TA-LHCf joint meeting

Trigger System and Simulation for the LHCf-ATLAS Common Experiment

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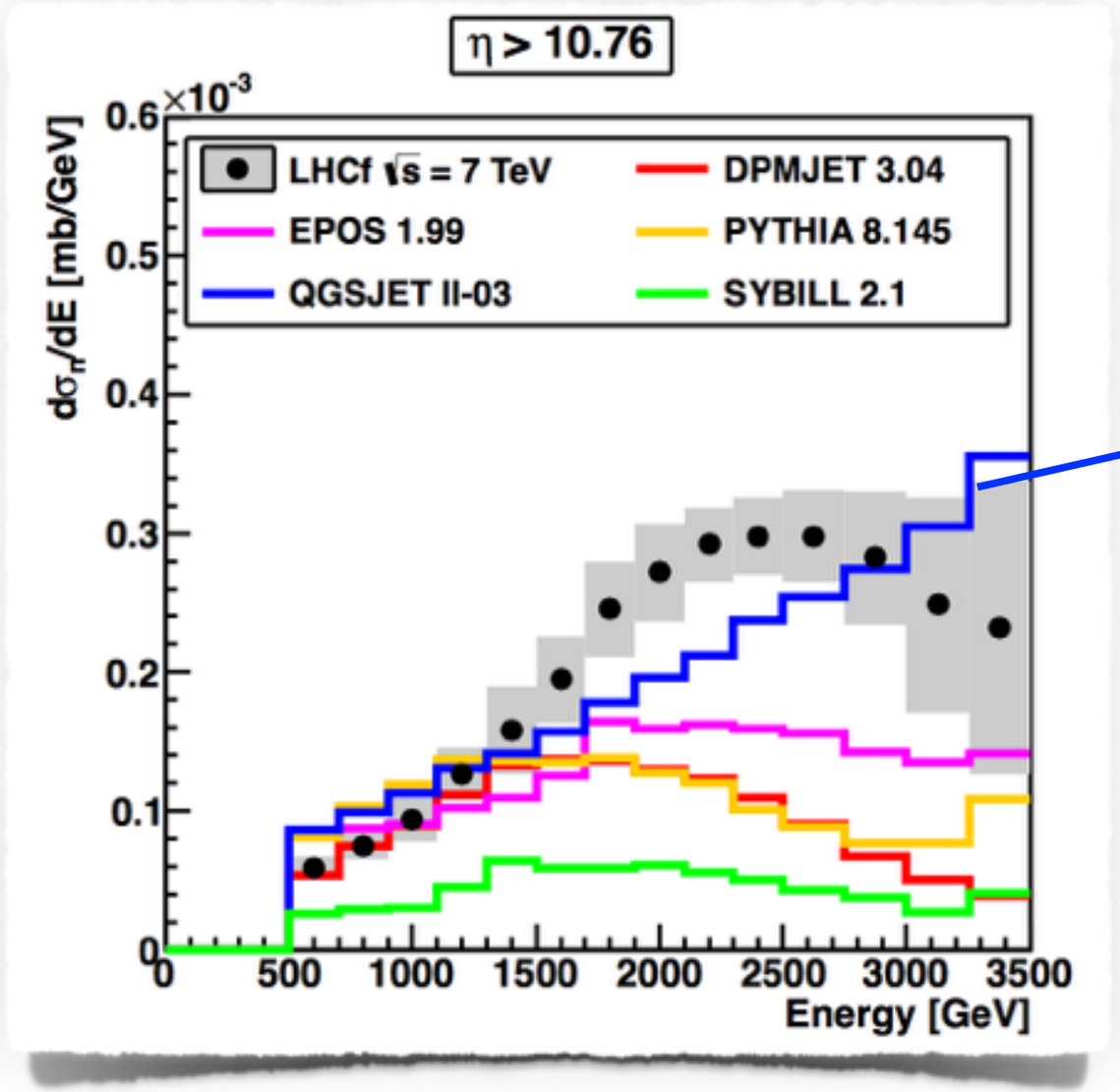
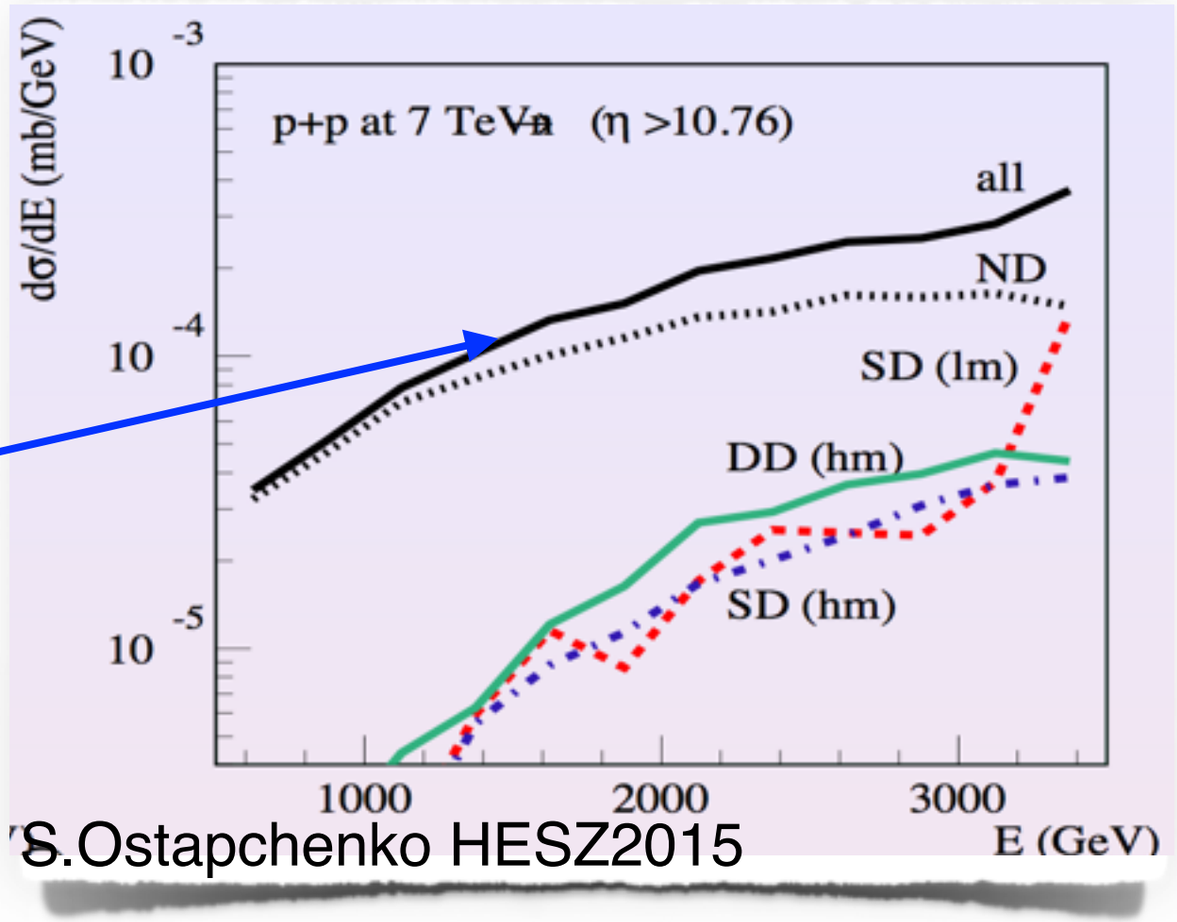
2015/11/27

