

Recent results from LHCf

G. Mitsuka (Nagoya University)
on behalf of the LHCf Collaboration

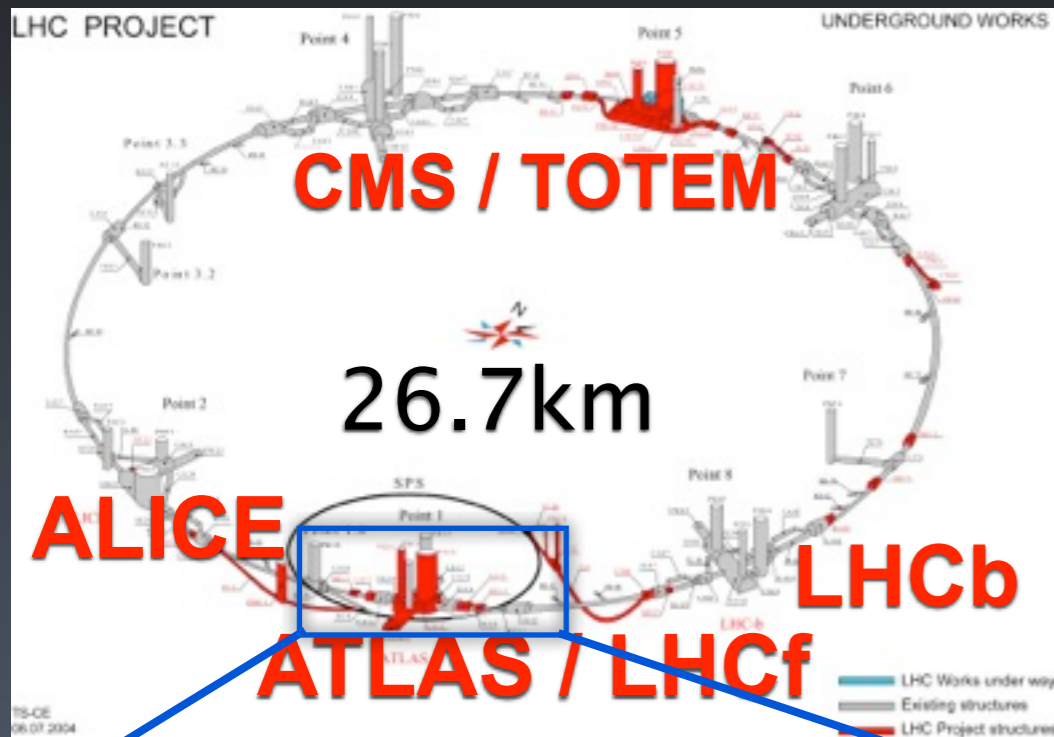
UHECR2012, Feb 13–16, CERN



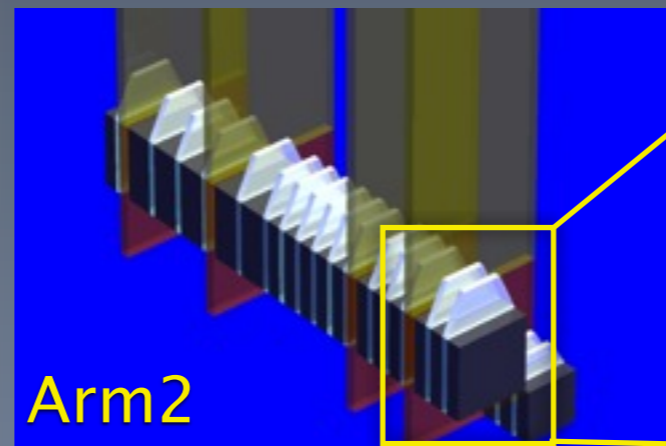
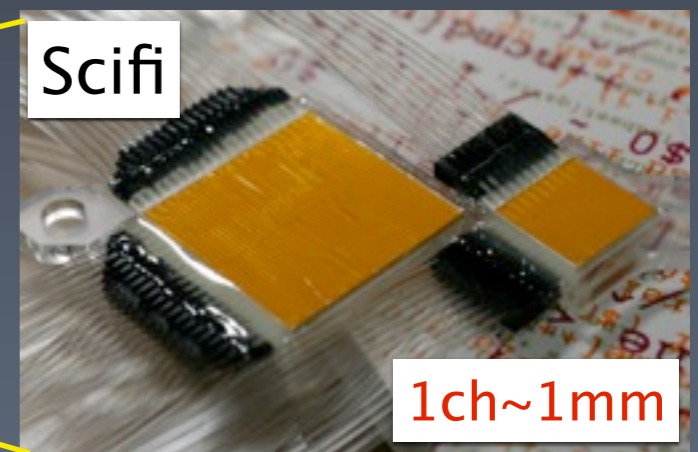
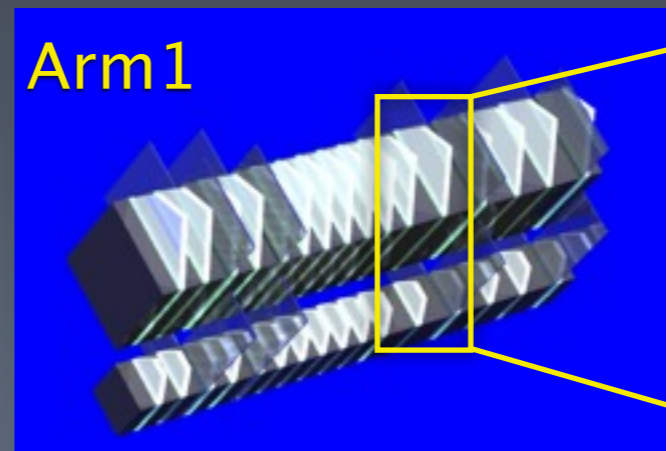
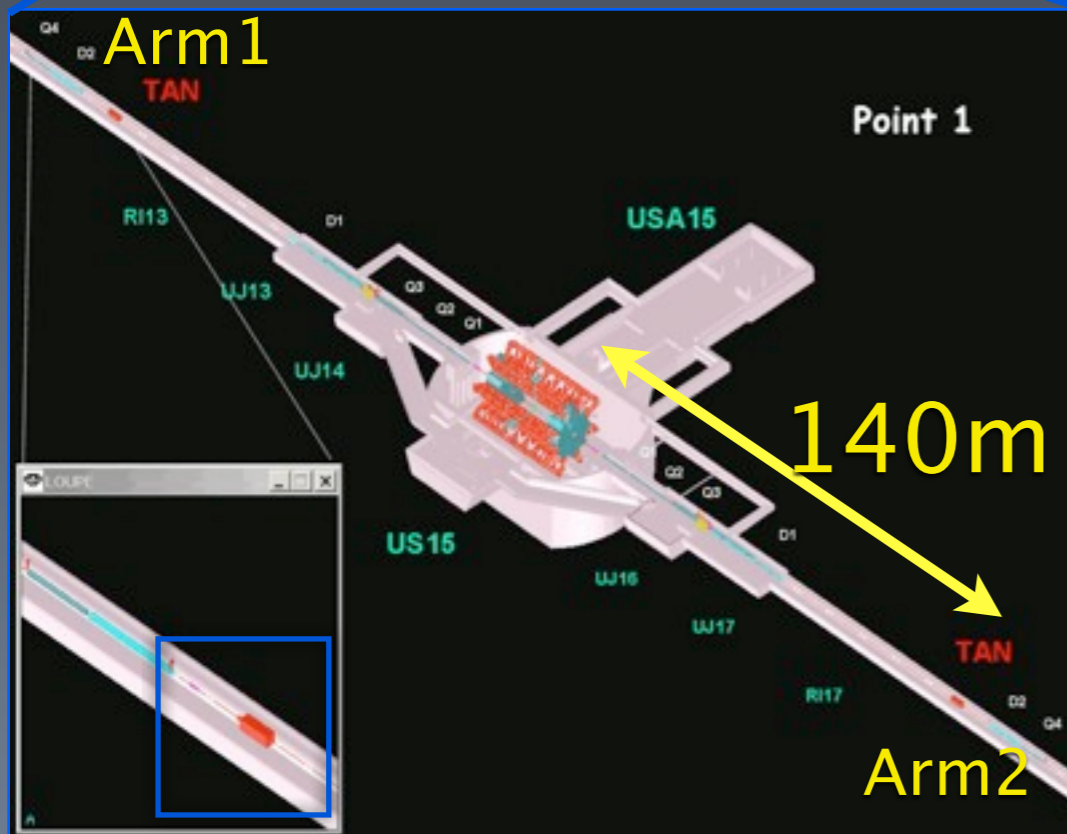
Outline

- Introduction and Physics motivation
- Status of LHCf
- Photon event analyses
 - 900GeV photon analysis
 - 7TeV π^0 analysis
- Conclusions and Future prospects

Introduction and Physics motivation



- Zero degree instrumentation slot at 140m away from IP1(ATLAS).
- p-p collision at $\sqrt{s}=14\text{TeV}$ corresponds to $E_{\text{lab}}=10^{17}\text{eV}$.
- Detectors are located at the best position to measure the large energy flow that strongly contributes the air-shower development.



Status of LHCf

Physics program at CERN

2004, 2006, and 2007

- Calibration at SPS
(*NIMA 671 (2012) 129–136*)

2008

- First data taking at 900GeV (only FC)

2009

- First data taking at 900GeV

2010

- Physics program at 900GeV/7TeV was completed

(*Luminosity : JINST 7 T01003 (2012)*
7TeV photon : Phys. Lett. B 703 128-134 (2011))

- Post-calibration at SPS

2012

- Possibly pA run ?
(*CERN-LHCC-2011-015 ; LHCC-I-021*)

R&D for 14TeV run

2009, 2010

- Beam test of GSO scintillator at HIMAC (JAPAN, Chiba)
(*JINST 6 T0900 (2011)*)

2011

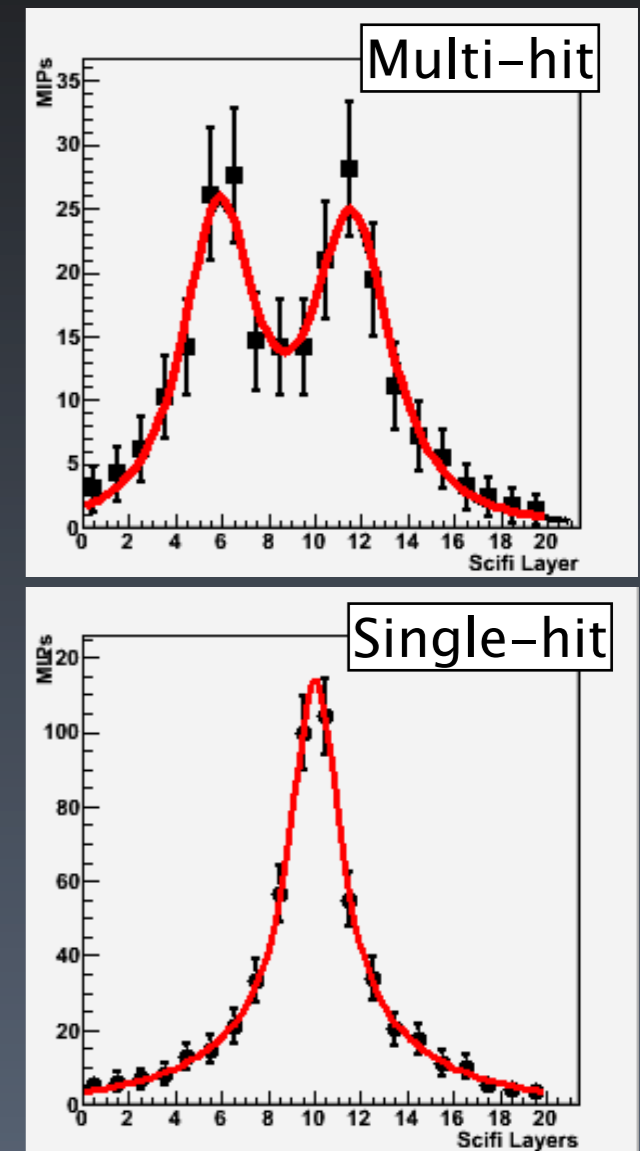
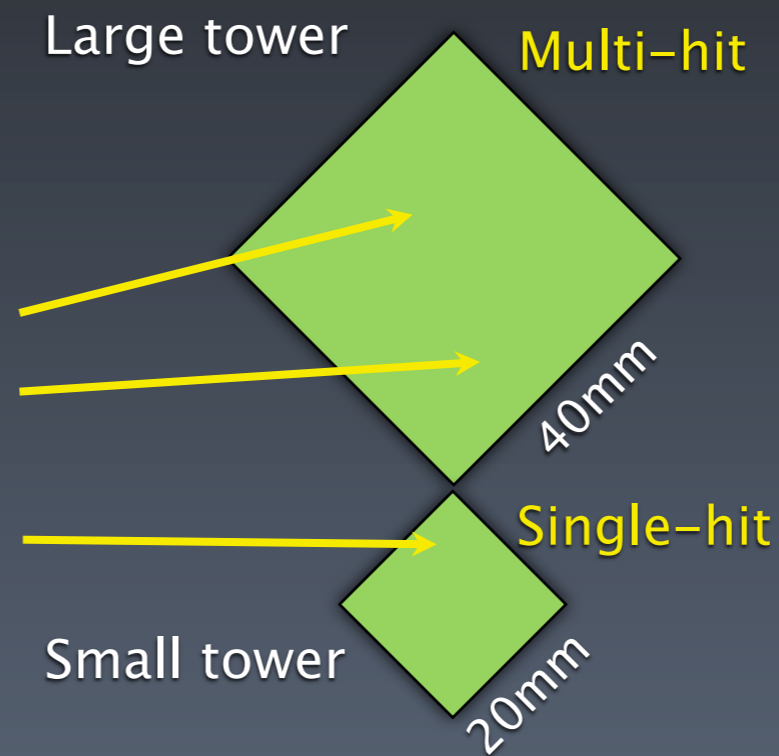
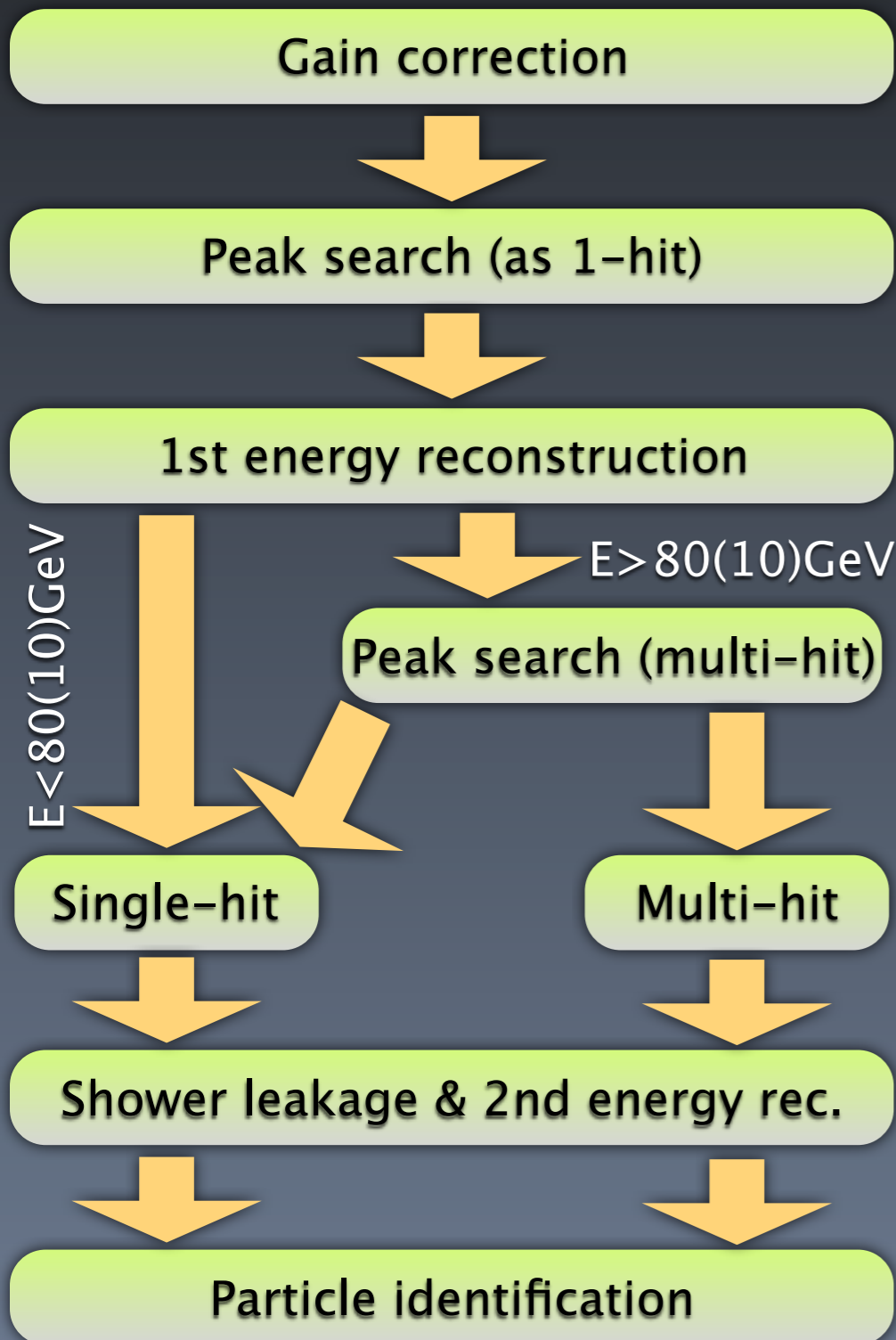
- Beam test of the LHCf Arm1 detector with GSO scintillator at HIMAC (JAPAN, Chiba)



