LHCf: Luminosity monitoring and measurement

Takashi SAKO

for the LHCf Collaboration

Joint LHC Machine-Experiments workshop on the luminosity monitoring and measurement 26 Jan 2007, at CERN (AT

CONTENTS

Brief introduction to the LHCf
(physics & detector)

Ralative Luminosity measurement
(single event, double arm, pi0)

Background (beam-gas)

Problems in the high-energy CR

- **Existence of the GZK cutoff (extla Galactic)**

  Cosmic microwave backgroud prevents CRs of >10^{20}eV from traveling over 20Mpc

  Cutoff in the energy spectrum is expected.

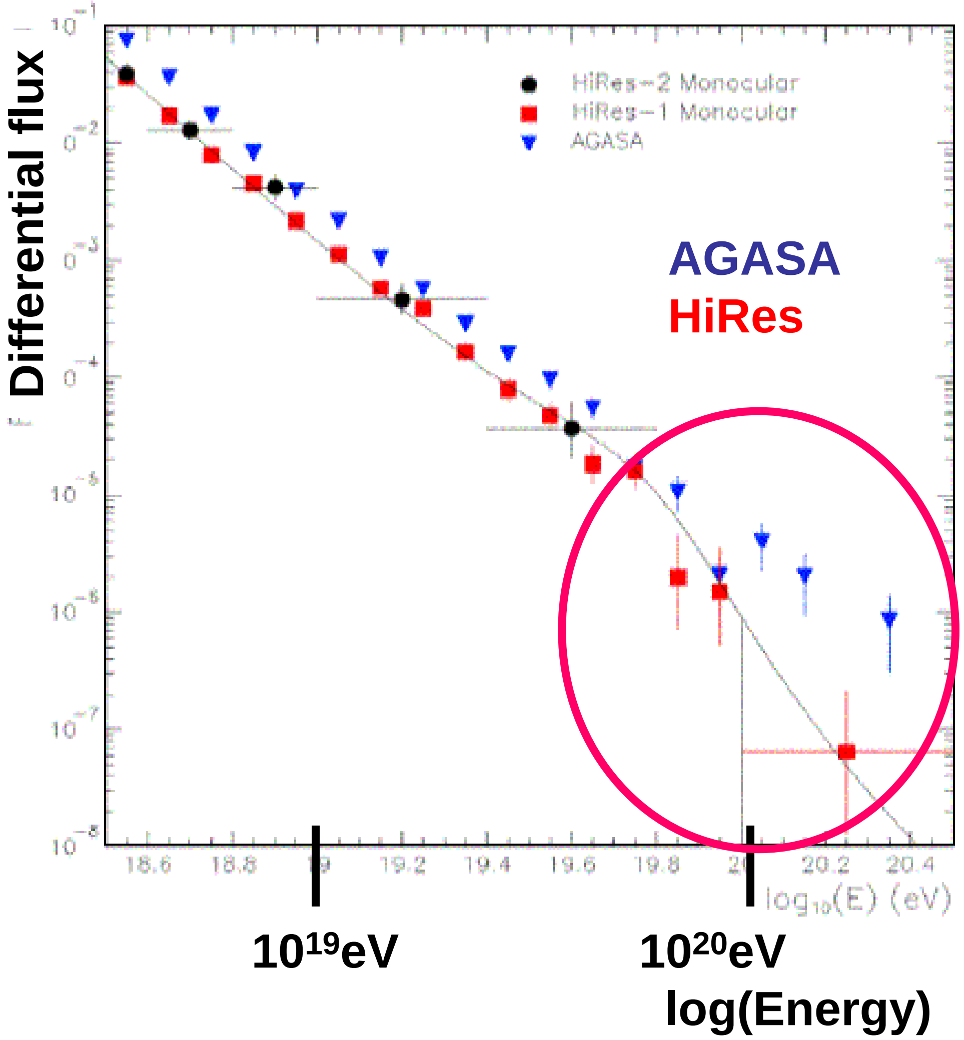
- **Chemical composition (Galactic <10^{18}eV)**

  Acceleration limit will be determined by rigidity ($\propto$p/z).

  Maximum energy depends on z

  CR composition must change at around acceleration limit.

GZK cutoff



Existence of cutoff is not clear.

If no cutoff, exotic solutions will come out.

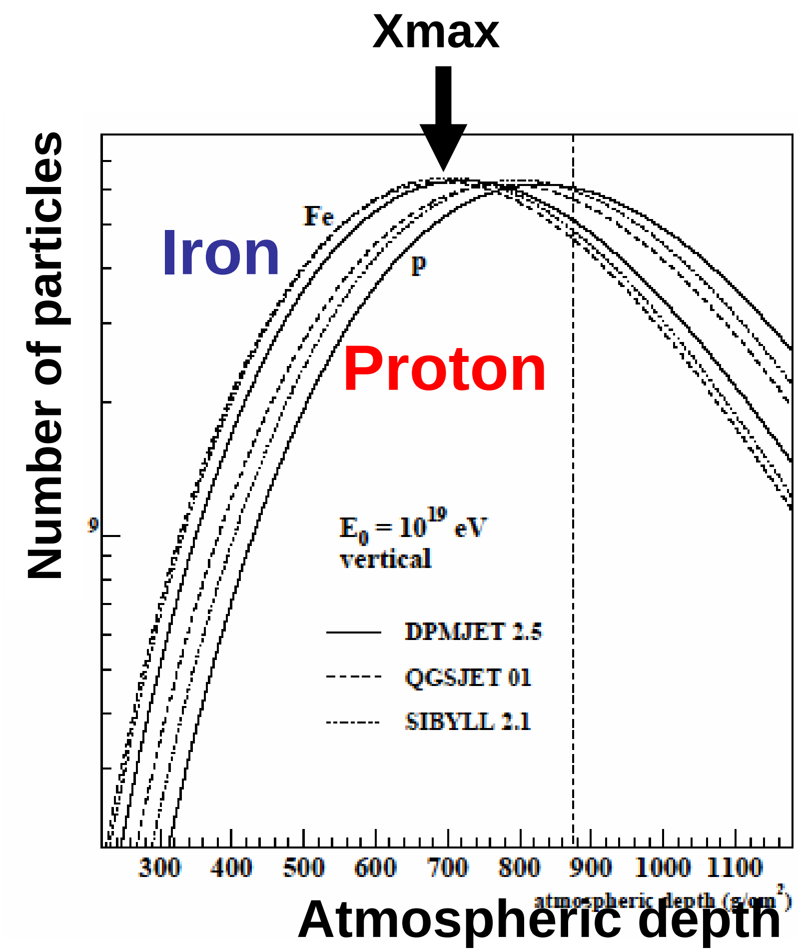
AGASA reports 18% systematic uncertainty in energy determination.

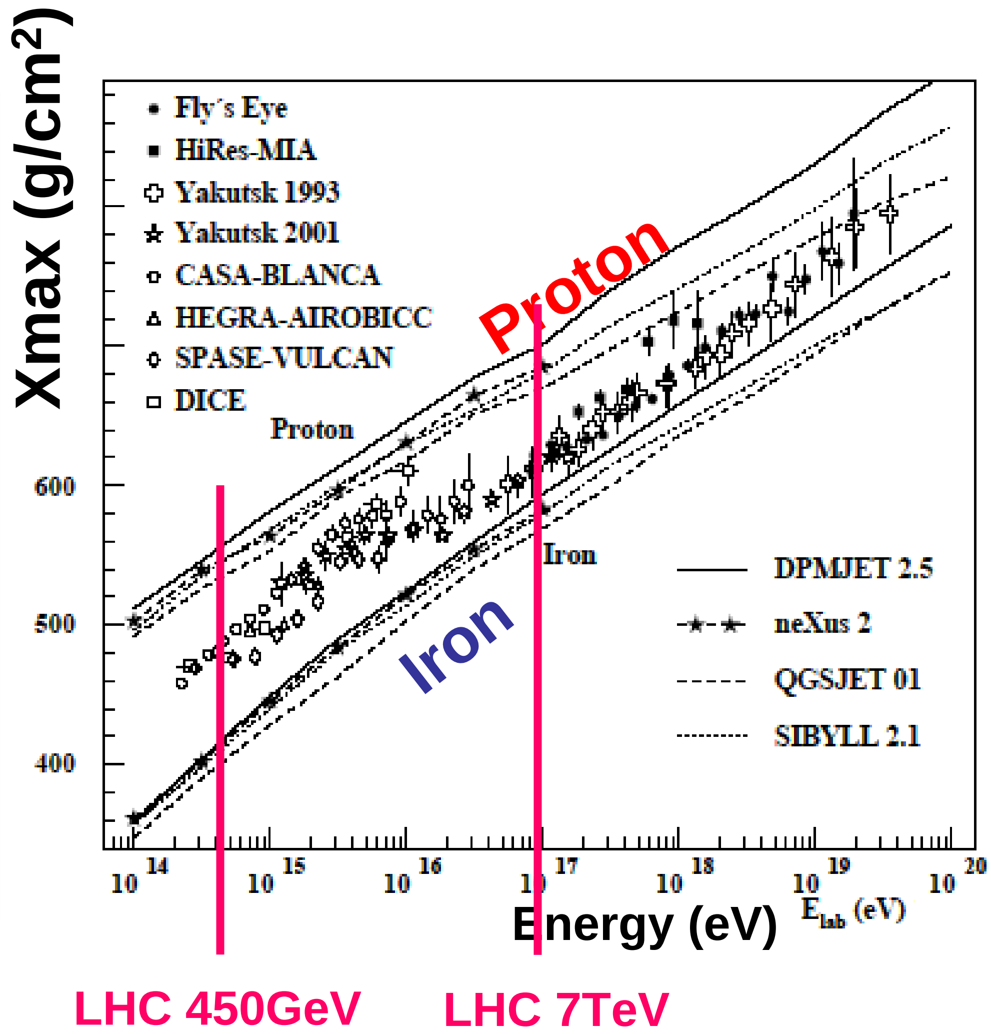
10% of systematic is due to interaction model.

