The LHCf experiment
~ Cosmic rays and forward hadron physics at LHC energy~

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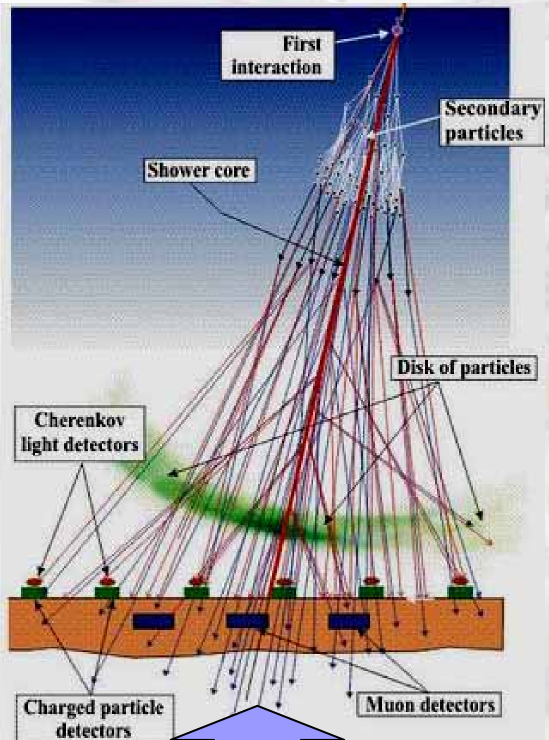
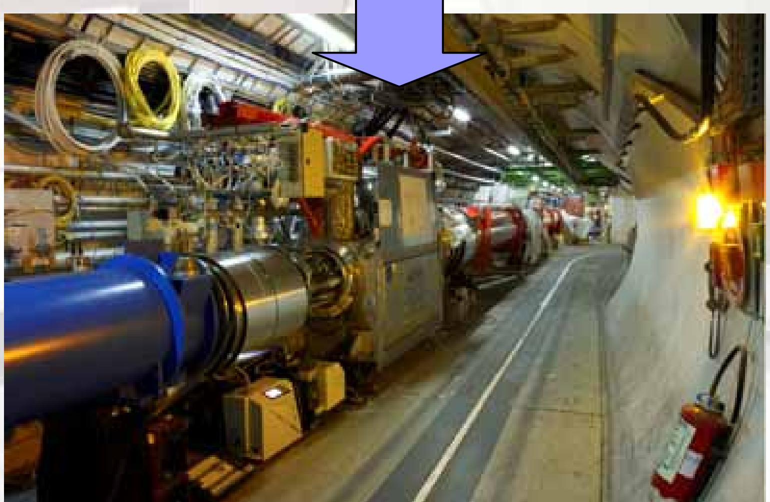
for the LHCf collaboration

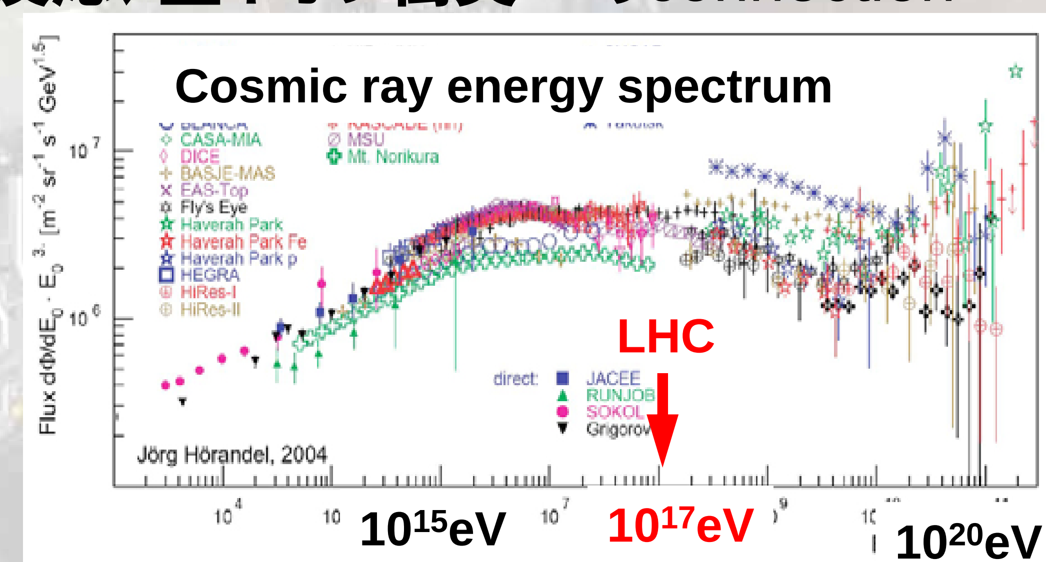
多彩なフレーバーで探る
新しいハドロン存在形態
Nov 27-28, 2009, **名古屋大学**

LHCf physics motivation

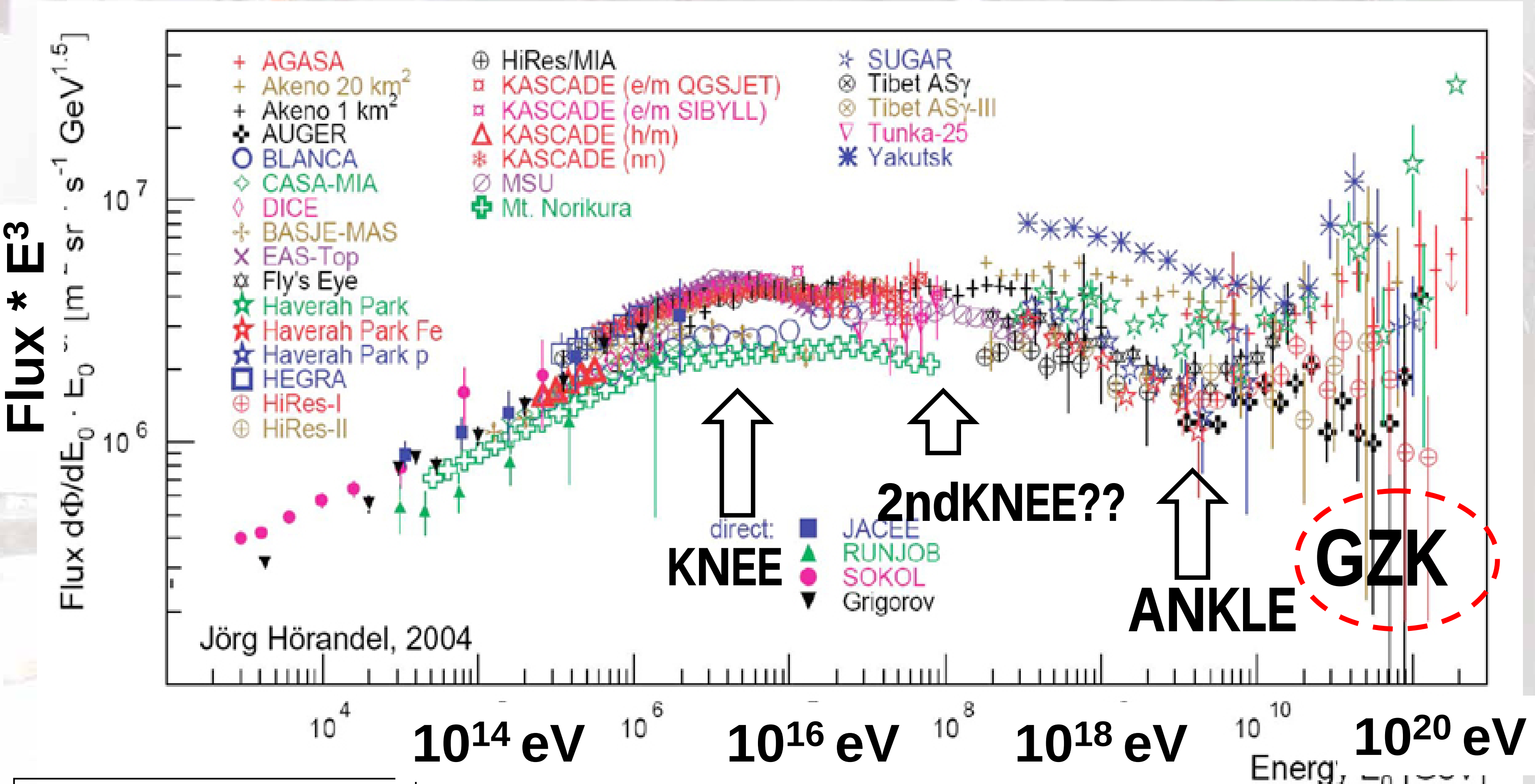


- **超高エネルギー宇宙線のハドロン相互作用を**LHC energy ($E_{CR}=10^{17}$eV)**で検証したい。**
- **宇宙線の空気シャワーに重要な超前方** π^0,γ ,n **のエネルギー、**Pt**を**0**度電磁カロリメーターで測定する。**
- >LHC**エネルギーでの超前方ハドロン反応、重イオン衝突への**connection