Poster contributions

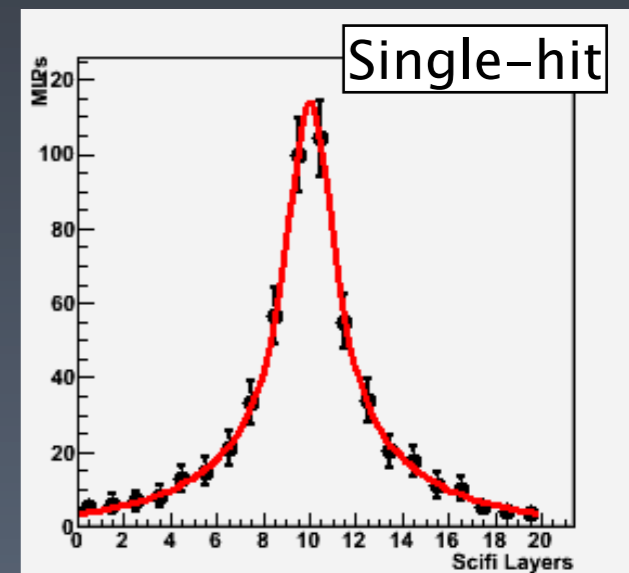
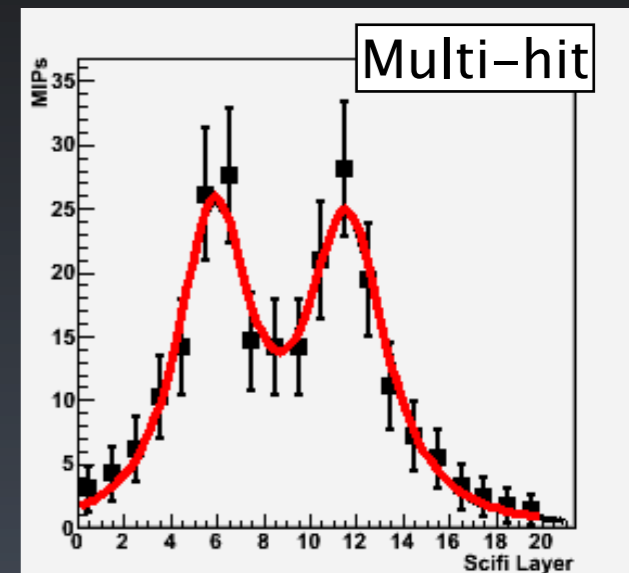
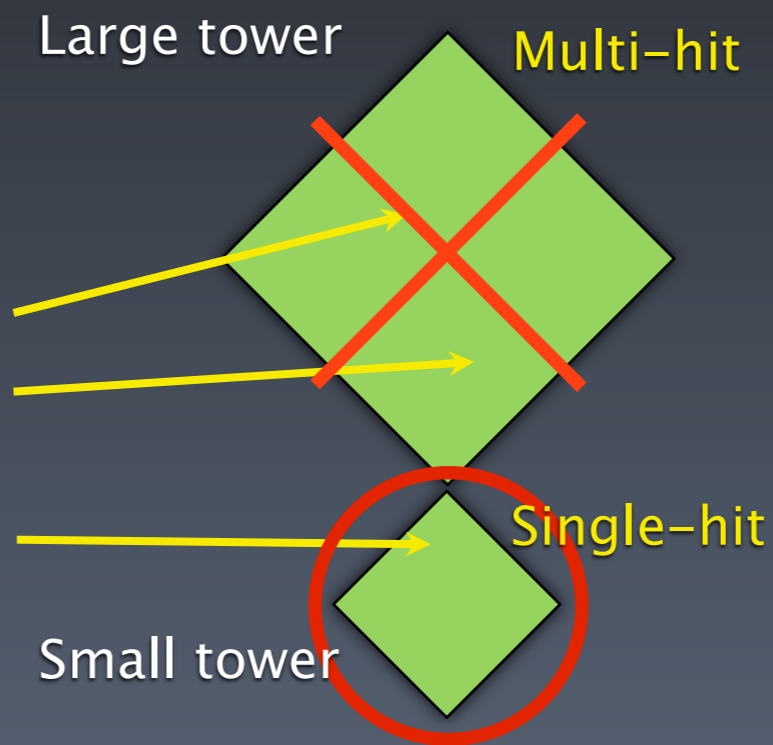
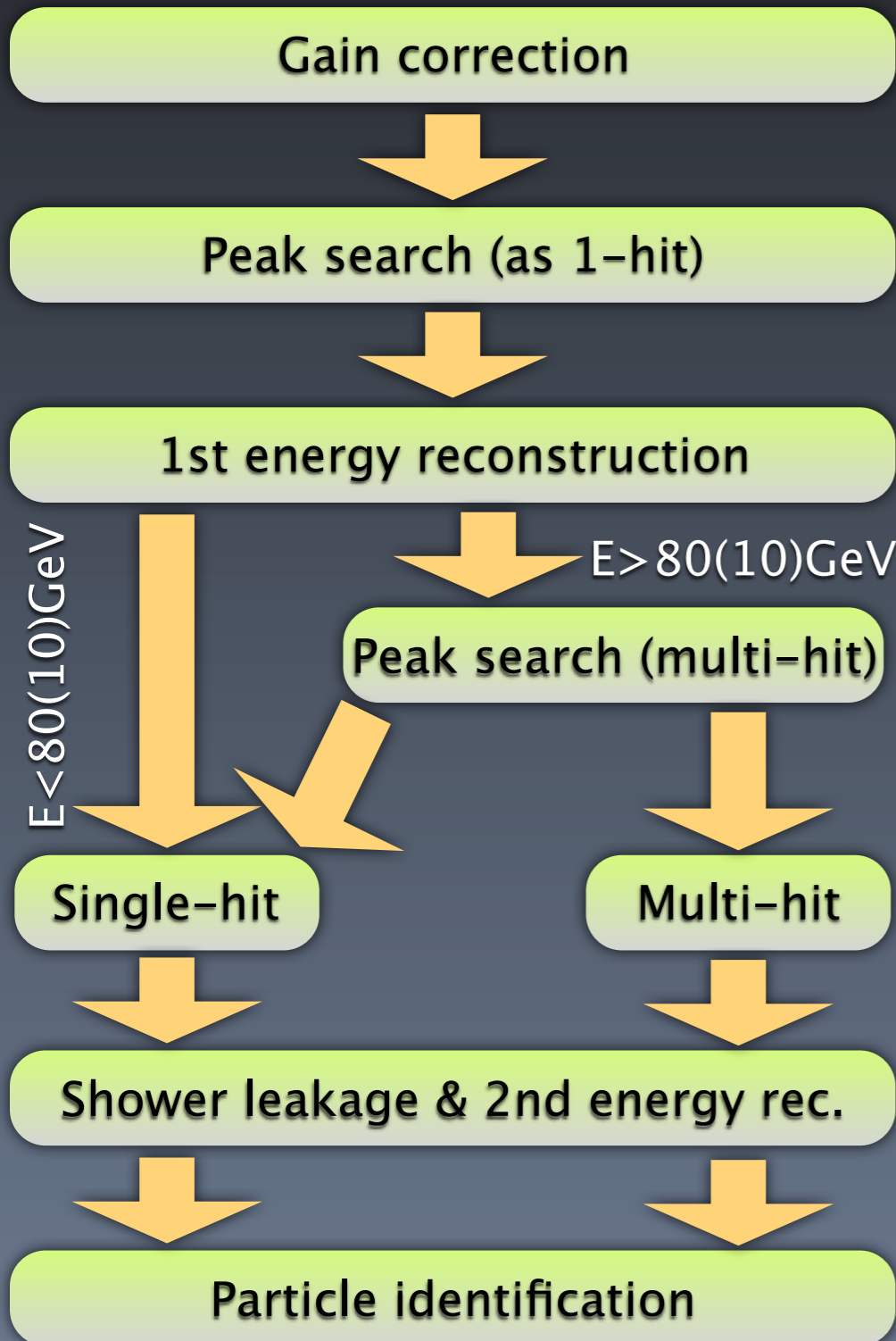
- The current status of LHCf experiment and Future plan (K. Kawade)
- LHCf plan for p-Pb forward particle measurement (T. Sako)

Photon event analysis



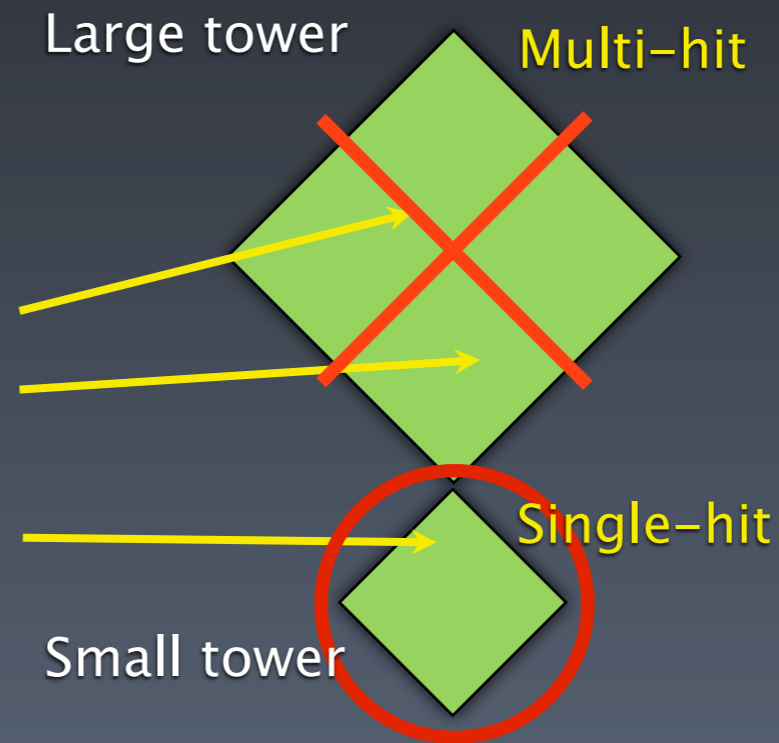
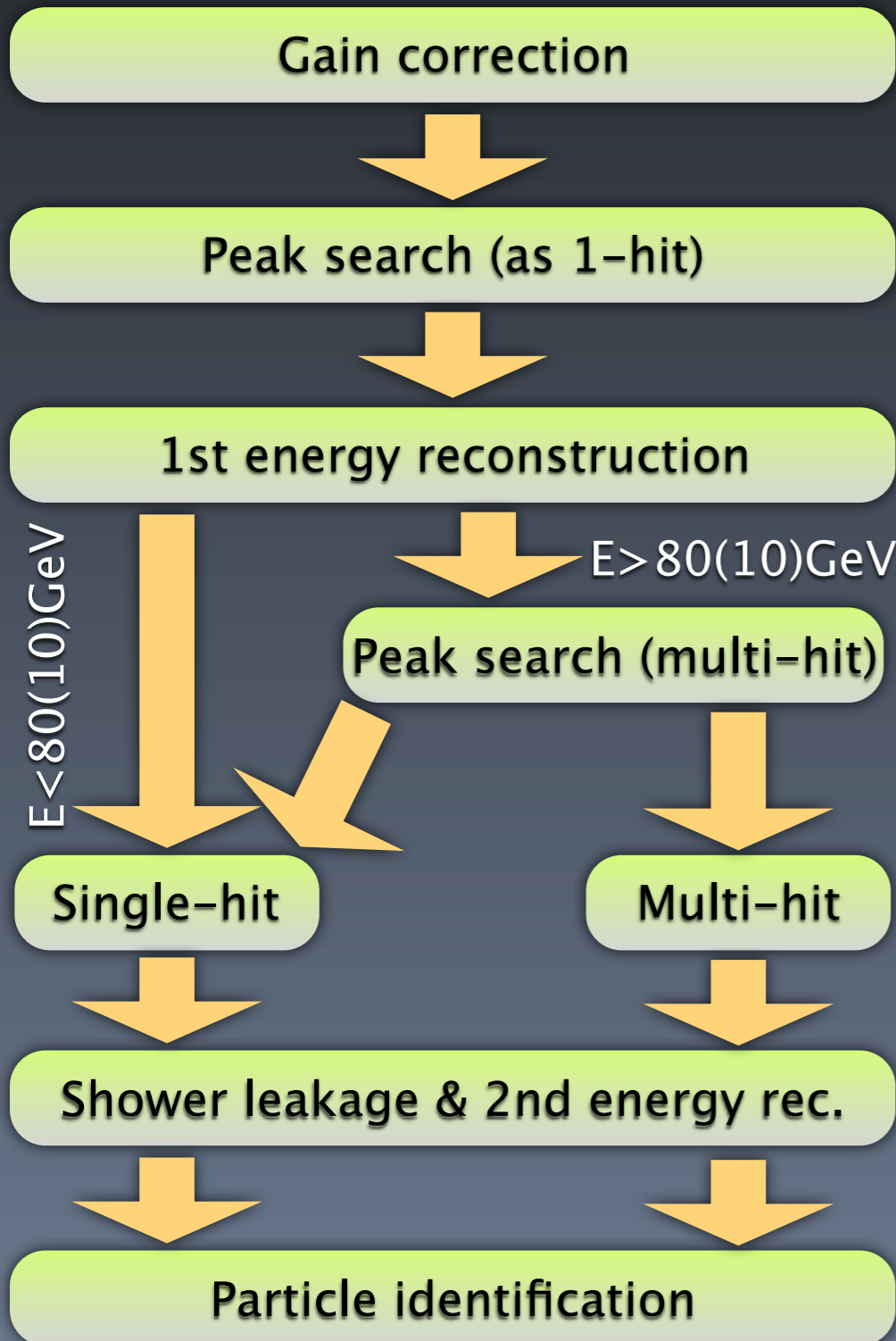
- 1st energy reconstruction is needed to remove low-energy events where multi-hit selection efficiency is quite low.
- Only single-hit events are used in the following physics analysis, since the performance of energy reconstruction of multi-hit events is still worse.

Photon event analysis

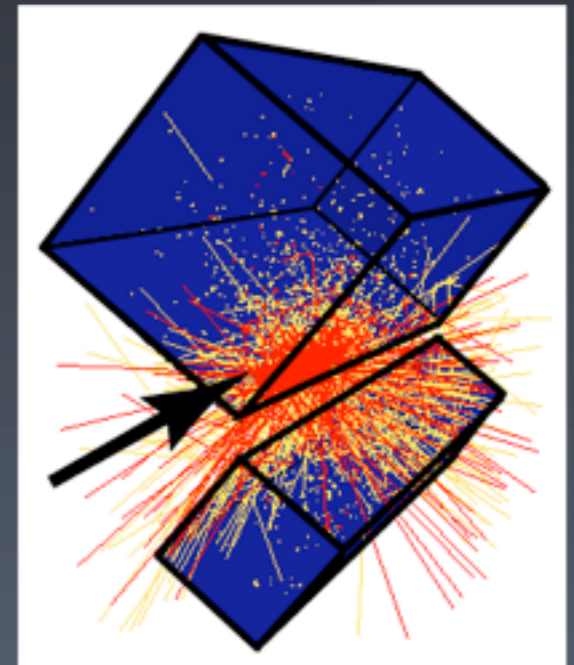


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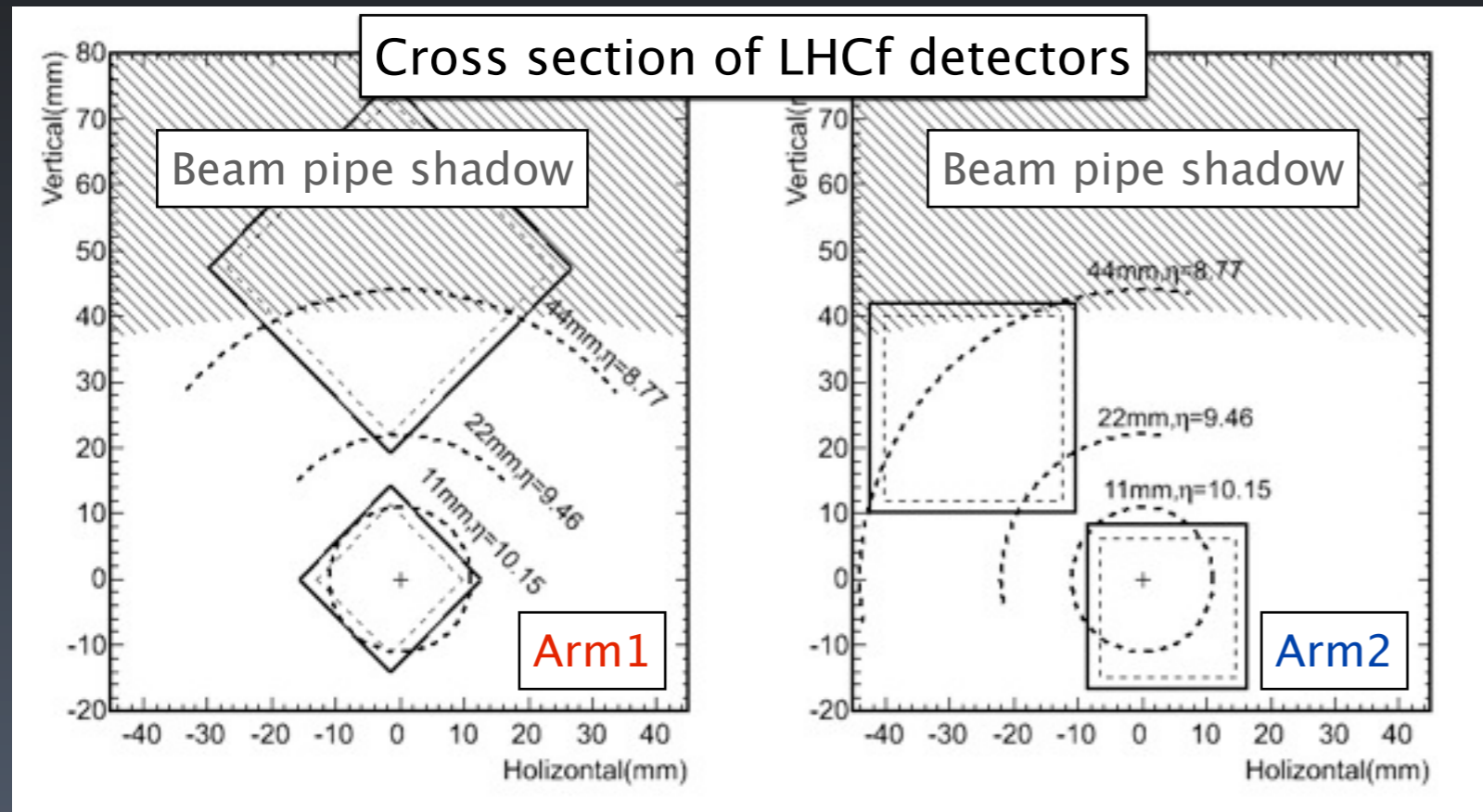


Shower leakage-in/out



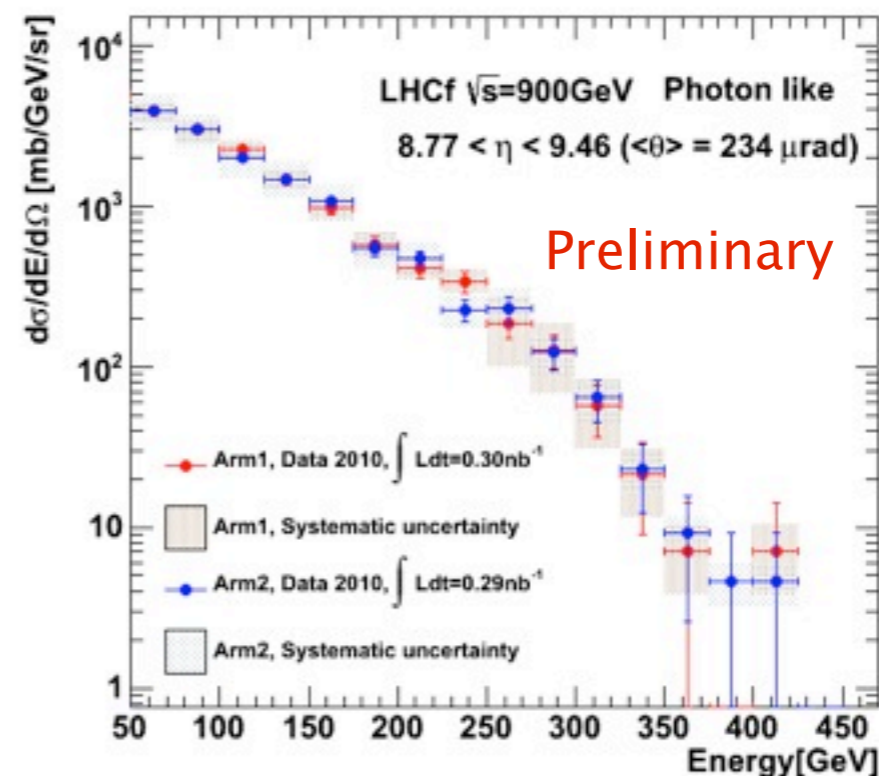
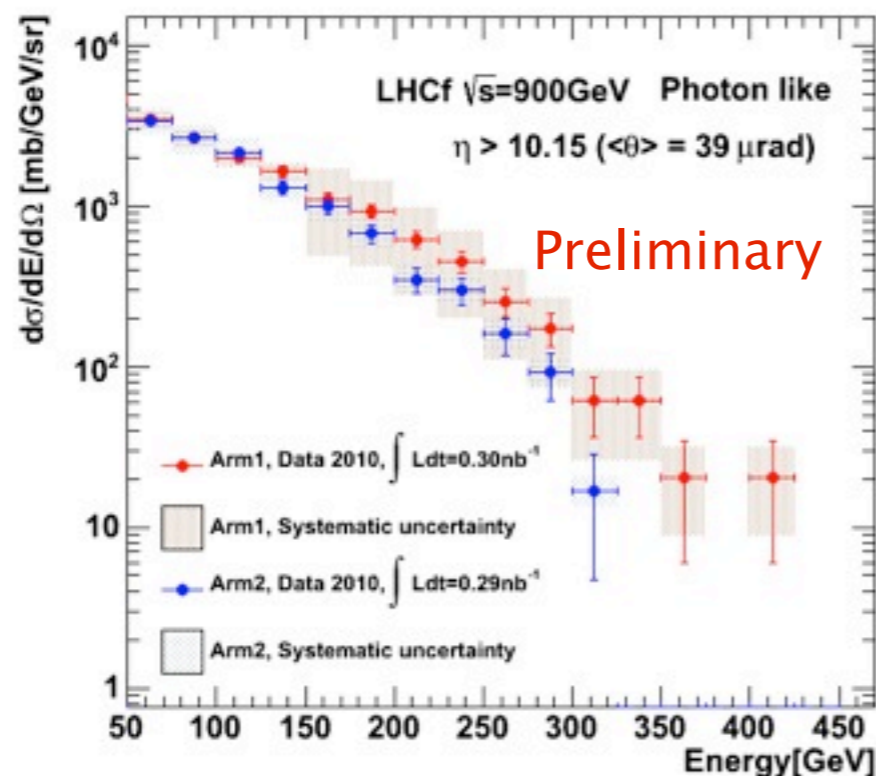
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900GeV photon analysis

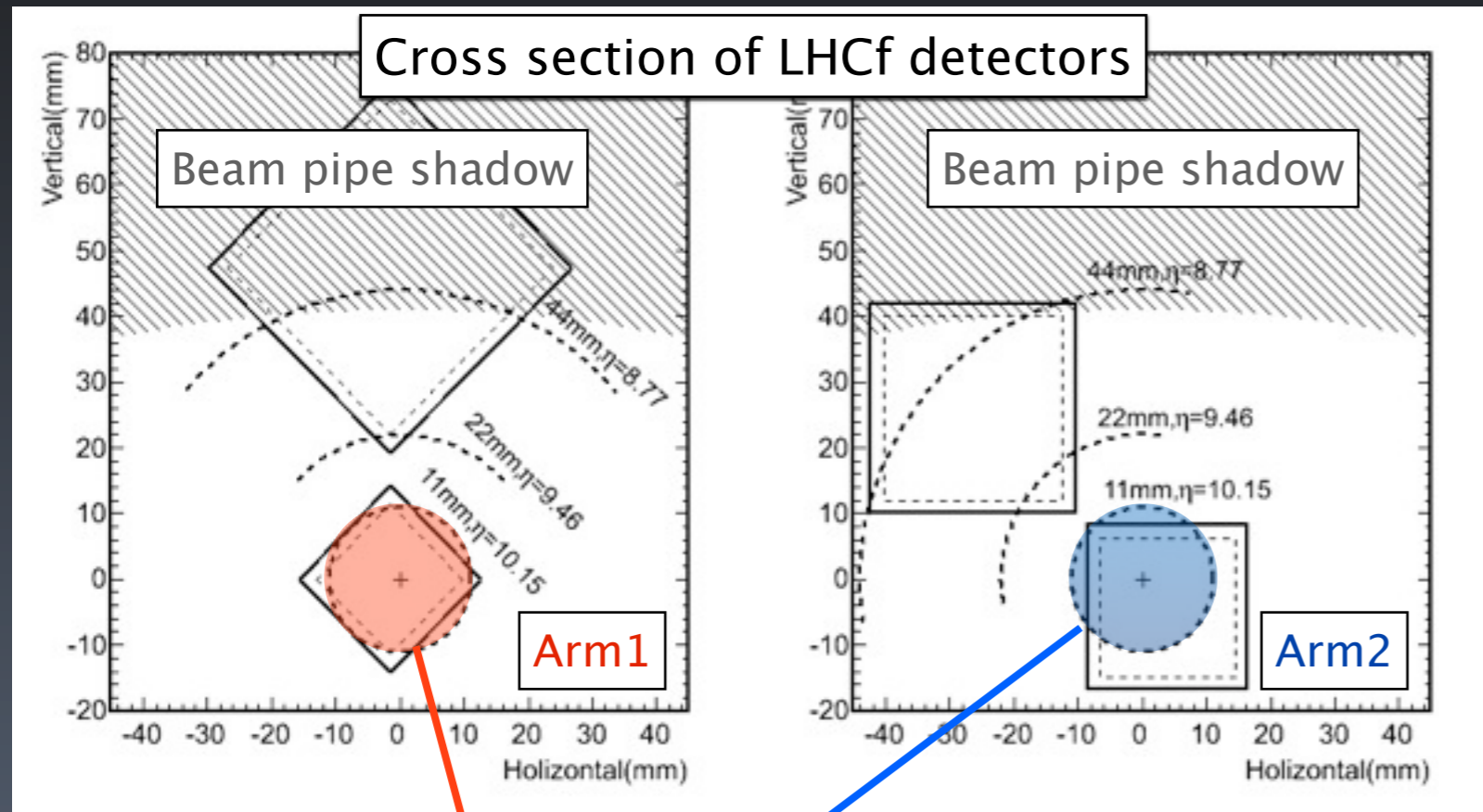


- Photon like events are categorized into two rapidity ranges:
 - $\eta > 10.15$
 - $8.77 < \eta < 9.46$
- Unavoidable PID inefficiency and impurity are corrected in each bin.
- Integral luminosity $\sim 0.3\text{nb}^{-1}$, and uncertainty is 21%.
- Independent data analysis using the Arm1 and Arm2 data show an overall good agreement within their systematic uncertainties.