Outline

- ✦Introduction
  - ‣The motivation of LHCf-ATLAS common experiment
  - ‣The diffractive and non-diffractive collisions
- ✦A MC study about identification of diffractive events by LHCf-ATLAS common data acquisition.
- ✦ LHCf-ATLAS common trigger
  - ‣The common trigger
  - ‣Performance

Motivation of common experiment





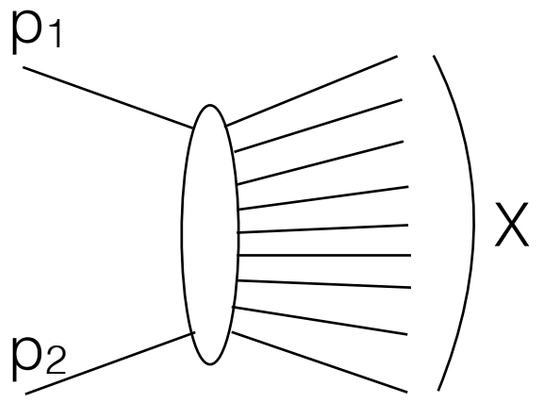
S.Ostapchenko HESZ2015

ND(Non Diffraction),
SD(Single Diffraction),
DD(Double Diffraction),

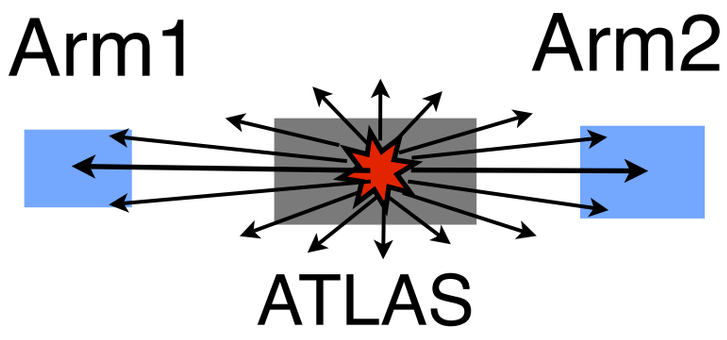
No model can represent
LHCf neutron data perfectly

The identification of diffractive collision can improve the hadronic interaction models.