Huge experiment (Auger, TA) will solve the statistics, but not for interaction model.

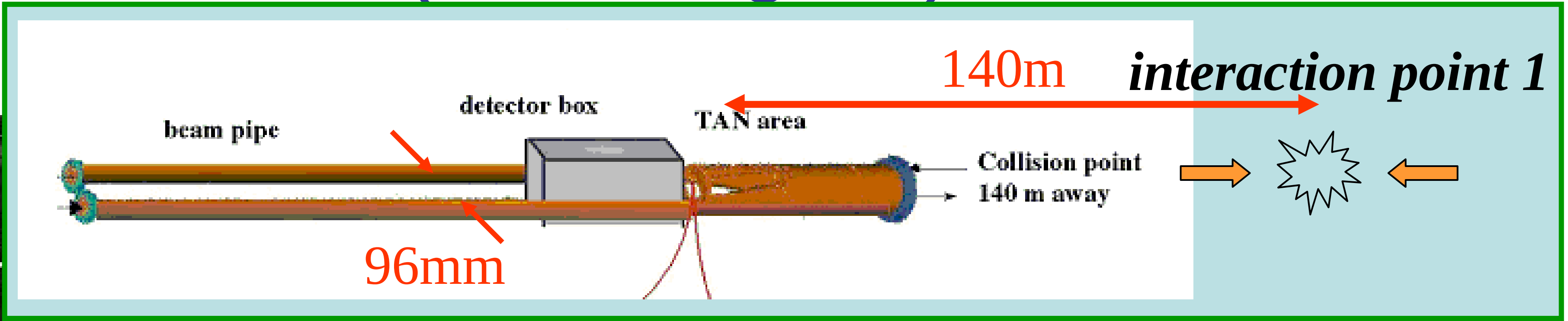
Accelerator calibration is necessary.

Composition



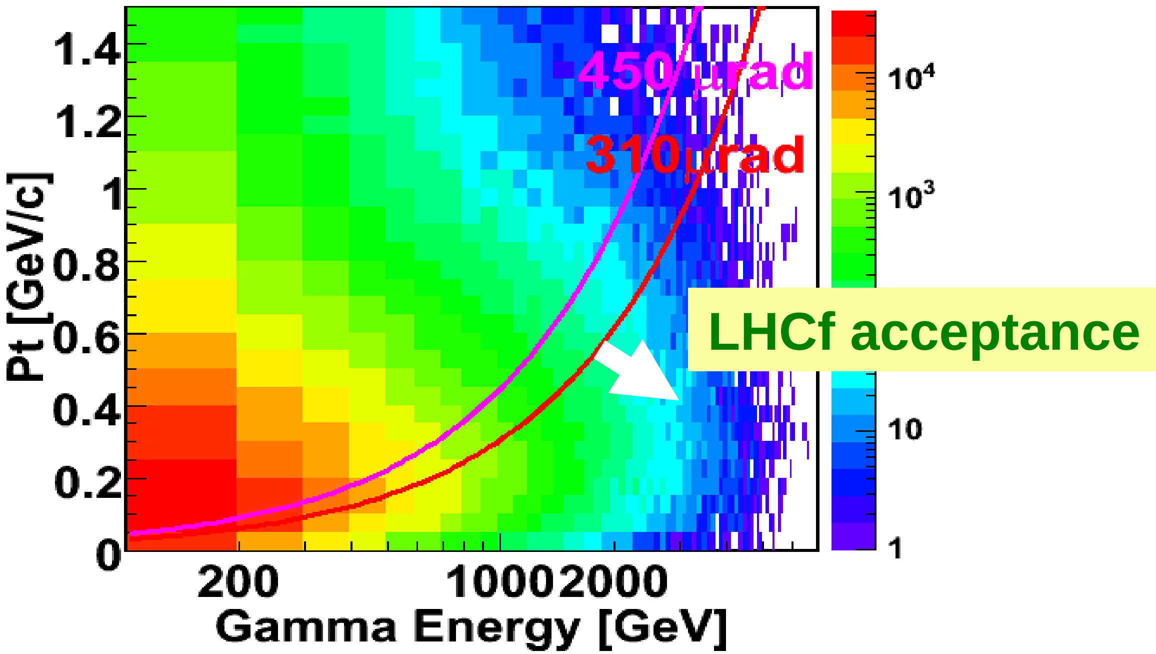


Forward (zero degree) measurement



Beam pipes are separated into two in the TAN by 96mm

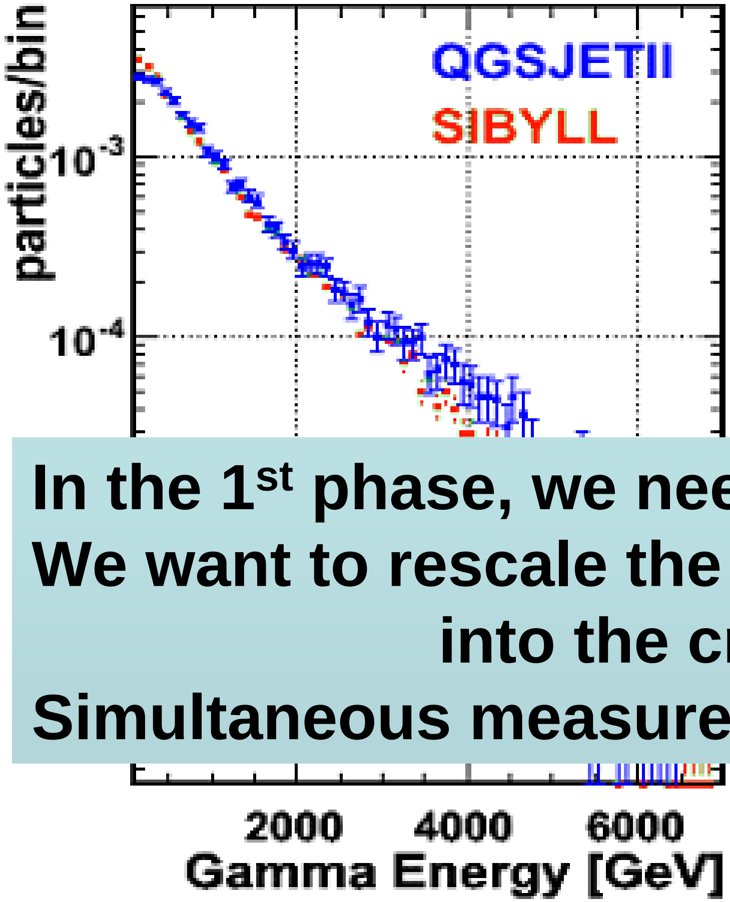
Most of the HE secondary neutral particles enter in this gap