Arm1 data vs Arm2 data

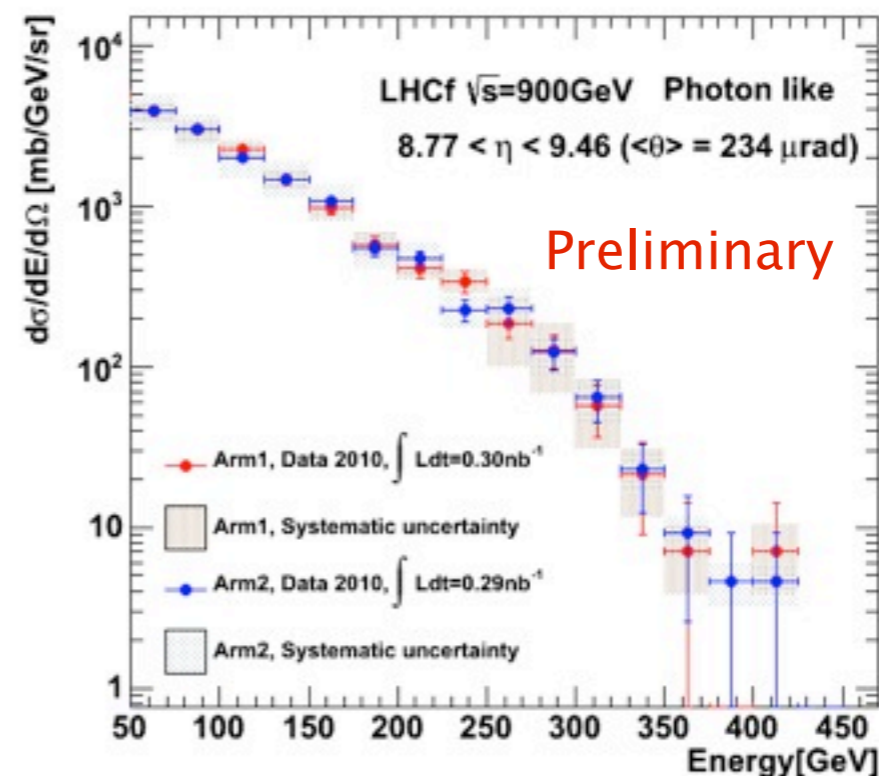
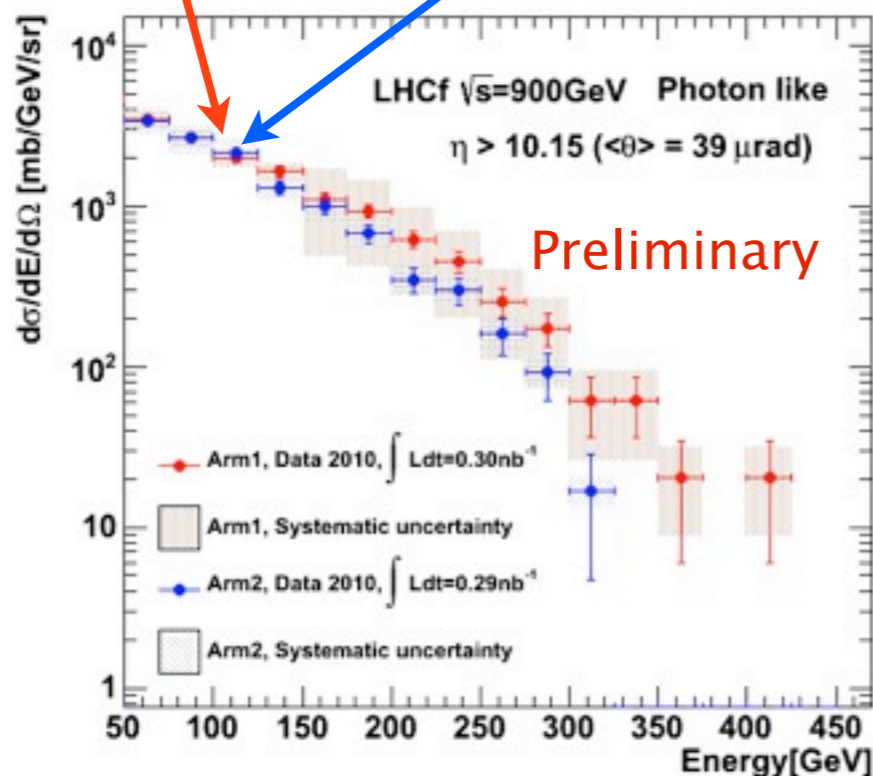


900GeV photon analysis

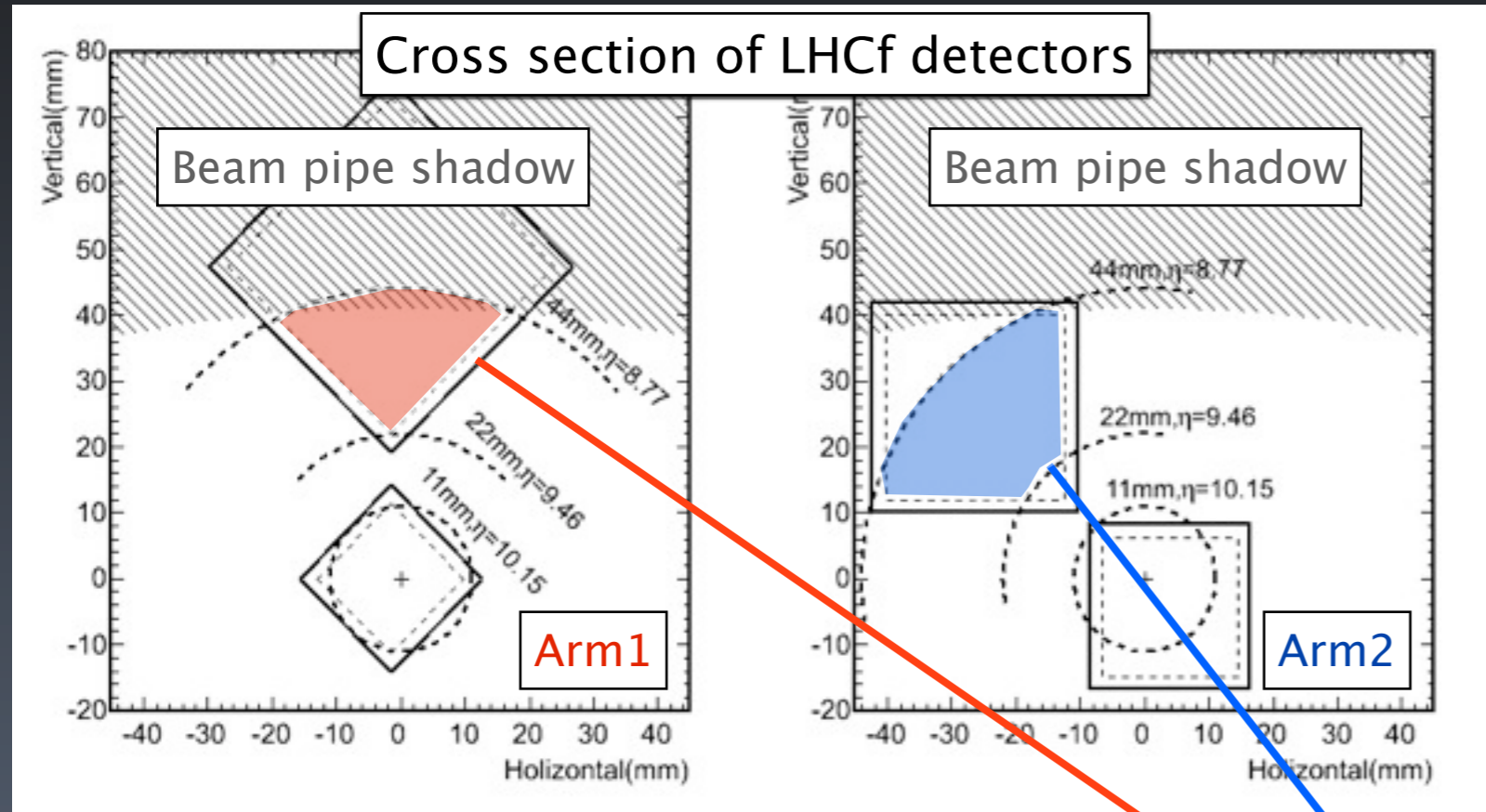


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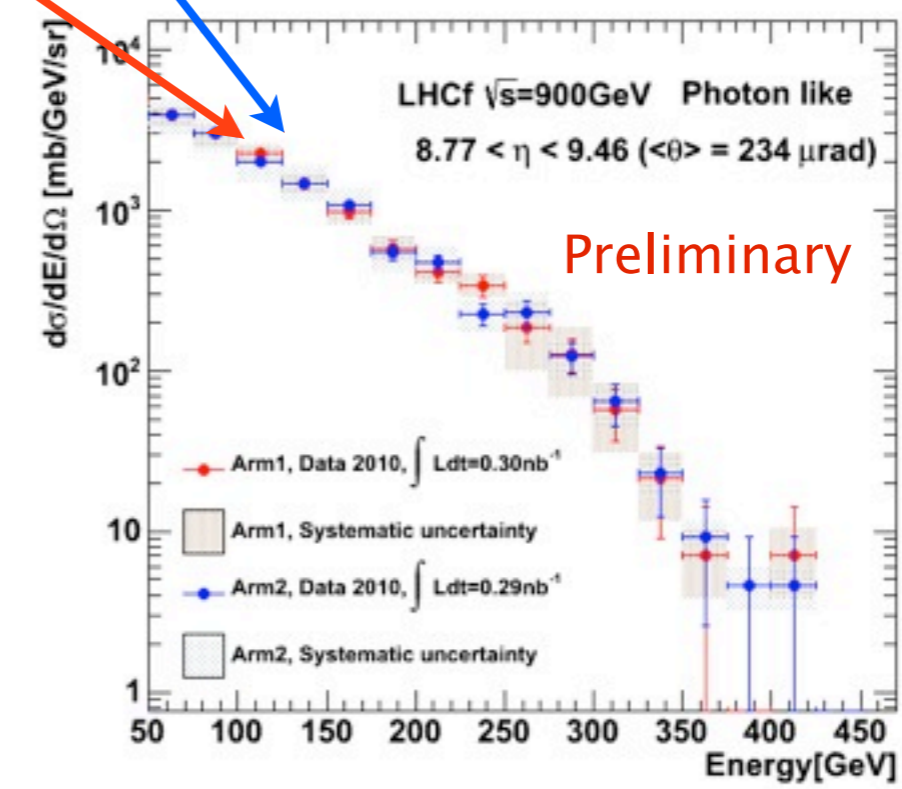
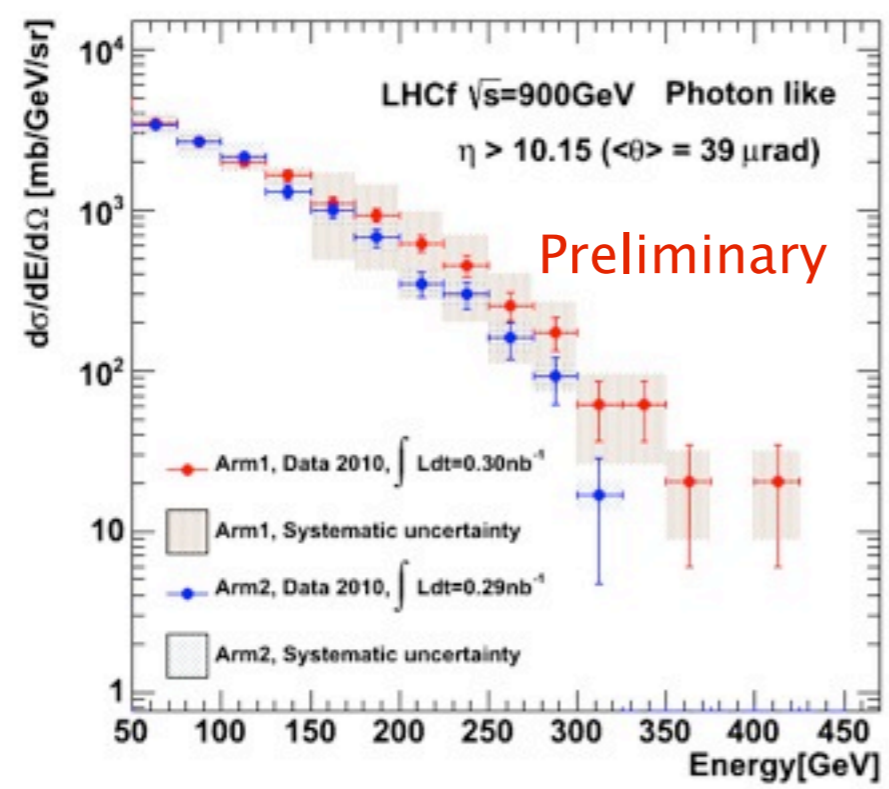


900GeV photon analysis

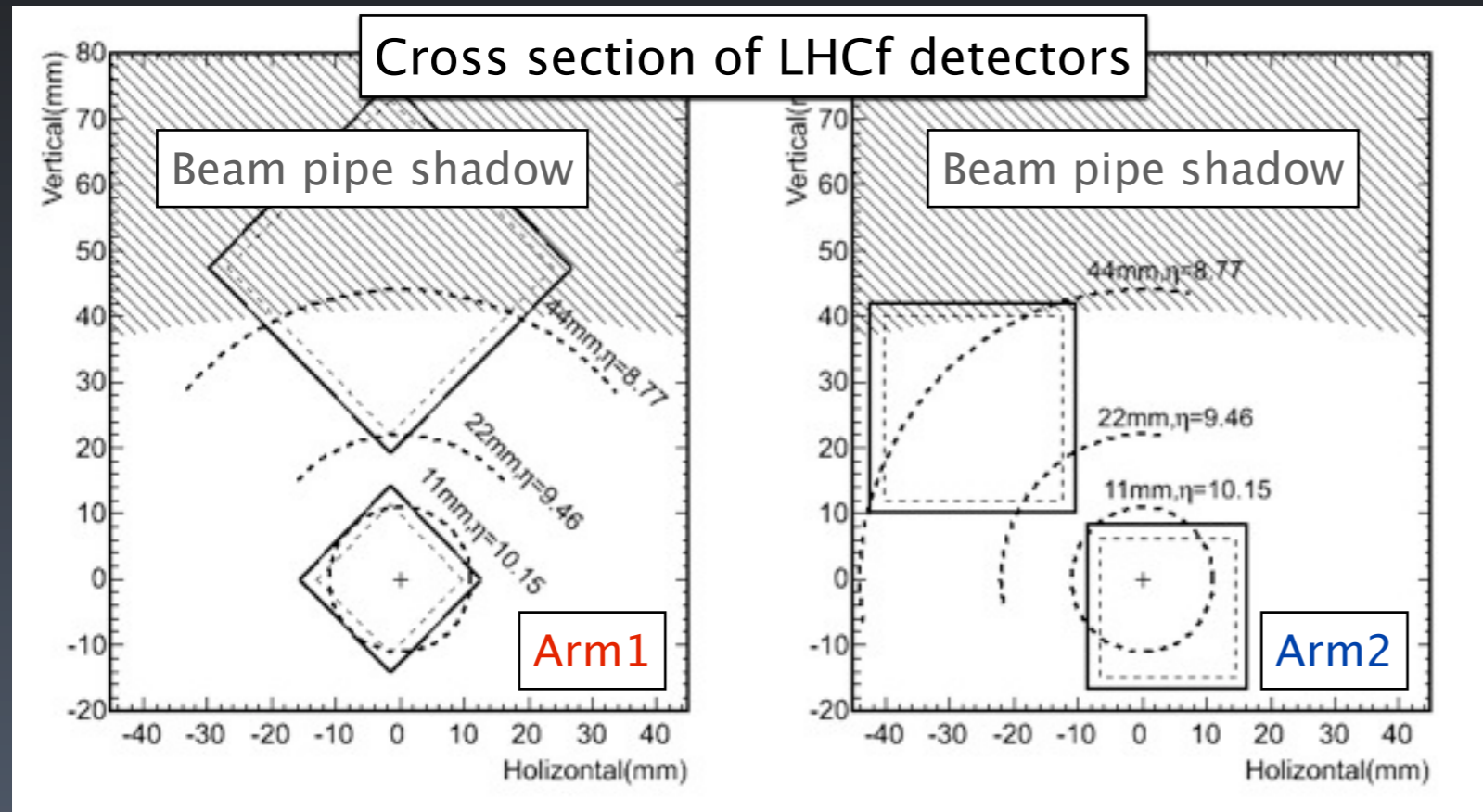


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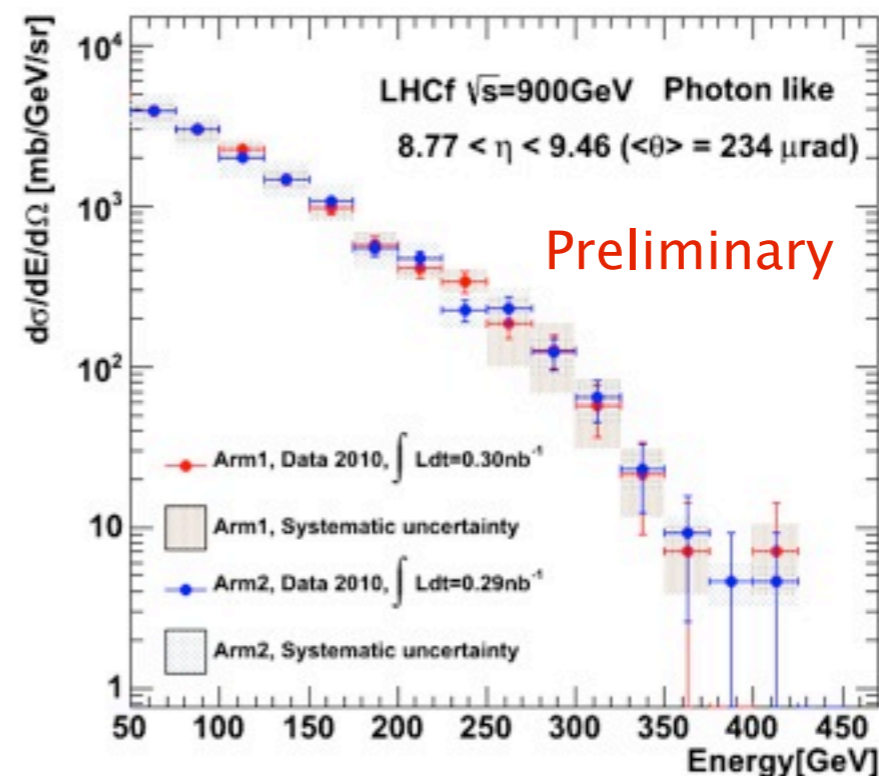
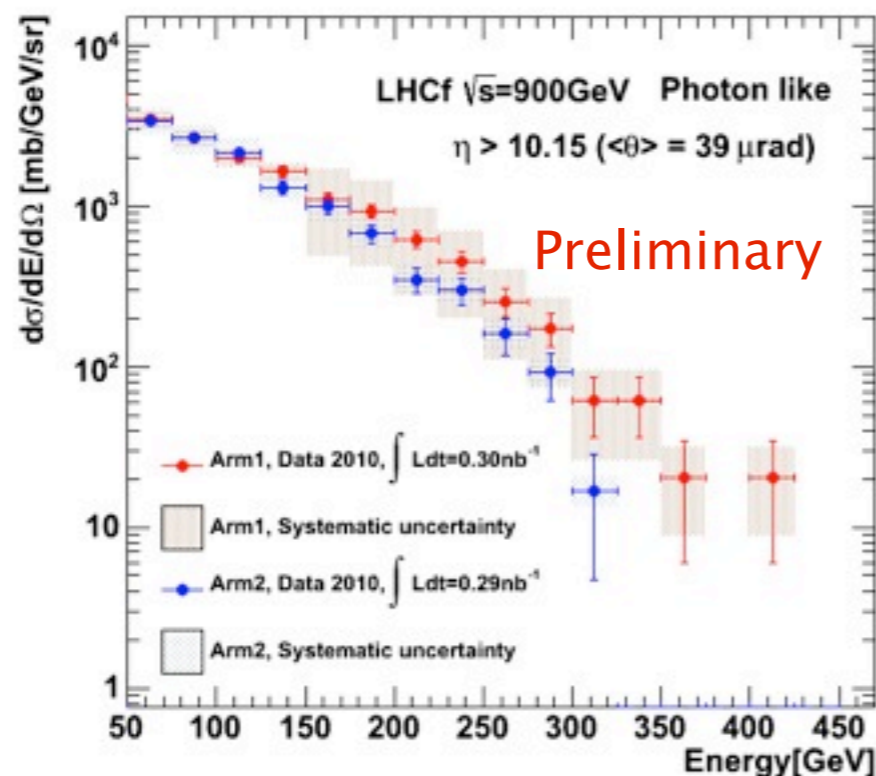