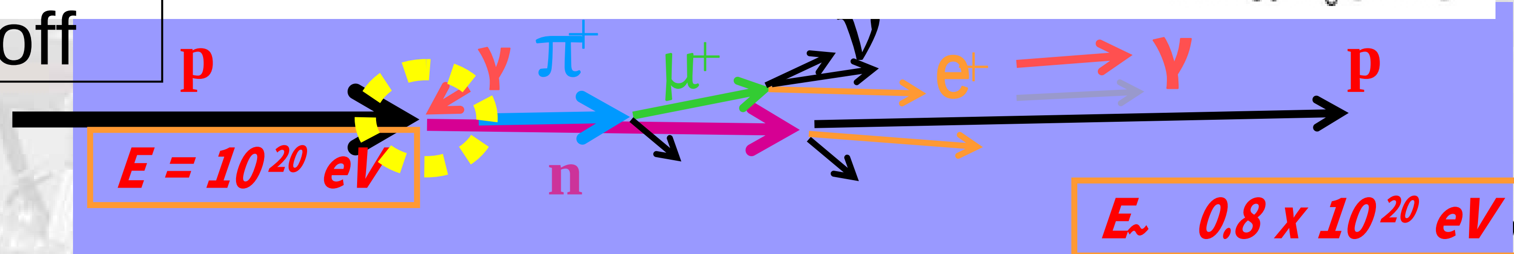




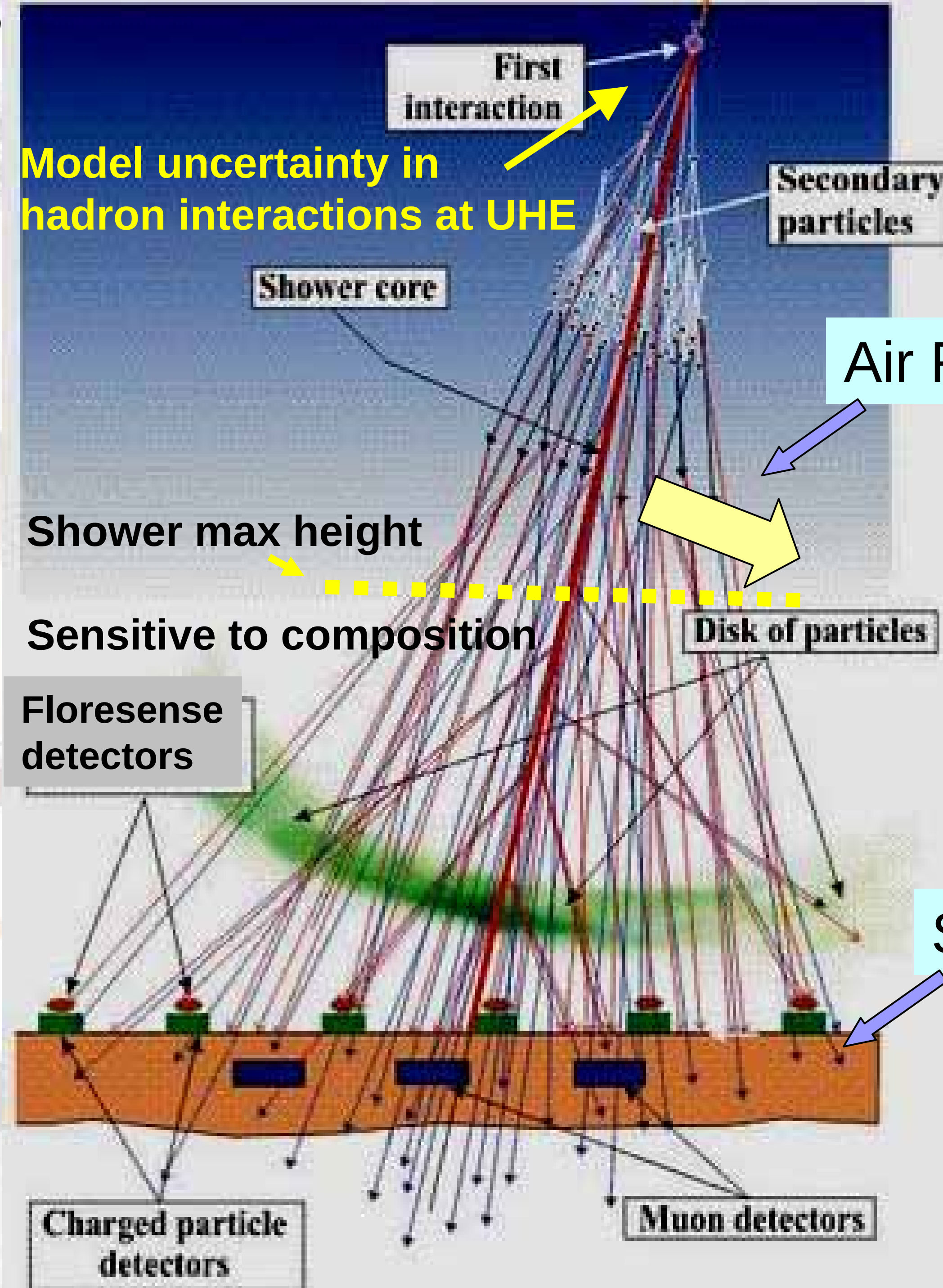
Energy spectrum of UHE cosmic rays



GZK cut off



Air shower observation



Air Florescence telescope (FD)

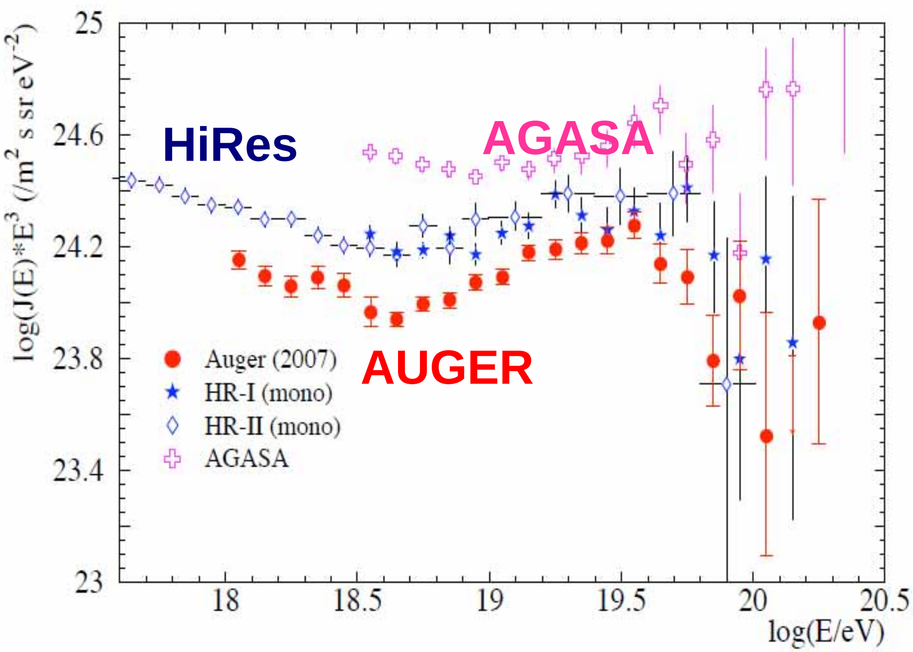
EM component
(most of energy)

- Scintillation lights
- Shower directions
- Shower max alititude

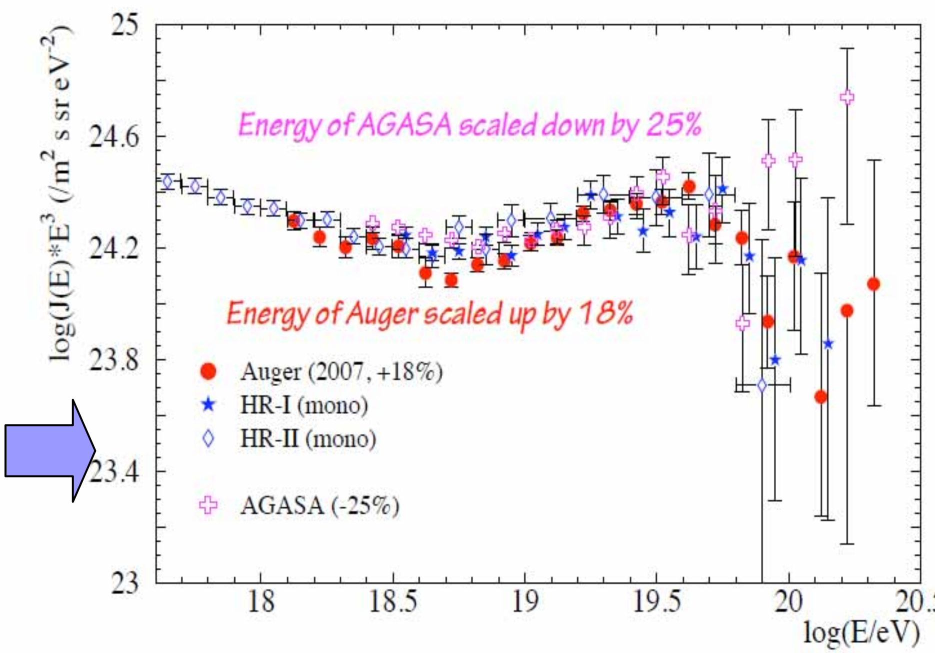
Surface Detectors (SD)

- Number of partciles
- Arrival timing
- Muon or EM component
  (at given altitude)

Energy scale issue; GZK cut off feature in AGASA, HiRes and AUGER （2007 summer）



Energy scaling by +-25%



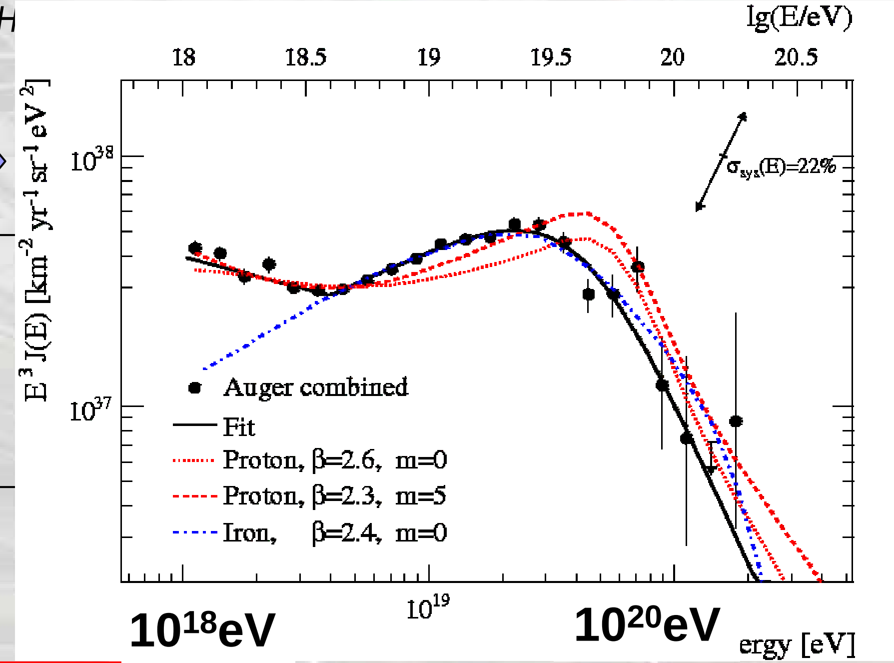
c.f. Energy scale was determined by fluorescence detector