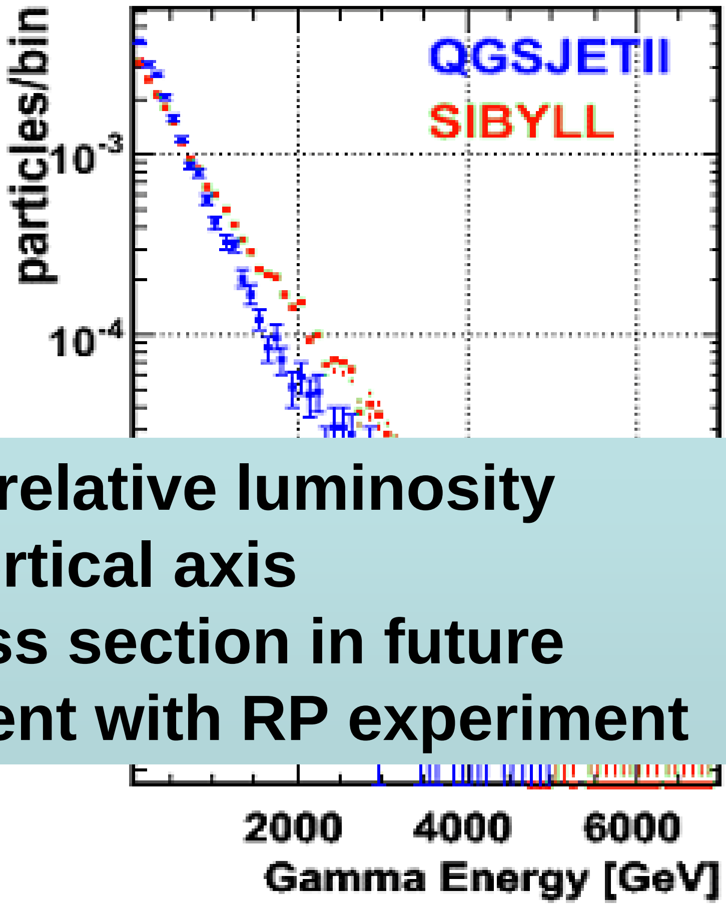
Model discrimination at 7 TeV

QGSJETII⇔SIBYLL

θ ~ 0 radian



θ ~ 270 μ radian

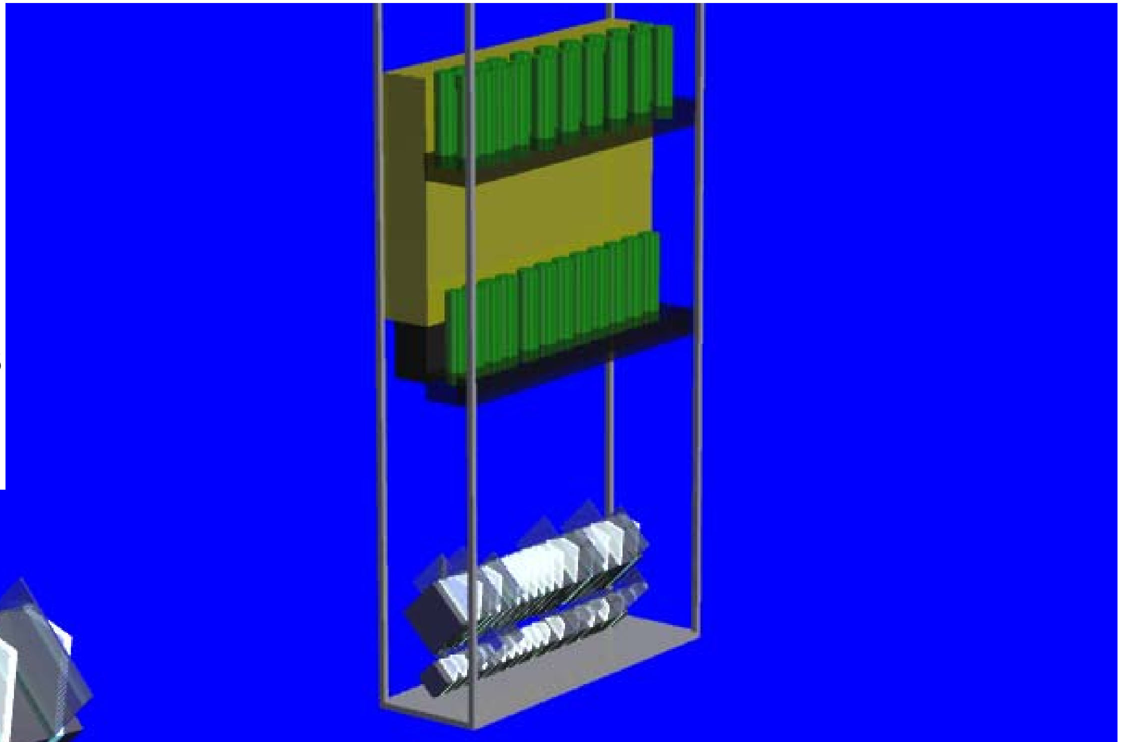


In the 1st phase, we need relative luminosity
We want to rescale the vertical axis
into the cross section in future
Simultaneous measurement with RP experiment

Gamma-ray spectrum at the neutral center and off-center expected from two models. 10^7 inelastic scat. is supposed.

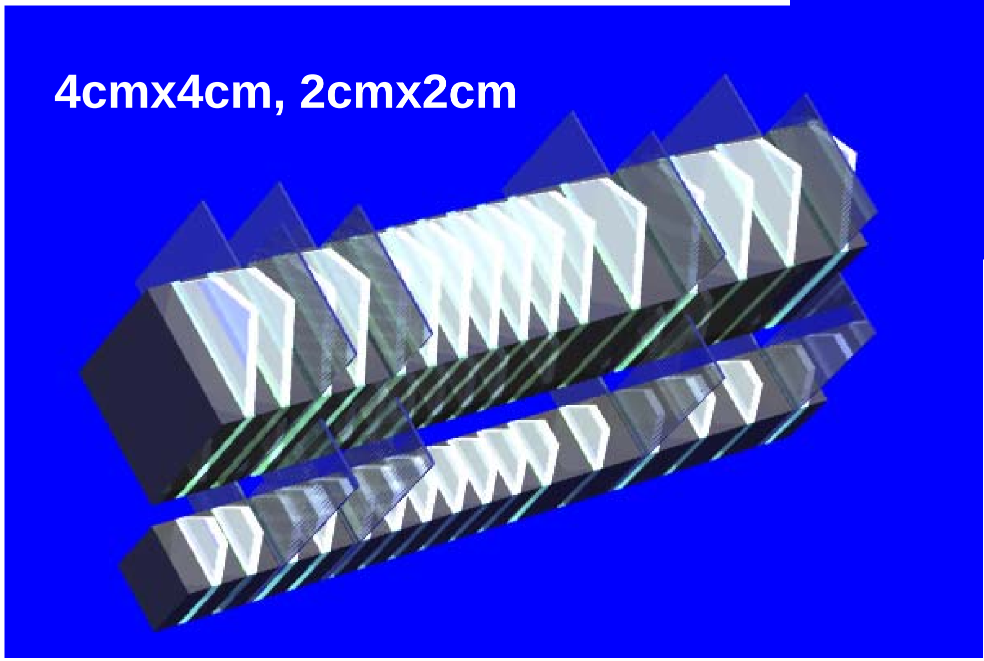
LHCf Detector

Position sensitive shower calorimeters in the TAN



Arm#1

Two shower calorimeters (44 rl)
Tungsten & 16 plastic scintillators
SciFi hodoscope

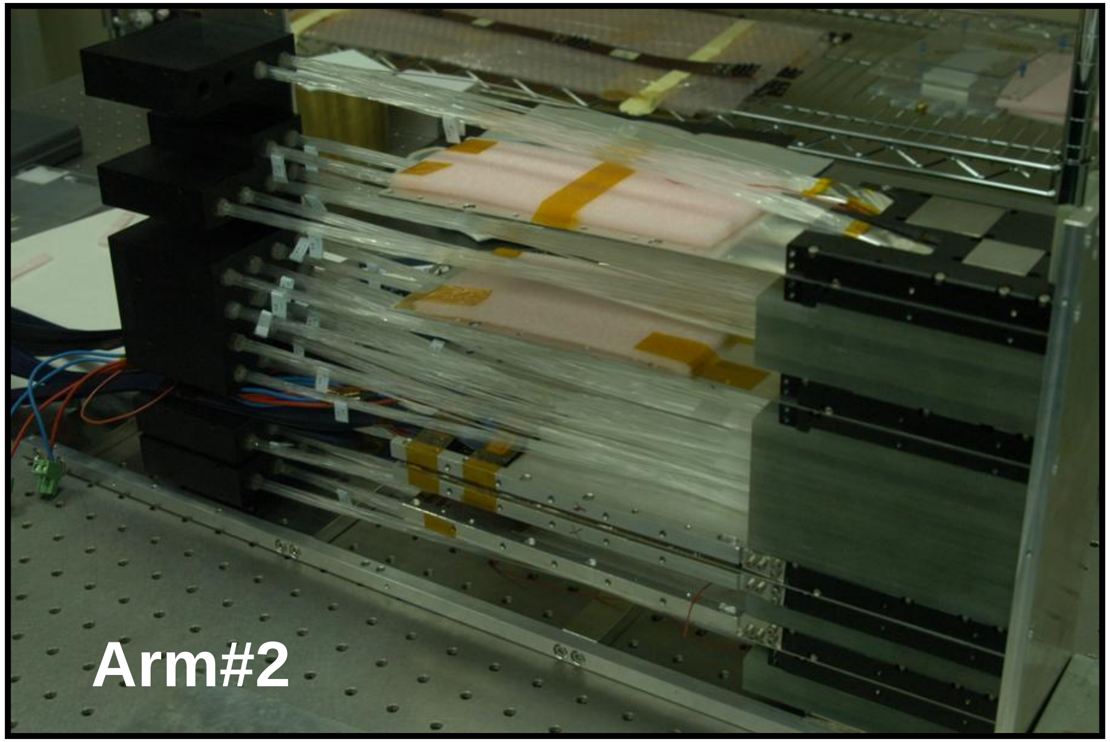


Scntillation light read by 32 PMTs
SciFi light read by 8 MAPMTs

Scintillators and PMTs are connected by optical fibers (not drawn)