900GeV photon analysis



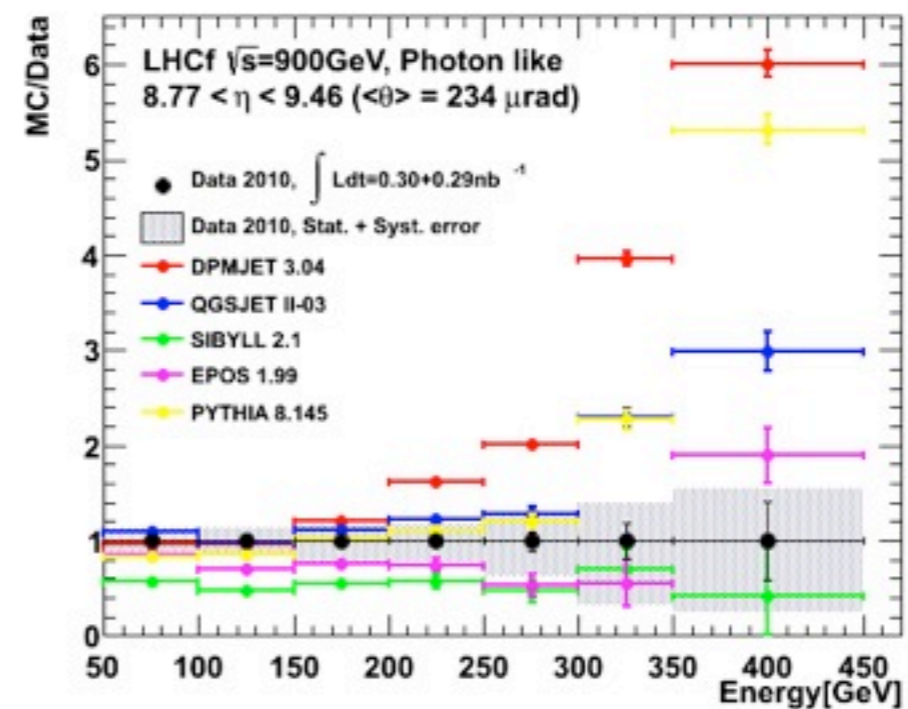
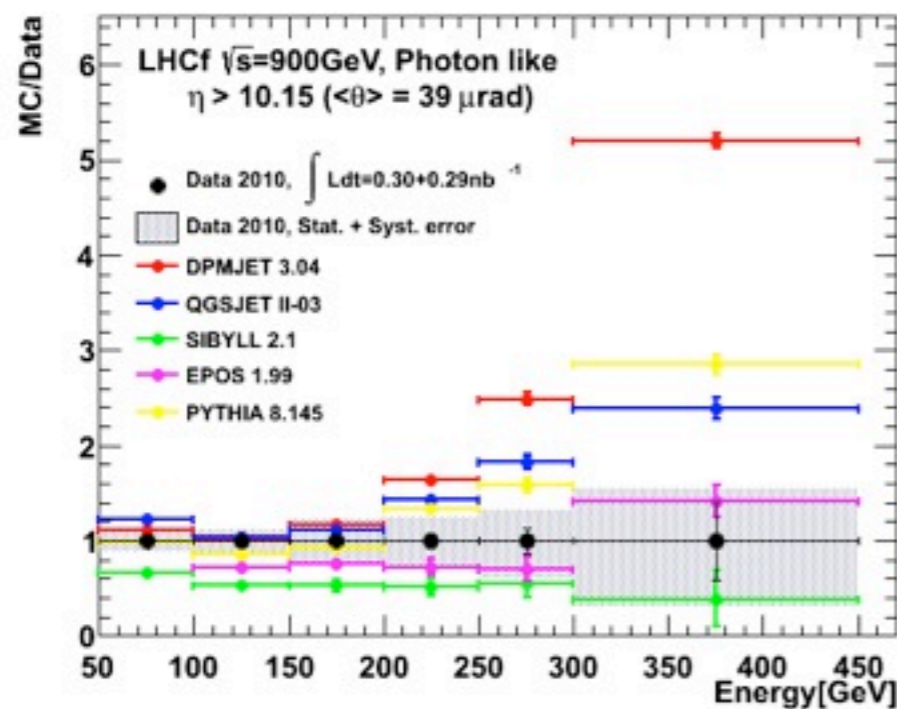
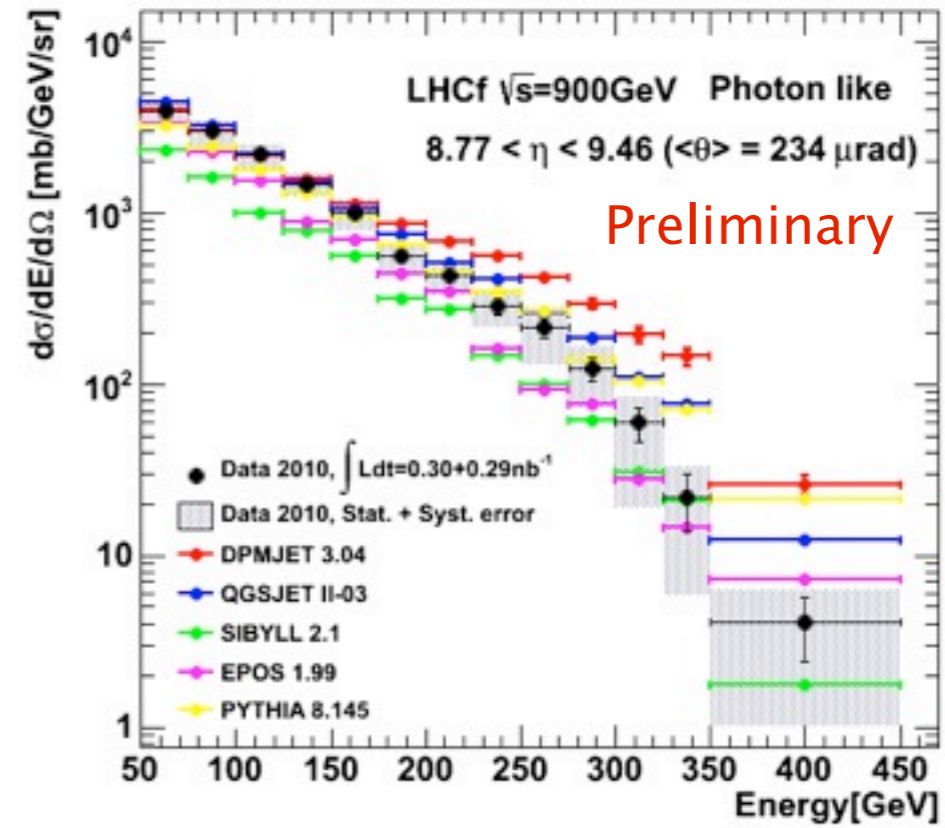
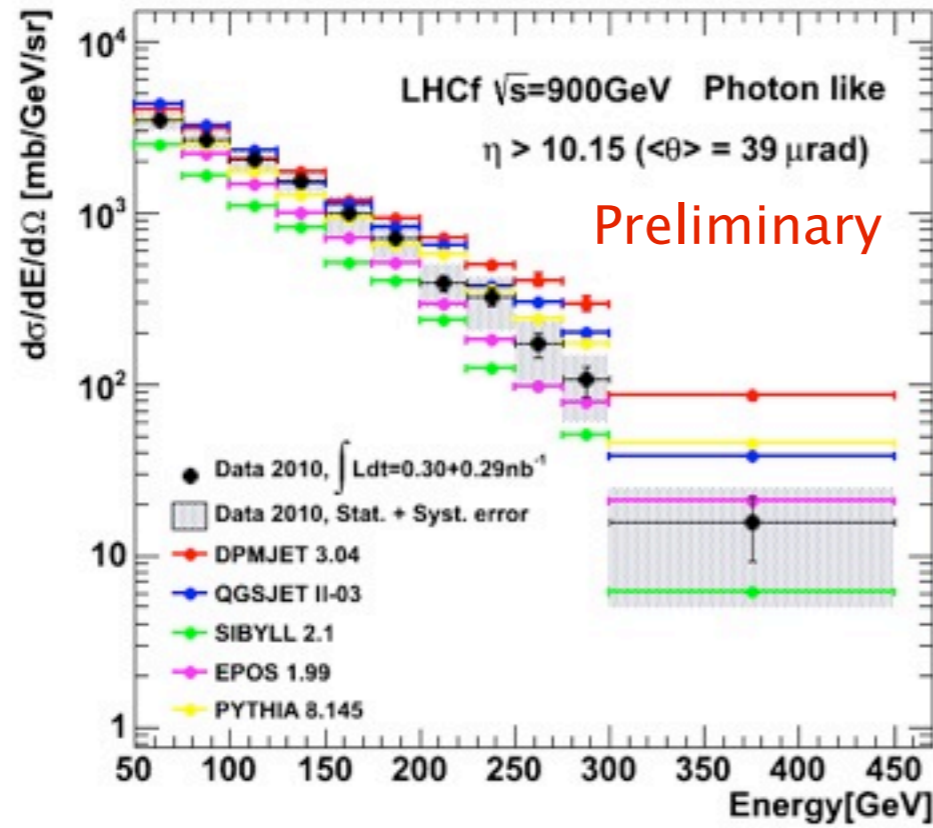
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Arm1 data vs Arm2 data

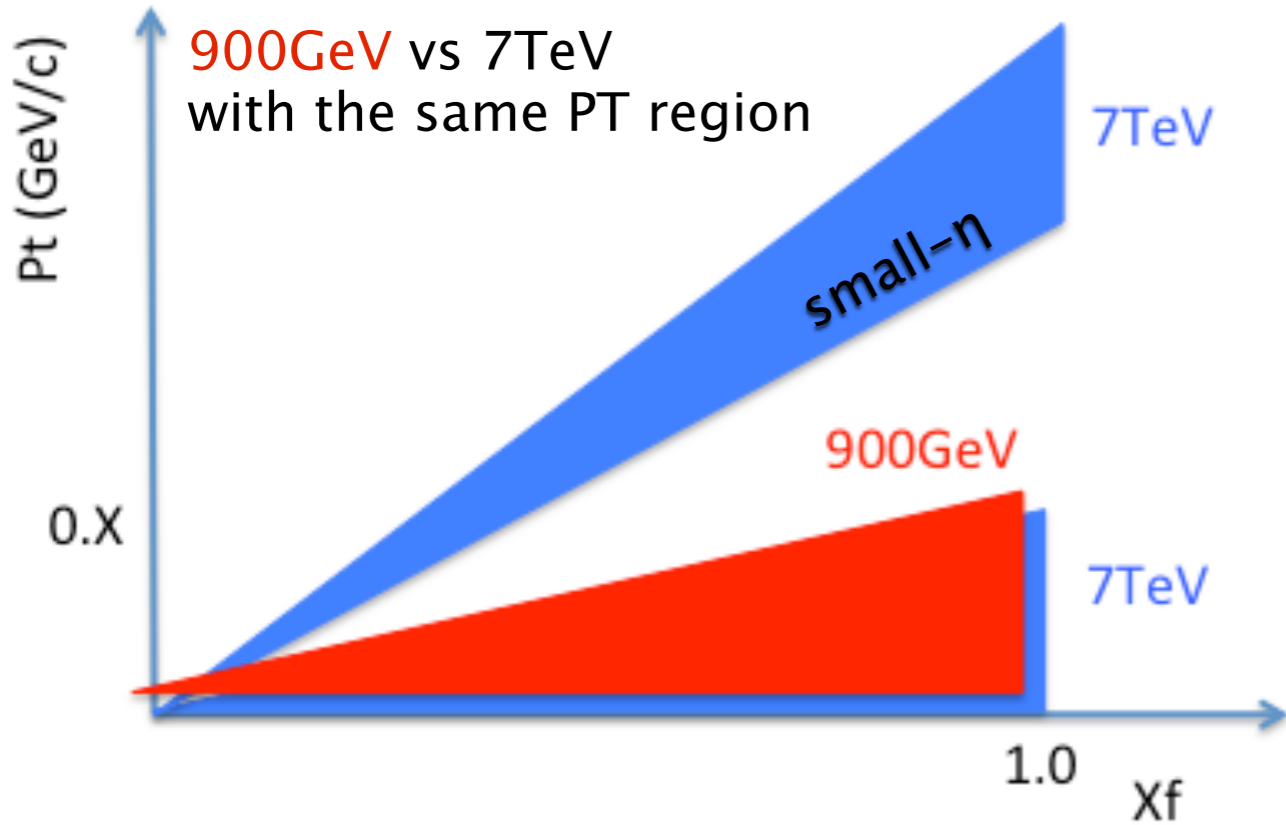


900GeV photon analysis

Combined data vs MC simulations



900GeV photon analysis

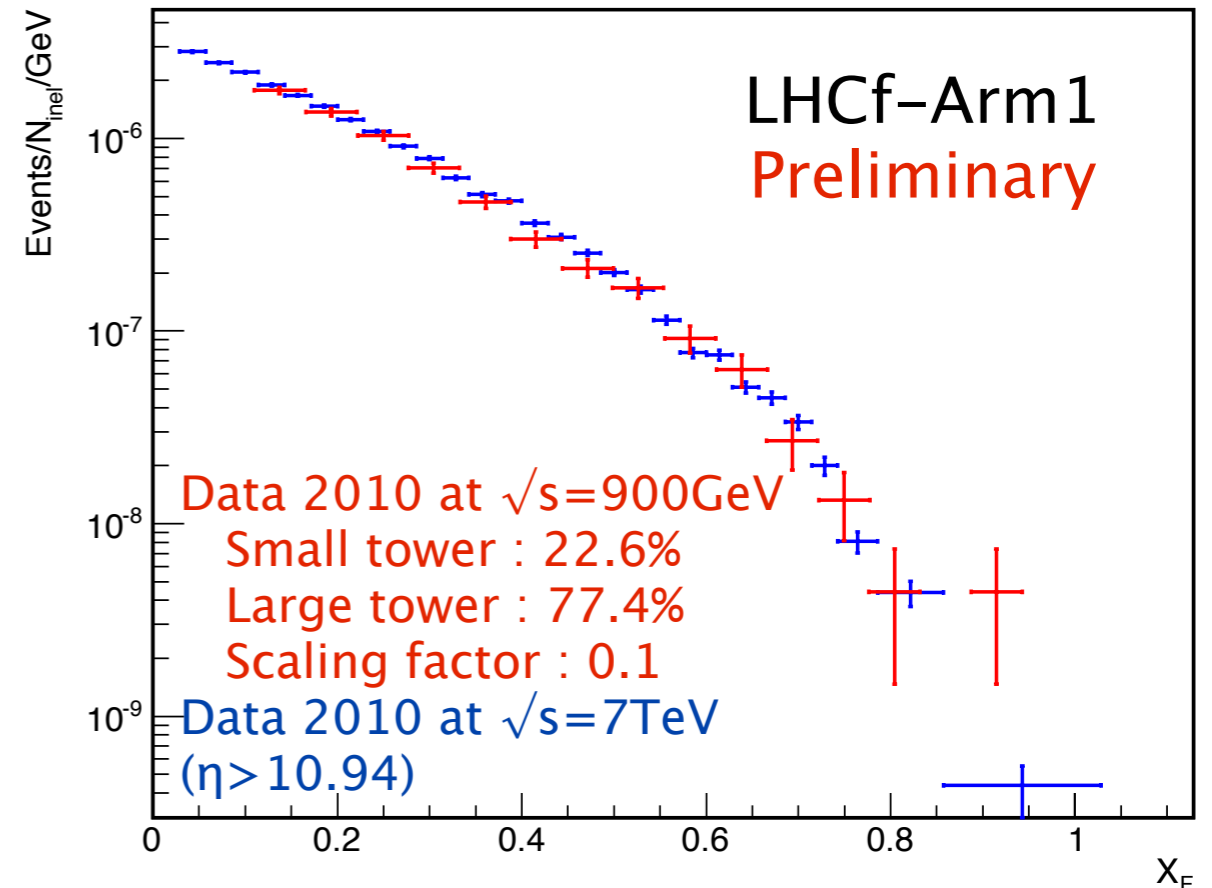


- Suppose a Pt of $\sqrt{s}=900\text{GeV}$ events can be scaled to the Pt at $\sqrt{s}=7\text{TeV}$ as

$$P_T(\sqrt{s} = 7\text{TeV}) = P_T(\sqrt{s} = 900\text{GeV}) \frac{7\text{TeV}}{900\text{GeV}}$$

- Then the spectrum inside $R=5\text{mm}$ at $\sqrt{s}=7\text{TeV}$ would be equivalent to that $R<38.9\text{mm}$ at $\sqrt{s}=900\text{GeV}$.