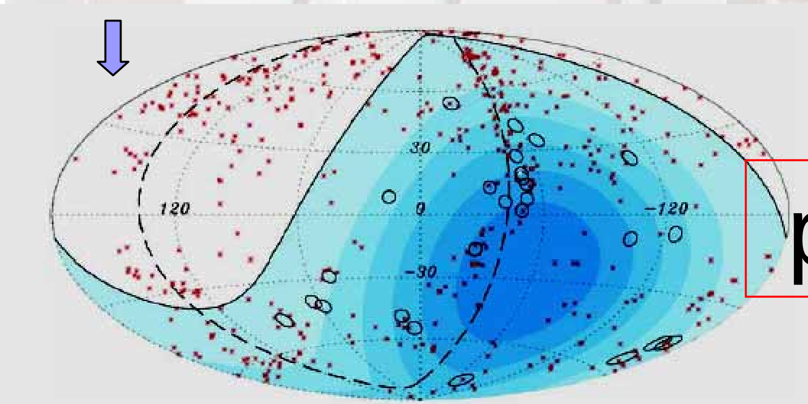
J. Bluemer @ICRR, Mar. 2008

UHECR GZK Problem

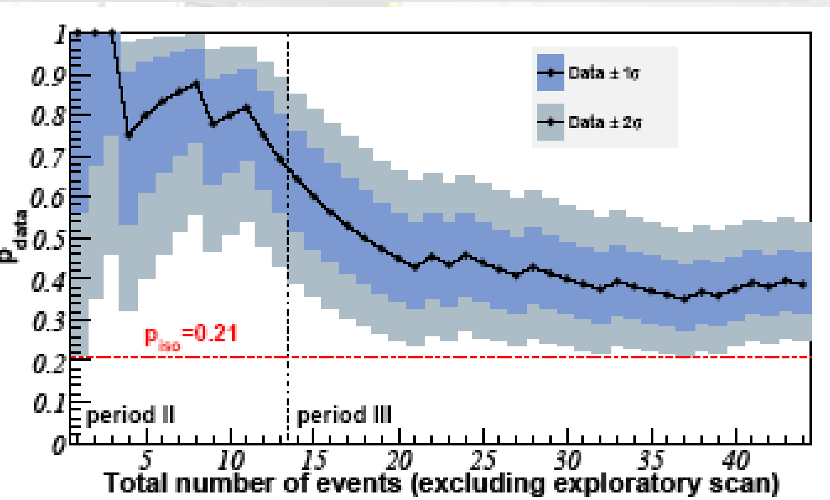
~ recent situation ~

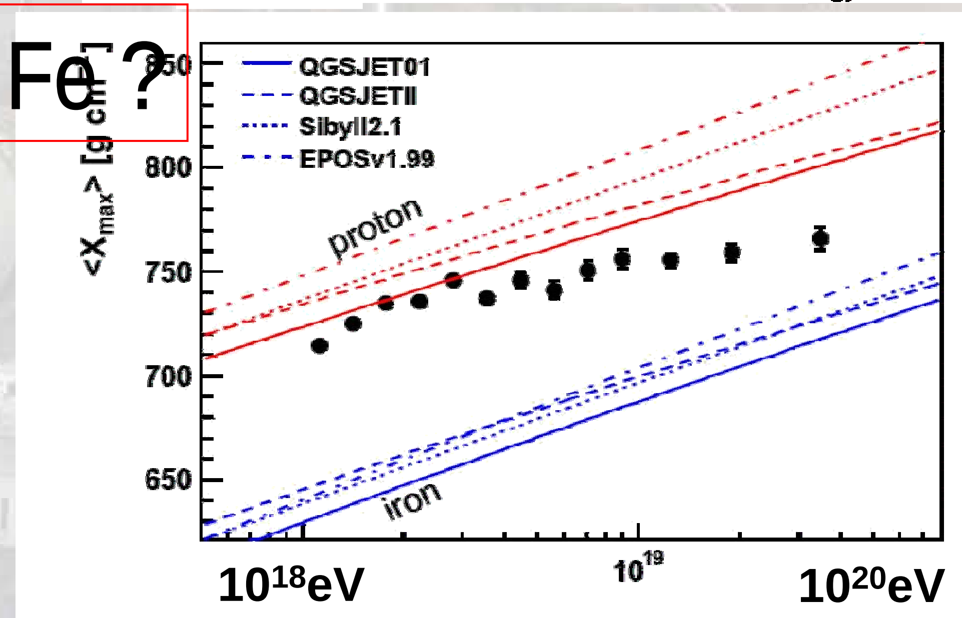
AUGER reported clear “cut off” feature and directional correlation to AGN ,suggesting UHECR is proton, while it got weaker for newer data (ICRC09)





p or Fe ?





AUGER shower max position data suggests composition gets heavier, not protons.

Hadron Interaction models used in air shower simulations

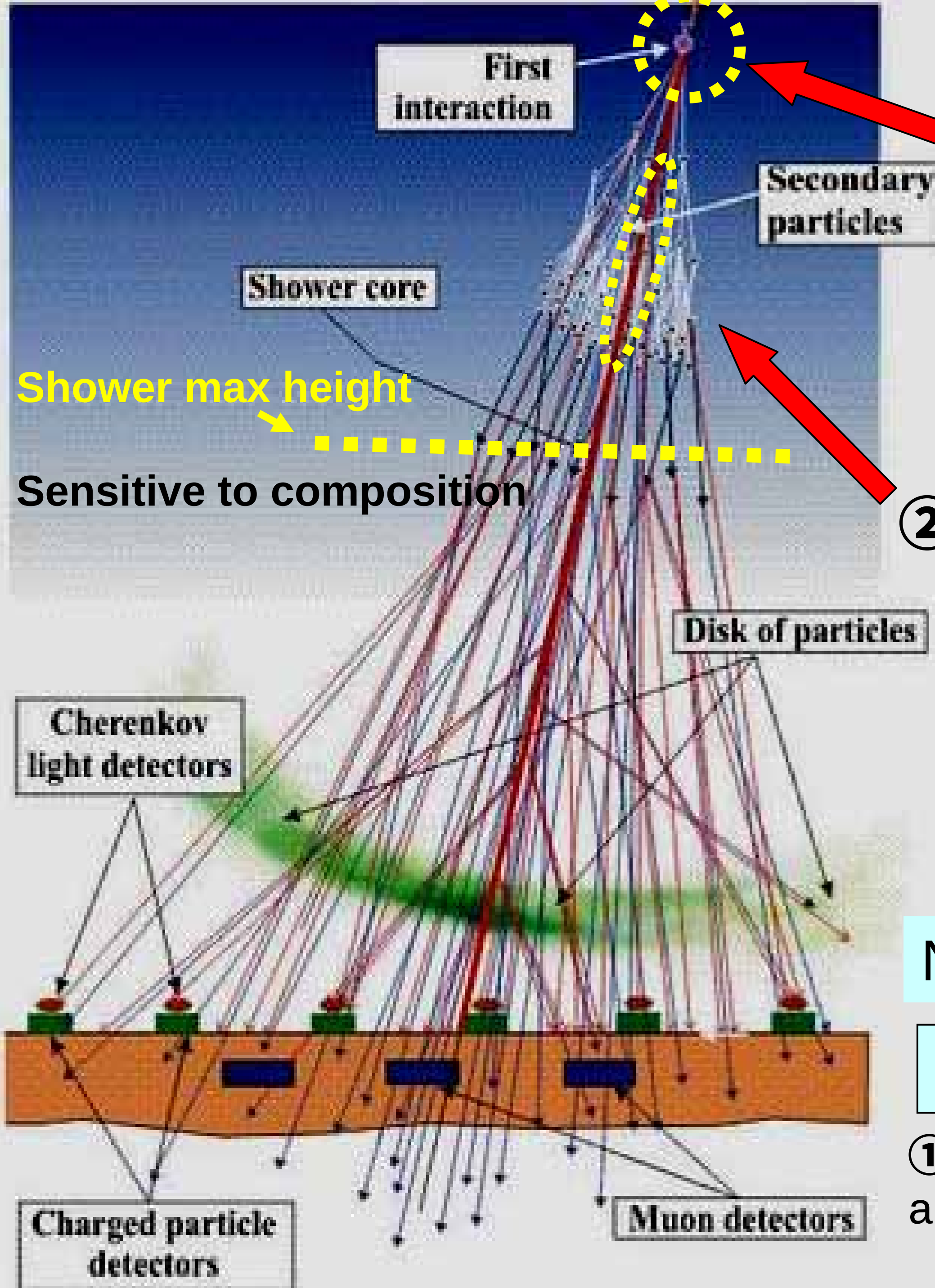
- QGSJET Ⅰ、Ⅱ
- DPMJET
- SIBYLL
- EPOS

……..

Affect air-shower observables

E-scale ?

Composition ?



