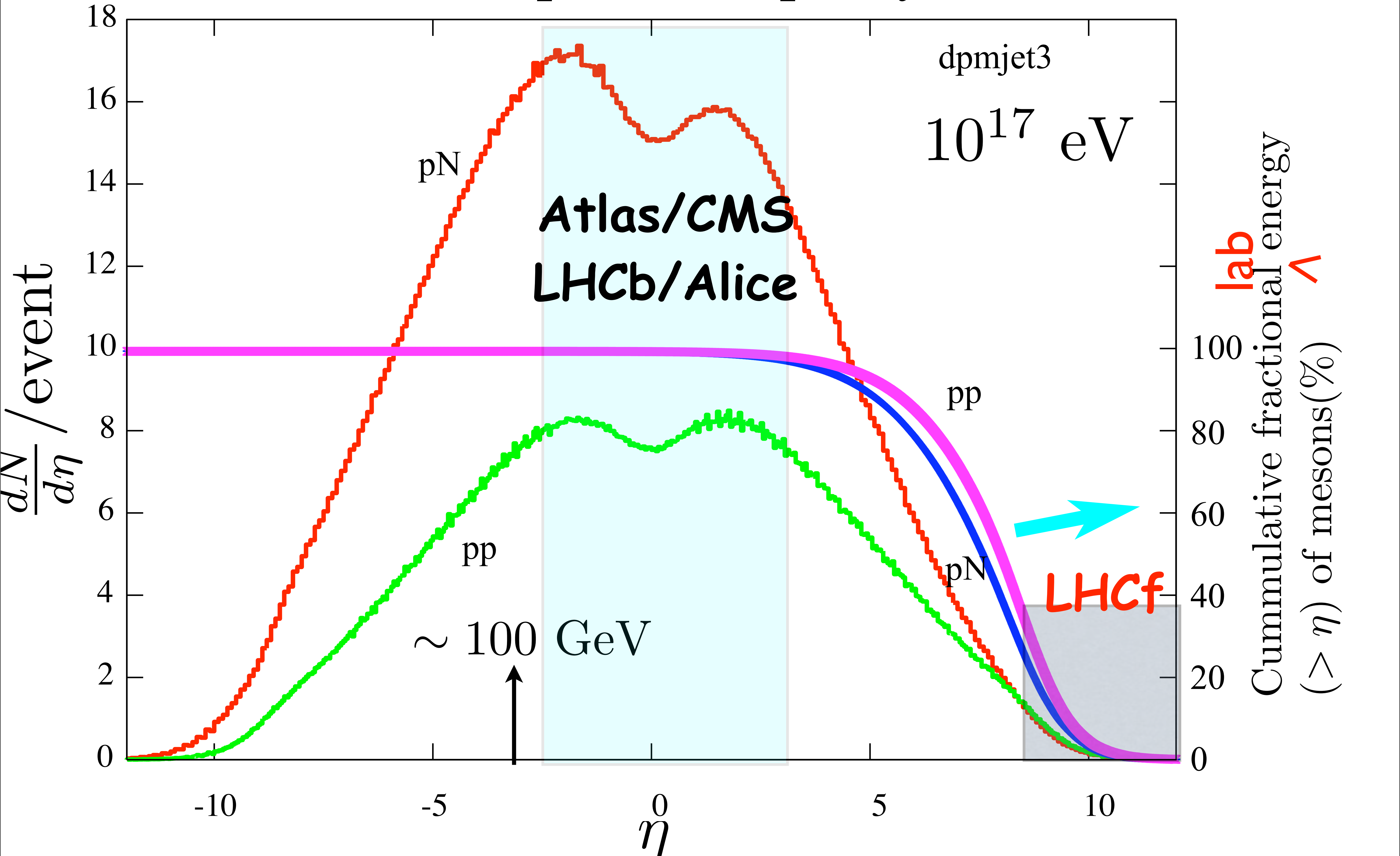


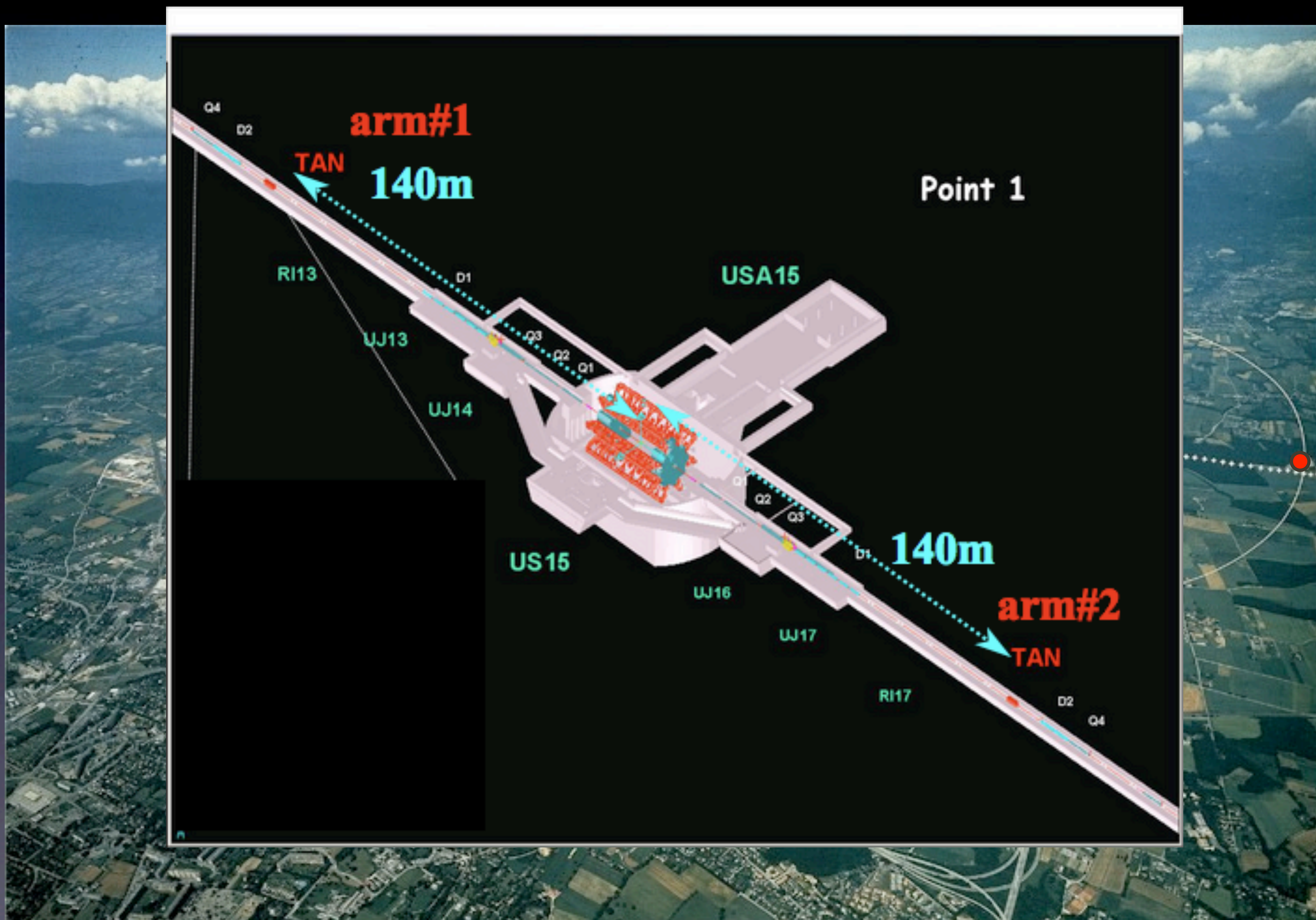


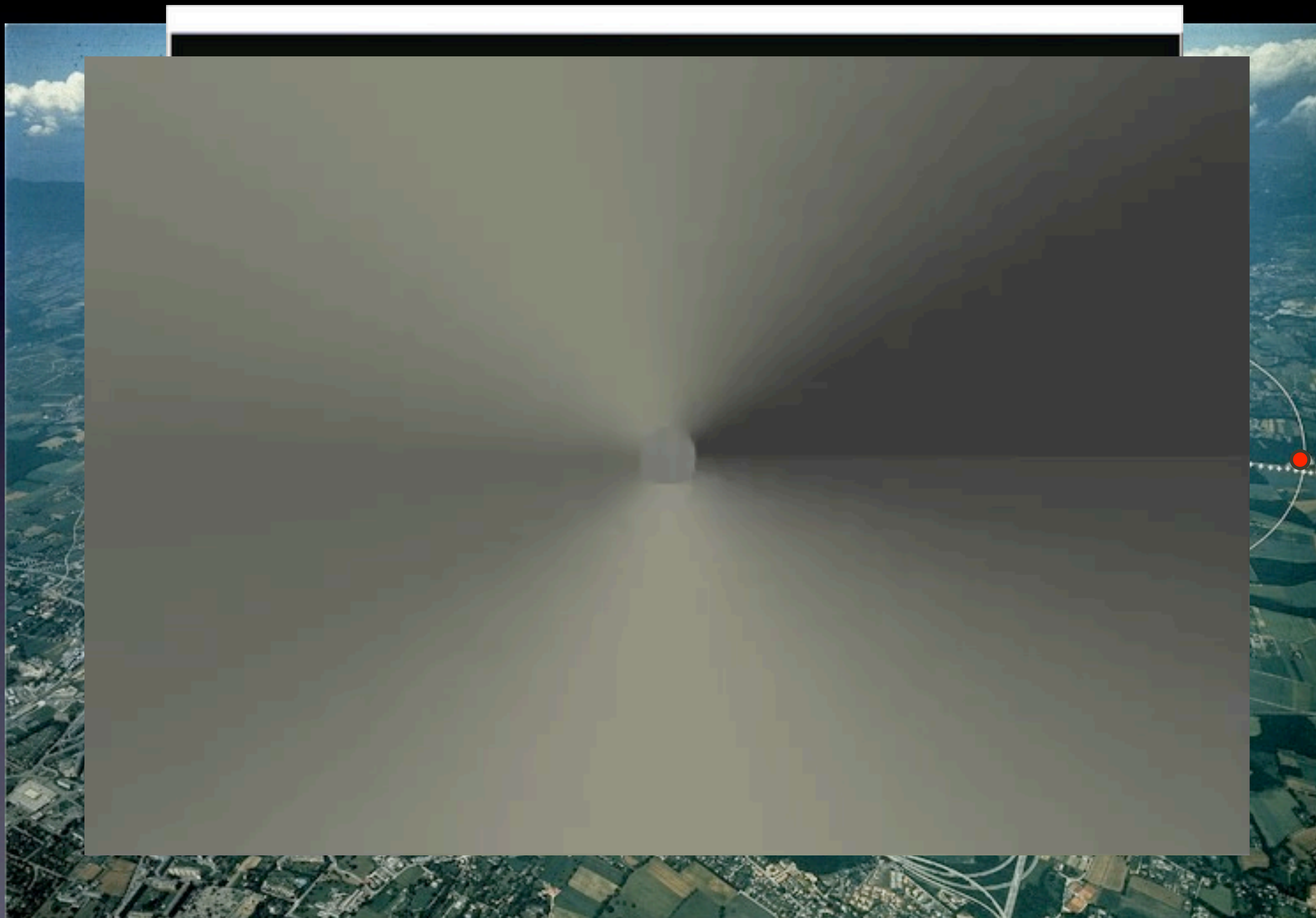
In terms of number and energy in CMS

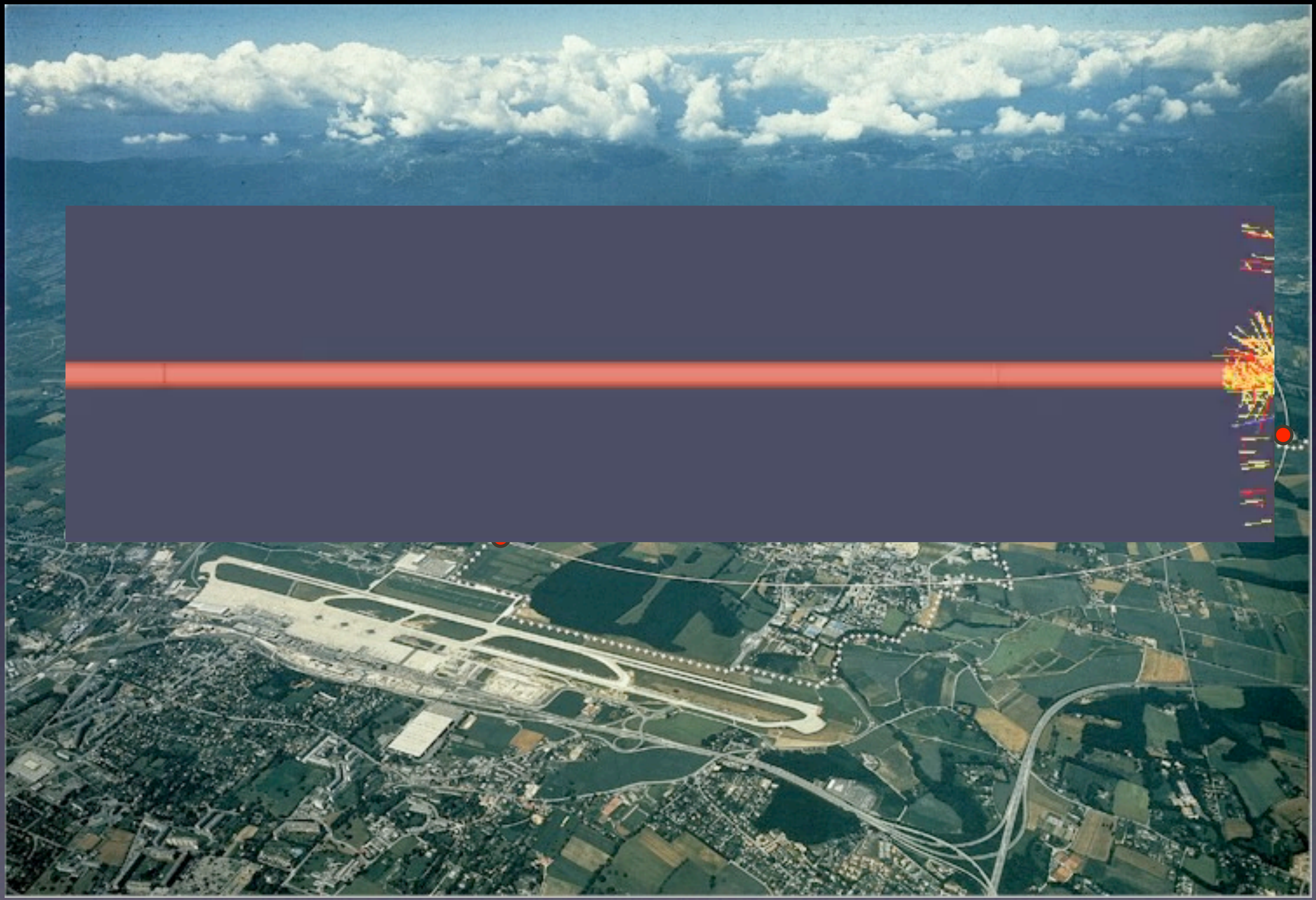