X_F spectra : 900GeV data vs 7TeV data



- No systematic error is considered in both collision energies, although this treatment may not change an impression of the comparison.
- **Good agreement of each X_F scaling spectrum indicates a weak Pt dependence of the energy spectrum.**

7TeV π^0 analysis

Standard LHCf photon reconstruction

Two-photon selection

Invariant mass reconstruction

Signal window

Sideband

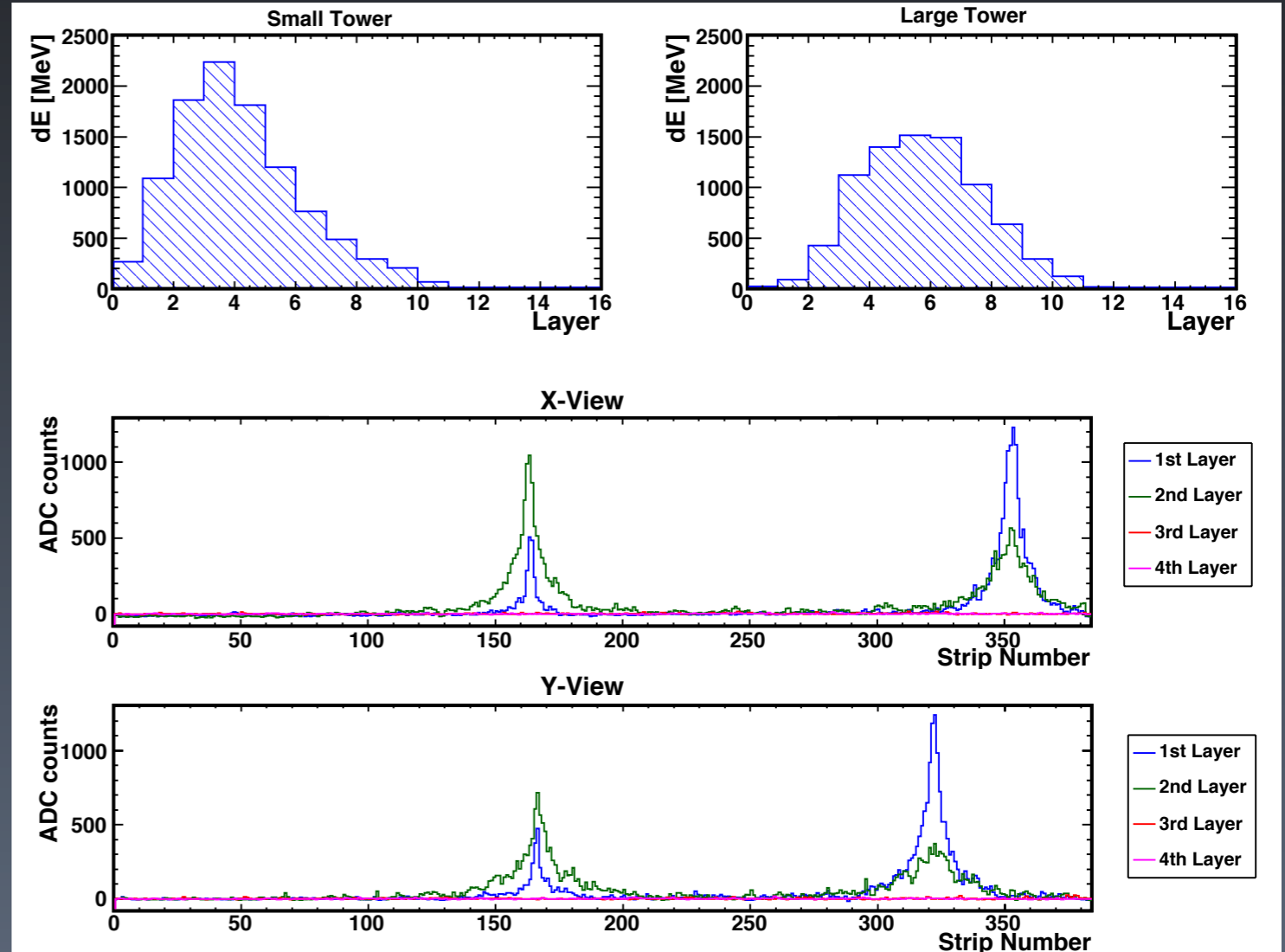
BG subtraction

Unfolding (det. response correction)

Acceptance correction

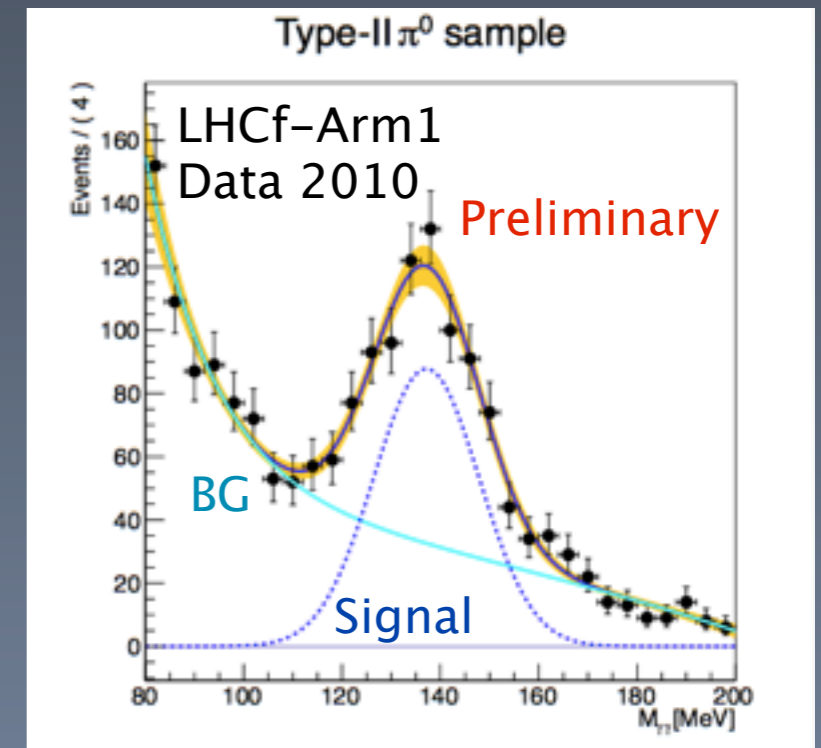
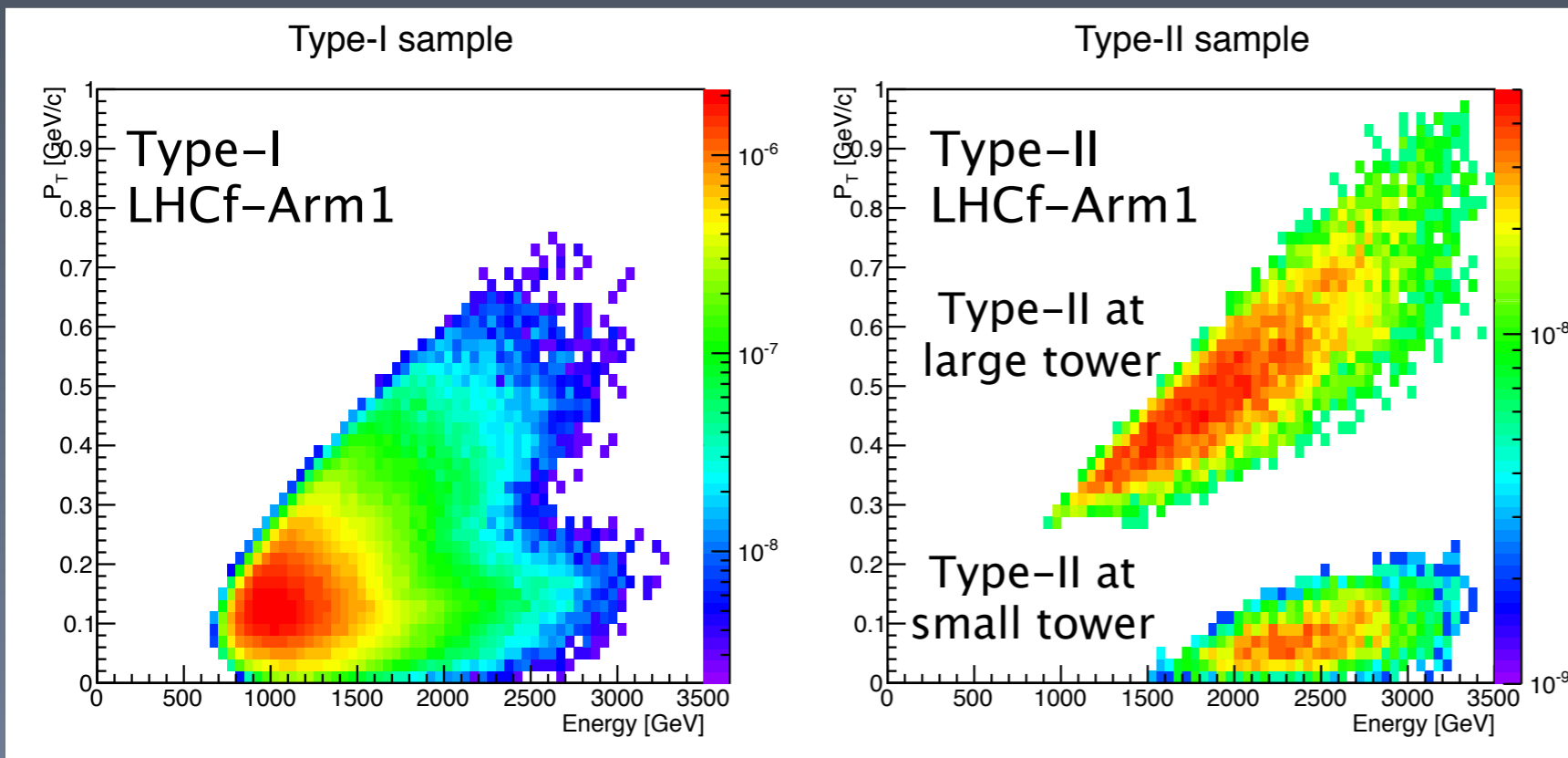
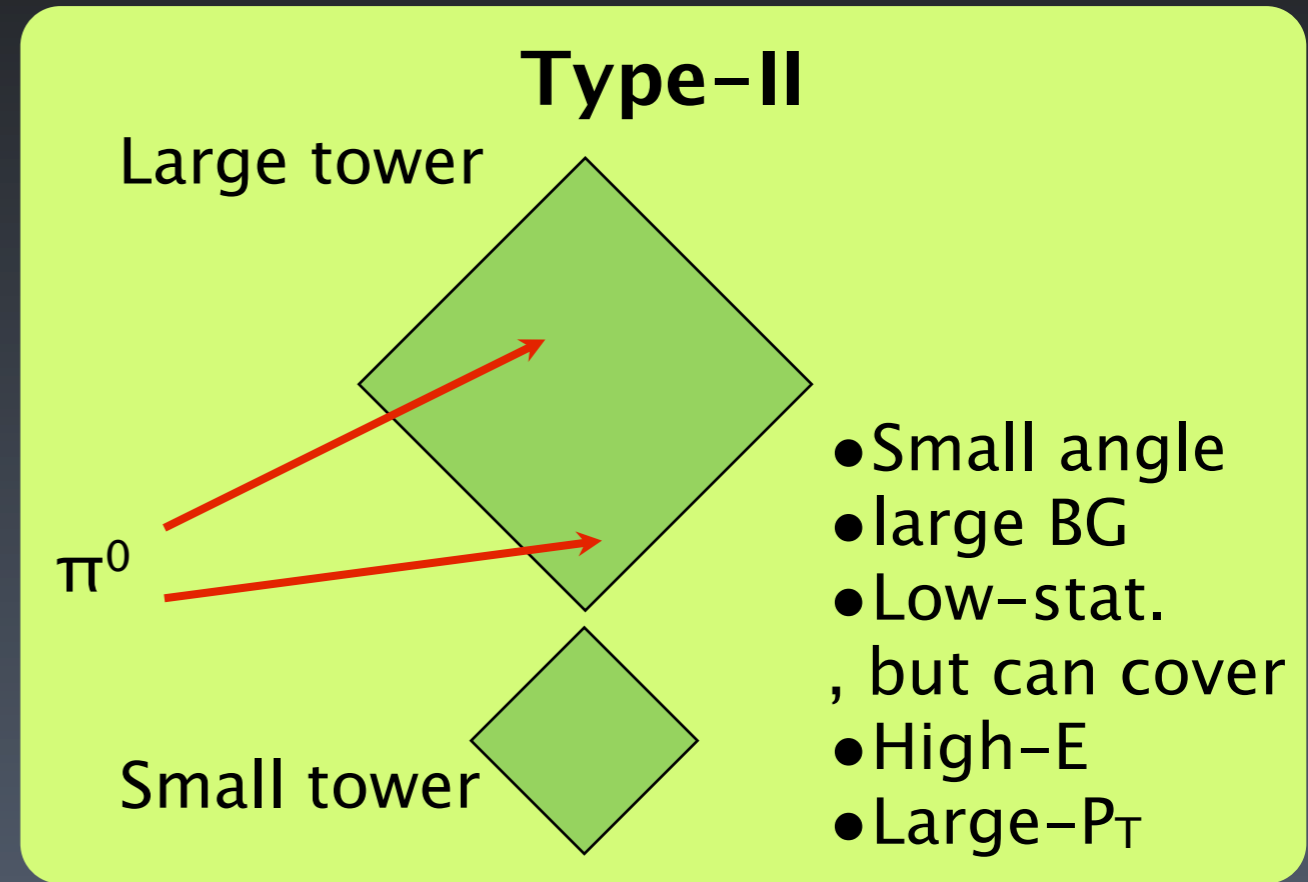
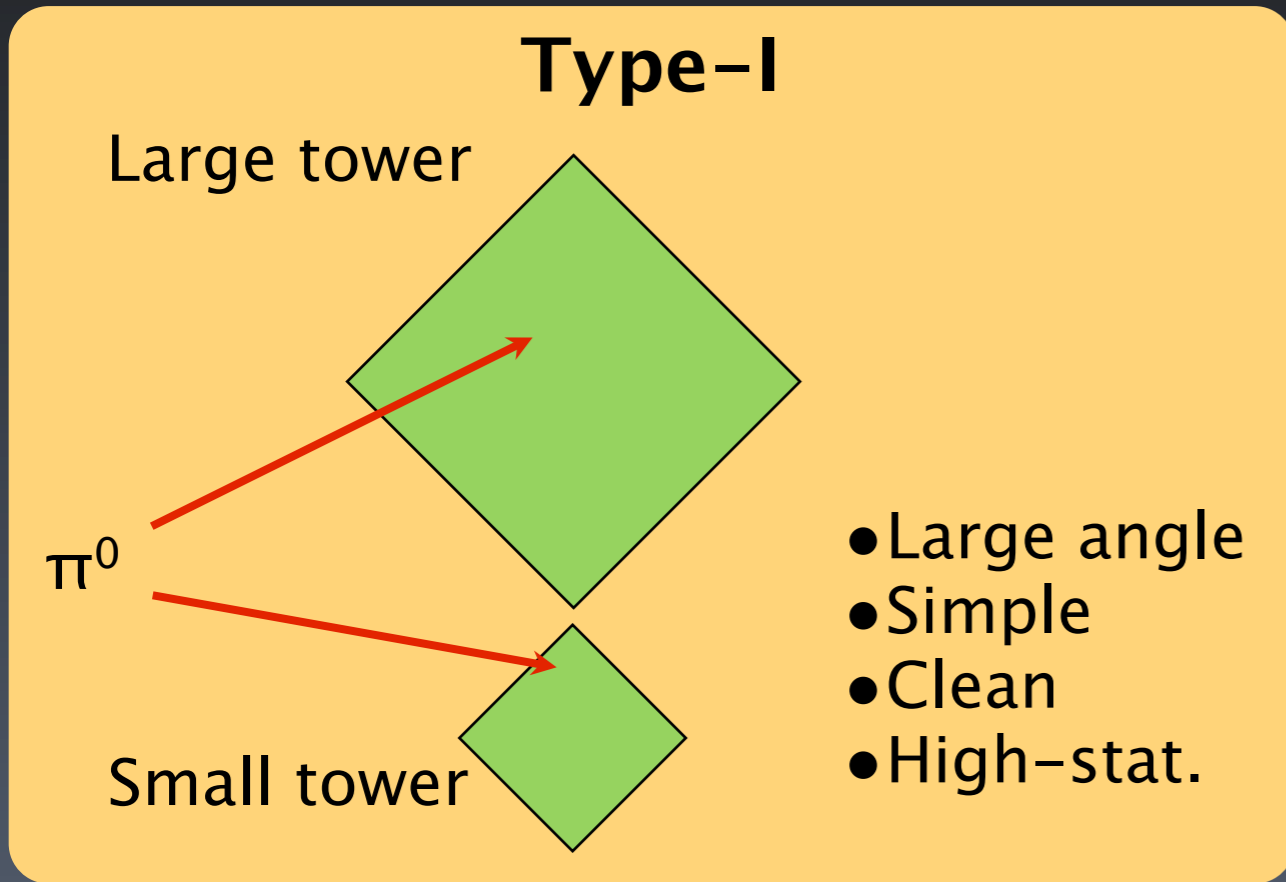
Combining Arm1 and Arm2