① Inelastic cross section

If large σ
    rapid development
If small σ
    deep penetrating

② Forward energy spectrum
(or Inelasticity k)

If large k
    rapid development
If small k
    deep penetrating

Need both ① and ②

LHCf is dedicated to ②

① will be give by Roman Pod at LHC

The LHCf Collaboration

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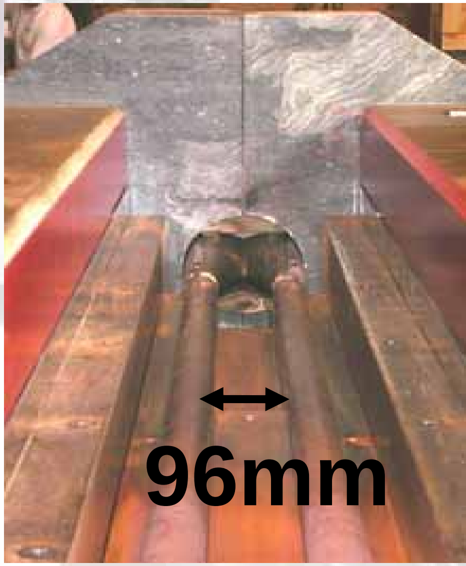
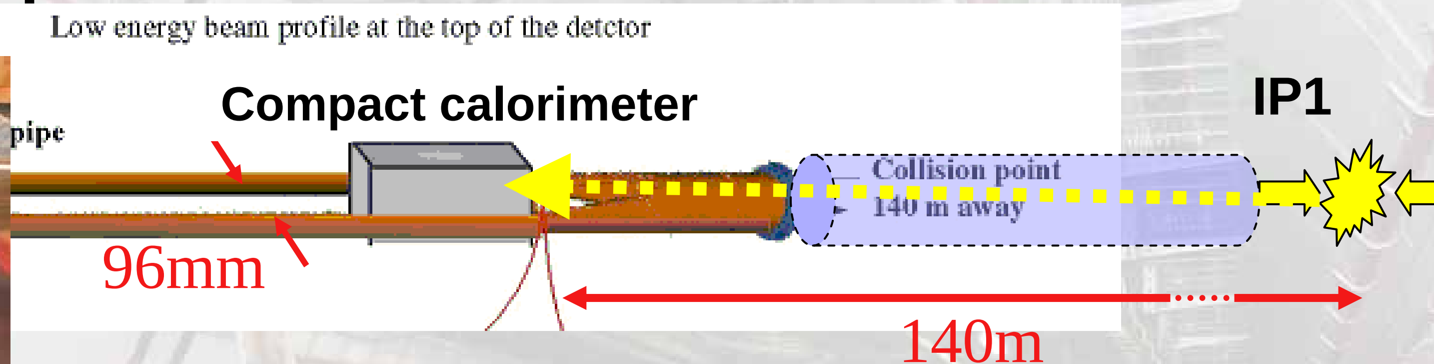
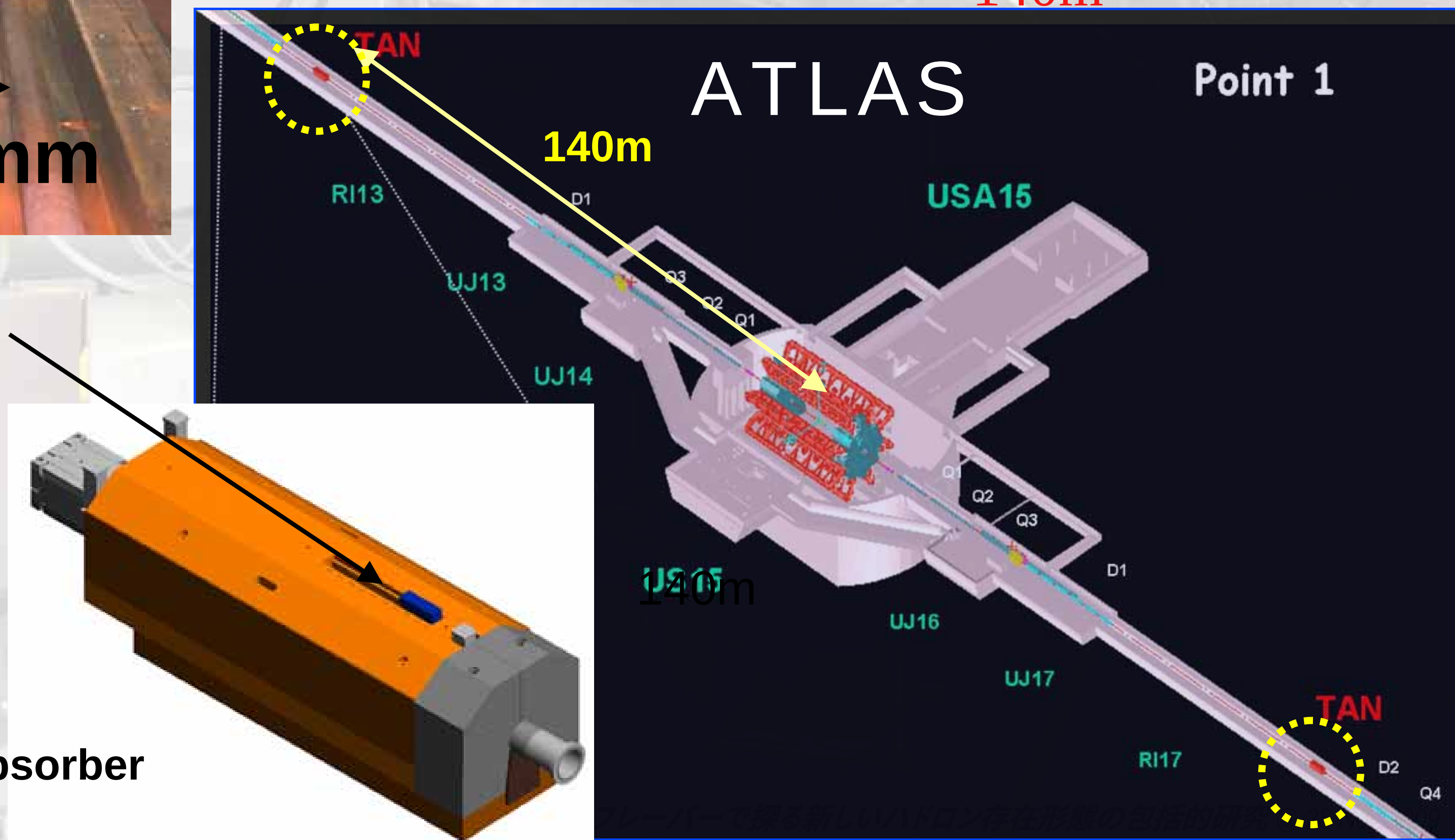
LHCf experimental site





LHCf



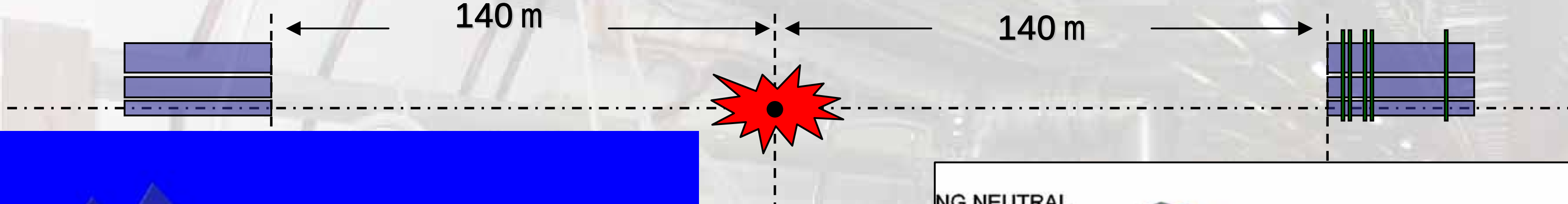
TAN absorber

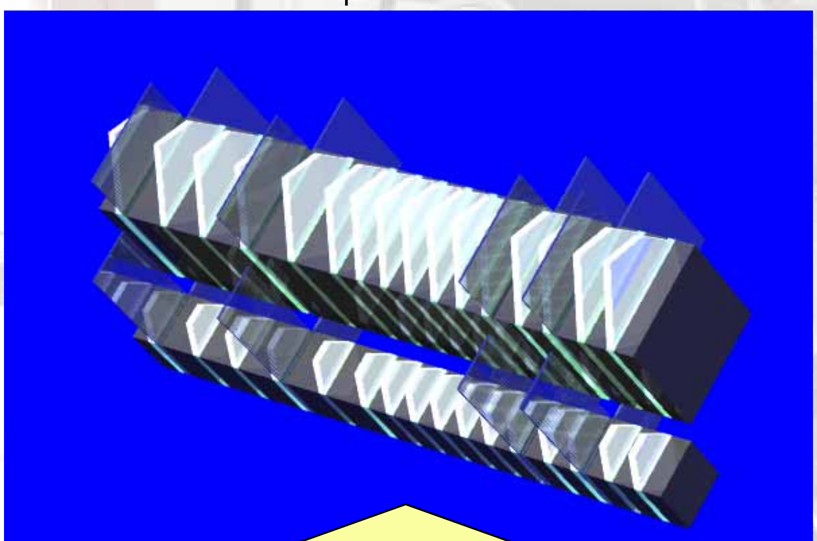
LHCf: location and detector layout

Detector I
Tungsten
Scintillator
Scintillating fibers

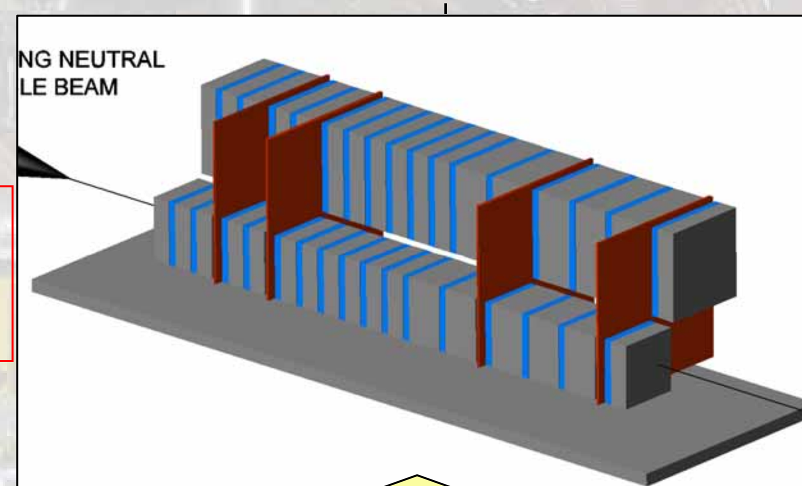
INTERACTION POINT
IP1 (ATLAS)