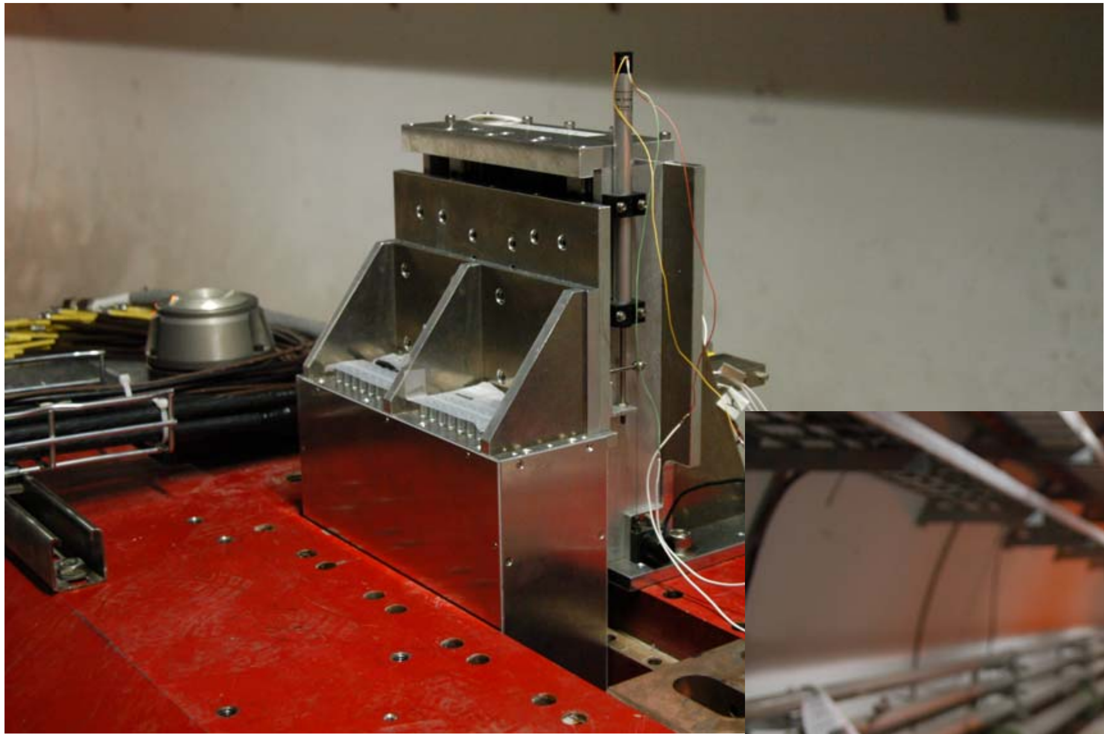
LHCf Arm#1 & Arm#2

Detectors at either side of the IP1



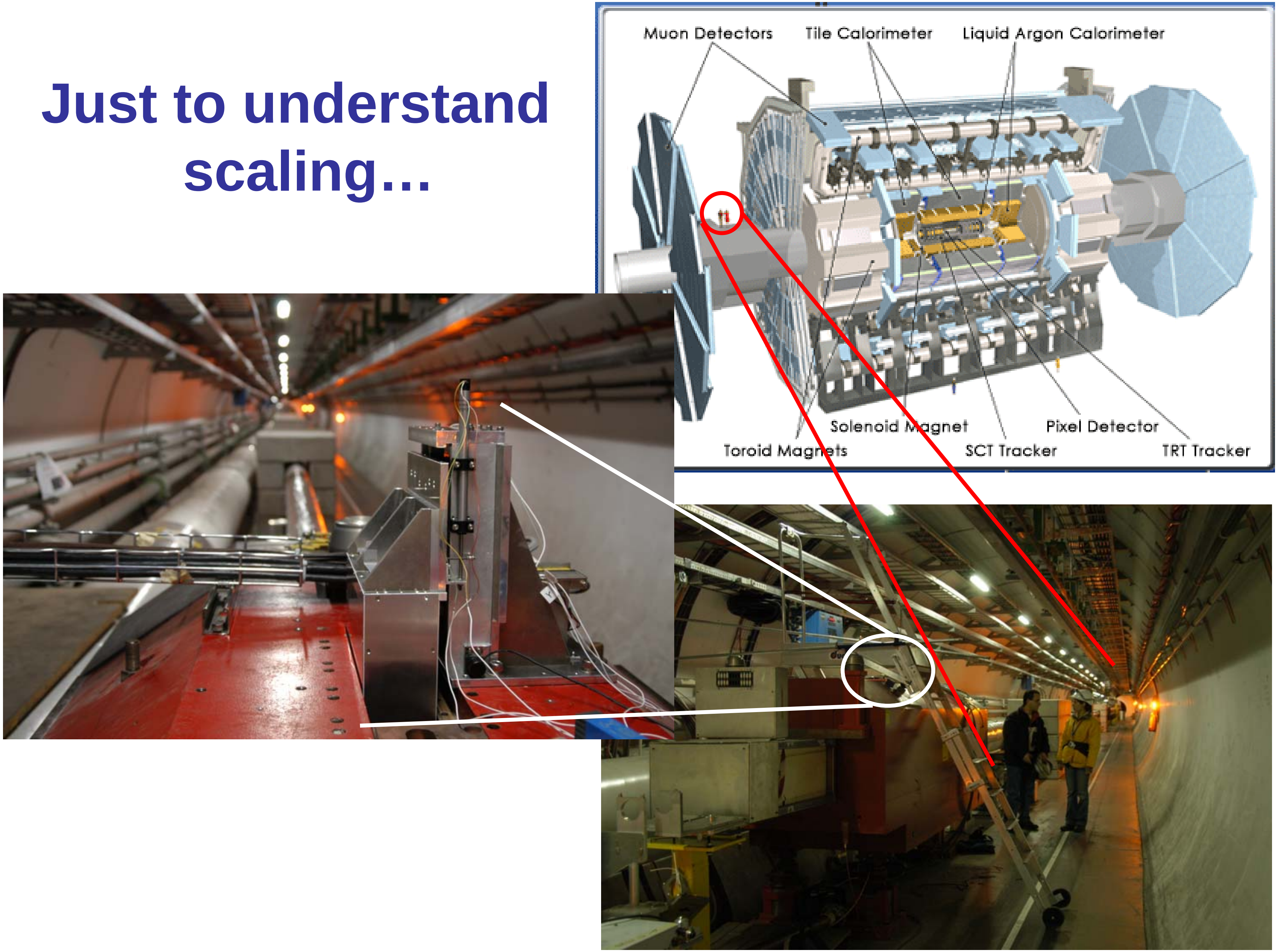
Silicon μ strip instead of SciFi
Final assembly finishes in April

Photo of 15-Jan-2007



IP1 is 140m away

Just to understand scaling…



LHCf "Event"

- BC identification by two BPTX signals (level1)
- >100GeV shower identification in any 1 of the calorimeters (>10GeV at 450GeV) (level2)

  $\Rightarrow$ single event
- Two gamma-ray showers in a single detector

  $\Rightarrow \pi^0$ decay gammas

  (available only at 7TeV run)
- Coincident showers in the two detectors
- Front counter (in preparation)

LHCf operation plan

- LHCf detector & electronics require

  >2 μ sec event separation

  $\Rightarrow$ operation at 43 bunch.

  <1kHz DAQ rate

  $\Rightarrow$ moderate upto $L=10^{29}$ $cm^{-2}sec^{-1}$

  radiation weak; ~0.5y lifetime @$L=10^{30}$

  several hours operation for science

LHCf measures the relative luminosity in the commissioning phase.

Absolute normalization in future with RP

Single event rate

- @L=10^{29} with σ_{inela} = 100mb,

  collision rate = 10^4 /sec

I use these numbers in this talk. Event rates are scalable in L except for offline information.

- Acceptance of the LHCf;

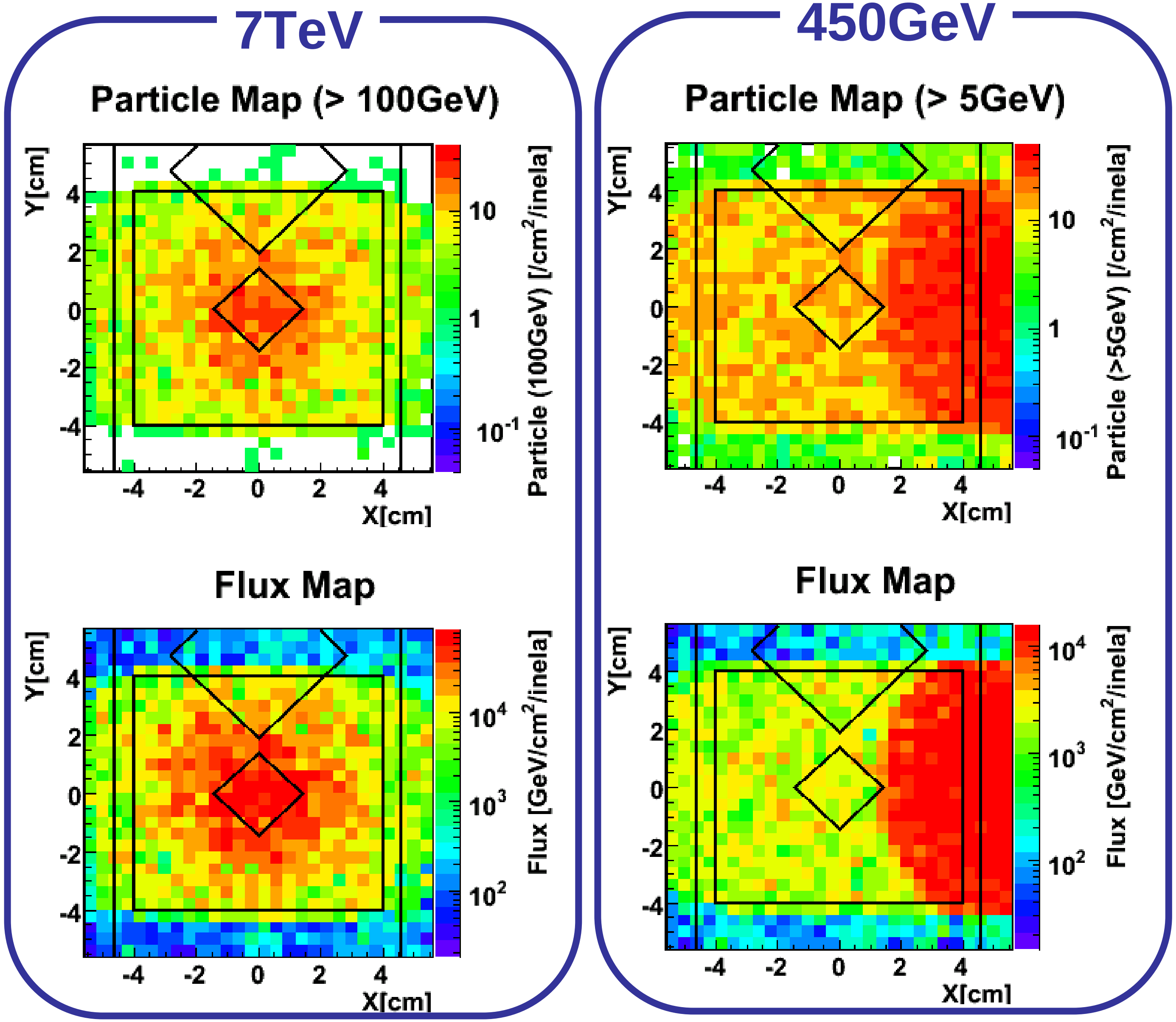
  ~0.1 single event / collision @ 7 TeV

  (event rate ~1kHz = DAQ limit)