Event example of π^0 candidate

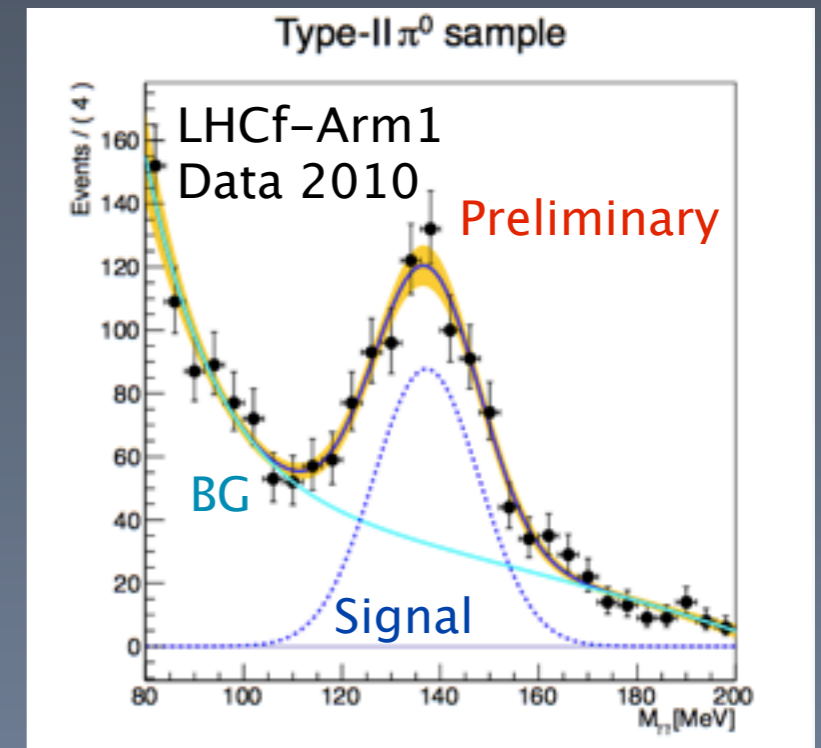
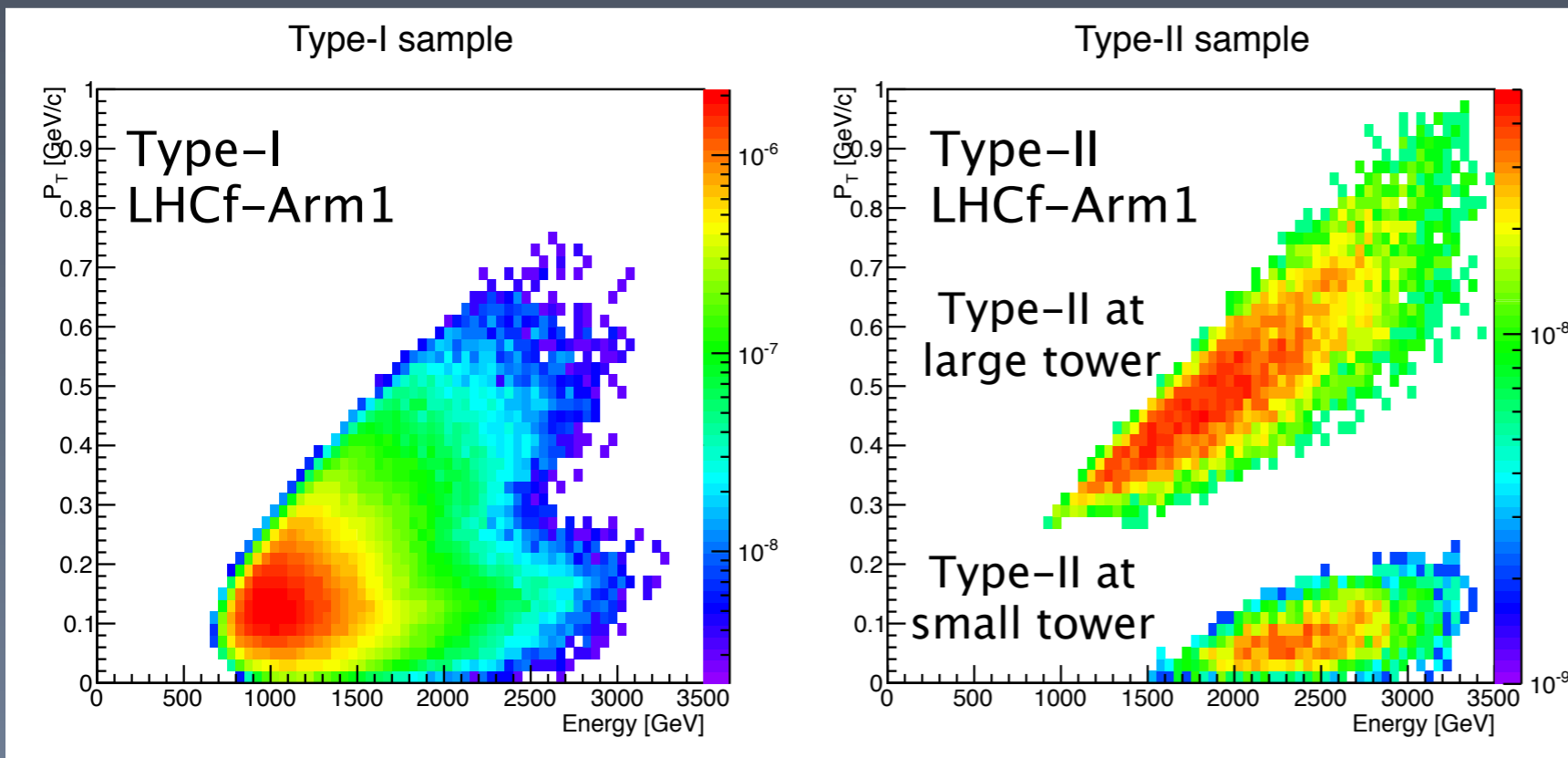
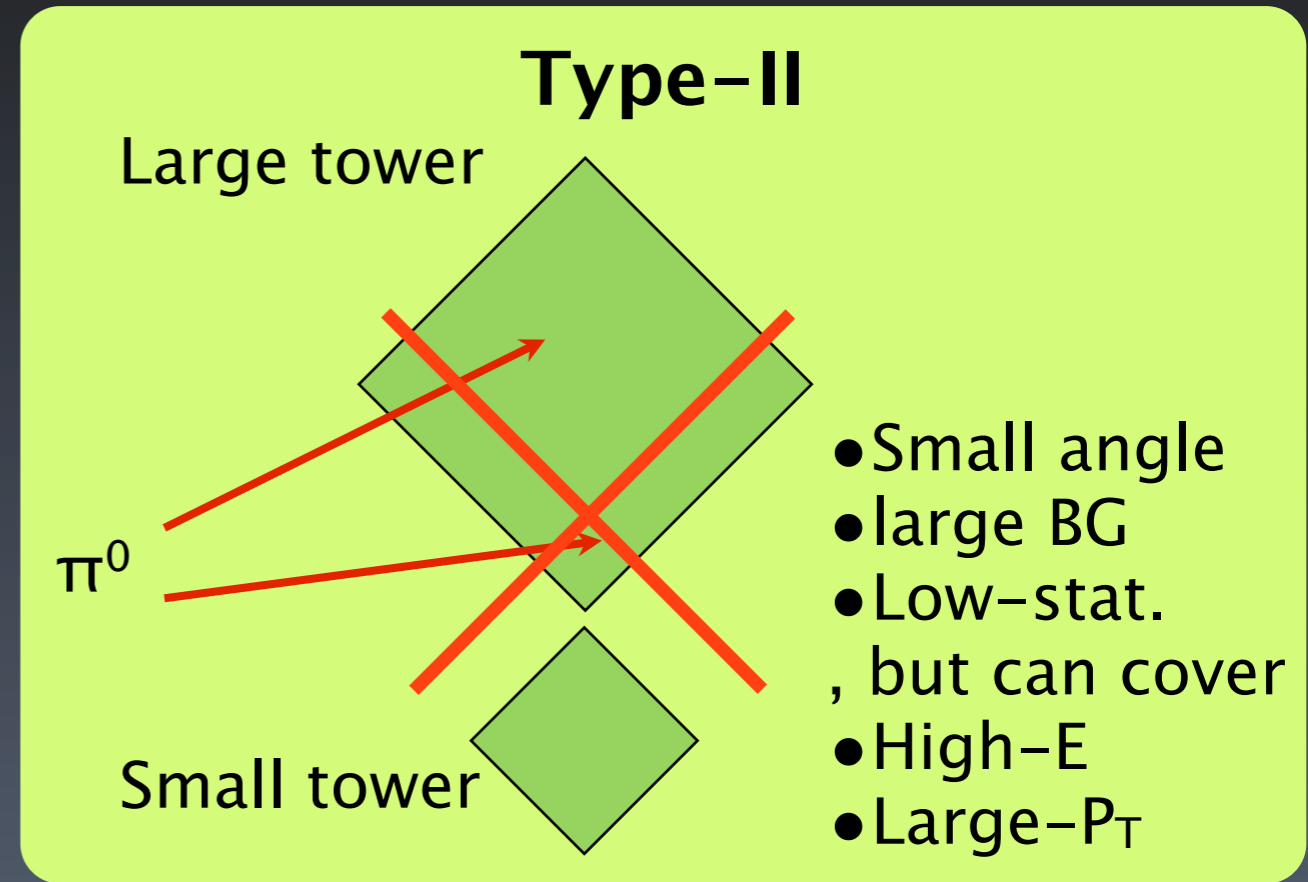
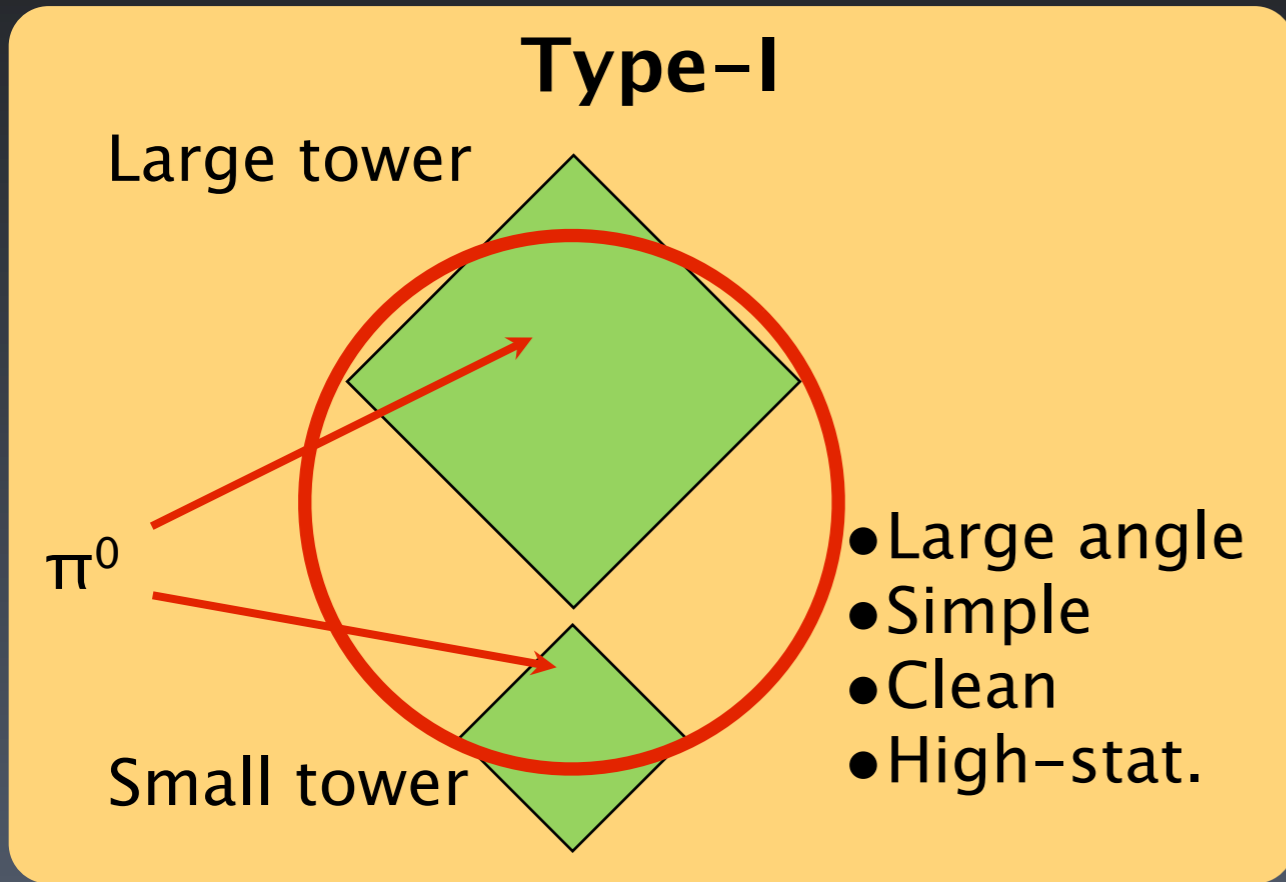


- Imperfect detector response to π^0 events should cause a large distortion of spectra, thus spectra must be corrected for the detector response.
- The LHCf detector can not cover 2π azimuthally. Acceptance inefficiency is corrected as a function of E_π and P_T .

7TeV π^0 analysis

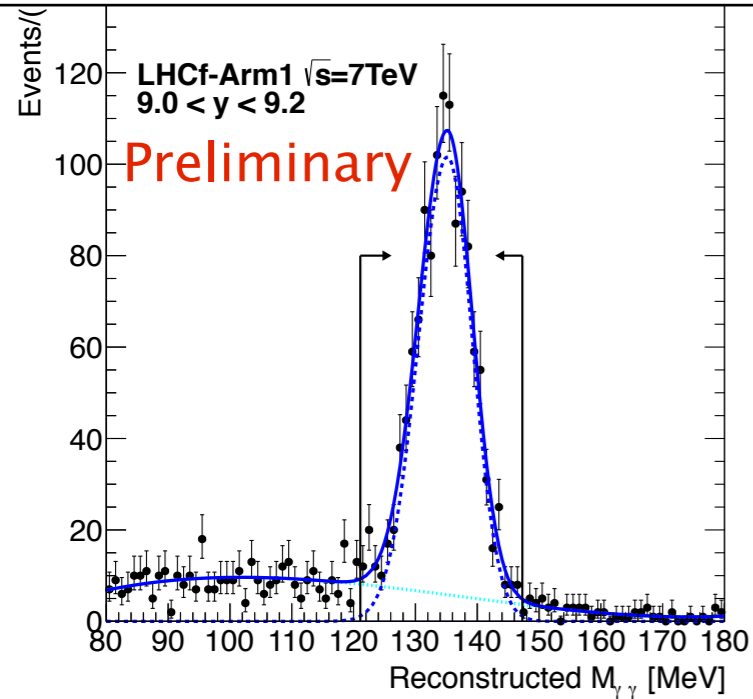


7TeV π^0 analysis



7TeV π^0 analysis

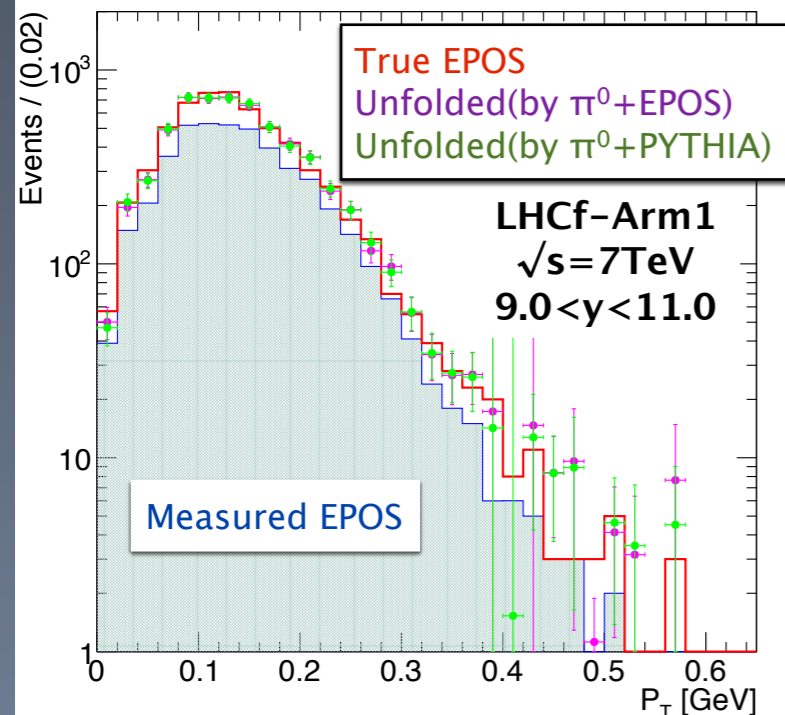
Signal window : $[-3\sigma, +3\sigma]$
 Sideband : $[-6\sigma, -3\sigma]$ and $[+3\sigma, +6\sigma]$



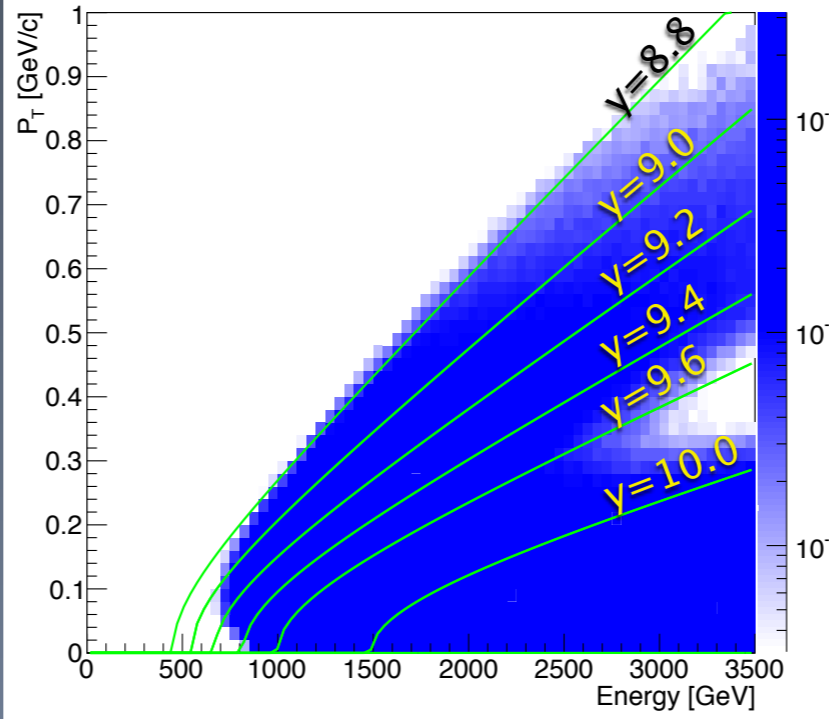
- Remaining background spectrum is estimated using the sideband information, then the BG spectrum is subtracted from the spectrum made in the signal window.

$$Signal = f(E, P_T)^{signal} - \frac{\int_{\hat{M}-3\sigma_l}^{\hat{M}+3\sigma_u} \mathcal{L}_{BG} dM}{\int_{\hat{M}-6\sigma_l}^{\hat{M}-3\sigma_l} \mathcal{L}_{BG} dM + \int_{\hat{M}+3\sigma_u}^{\hat{M}+6\sigma_u} \mathcal{L}_{BG} dM} f(E, P_T)^{BG}$$

Validity check of unfolding method

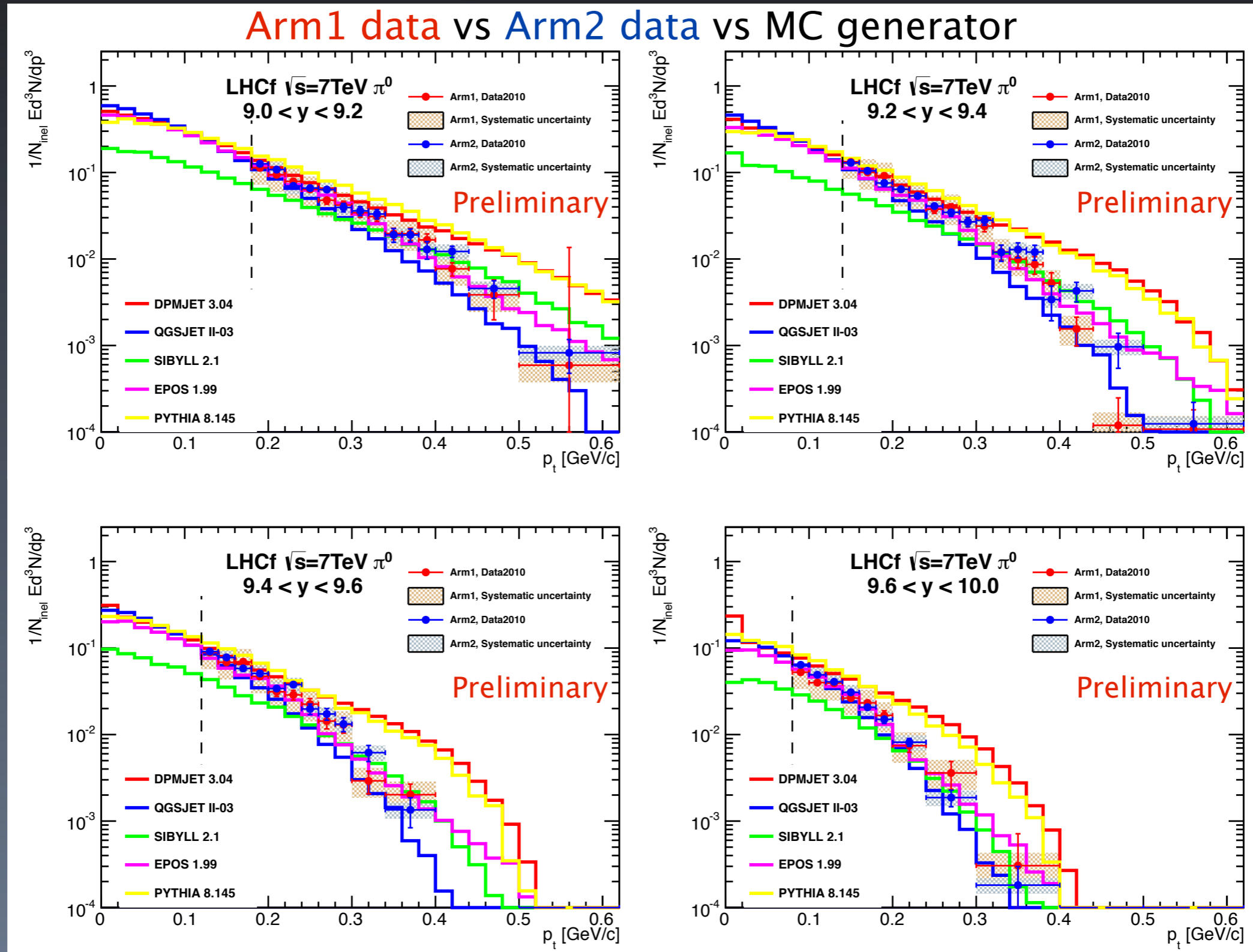


Acceptance for π^0 at LHCf-Arm1



- Detector responses are corrected by an unfolding process that is based on the iterative Bayesian method. (G. D'Agostini NIM A 362 (1995) 487)
- Detector response corrected spectrum is proceeded to the acceptance correction.