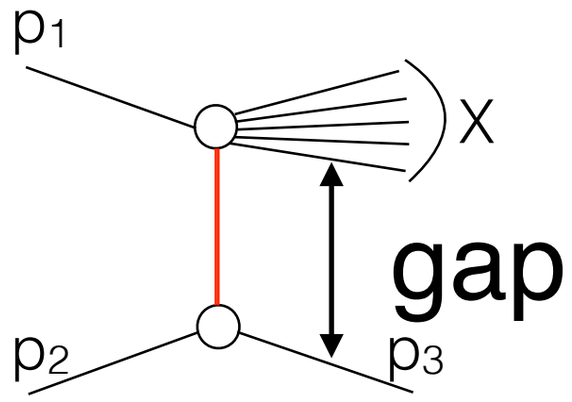
Diffraction collisions



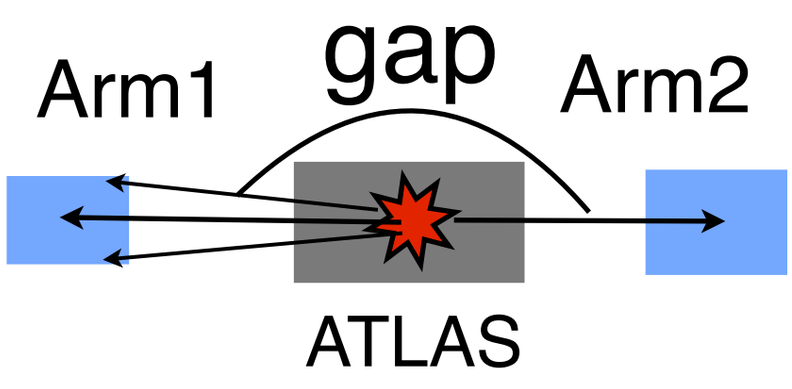
p p—>X



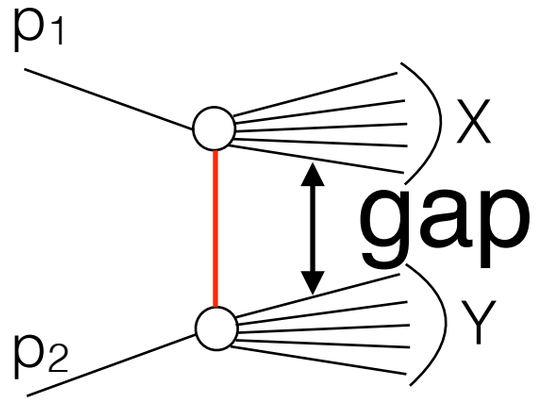
non-diffraction



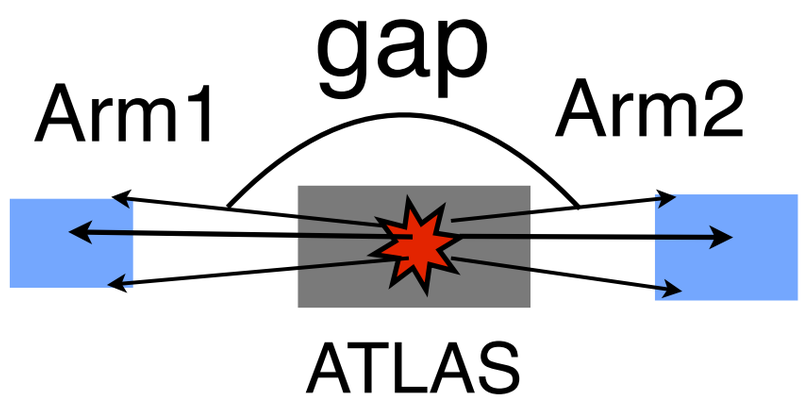
p p—>p X



single diffraction