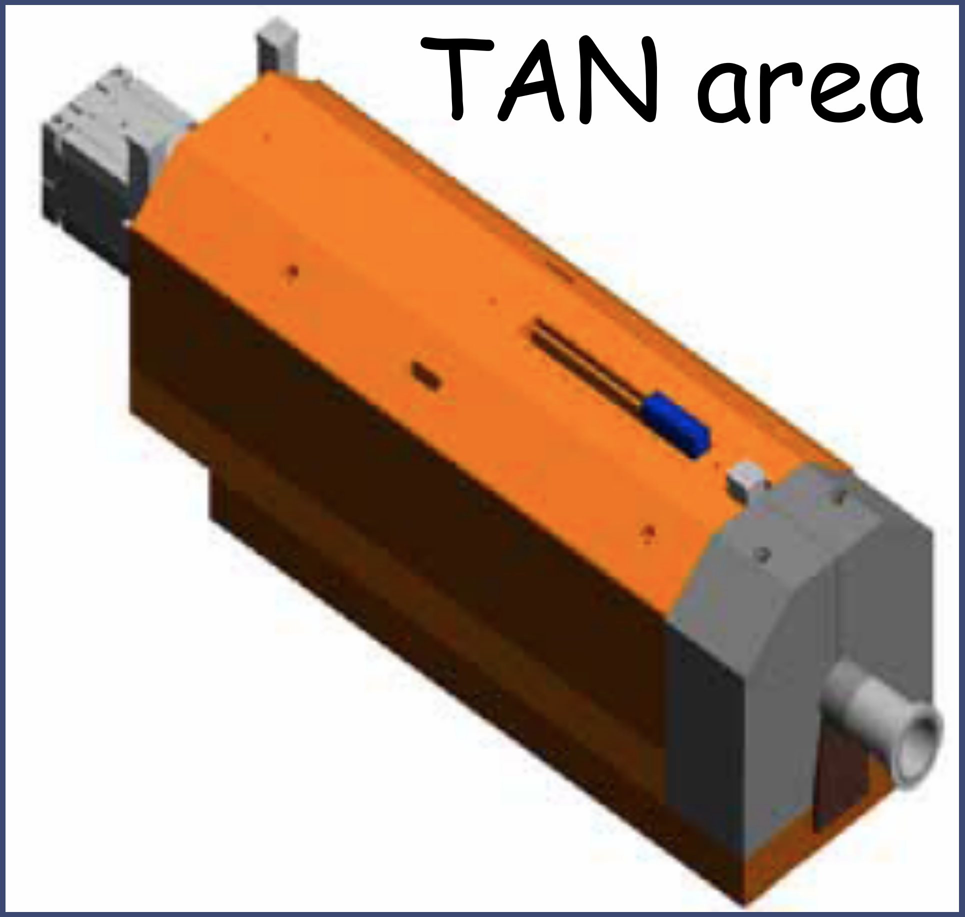
Meson pseudo rapidity

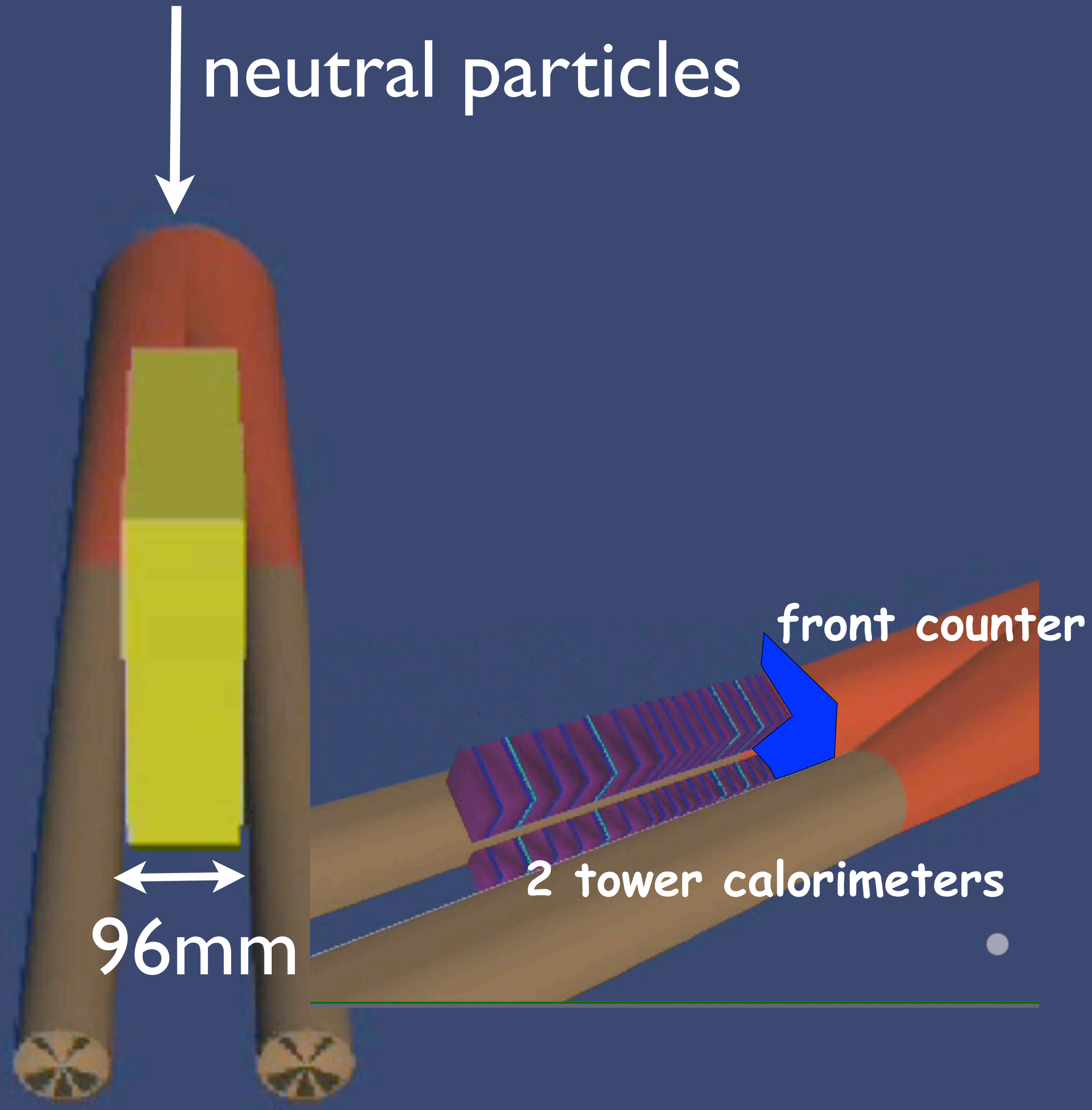



Q4
D2
arm#1
TAN
140m
Point 1
RI13
D1
USA15
UJ13
Q3
Q2
Q1
UJ14
Q1
Q2
Q3
US15
D1
140m
UJ16
UJ17
arm#2
TAN
RI17
D2
Q4