Detector II
Tungsten
Scintillator
Silicon μstrips





$44X_0$,
$1.6\ \lambda_{int}$



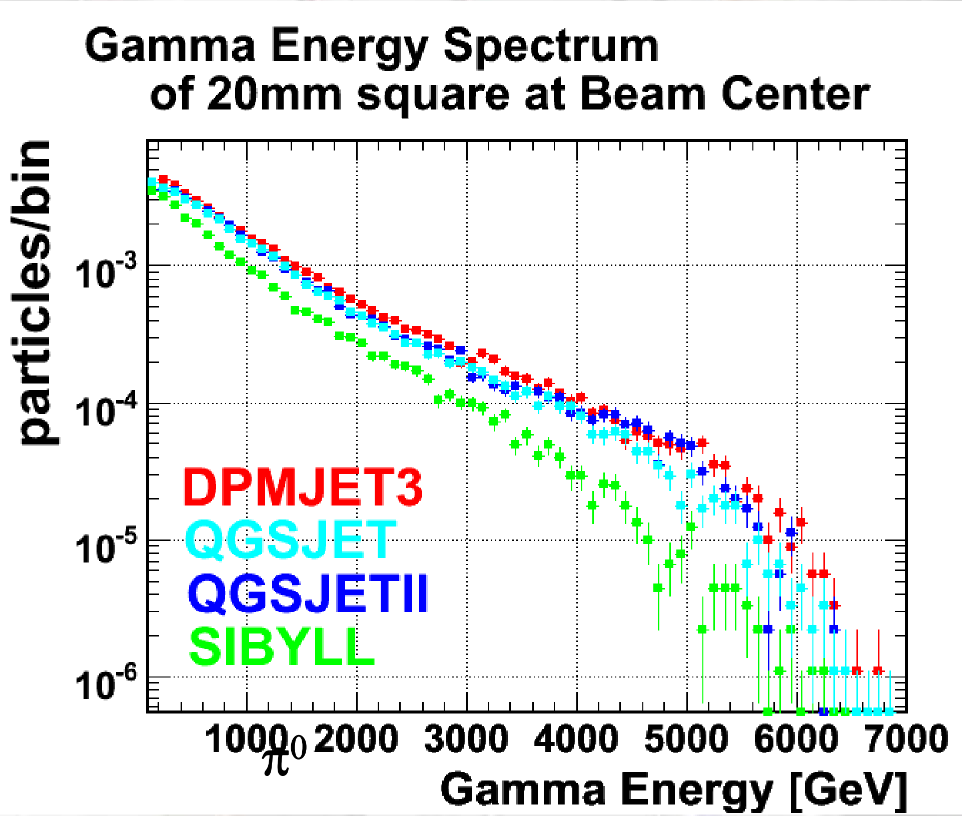
Arm#1 Detector
20mmx20mm+40mmx40mm
4 SciFi tracking layers

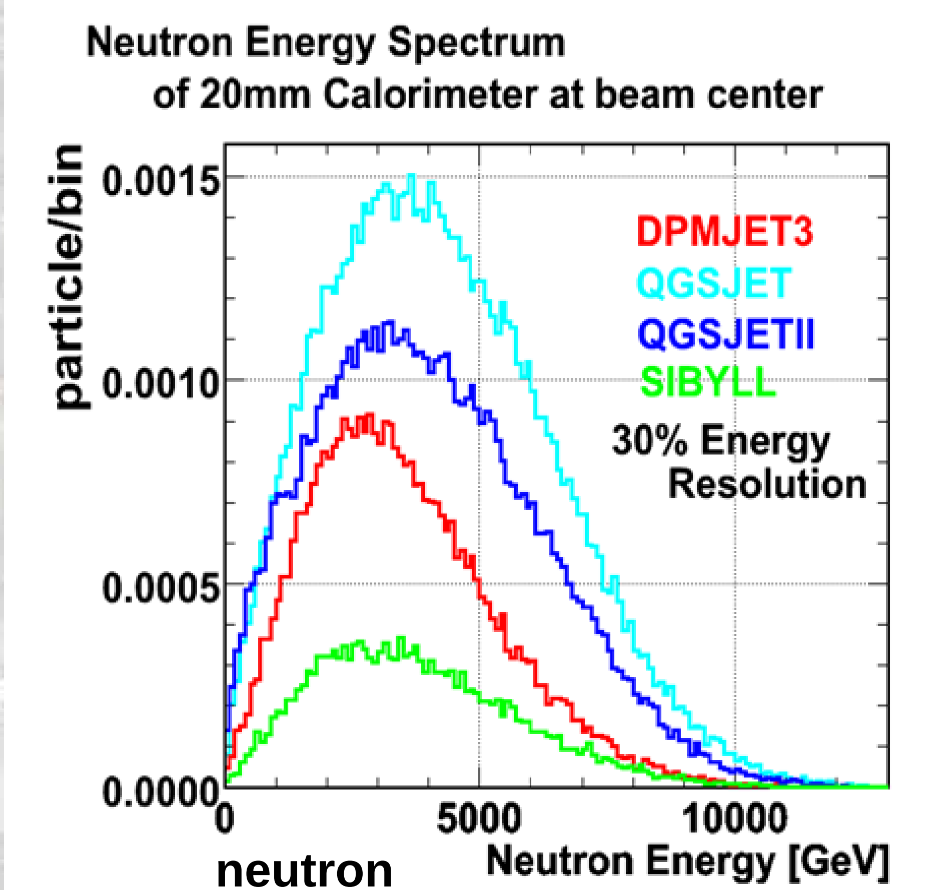
Arm#2 Detector
25mmx25mm+32mmx32mm
4 Silicon strip tracking layers

LHCf calorimeters

Model dependence of forward energy spectra

- Single γ / neutron samples

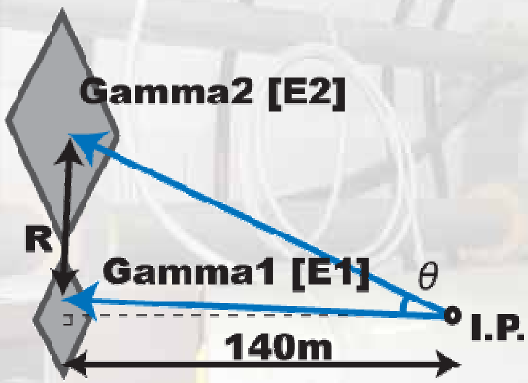


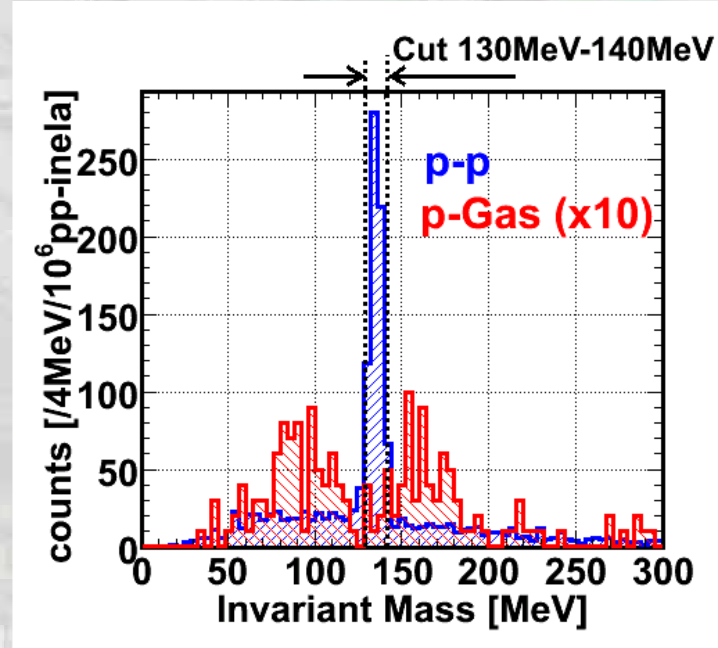


Various distributions at 7+7 TeV

The basic sample ; π^0

- A clean sample against beam-gas background.
- Energy scale can be checked by data itself