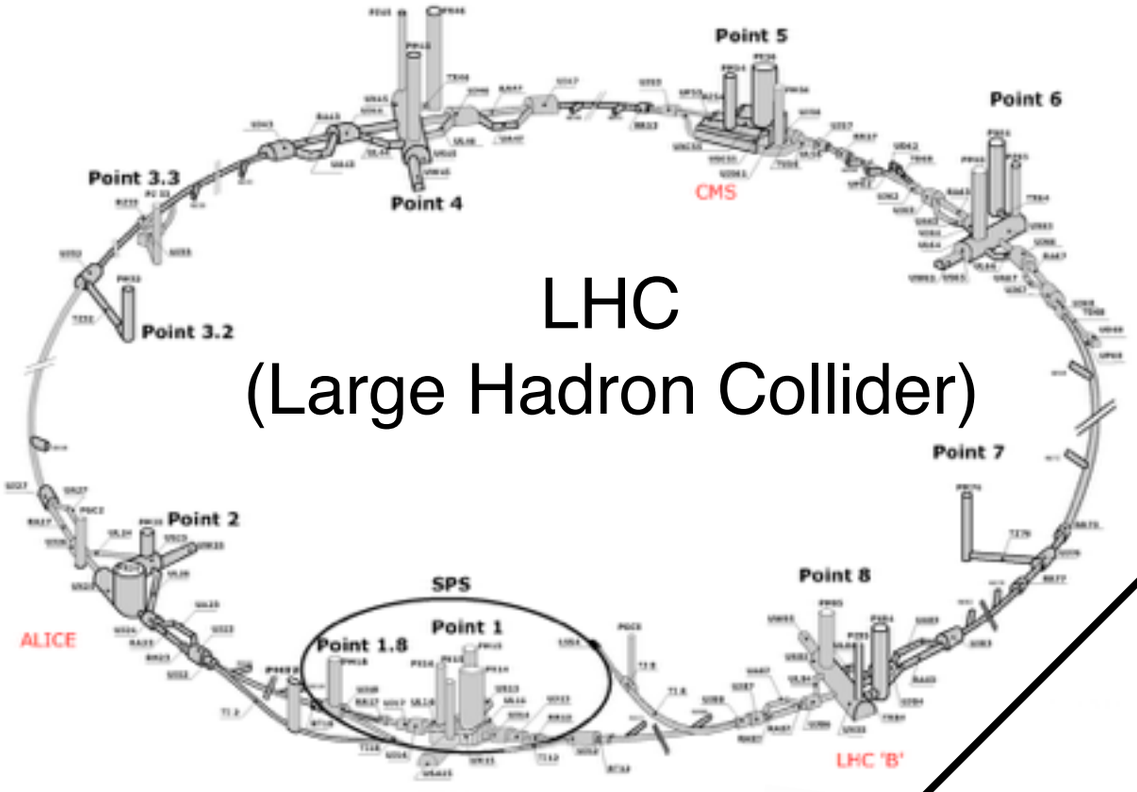


p p—>X Y



double diffraction

Location of the LHCf experiment



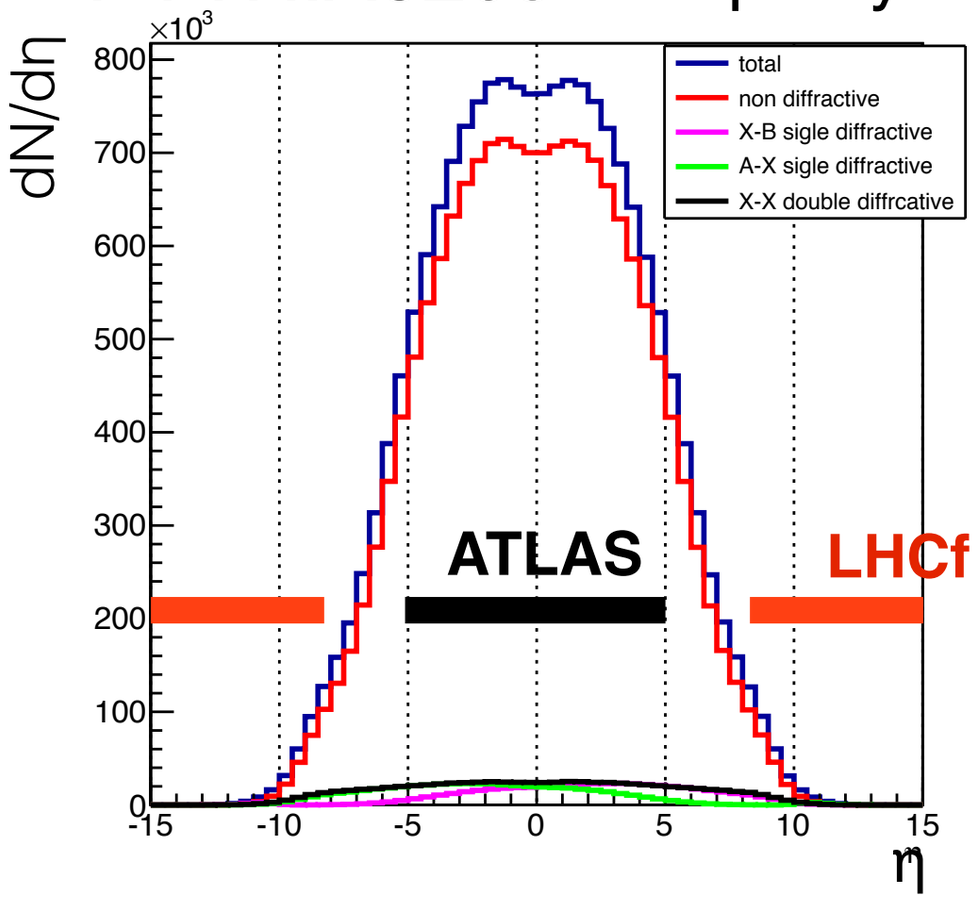
LHCf and ATLAS are observing the particles from the same collision, but different position