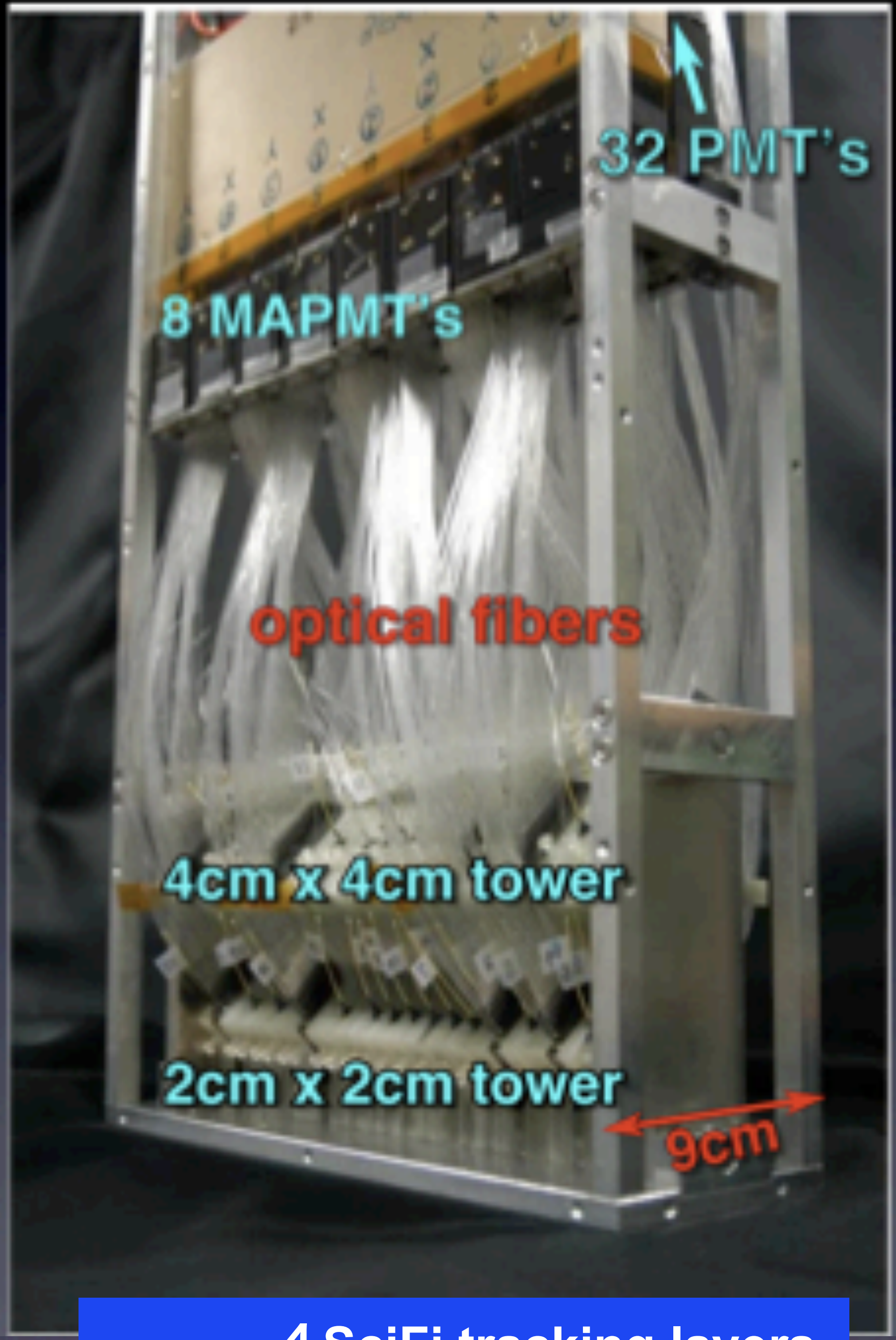



TAN area

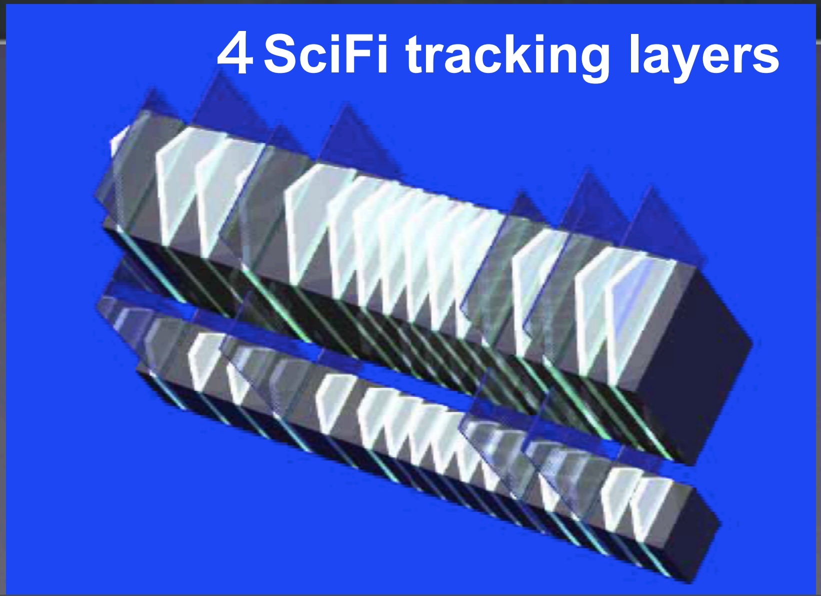

neutral particles
front counter
2 tower calorimeters
96mm

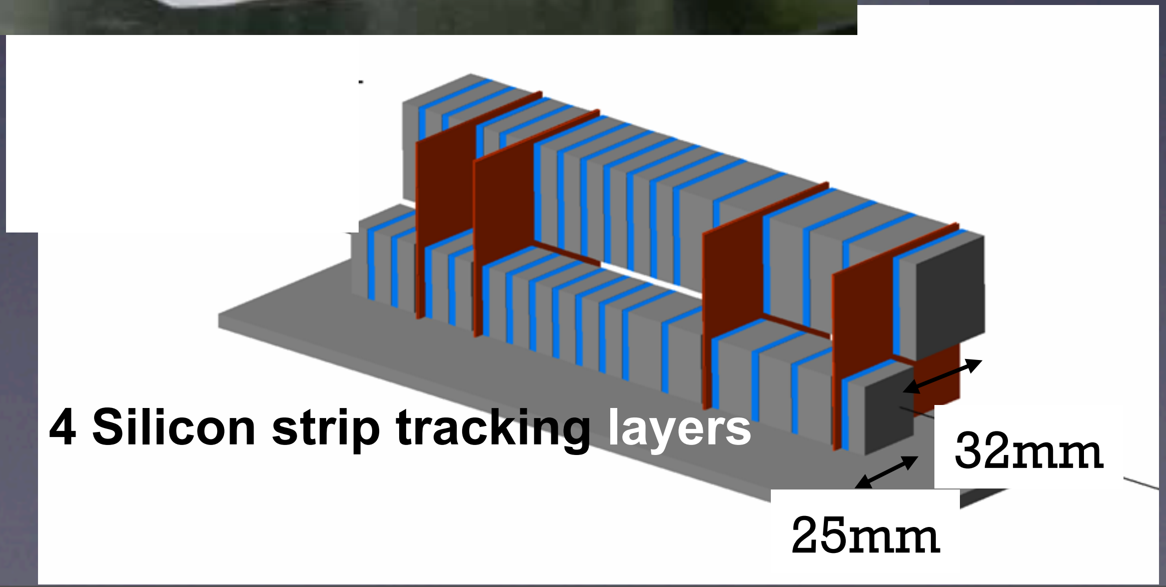
W 44X0
1.7λc

Arm #1

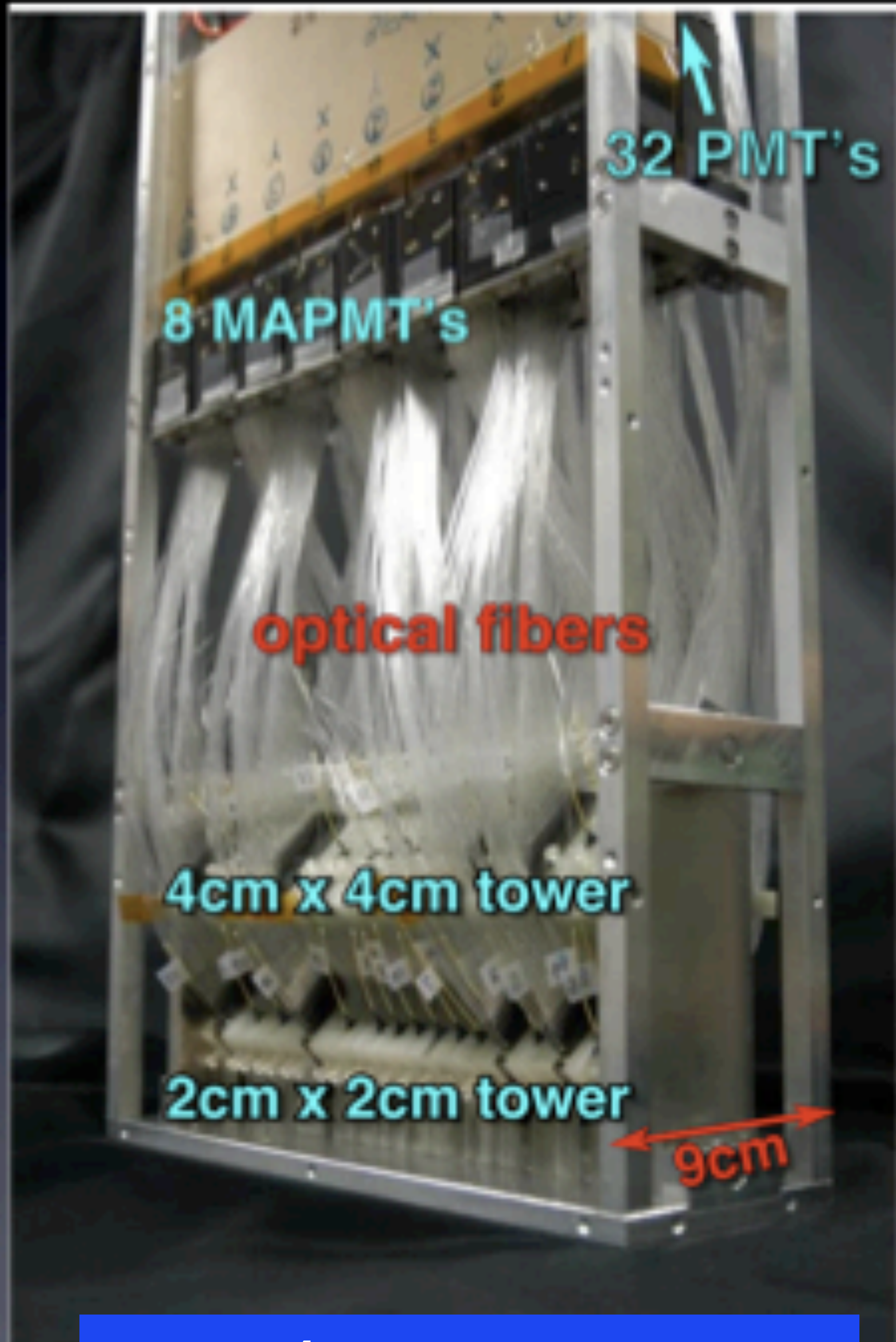