  ~0.002 single event / collision @ 450 GeV

  (event rate ~20Hz) ⇒ discuss later

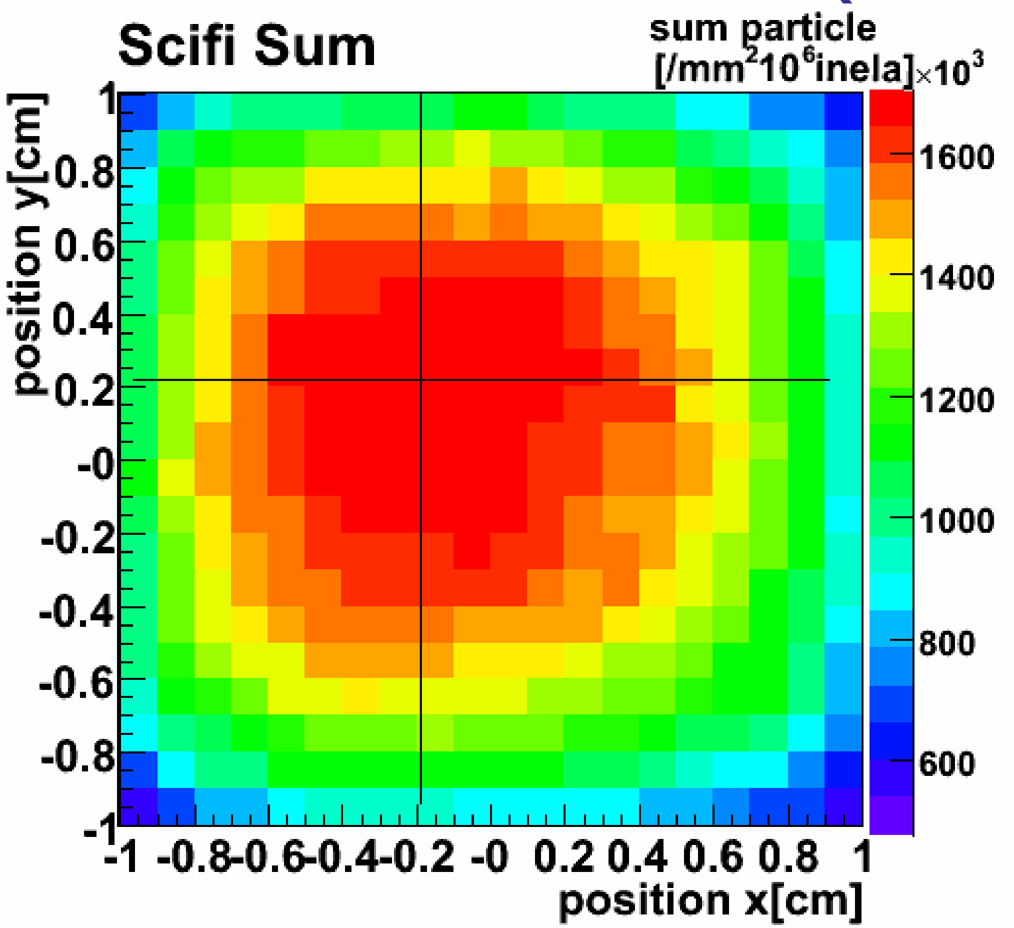
Particle in front of the TAN



Number flux

Energy flux

Resolution of the neutral center determination (7TeV run, offline)



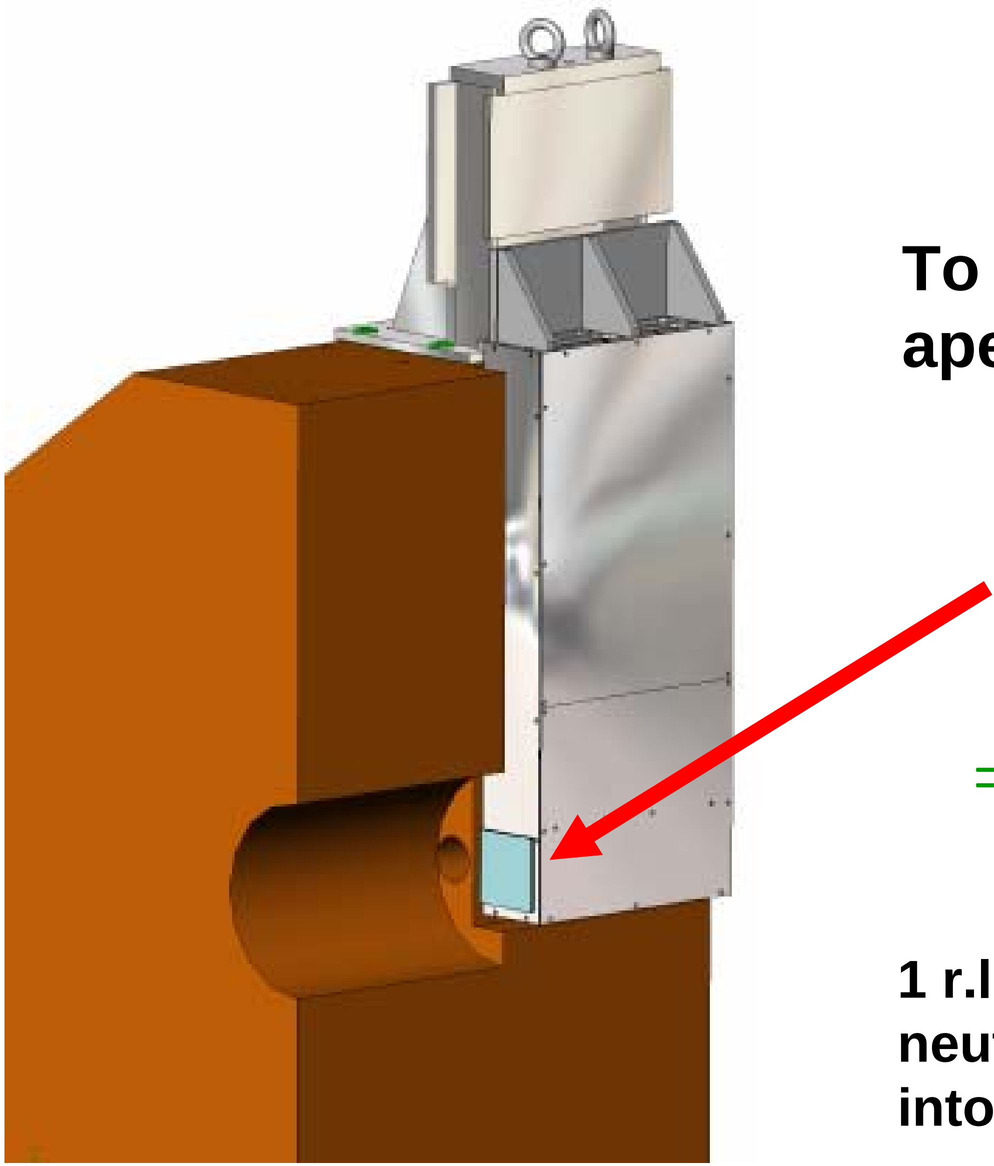
SciFi intensity map for decentered collision (cross; simulated neutral center)

10^6 inelastic interactions ~100 sec at $L=10^{29}$ cm^{-2} s^{-1}
Using a simple peak finding analysis
0.1 mm resolution is obtained

Event rate summary for 7 TeV run (relative luminosity monitoring)

- Single event rate; ~1kHz @L=$10^{29}cm^{-2}s^{-1}$
- Double arm coincidence (10%×10%=1% aperture ~100Hz) is powerful to reduce beam-gas, beam halo background.
- Pi0 mass reconstruction also reduces the background with 1% aperture (100Hz; offline)
- Position resolution for the neutral center (offline)

Front Counter (in preparation)



To overcome the small aperture in the 450GeV run

Double layer thin plastic scintillator 80mm×80mm

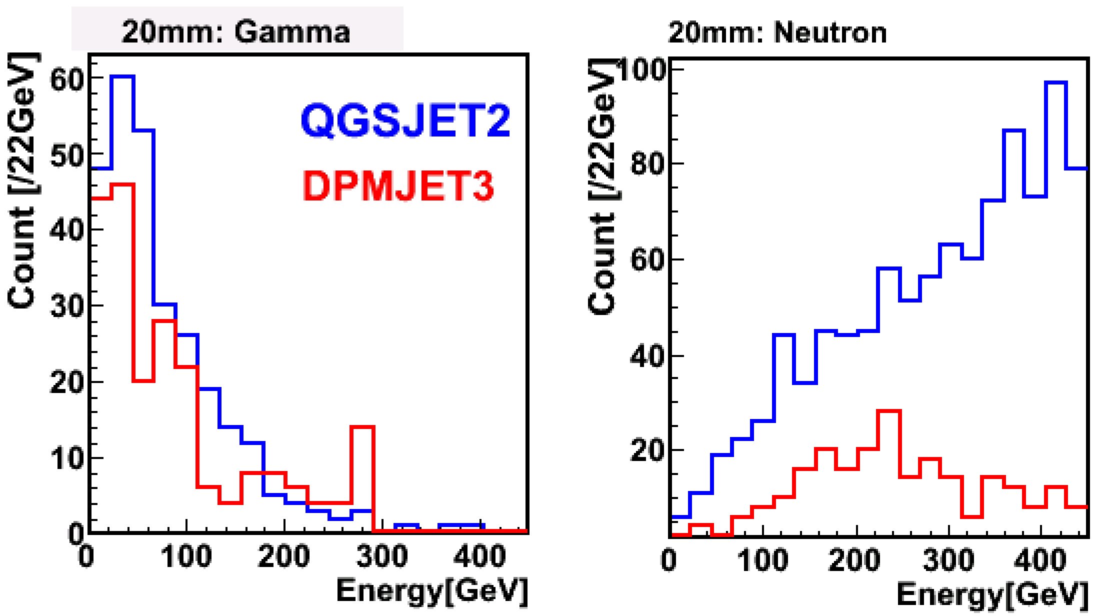
⇒0.02 events/collision @ 450GeV run

1 r.l. of the beam pipe converts neutral particles (mainly gammas) into charged particles.

Event rate summary for 450GeV run (relative luminosity monitoring)

- Single event rate; 20Hz@L=10^{29}
- Single event of the front counter; 200Hz
- Position dependence … unable
- Double arm coincidence of front counter
  (～2%x2%=0.04%) 4Hz
- Pi0 reconstruction … unable
- Model dependence (science goal)

Model discrimination at 450 GeV



Expected gamma, neutron spectrum at 10^6 inelastic interactions
Incident on detector
It corresponds to ~100 sec at L=10^{29} $cm^{-2}s^{-1}$.
Detector response, analysis not included.