Shape comparison

QGSJETII

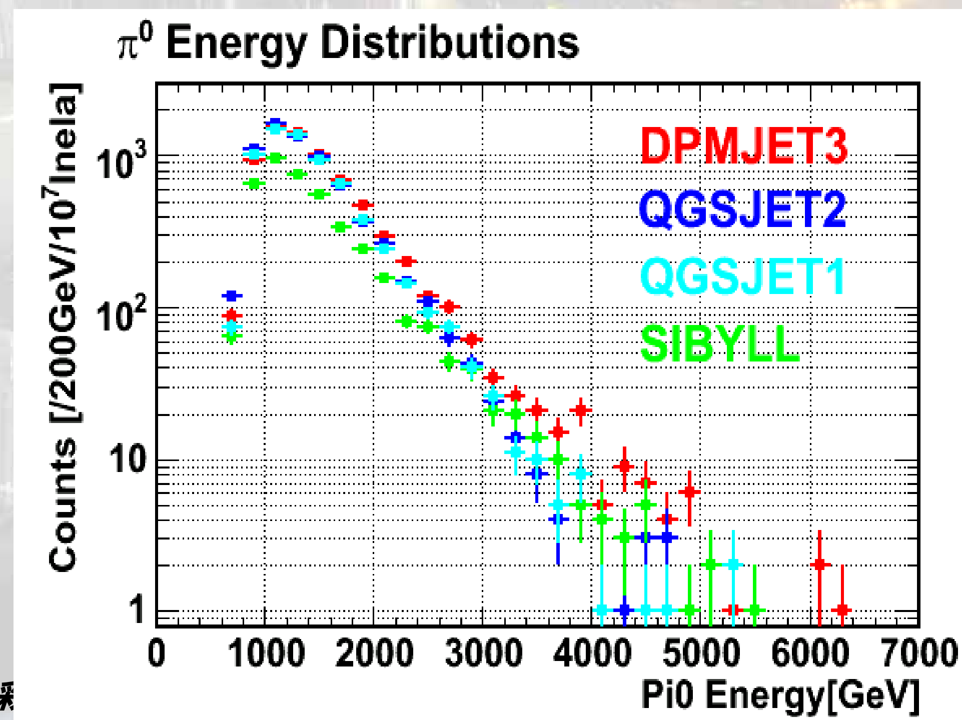
⇔ DPMJET3 χ^2= 106 (C.L. <10^{-6})

⇔ SIBYLL χ^2= 83 (C.L. <10^{-6})

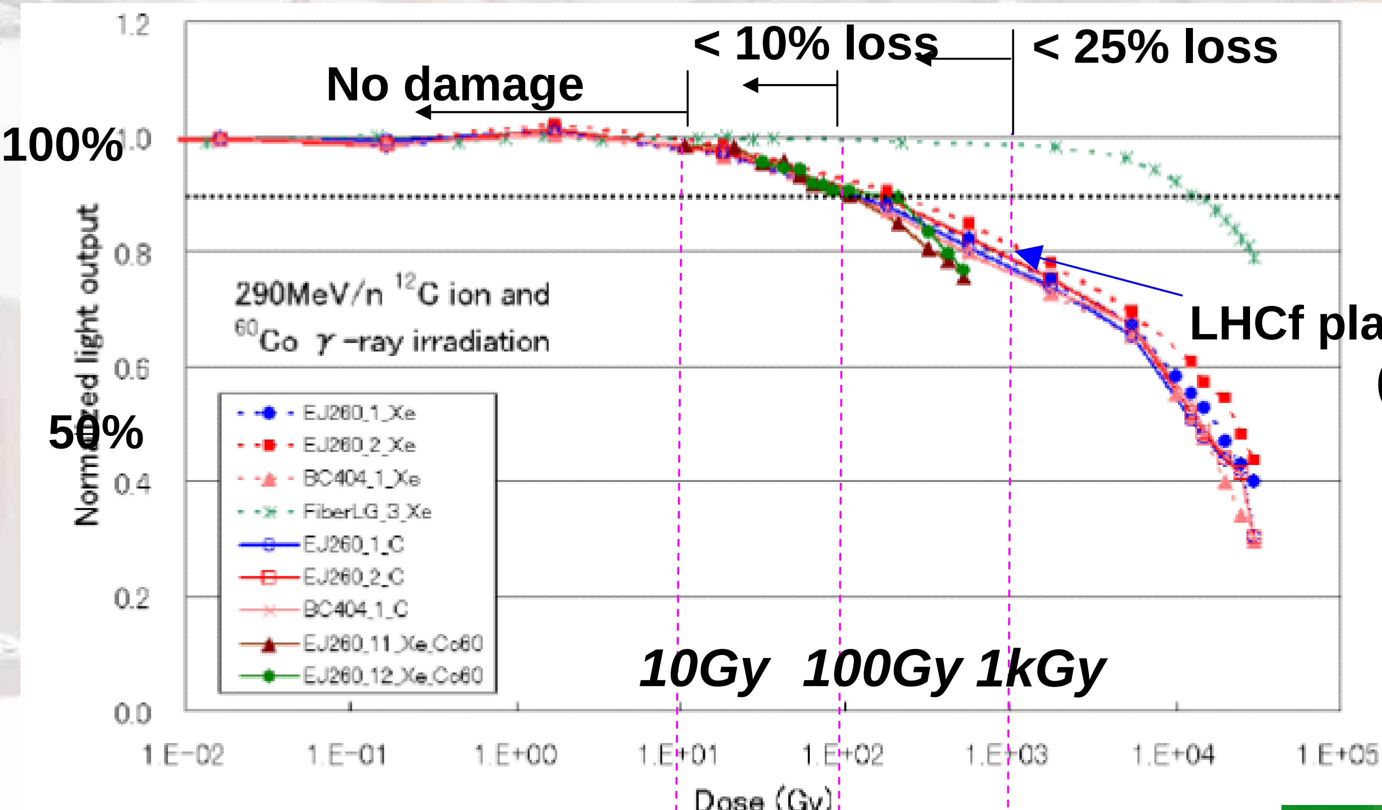
DPMJET3

⇔ SIBYLL χ^2= 28 (C.L.= 0.024)

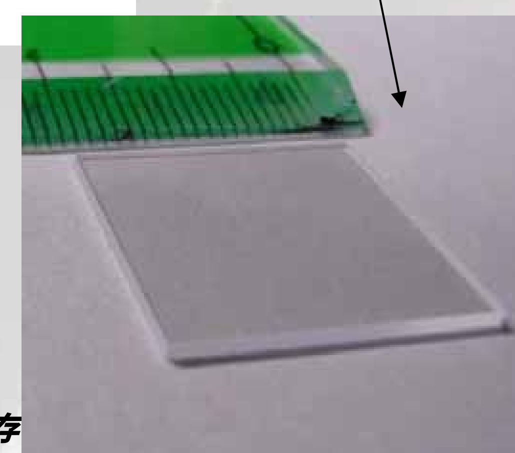
10^7events DOF = 17-2=15



Expected dose and degradation of plastic scintillators



GSO scintillator
(OK for $>10^6$Gy)



Integl. L (nb^{-1})

3.5+3.5TeV 19 nb^{-1} 190nb^{-1}

#of π^0 **3.8E5 π^0**

5+5 TeV 5.9 nb^{-1} 59 nb^{-1}

2.5E5 π^0

$L=10^{29}cm^{-2}s^{-1}$
$= 8.64nb^{-1}/d$

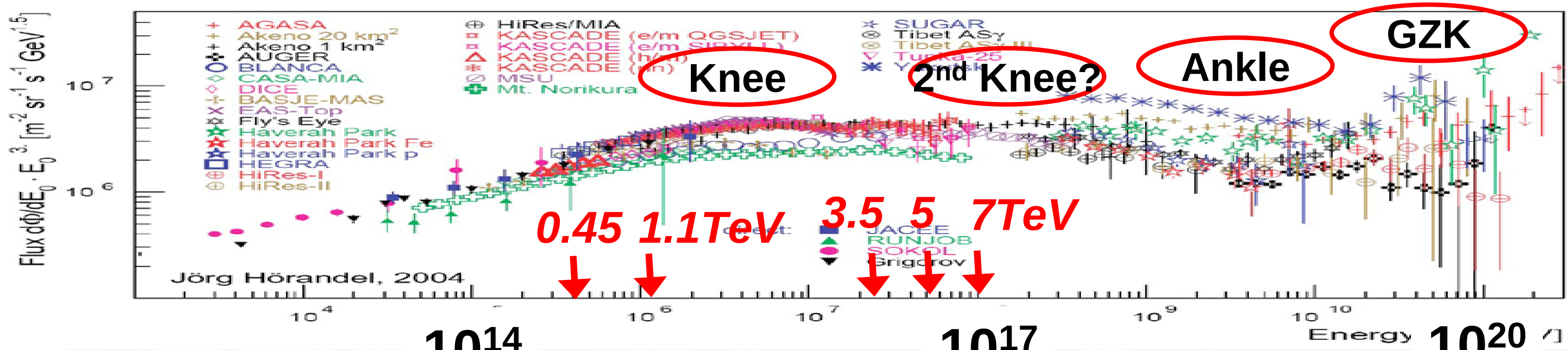
~1days @ $L=10^{30}$

LHCf takes data every when LHC increases energy

HEAT

TALE

AUGER, TA



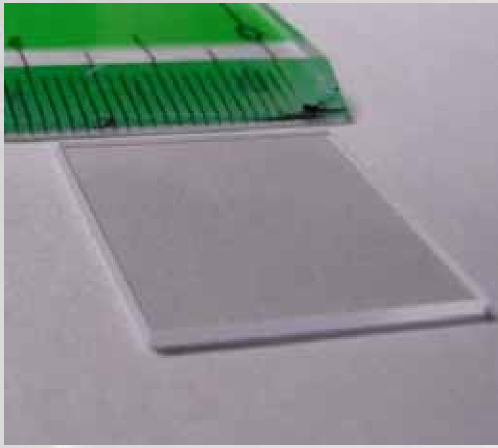
LHC energy schedule

2009		2010			2011	
450GeV	1.1TeV	3.5TeV	5TeV	Pb+Pb	5TeV	7TeV
Nov.	Dec.					