Arm #2





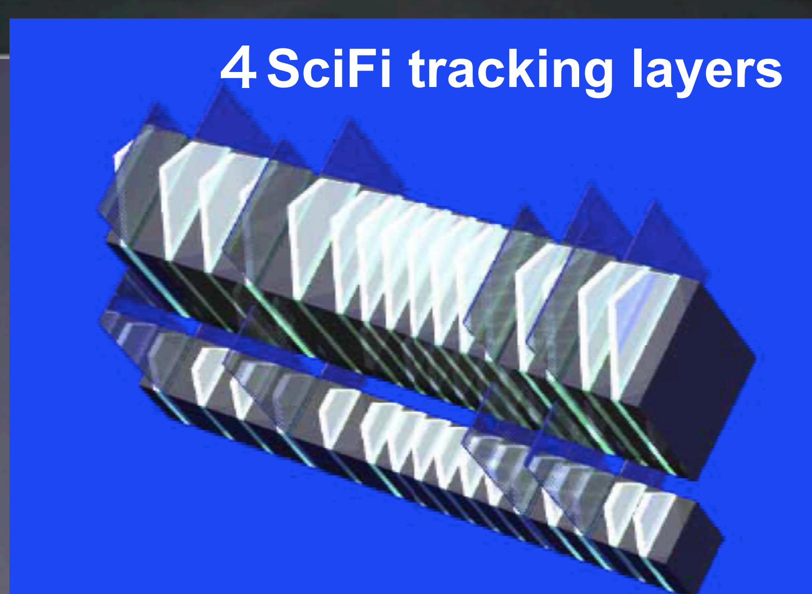
Arm #1

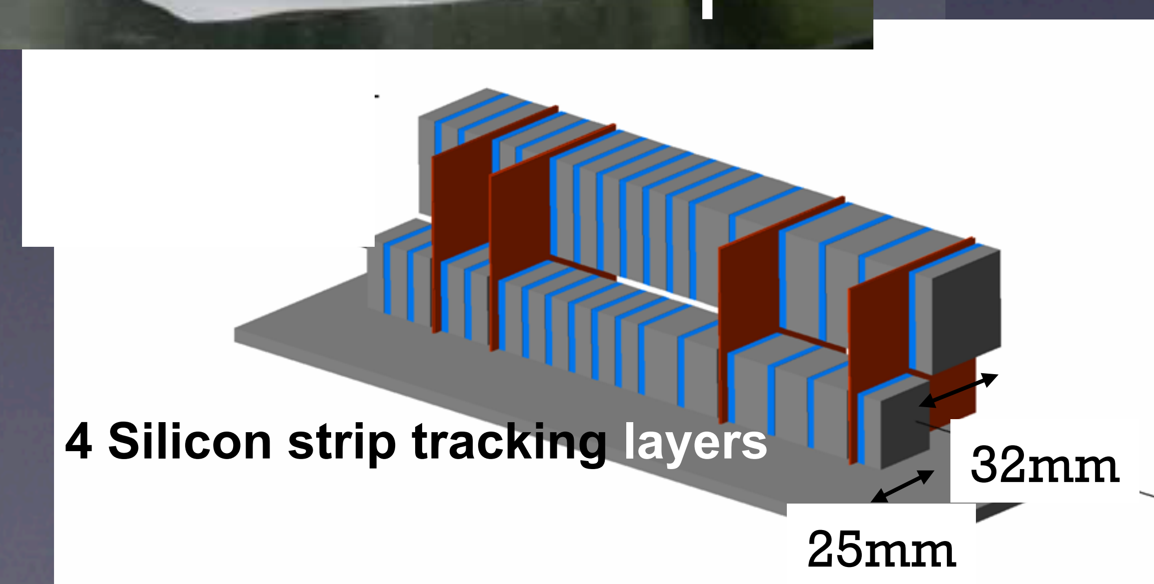


Arm #2

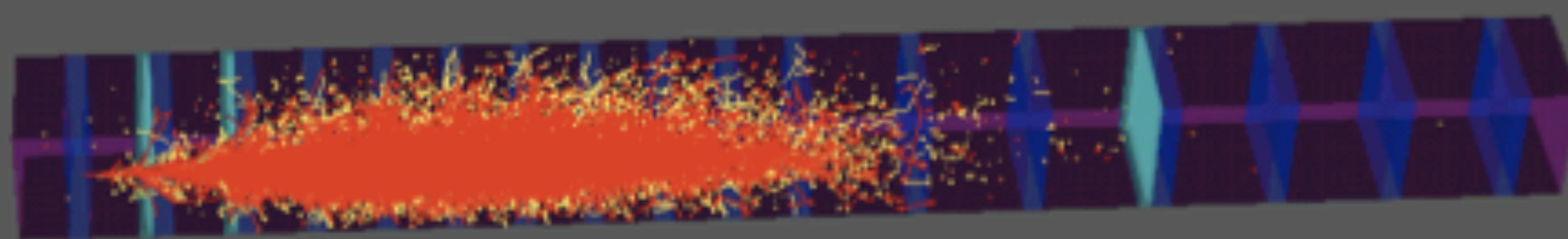
W 44X0
1.7λc

Sampling calorimeter
W of 44 X0
Plastic scinti.
4 pos. sensitive layers:
Arm1: SciFi
Arm2: Si strip