BG for relative lumi measure

- Beam-gas collision

  Rcollision/Rgas depends on the vacuum condition and the beam optics.

  with $N_{H2\ equiv} = 4 \times 10^{12}\ m^{-3}$ (*), ratio is <0.01 at the worst estimate in the LHCf operation

* A. Rossi LHC Project Report 783 (2004)

R.Balley, LHCMAC, Dec2006

Performance at 450GeV

K_b	43	43	156	156
i_b (10^{10})	2	4	4	10
β^* 1 5 (m)	11	11	11	11
intensity per beam	8.6 10^{11}	1.7 10^{12}	6.2 10^{12}	1.6 10^{13}
beam energy (MJ)	.06	.12	.45	1.1
Luminosity 1 5	2 10^{28}	7 10^{28}	2.6 10^{29}	1.6 10^{30}
event rate [1] 1 5 (kHz)	0.7	2.8	10	65
W rate [2] 1 5 (per 24h)	0.8	3	11	70
Z rate [3] 1 5 (per 24h)	0.08	0.3	1.1	7

1. Assuming 450GeV inelastic cross section 40mb
2. Assuming 450GeV cross section $W \rightarrow l\nu$ 1nb
3. Assuming 450GeV cross section $Z \rightarrow ll$ 100pb

Beam-gas event at 450 GeV

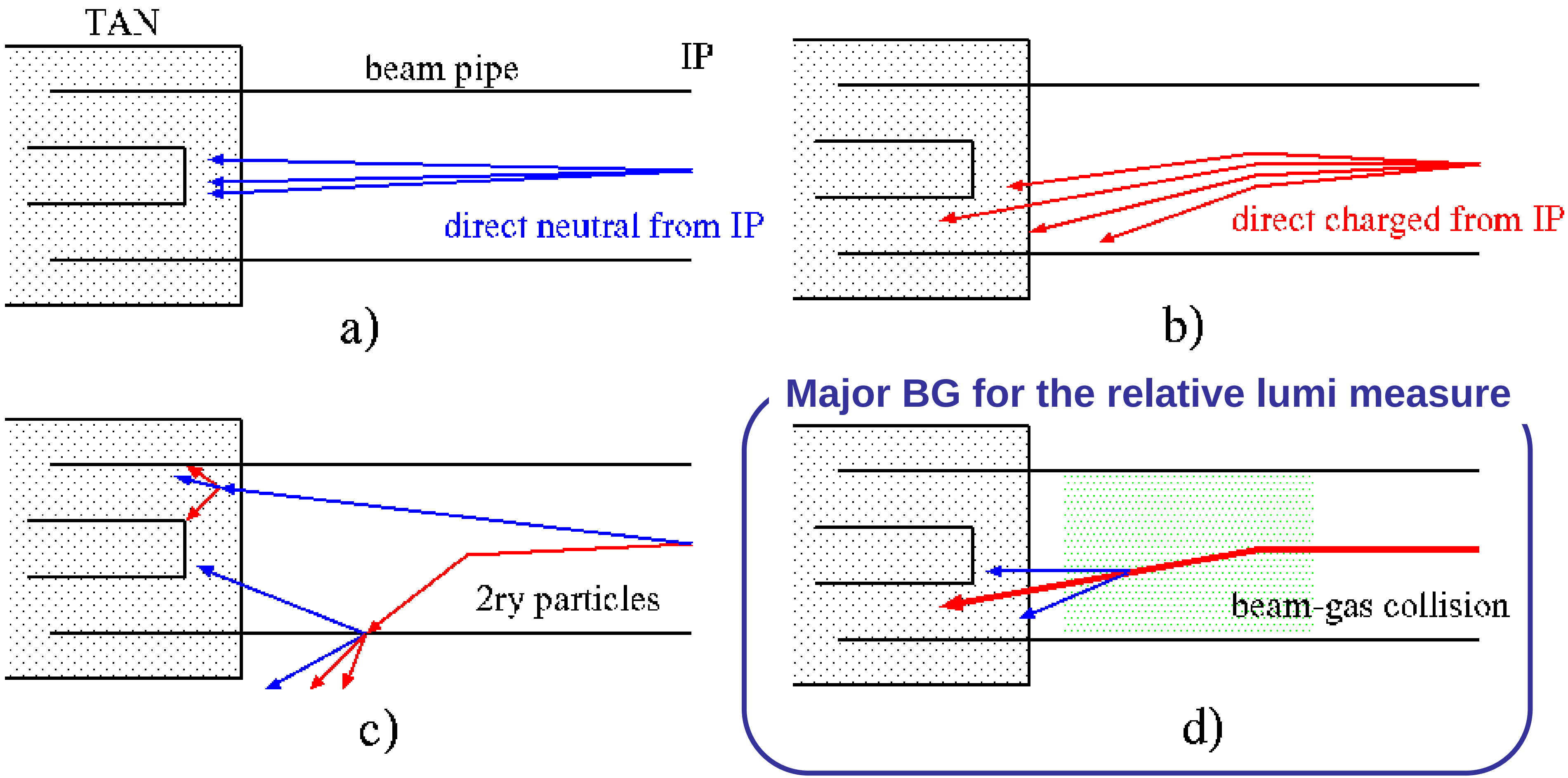
- Gas pressure is estimated to be 10^{-8} Torr (R.Bailry, 2006)
- 10^{-8} Torr corresponds to $2x10^{15}$ H_2/m^3
- Beam-gas event rate, comparable to the collision event rate.
- Gas distribution is necessary for detailed estimation
- Double arm (front counter) coincidence
- Estimation before collision

Conclusion

- LHCf can measure relative luminosity at the commissioning phases.
- 1kHz(@7TeV) and 20Hz(@450GeV) single event rates are expected.
- Double arm event and Pi0 reconstruction (offline, 7TeV only) are useful to eliminate beam-gas BG.
- Front counters raise the event rates.
- Position resolution helps neutral center monitoring (offline, 7TeV only).

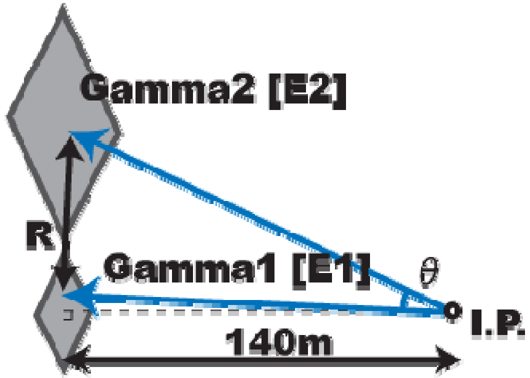
Backup

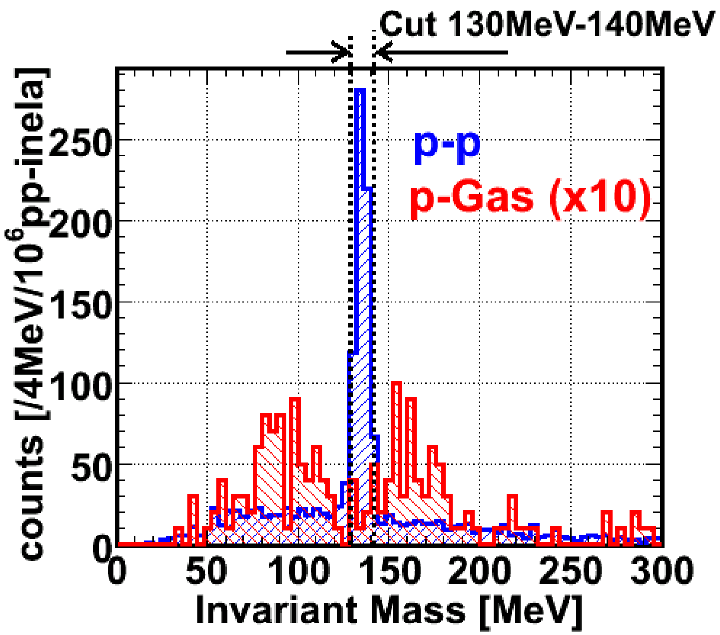
Event classification

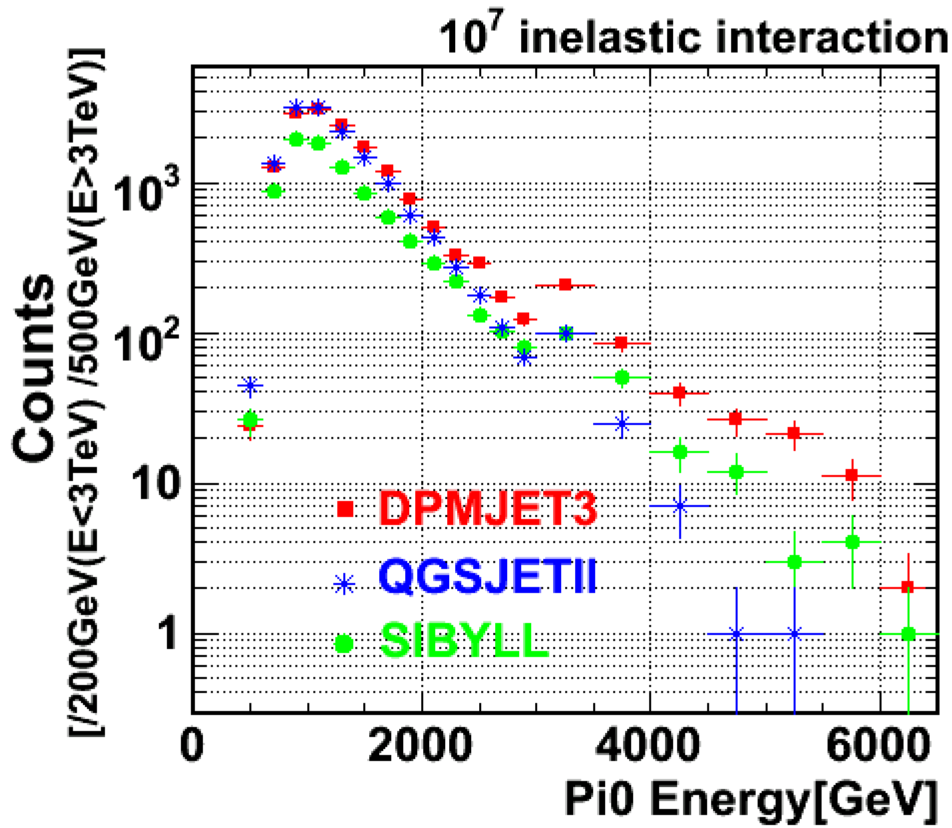


a, b, c are proportional to luminosity, but not d.
Double arm coincidence is necessary to eliminate d.