LHCf I

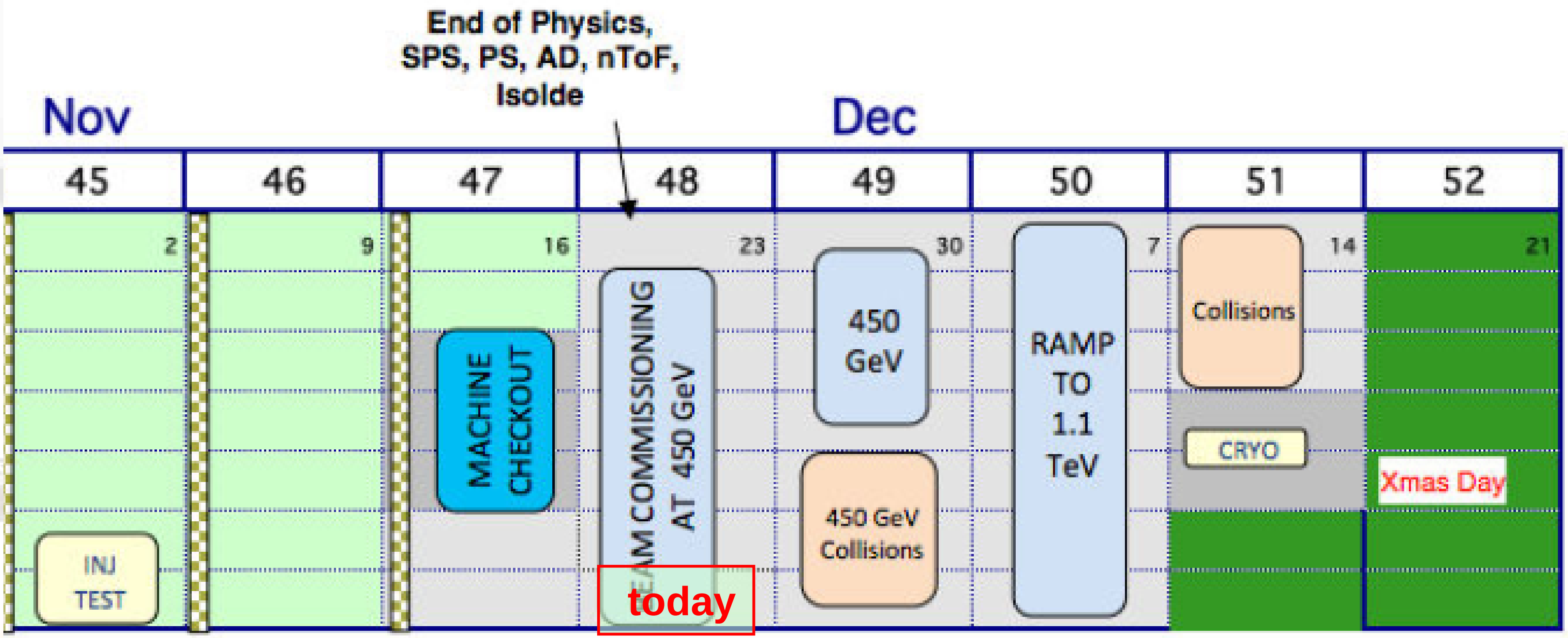
Detector upgrade

LHCf II

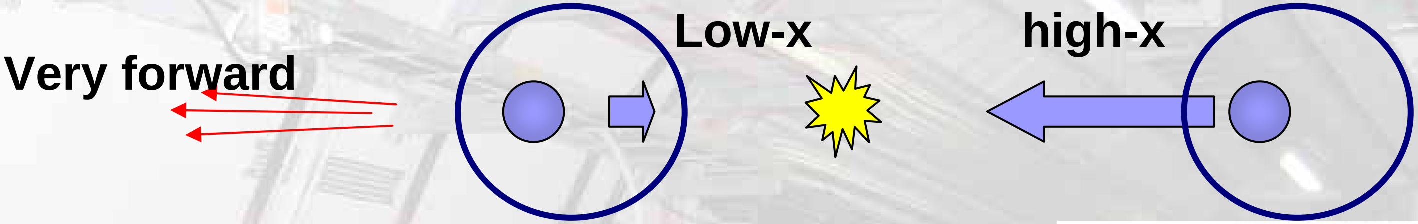


- **Current detector will be "burned" until 3.5TeV run**
- **New detector w/ rad-hard GSO scinitillator will be ready for 5 and 7 TeV runs**

LHC ; schedule in this year

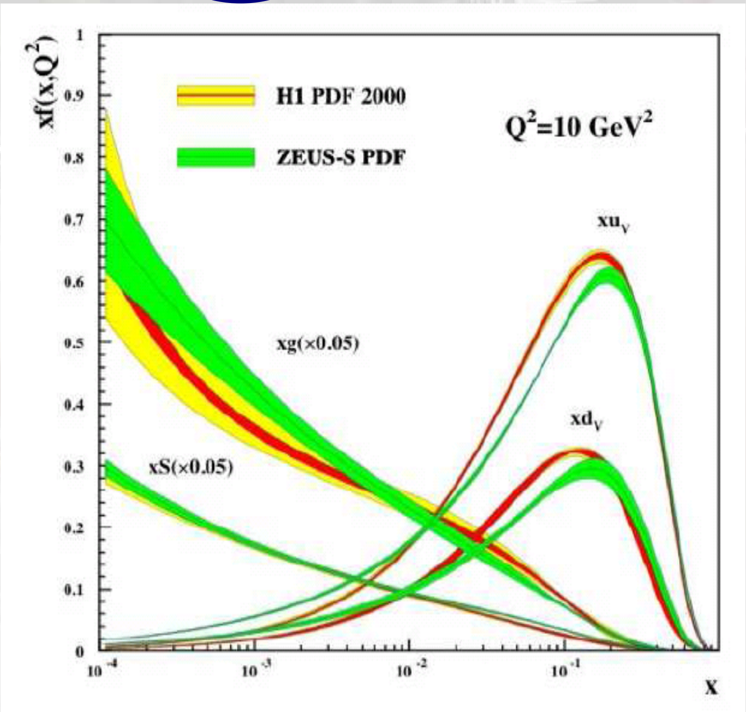


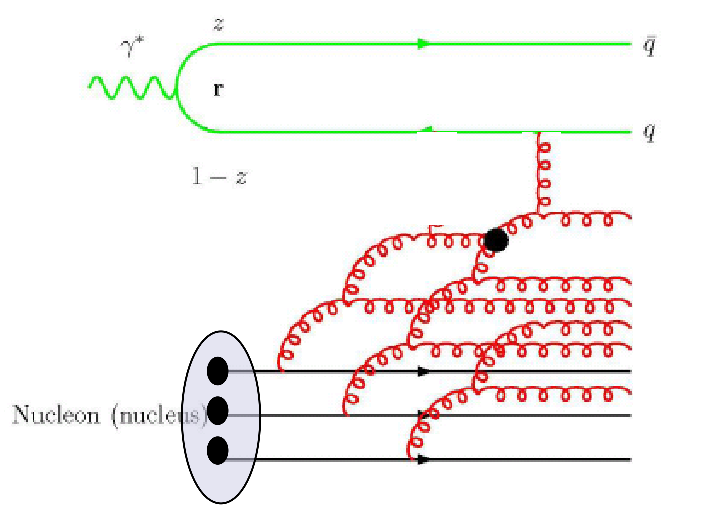
Very forward – connection to low-x physics



- Very forward region : collision of a low-x parton with a large-x parton
- Small-x gluons become dominating in higher energy collision.
- But they may be saturated

(Color Glass Condensation)





Naively CGC-like suppression may occur in very forward at high energy

Forward scattering at very high energy

→ Real situation is more complex, multi-pomeron exchange (not simple hard parton collsions but including soft + semi-hard)

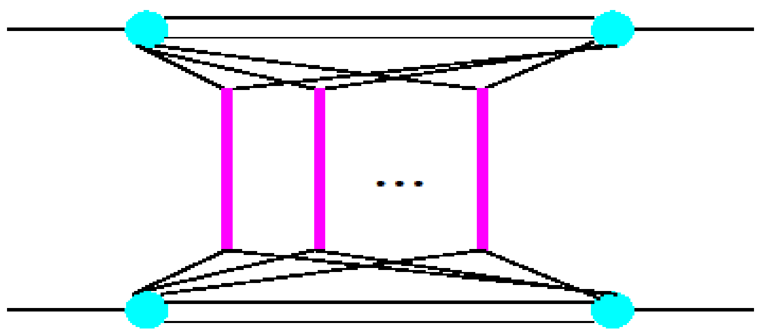
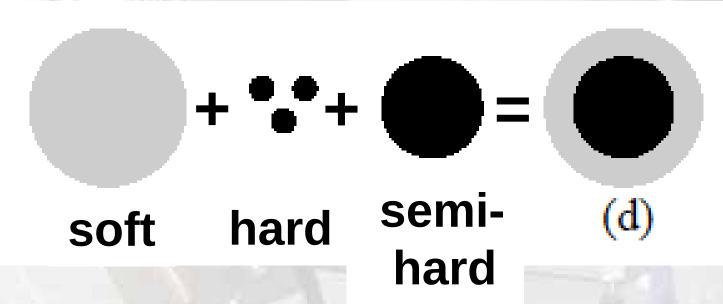
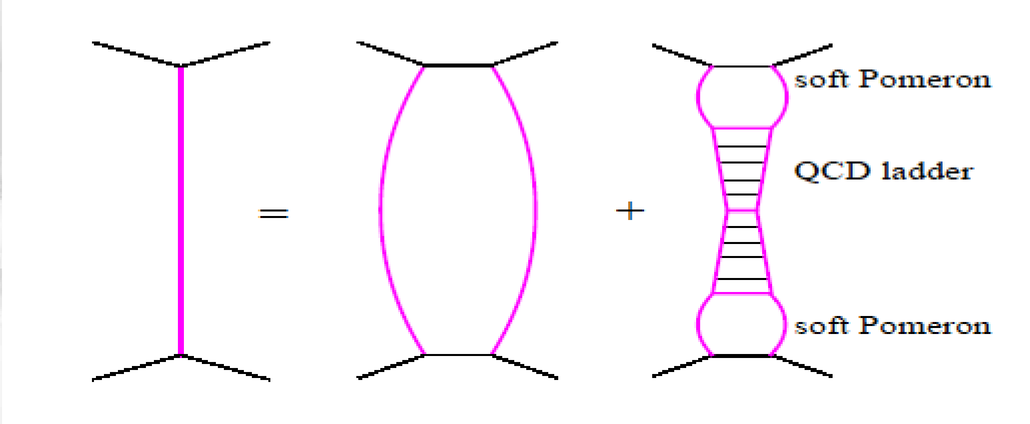


Figure 1. A general multi-Pomeron contribution to hadron-hadron scattering amplitude. Elementary scattering processes (vertical thick lines) are described as Pomeron exchanges; thin lines correspond to constituent partons, to which Pomerons are coupled.