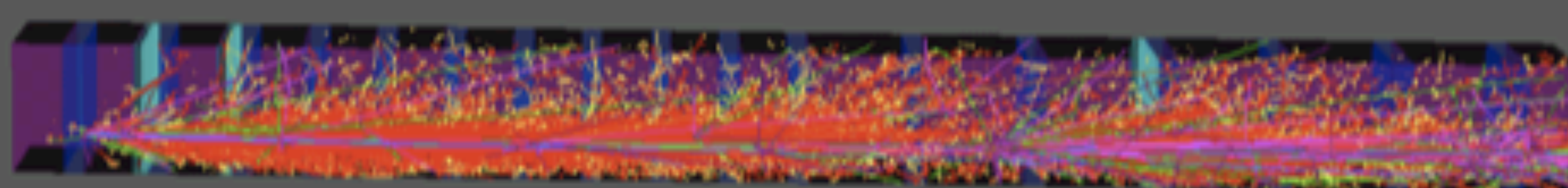




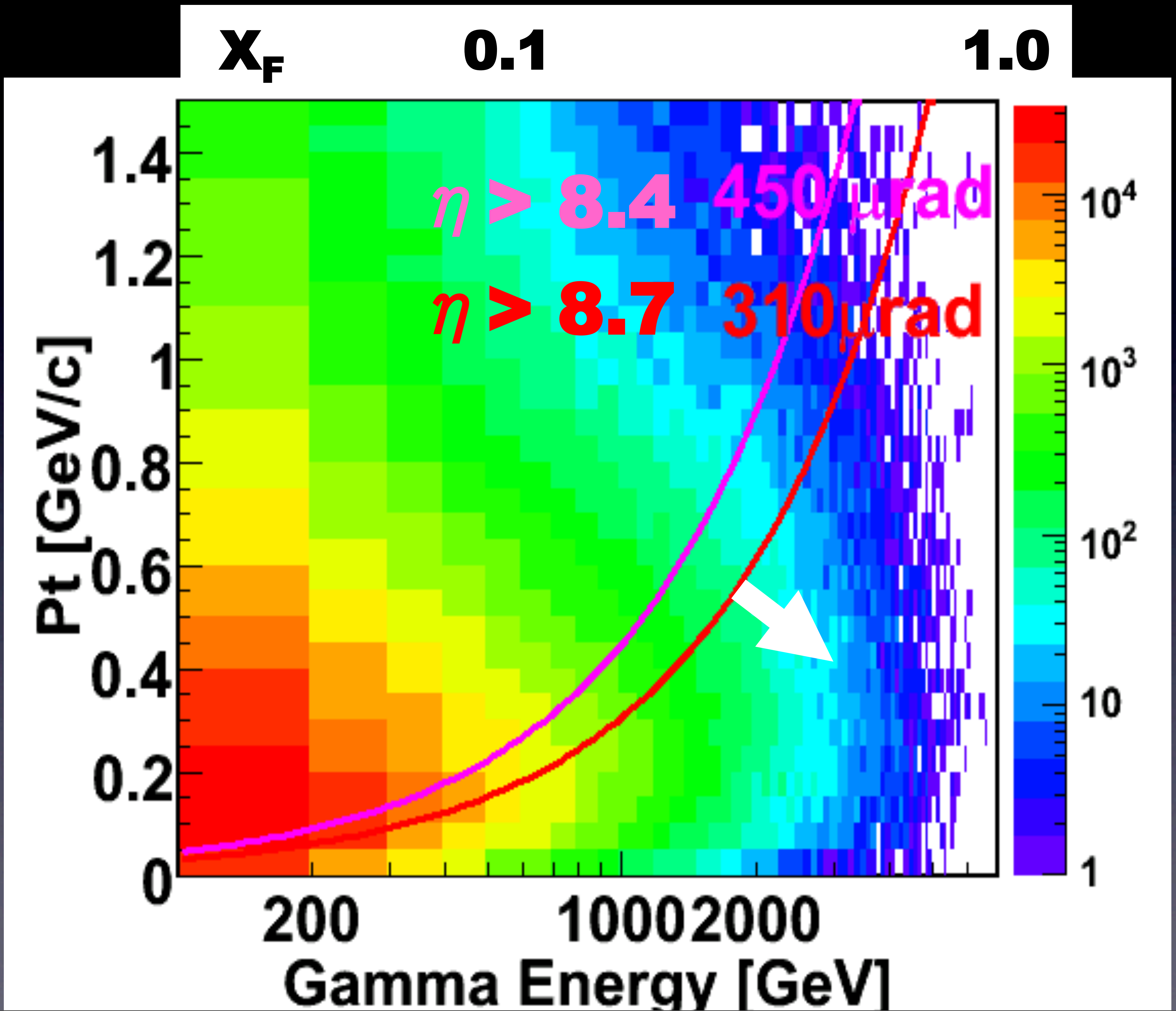
Photon vs Neutron



400 GeV photon



1TeV Neutron



x_F
0.1
1.0
η > 8.4 450 μrad
η > 8.7 310μrad
Pt [GeV/c]
1.4
1.2
1
0.8
0.6
0.4
0.2
0
200
1000
2000
Gamma Energy [GeV]
10^4
10^3
10^2
10
1

2009-2010 run summary

- $\sqrt{s}=$ 900 GeV run (no crossing angle)
  - 06 Dec.- 15Dec. 2009(27.7 hrs, 500k collisions
    - 2.8k/3.7k single showers at Arm1/Arm2
  - 02 May-27 May 2010(15 hrs. 5.5M collisions)
    - 44k/63k single showers at Arm1/Arm2
- $\sqrt{s}=$ 7TeV run (0 and 100 μrad crossing angle)
  - 30 Mar.- 19 July, 2010(~150 hrs.)
    - 172M/161M single showers at Arm1/Arm2
    - 345k/676k Pi0's at Arm1/Arm2
- Detectors were removed at 20 Jul. 2010

Inclusive photon spectrum

Data

Date : 15 May 2010 17:45-21:23 (Fill Number : 1104)

except runs during the luminosity scan.

Luminosity : (6.5-6.3)x10^{28}cm^{-2}s^{-1},

DAQ Live Time : 85.7% for Arm1, 67.0% for Arm2

Integrated Luminosity : 0.68 nb^{-1} for Arm1, 0.53nb^{-1} for Arm2

Number of triggers : 2,916,496 events for Arm1

3,072,691 events for Arm2

Detectors in nominal positions and Normal Gain

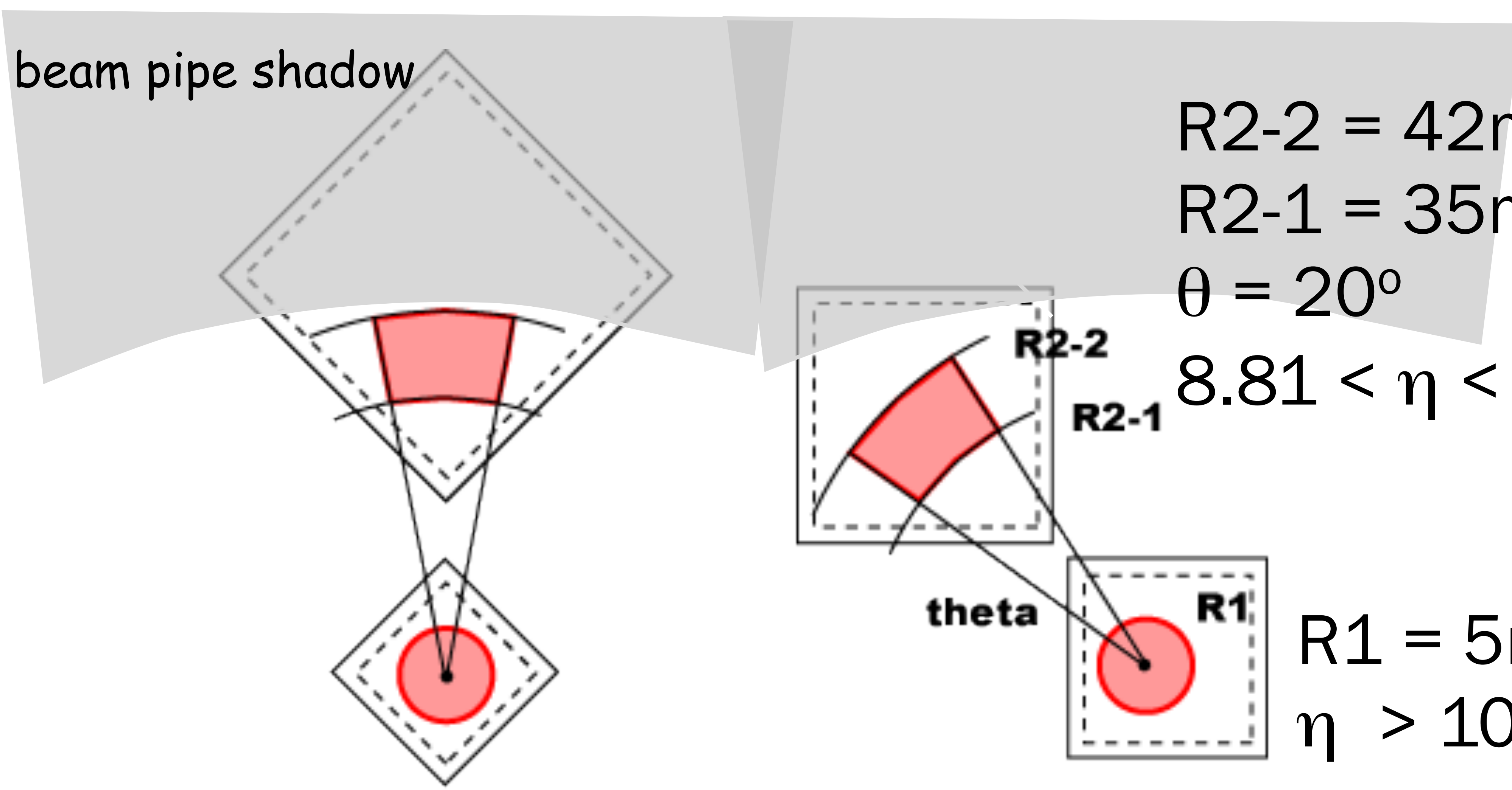
Monte Carlo

QGSJET II-03, DPMJET 3.04, SYBILL 2.1, EPOS 1.99 and PYTHIA8.145: about 10^7 pp inelastic collisions each