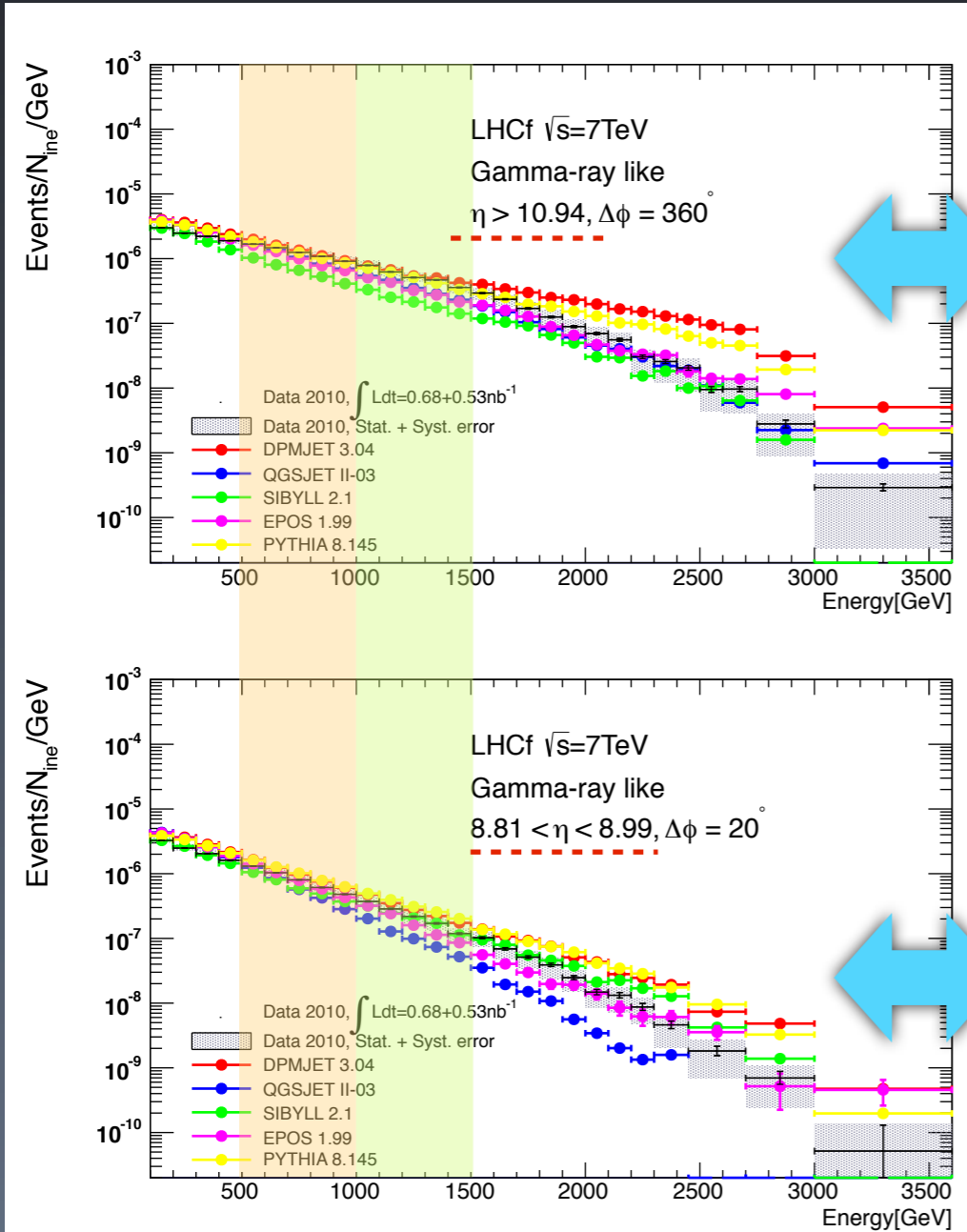
7TeV π^0 analysis



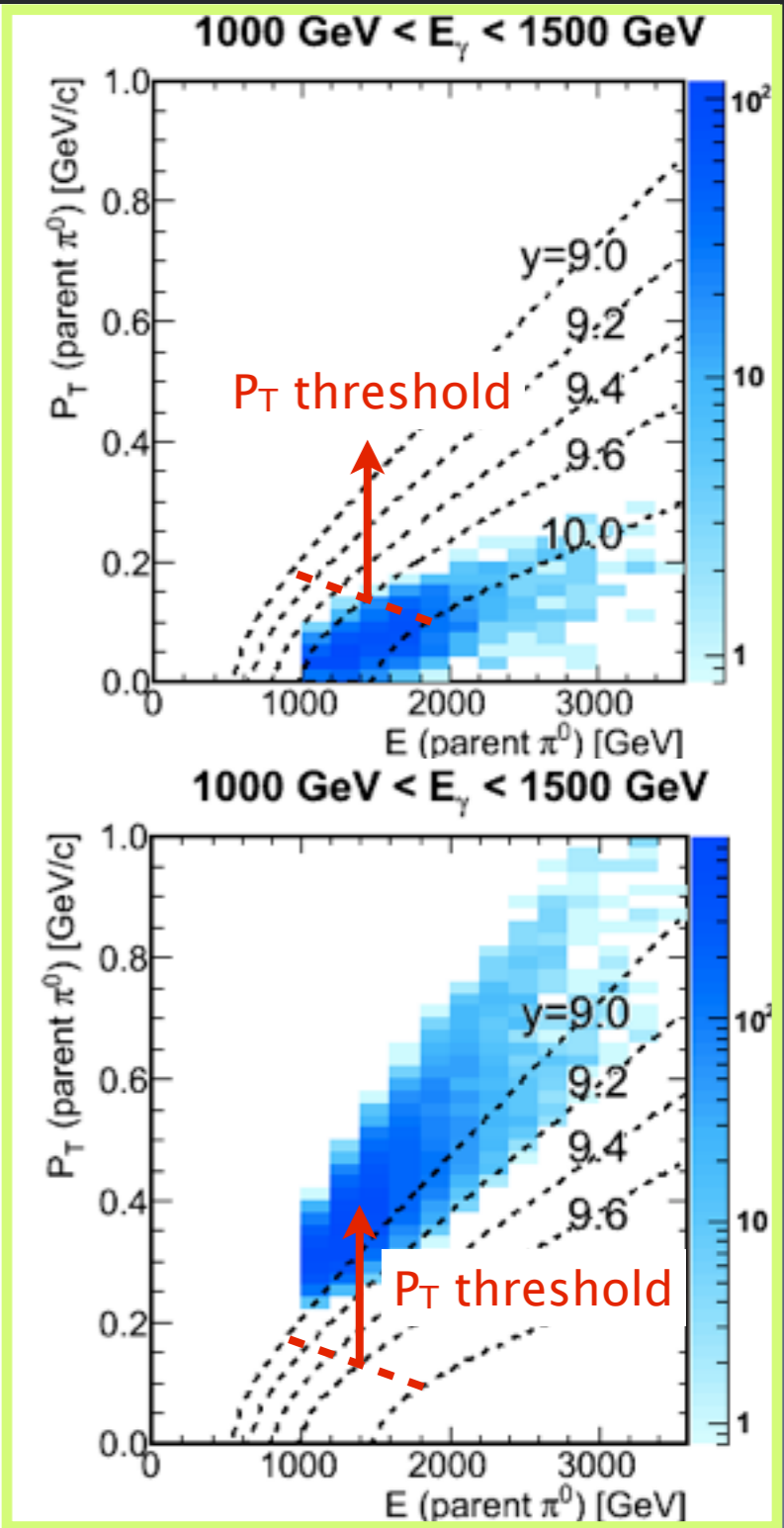
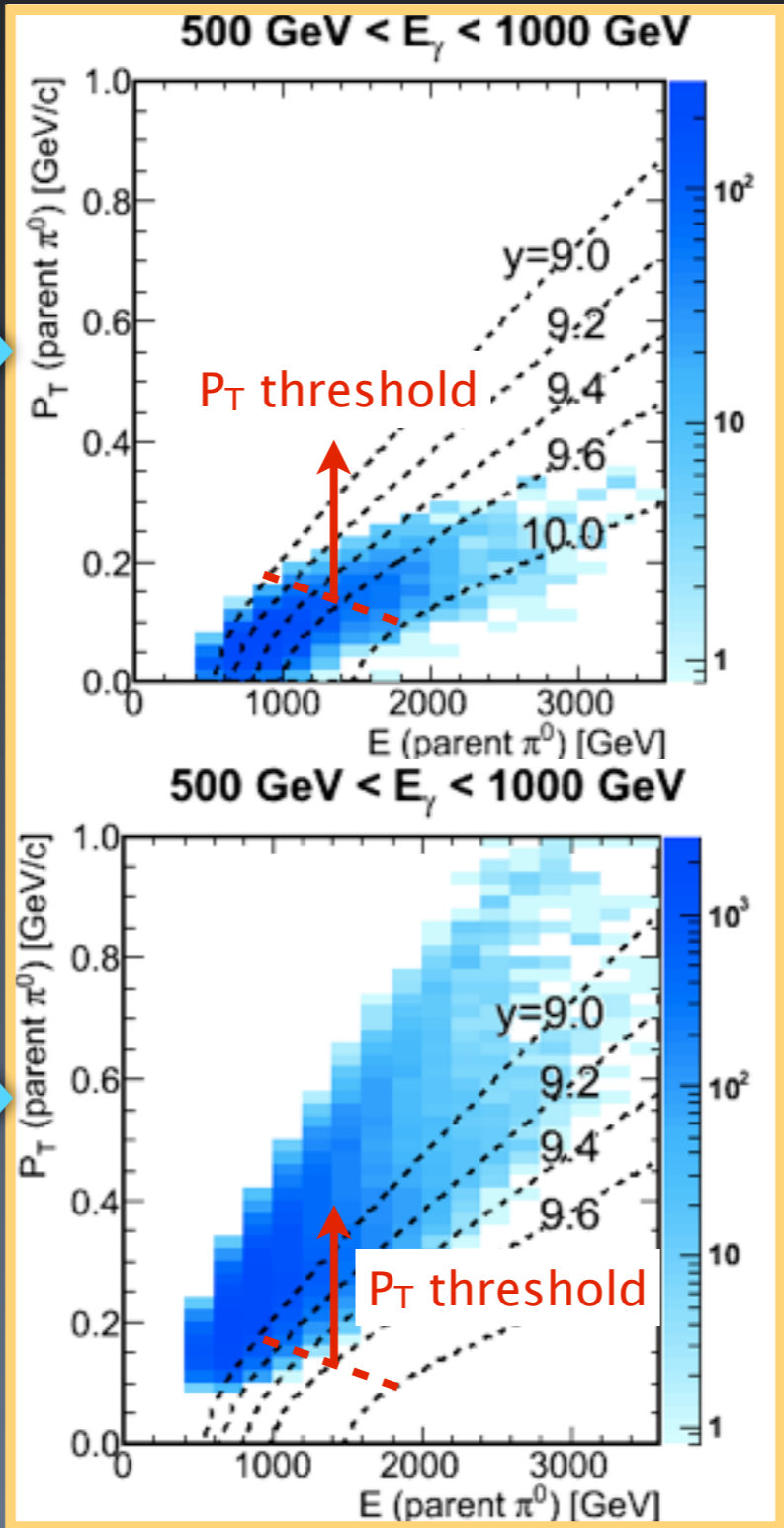
- No energy–scale systematic uncertainty quoted.
- Consistent spectra are obtained between Arm1 and Arm2.

7TeV π^0 analysis

7TeV photon spectra by LHCf



(Phys. Lett. B 703 128-134 (2011))



- Photon analysis and π^0 analysis compensate each missing information.
 - High energy photon originates from large $P_T \pi^0$ events.
 - Photon spectrum includes a contribution from other hadrons/baryons.

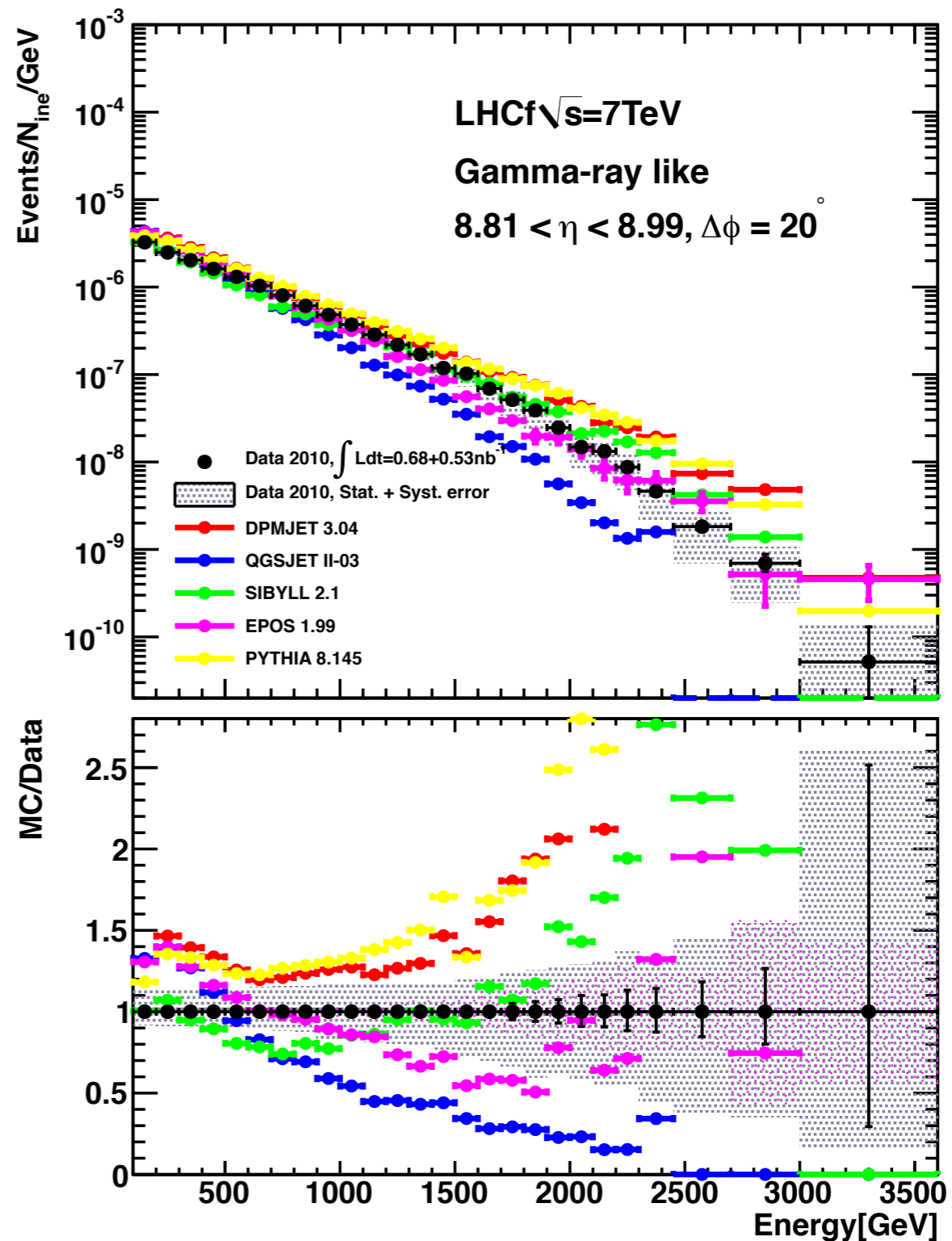
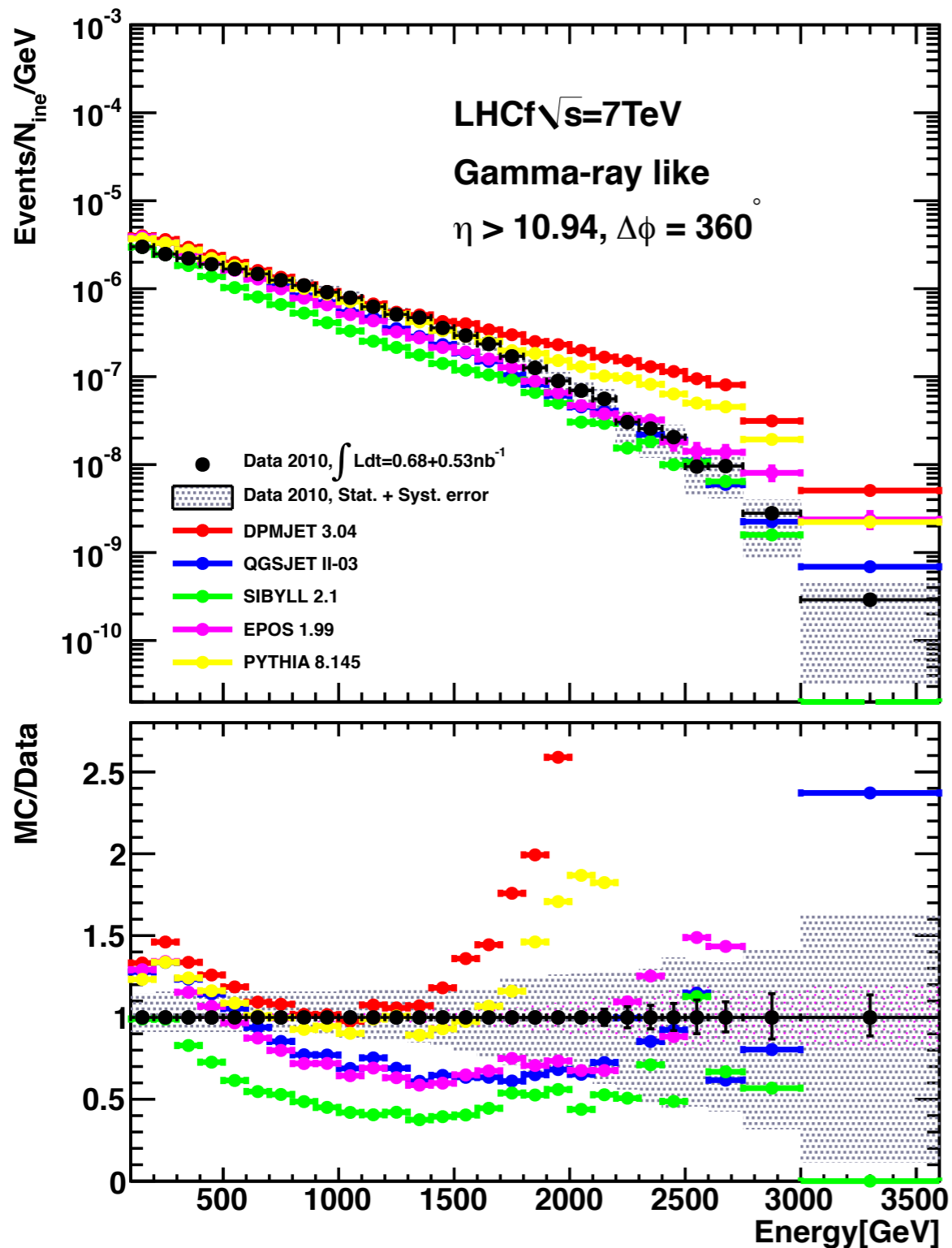
Photon P_T analysis can connect each measurement.

Conclusions and Future prospects

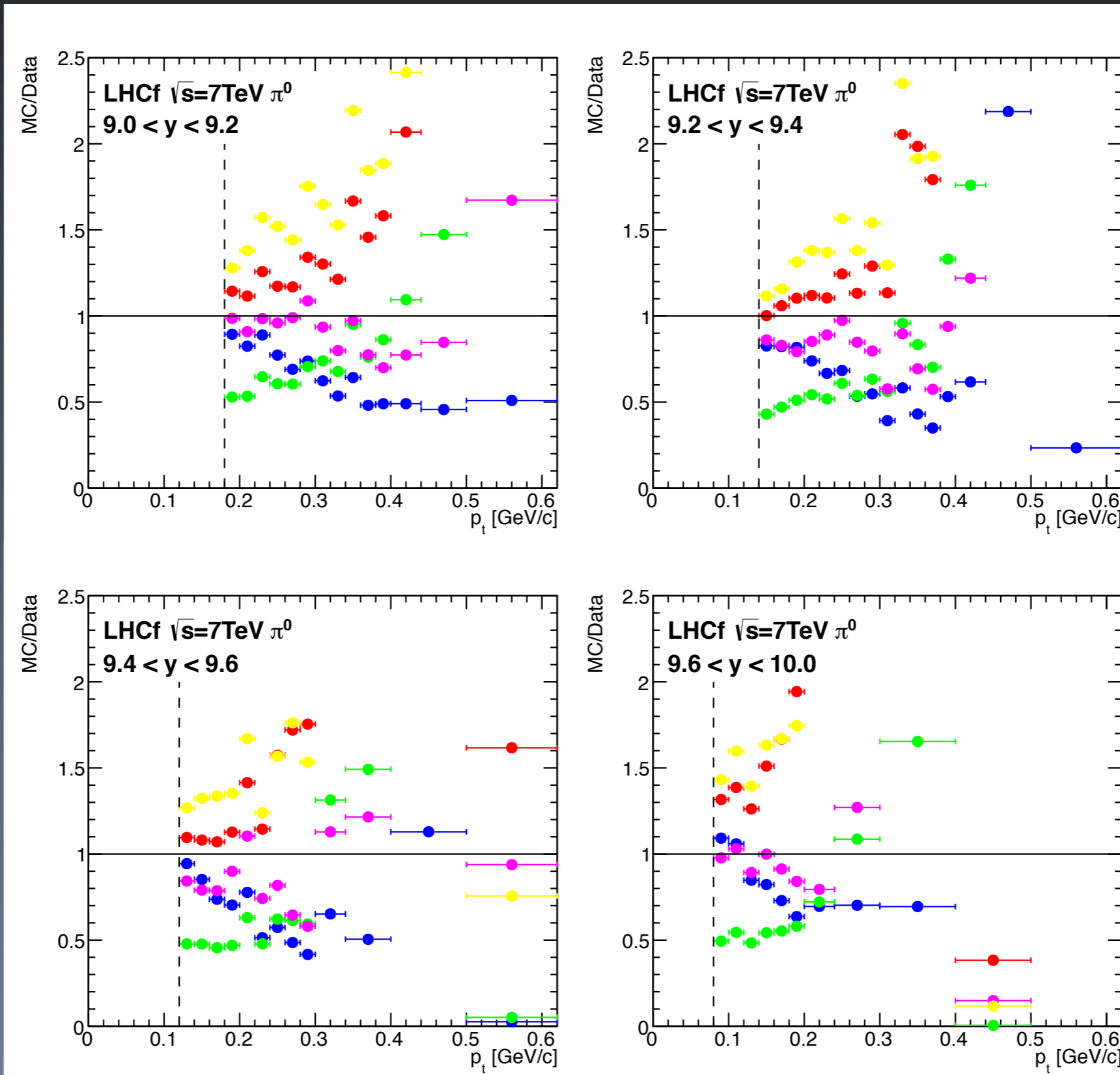
- LHCf has measured the energy and transverse momentum spectrum of the forward emitted particles at the 900GeV and 7TeV proton–proton collisions.
- Feynman scaling spectrum of the 900GeV and 7TeV photon events agree well each other. This may indicate a weak dependence of energy spectrum on its P_T .
- Consistent π^0 spectra are obtained between the Arm1 and Arm2 detector. Combined spectra and a comparison with various hadronic interaction models will be available soon.
- Many analyses are ongoing:
 - Photon P_T analysis
 - Hadron event analysis
 - p–Pb capability