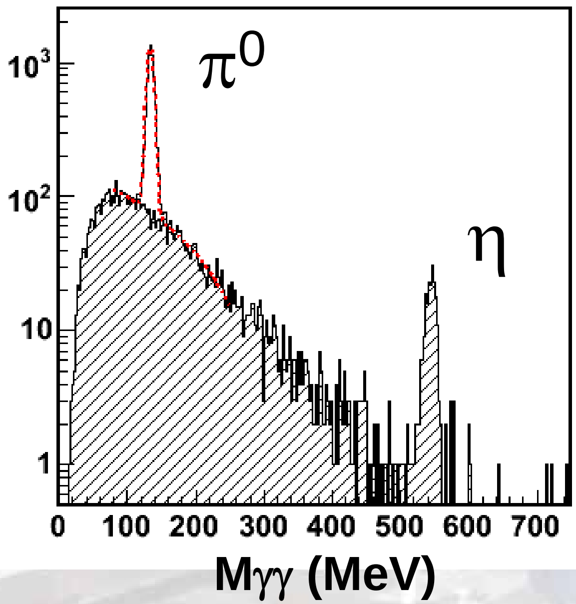


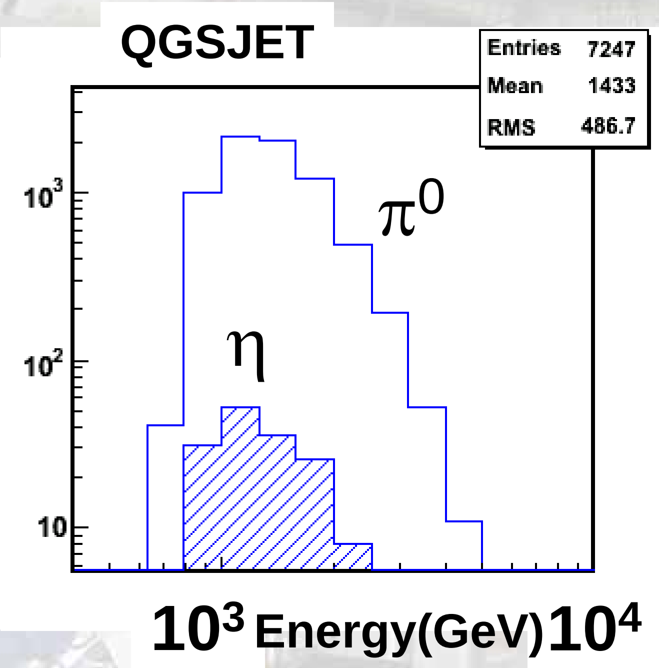


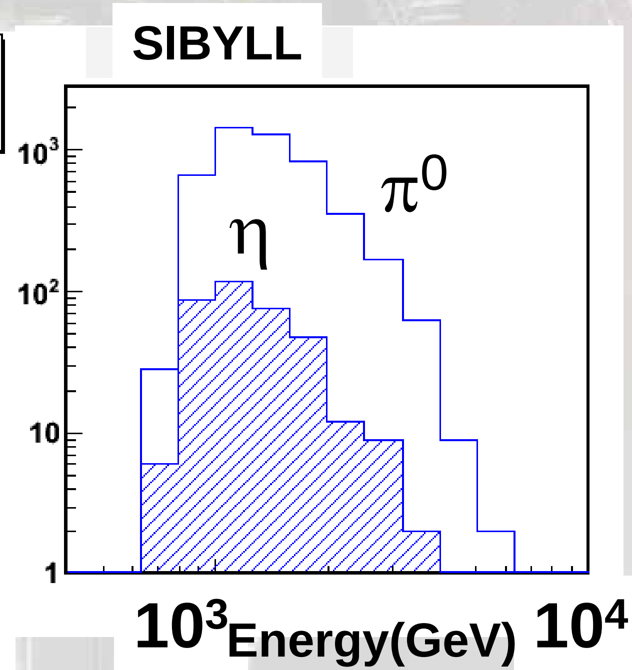
High static sample for very forward hadron productions

- ~10^7 π^0 can be corrected for a few 100 nb^{-1} each at 3,5 and 7TeV
- higher mass hadrons ($\eta \rightarrow \gamma\gamma$, $\Lambda \rightarrow n\pi^0$, etc) can be reconstructed.

7+7 TeV MC

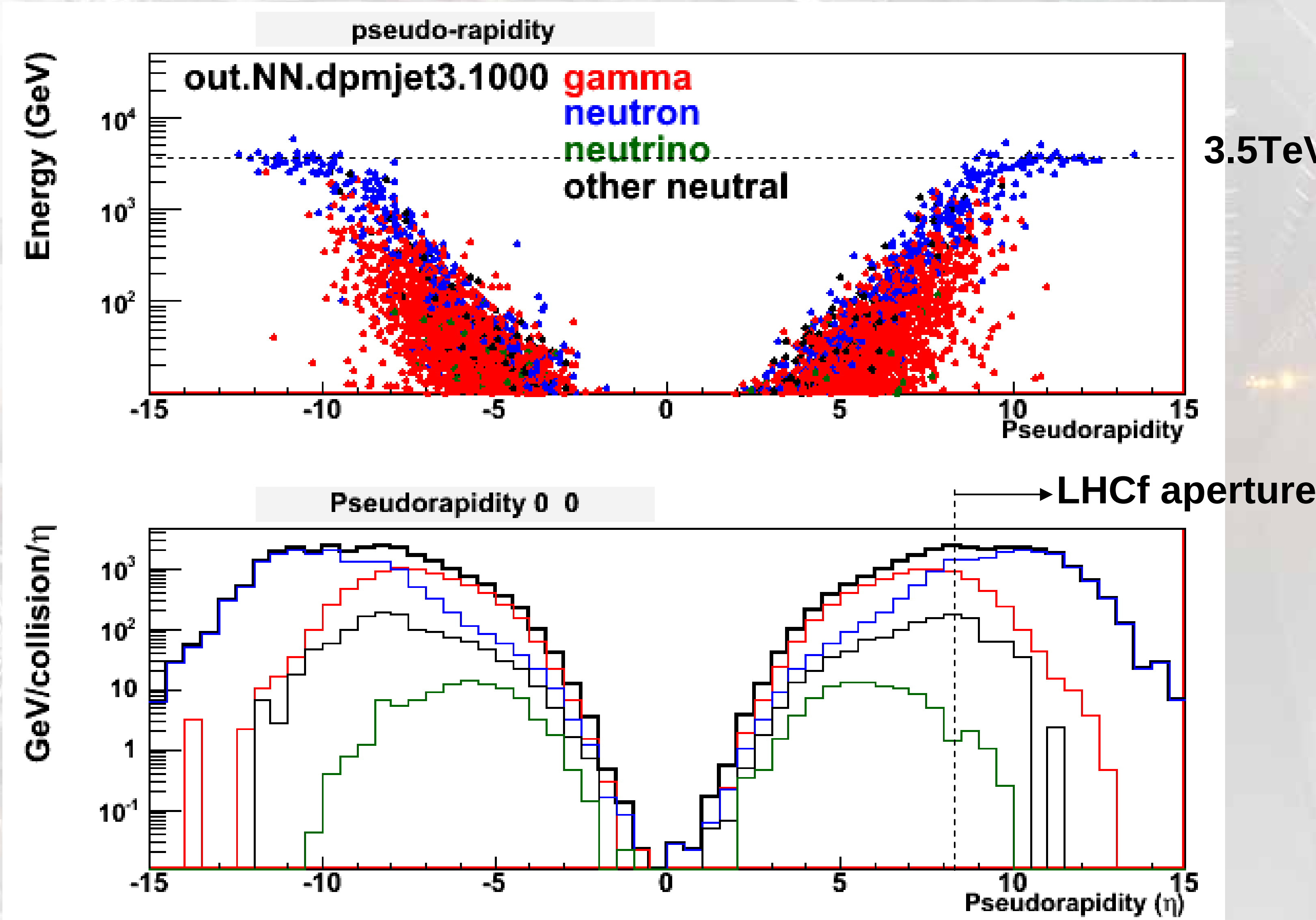






Future : Heavy (Light) ion collisions, A-A, p-A

Neutral from 3.5TeV/n N+N collisions(DPMJET3)



Summary

- LHCf : Dedicated measurements of neutral particles at 0 deg at LHC energy for the verfication of cosmic rays interaction models.
- Detectors are installed at IP1 in 2008, ready for collisions.
- As increasing energy of LHC, providing several calibration points at 10^{14}~10^{17}eV of cosmic rays.
- For 0.45, 1.1 3.5 TeV in 2009~2010 with LHCf-1.
- For 5 and ~7 TeV in > 2010 with upgraded LHCf-2 with rad-hard GSO scintillators.
- Connection to forward hadron physics. High stat. neutral hadron production data in LHCf.
- Future HI runs. R&D in progress.

UHECR data may hint ultra high energy interactions at beyond-LHC energy. To approach, LHCf will give firm base of understanding at 10^{17}eV.