Eta region for photon spectrum

Common region for Arm1 and Arm2

Arm1 Arm2



R2-2 = 42mm

R2-1 = 35mm

$\theta = 20^o$

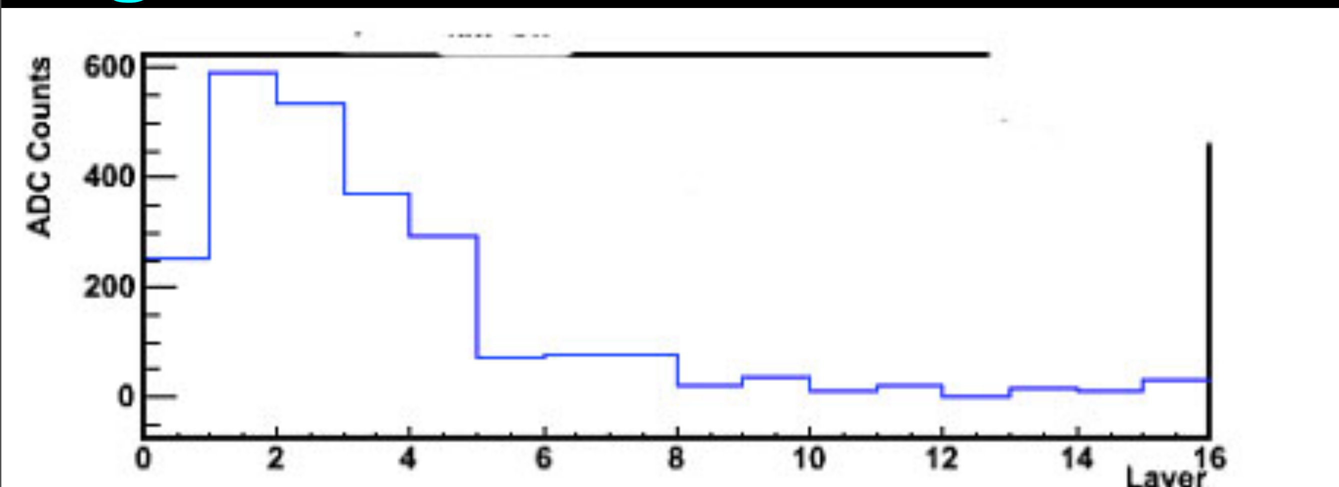
$8.81 < \eta < 8.99$

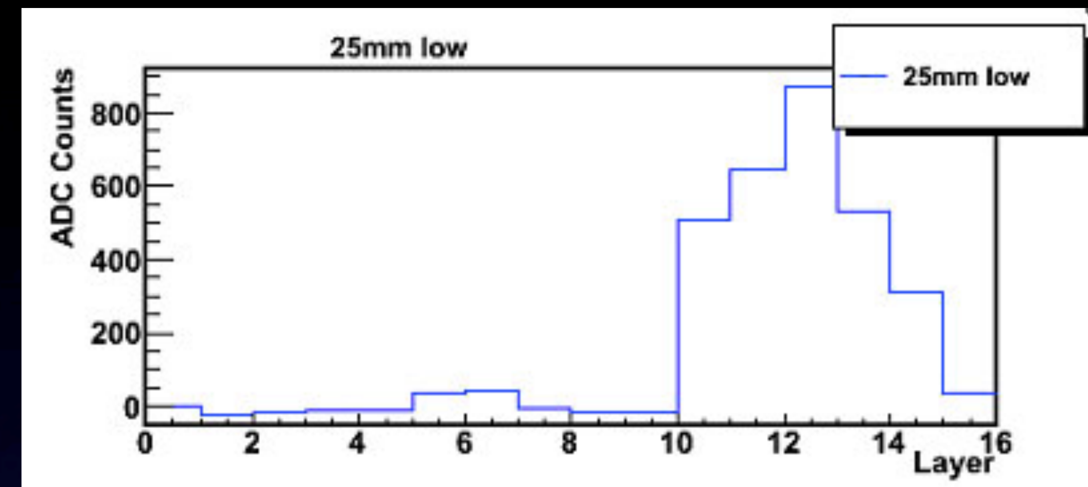
R1 = 5mm

$\eta > 10.94$

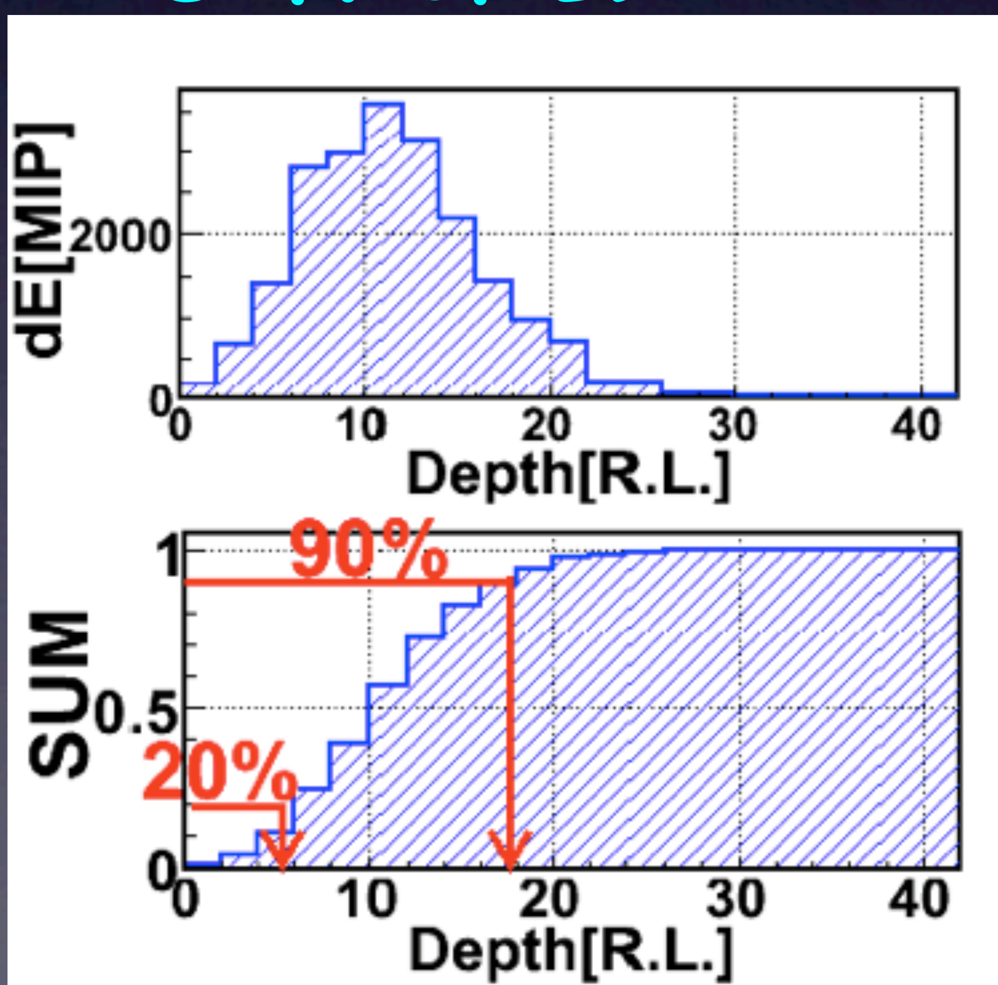
Partilce ID

gamma like   shower transition curve   hadron like

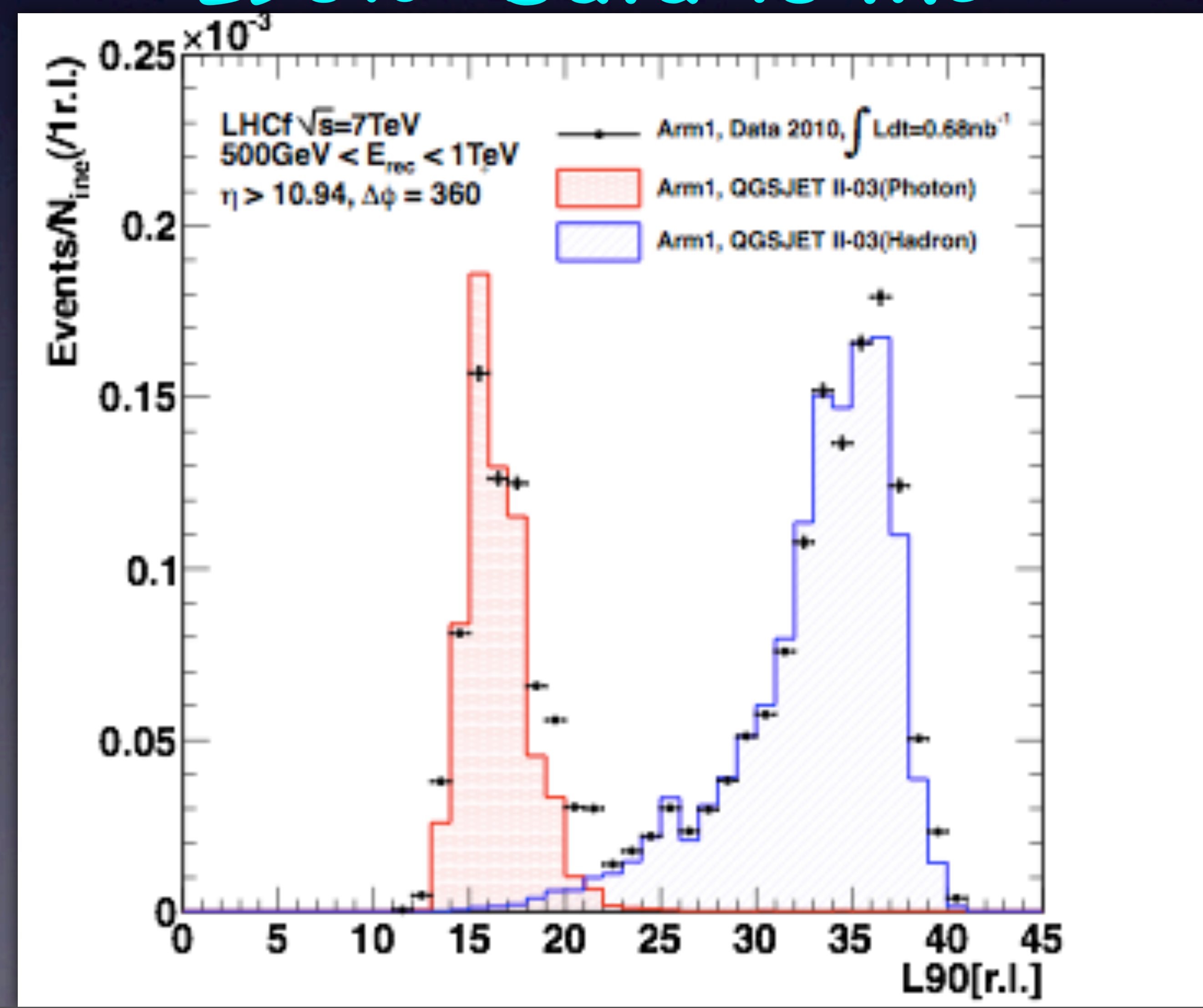




Def. of L90%



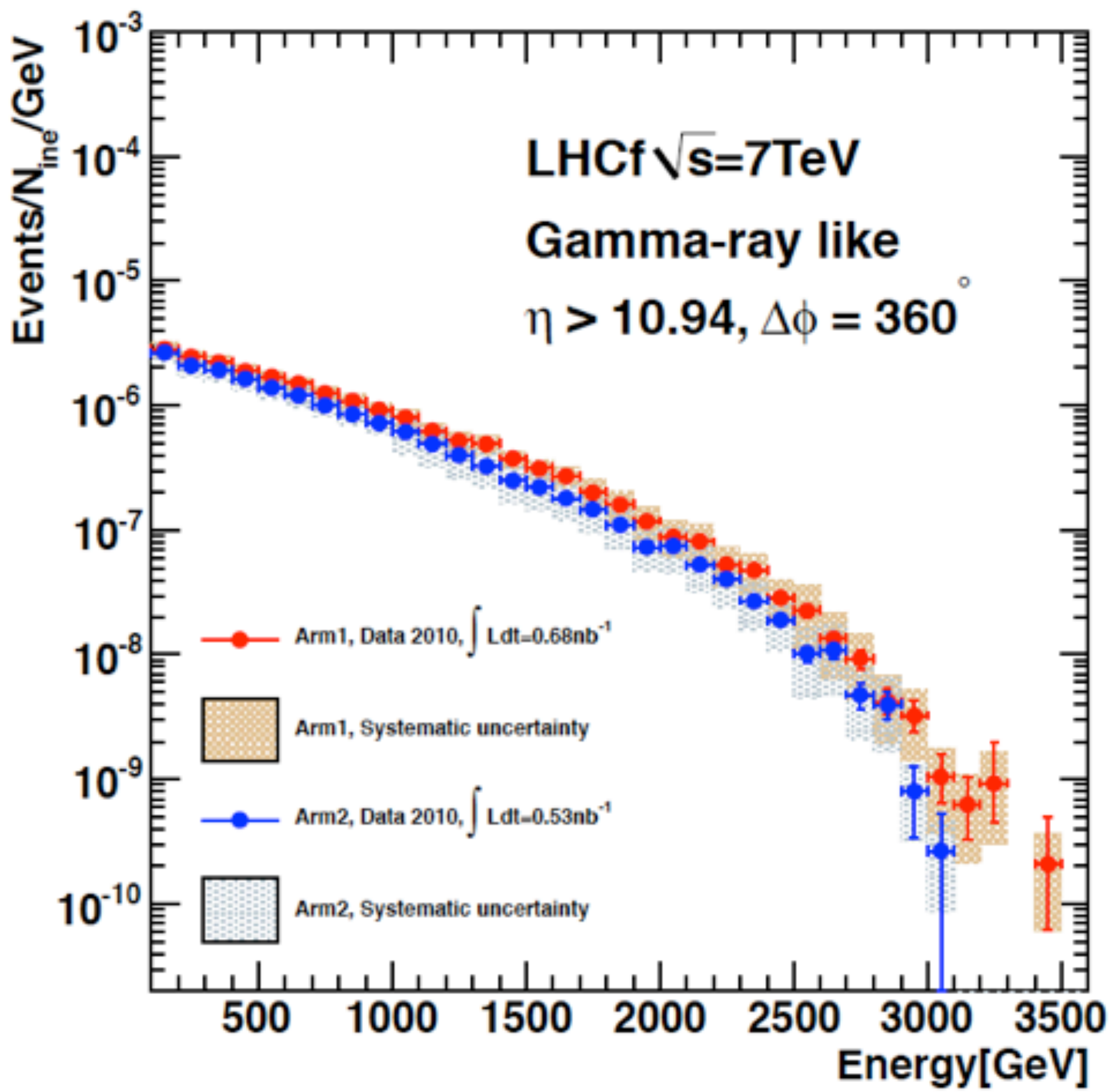
L90%: Data vs MC

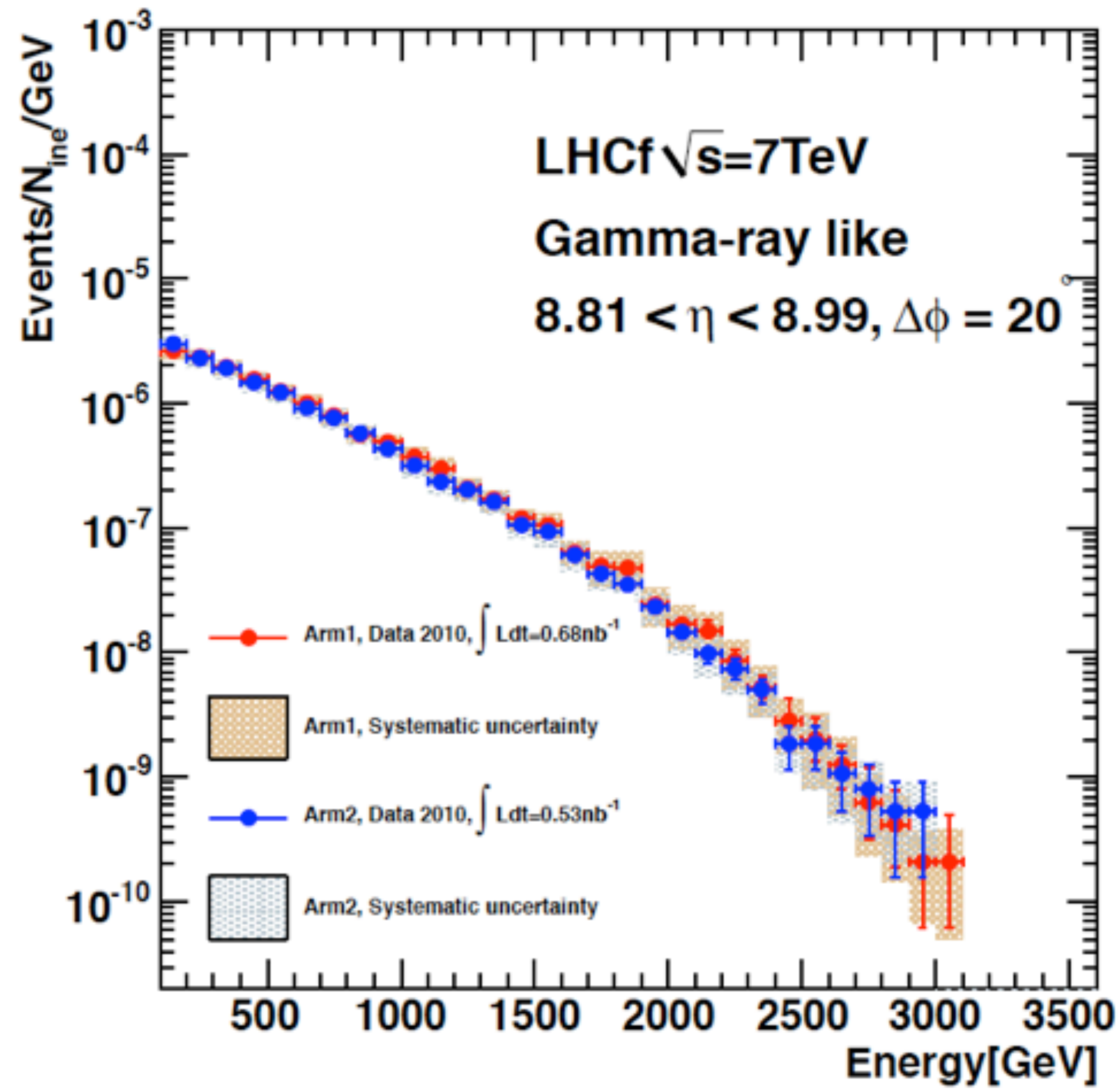


- Changing PID criteria:
  - We get the same energy spectrum

Inclusive photon spectrum: result

Small towers | **Large towers**