Backup

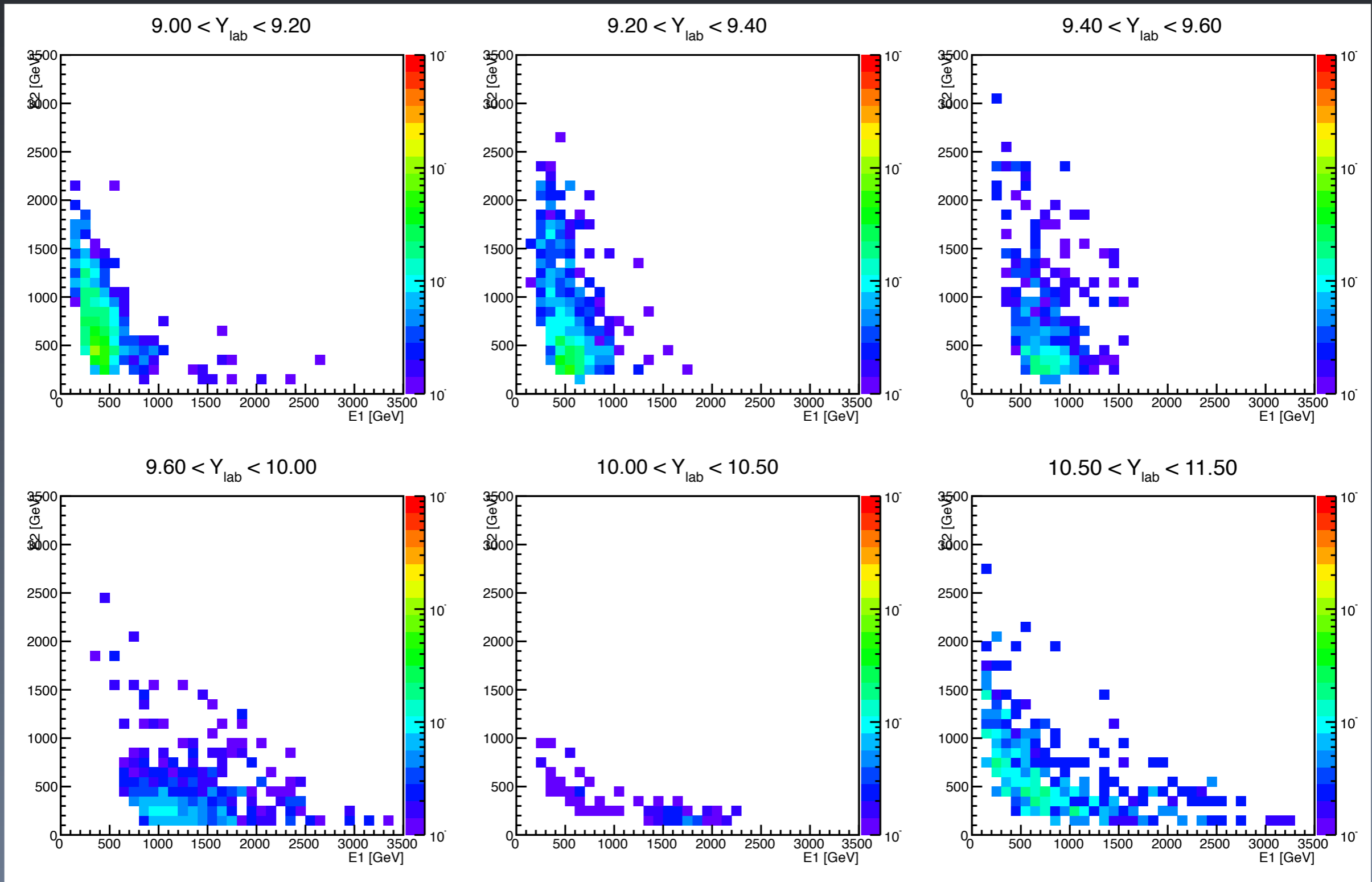
7TeV photon analysis



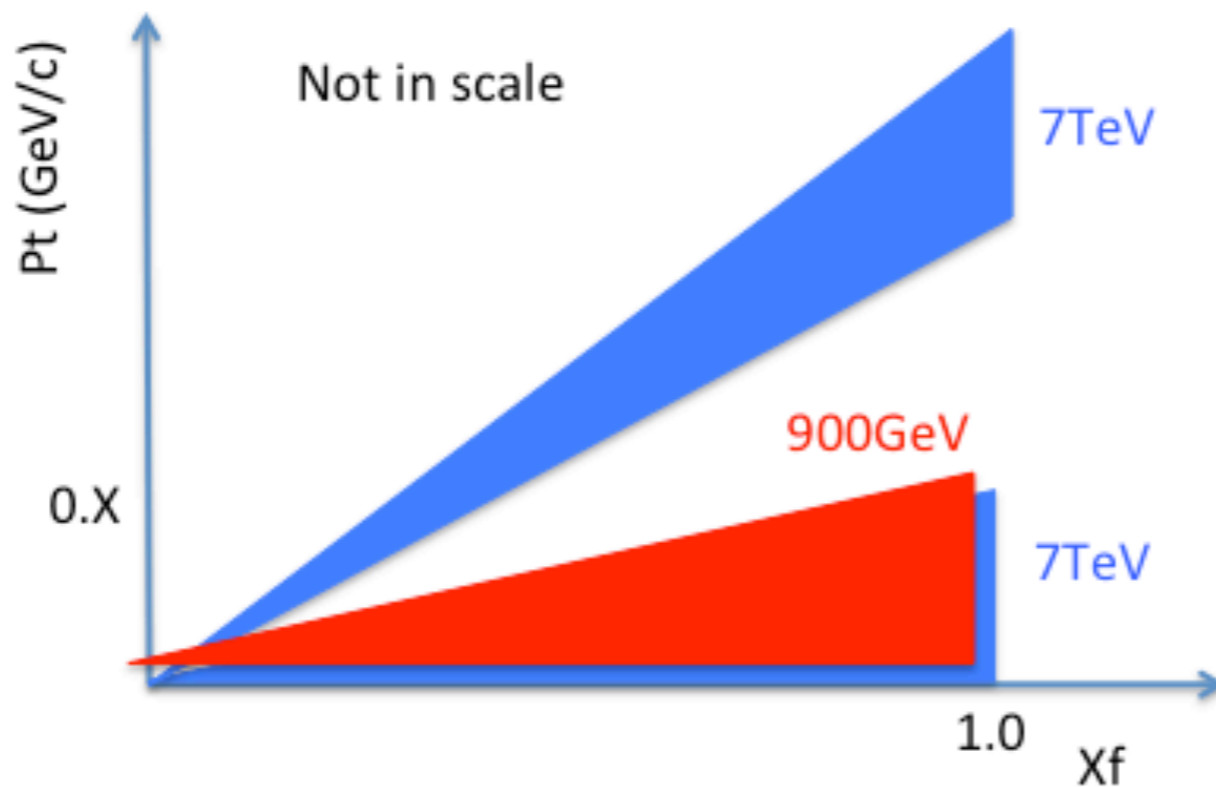
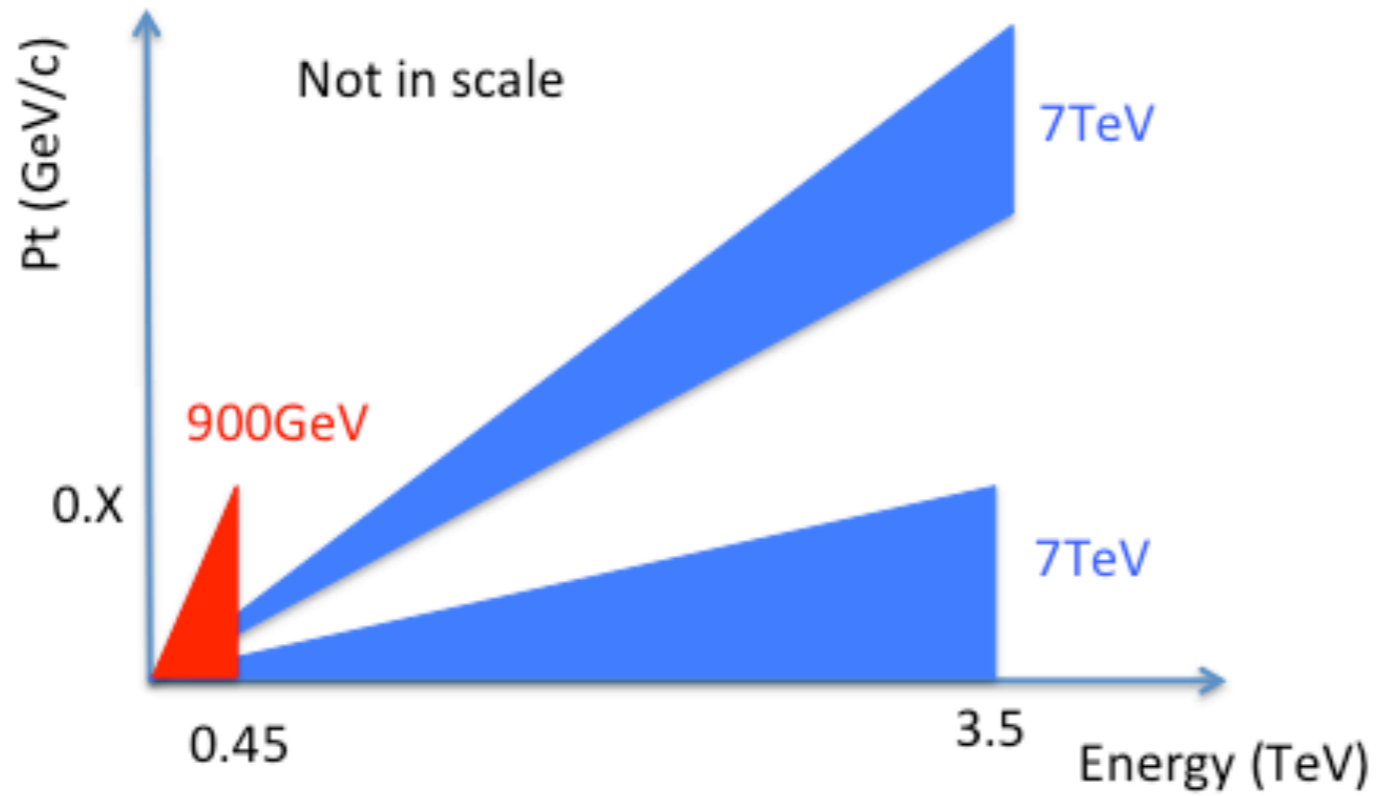
7TeV π^0 analysis



7TeV π^0 analysis

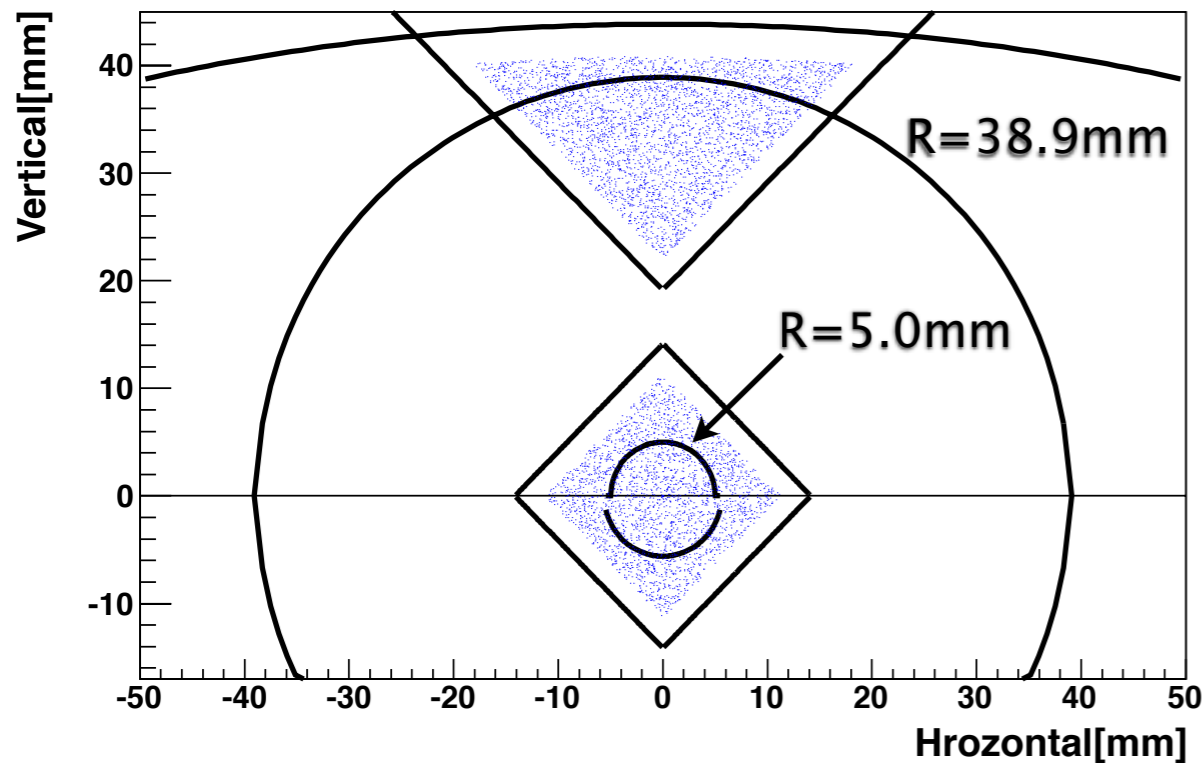


900GeV photon analysis

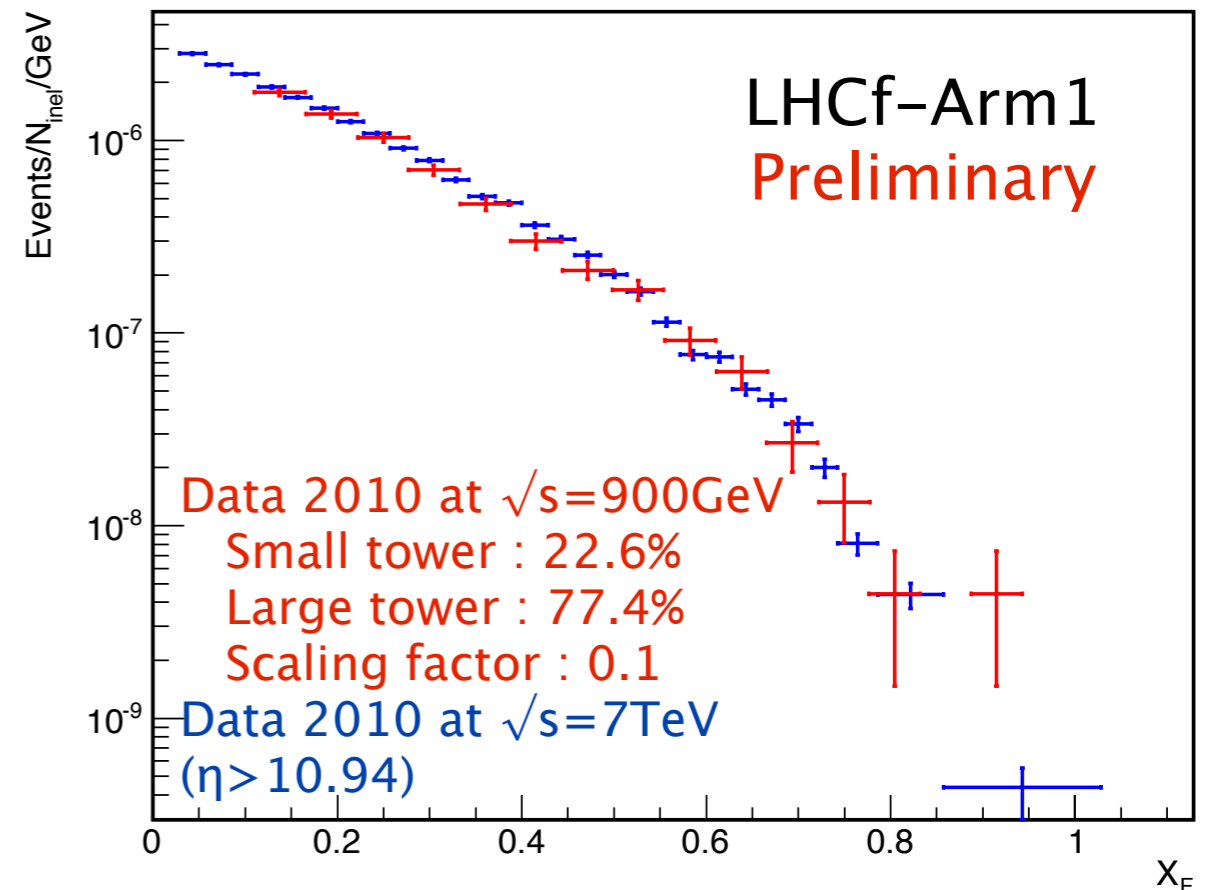


900GeV photon analysis

Hit map of photon events on Arm1



X_F spectra : 900GeV data vs 7TeV data



- Suppose a Pt of $\sqrt{s}=900\text{GeV}$ events can be scaled to the Pt at $\sqrt{s}=7\text{TeV}$ as

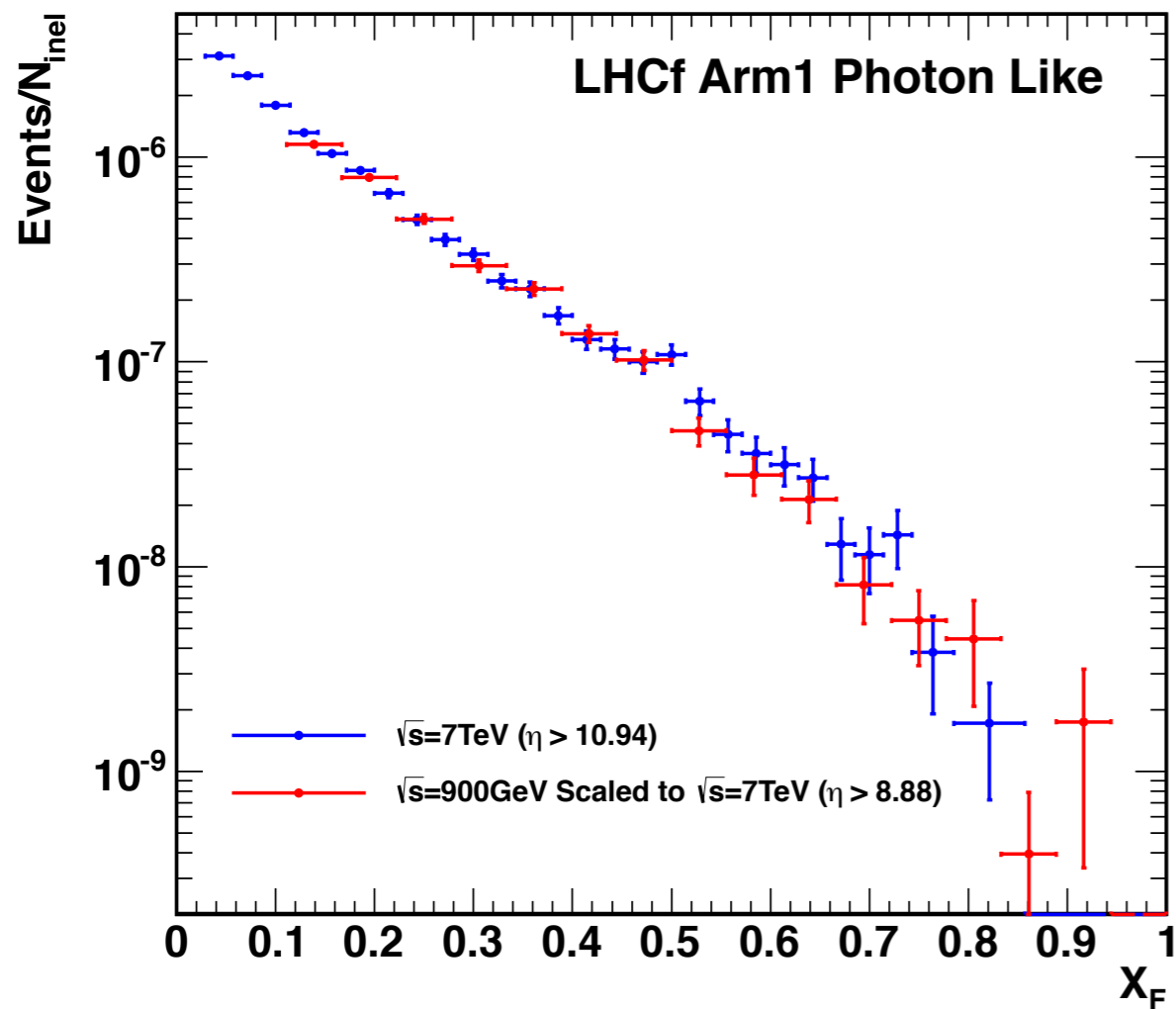
$$P_T(\sqrt{s} = 7\text{TeV}) = P_T(\sqrt{s} = 900\text{GeV}) \frac{7\text{TeV}}{900\text{GeV}}$$

- Then the spectrum inside $R=5\text{mm}$ at $\sqrt{s}=7\text{TeV}$ would be equivalent to that $R<38.9\text{mm}$ at $\sqrt{s}=900\text{GeV}$.

- No systematic error is considered in both collision energies, although this treatment may not change an impression of the comparison.
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900GeV photon analysis

EPOS



QGSJET II-03