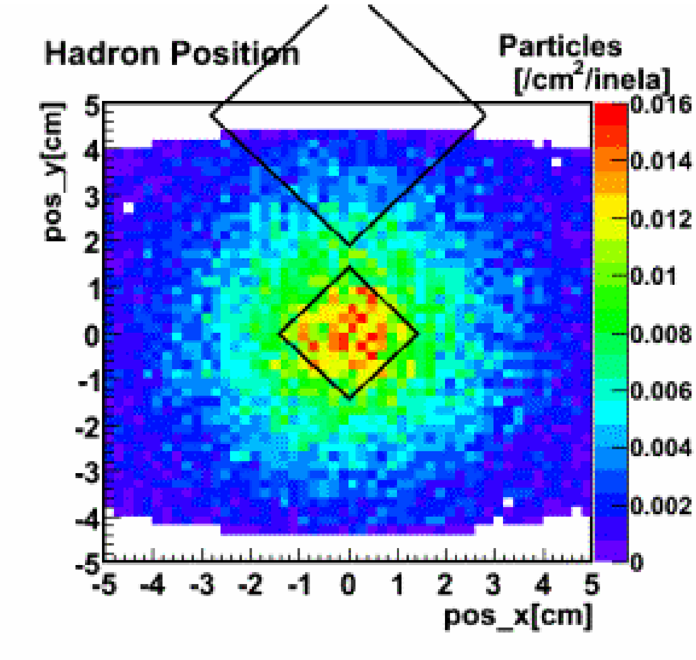
Pi0 mass reconstruction

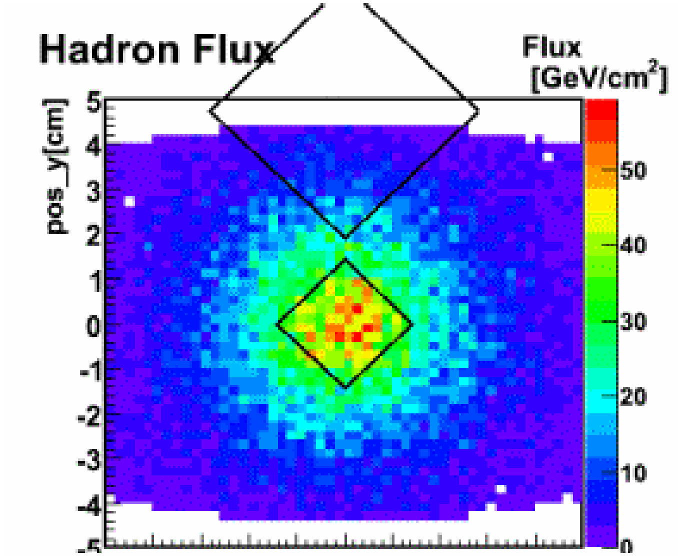


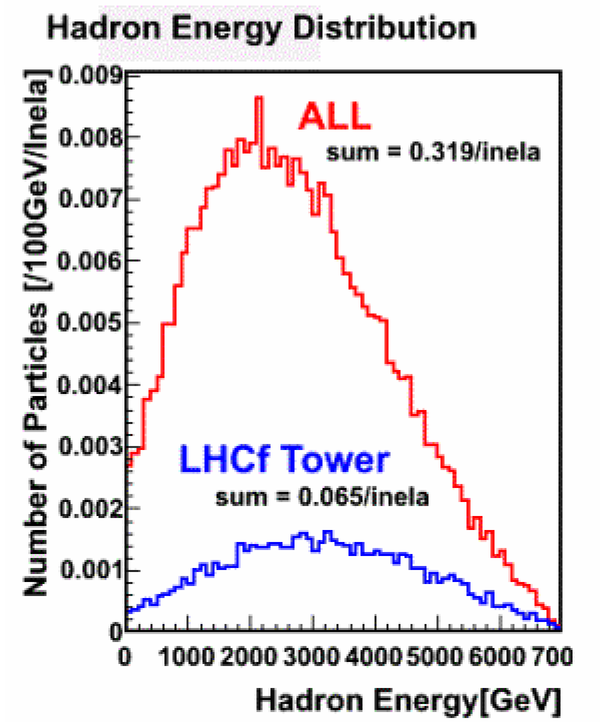


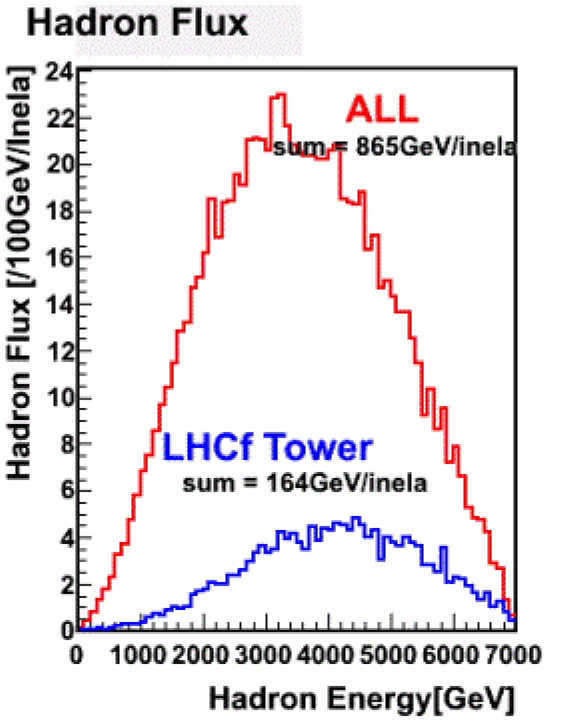


Effect on BRAN



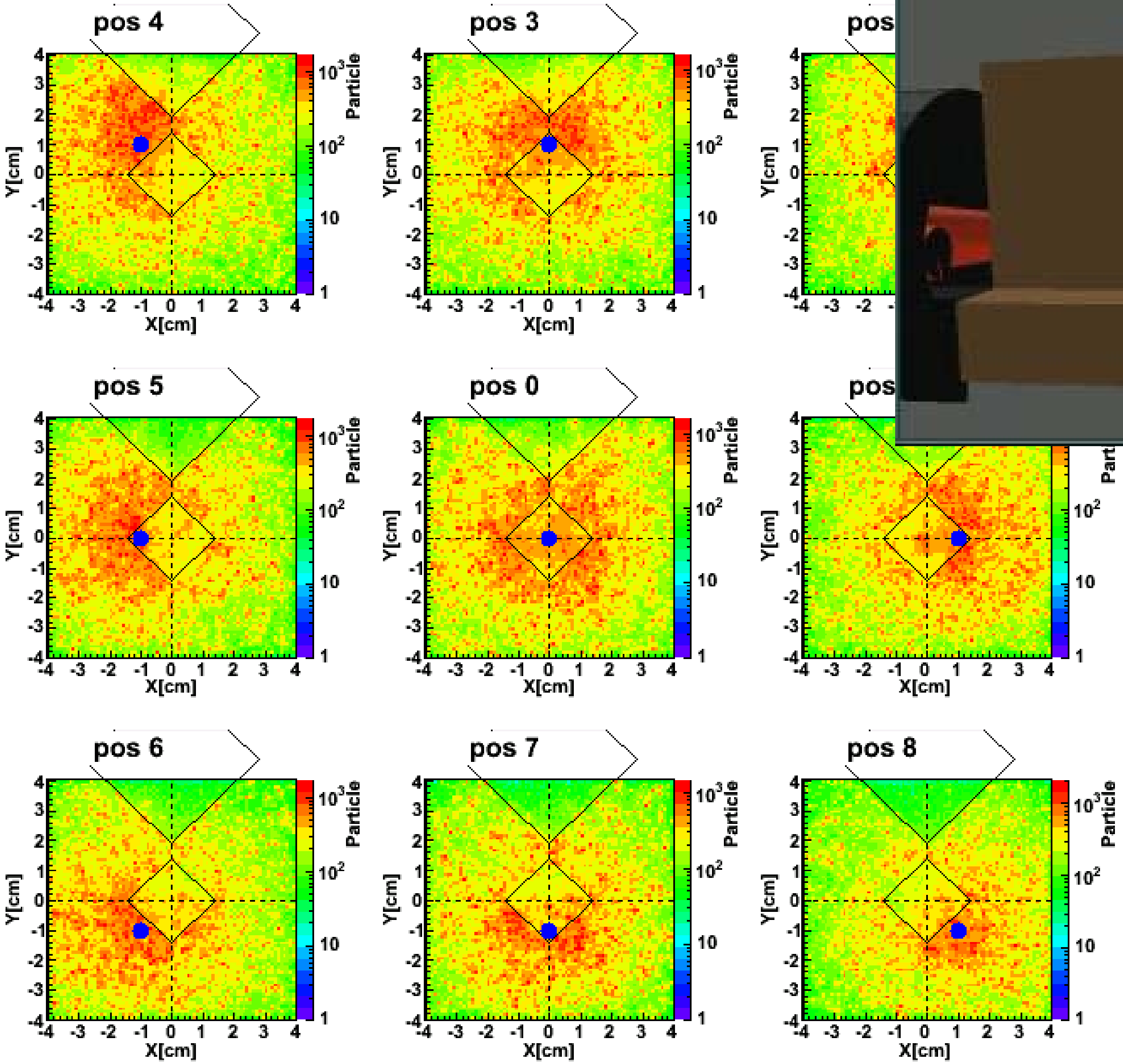


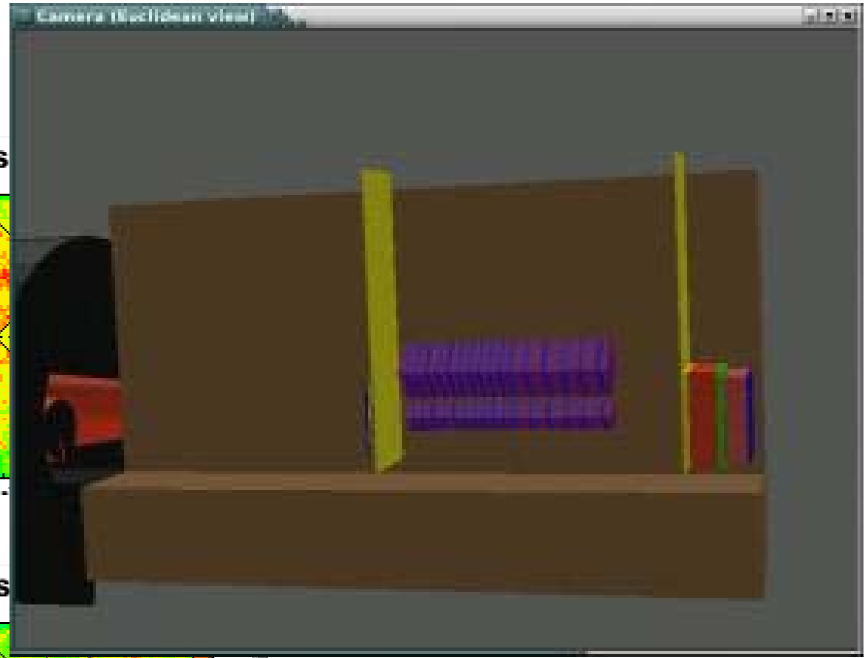




Same interaction length for copper bars and LHCf towers

Particle distribution in BRAN as a function of beam center