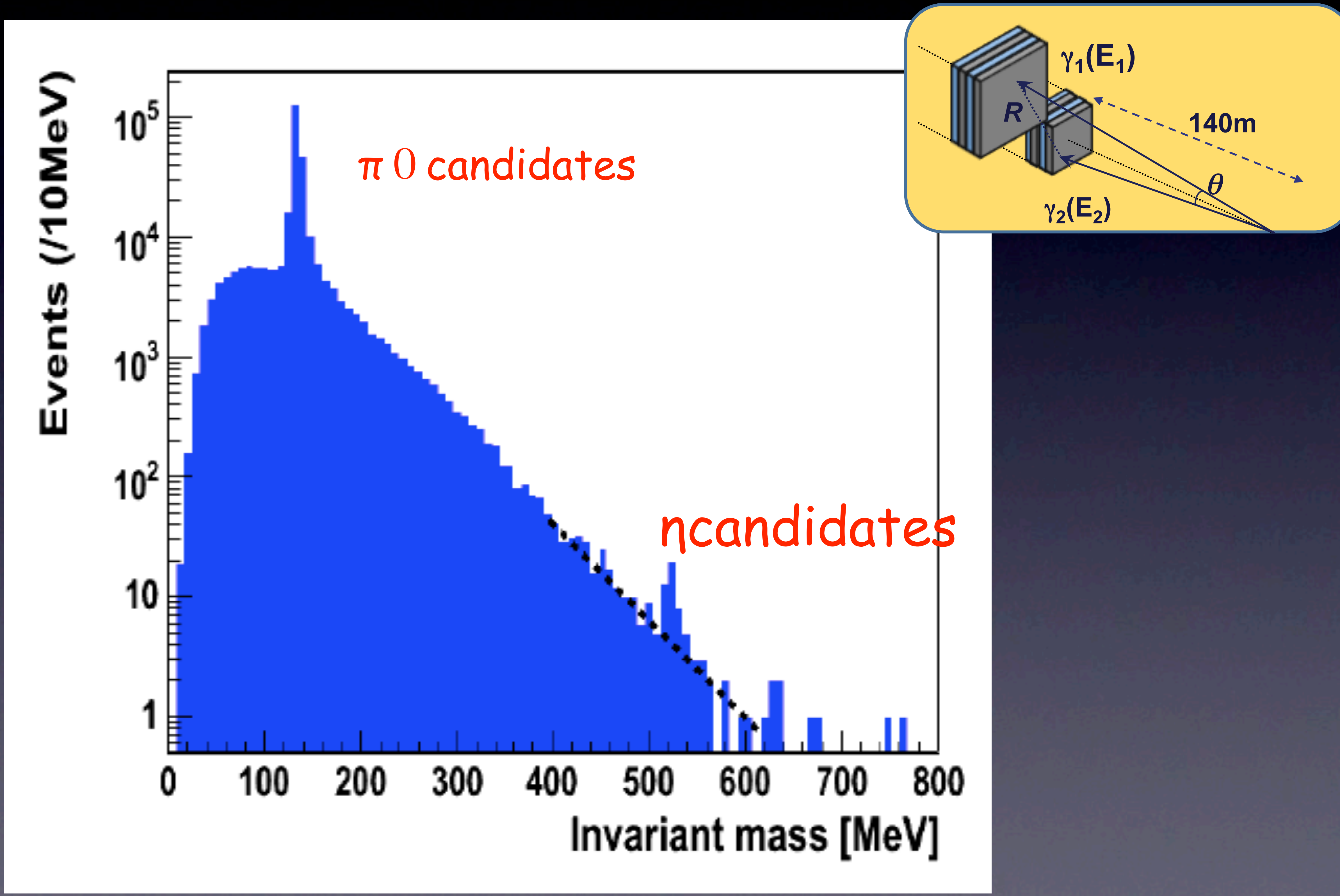




Error sources

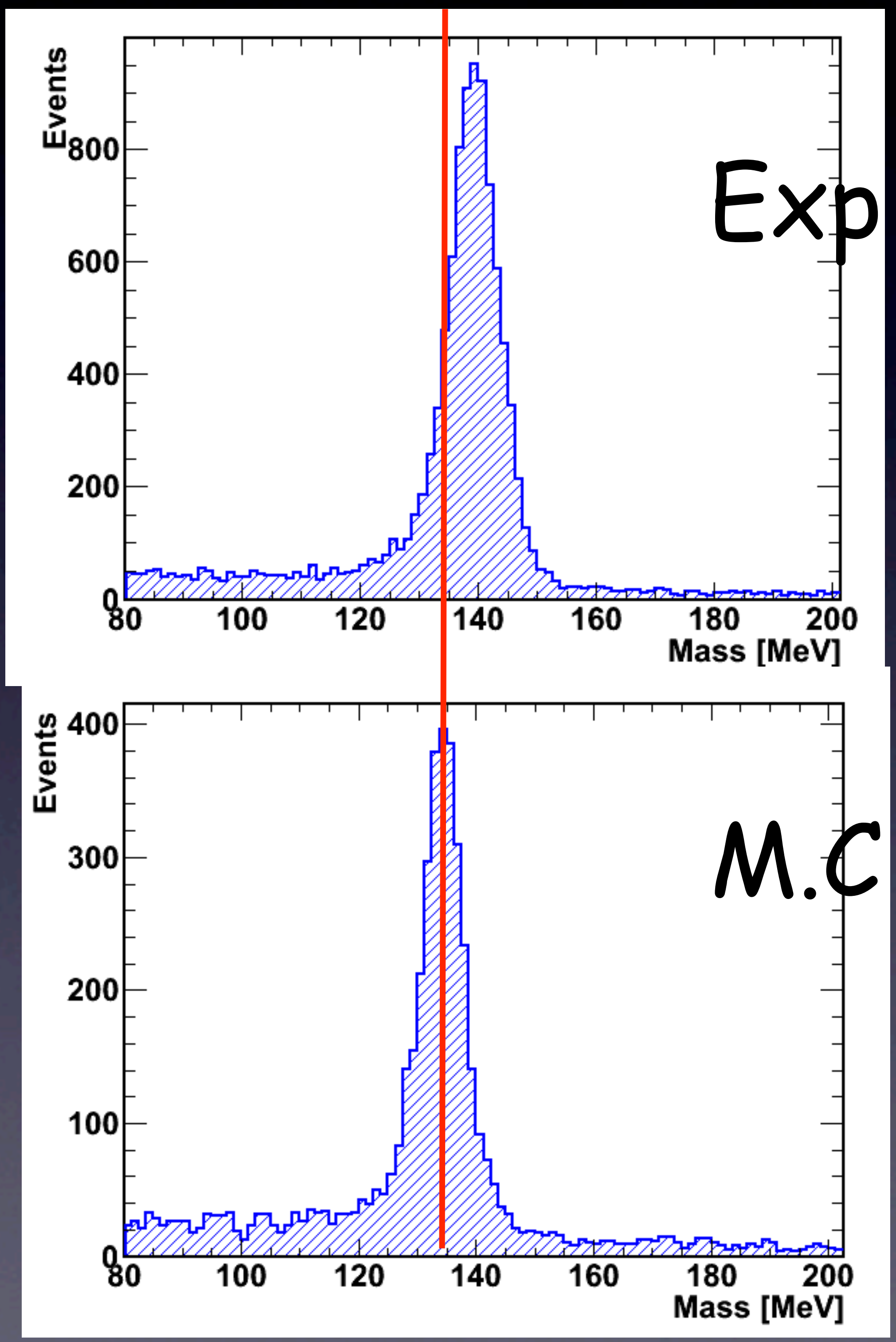
* Leak-out/Leak-in
* Light collec. scin pos. dependeht
* Incident position estimation
* Particle ID
* Multi-hit
* Pile-up
* Beam-gas collision
* B.G from beam pipe
* Beam center (crossing angle)
* Inelastic cross-section 71.5 mb

Energy calibration by π^0



π^0 mass =135 (MeV)

Arm2



	Exp.	M.C
Arm1	145.8 (+7.8%)	135.2
Arm2	140.0 (+3.5%)	135.0
	$\pm 0.1\mathrm{MeV}$	$\pm 0.2\mathrm{MeV}$

Systematic error:

charge to E conversion factor

+ non-uniform light yield+.. (3.5 %)

+ leakage-in (1%) + pos. error (2%)

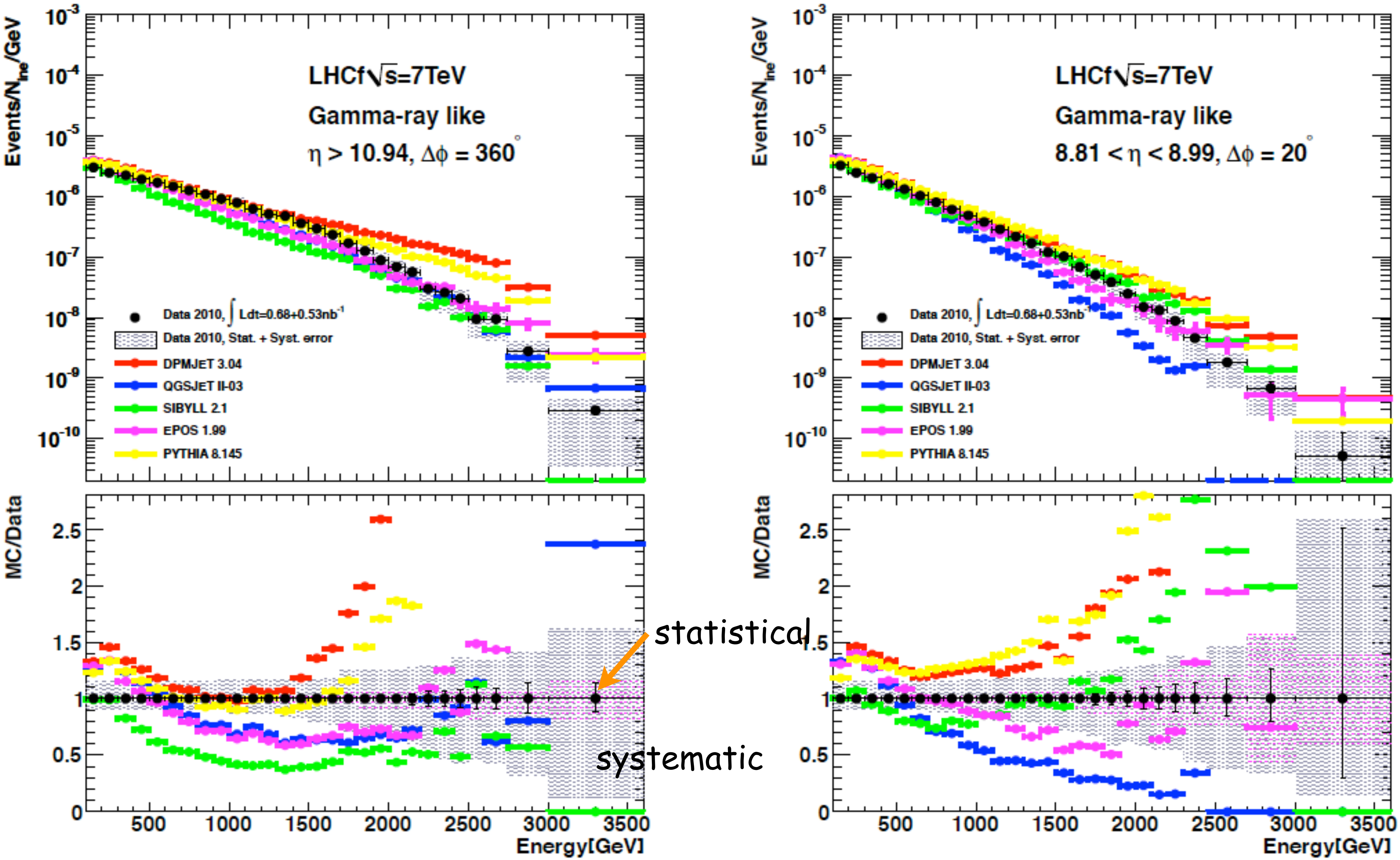
→ 4.2%

Arm2 is OK. But not Arm1

For the moment, we put the errors into energy scale

Comparison with M.C models (Arm1, 2 combined data)

DPMJET3.04 SIBYLL 2.1 EPOS 1.99 PYTHIA 8.145 QGSJET II-03



Summary

- Photon spectrum in the very forward region was obtained at $\sqrt{s} = 7$ TeV
- Non of the M.C models lies within the systematic errors of our data in the entire region
- But the departure is NOT very much surprising/ dramatic level
  - For all models, it's not monotonic wrt energy
  - Theoretical implication ? How to update MC ?
- Better model selection / estimate effect on AS.
  - Hadron (neutron) analysis. Inelastic cross-section...