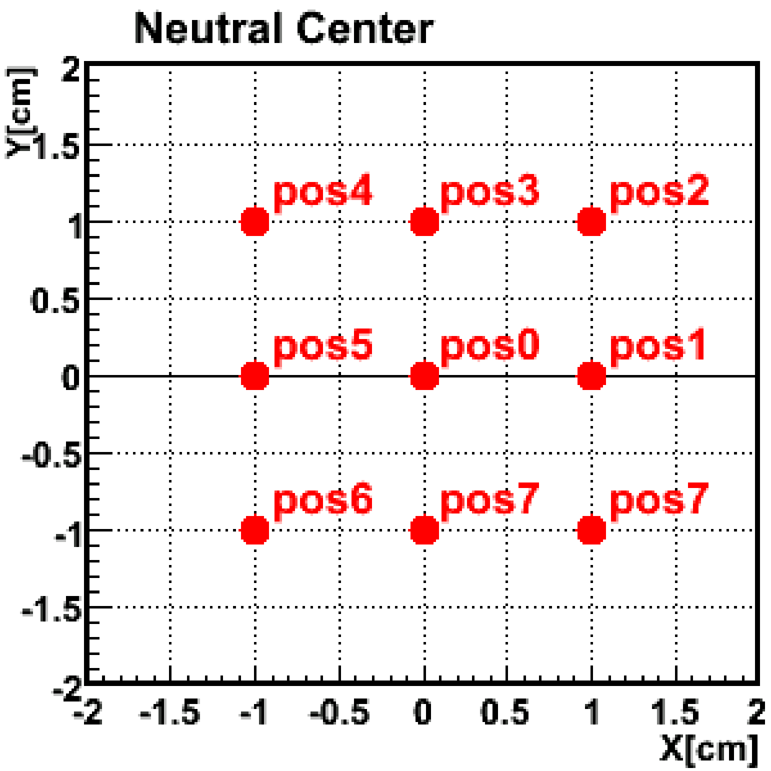


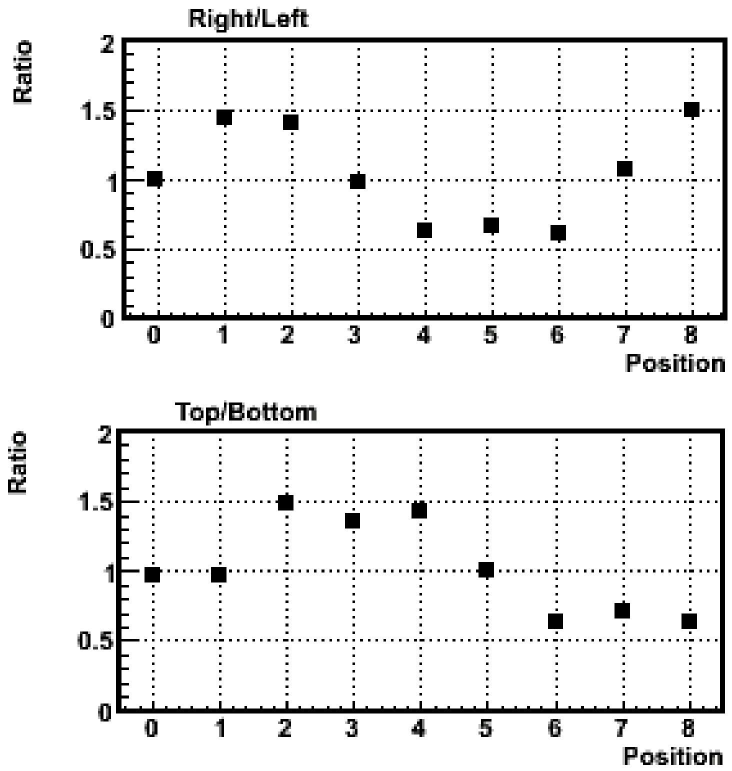


Full MC with beam-pipe, LHCf, BRAN

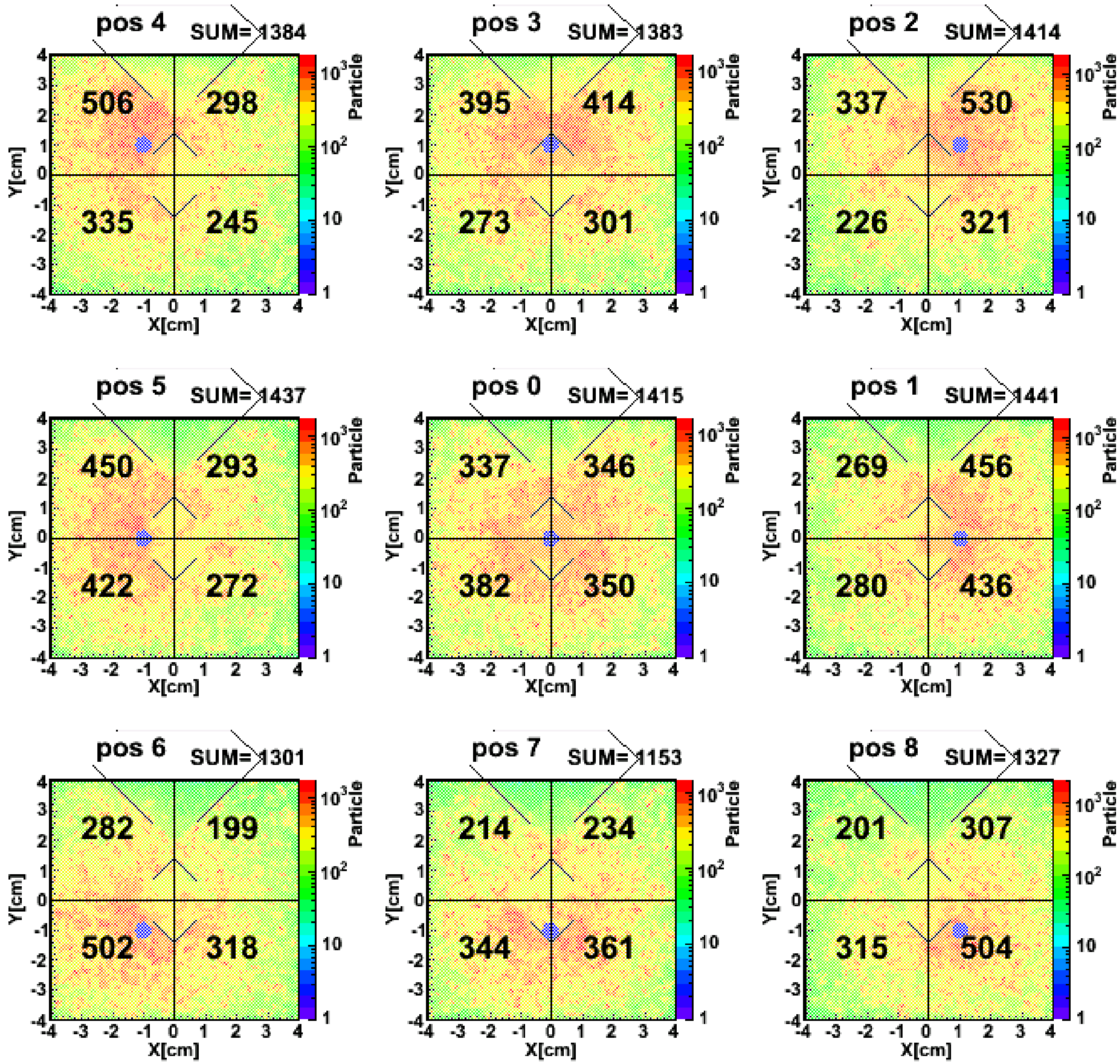
Out of LHCf; Gamma-ray showers developed in the beam pipe and BRAN itself

The ratio of particles detected by the 4 parts of the BRAN detector





The threshold of BRAN is set at > 500 particles



Position identification by the LHCf