Particle density and energy flow for 13TeV p-p

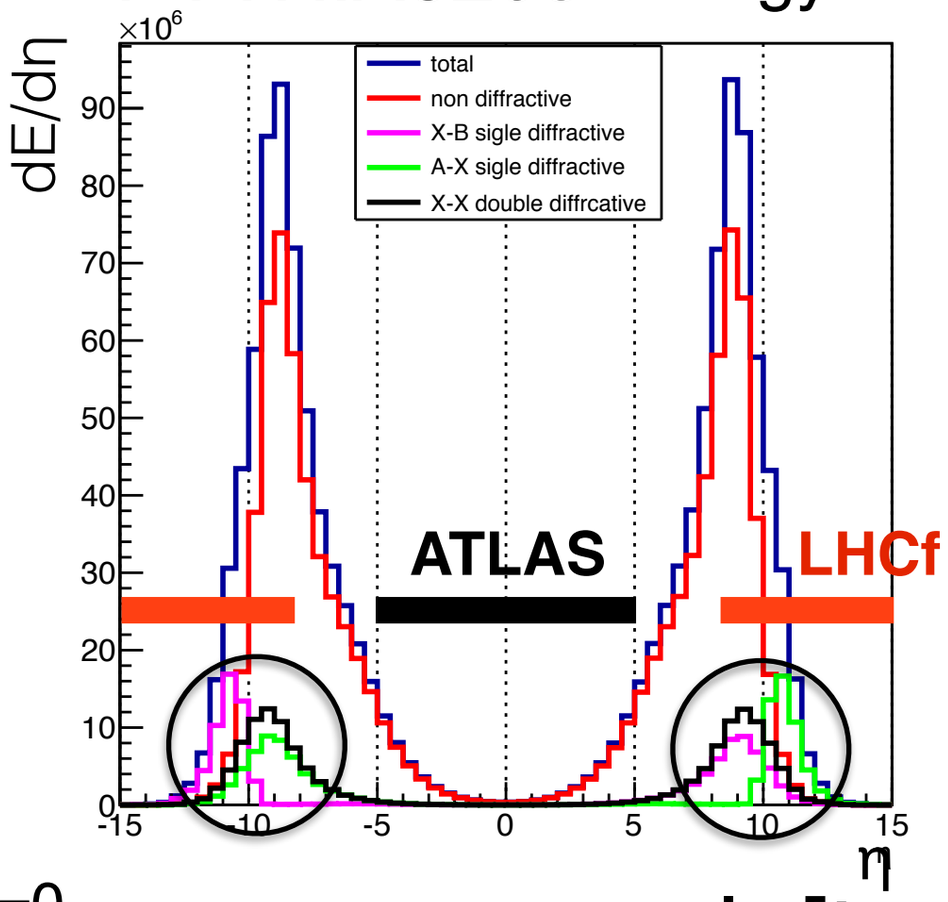
Most of secondary particles concentrate to the center

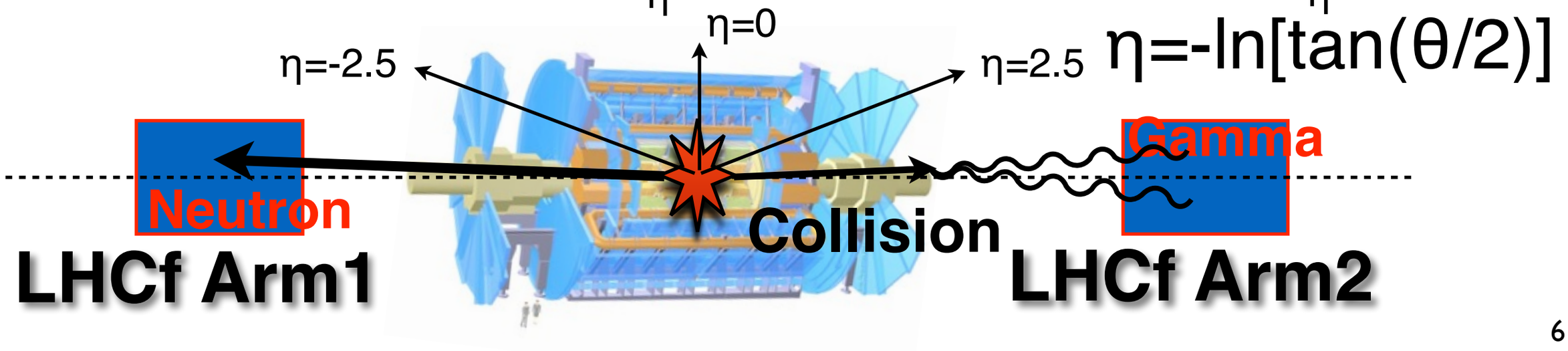
The most energetic secondary particles emitted to the very forward region (LHCf sensitive region)

PYTHIA8205 Multiplicity



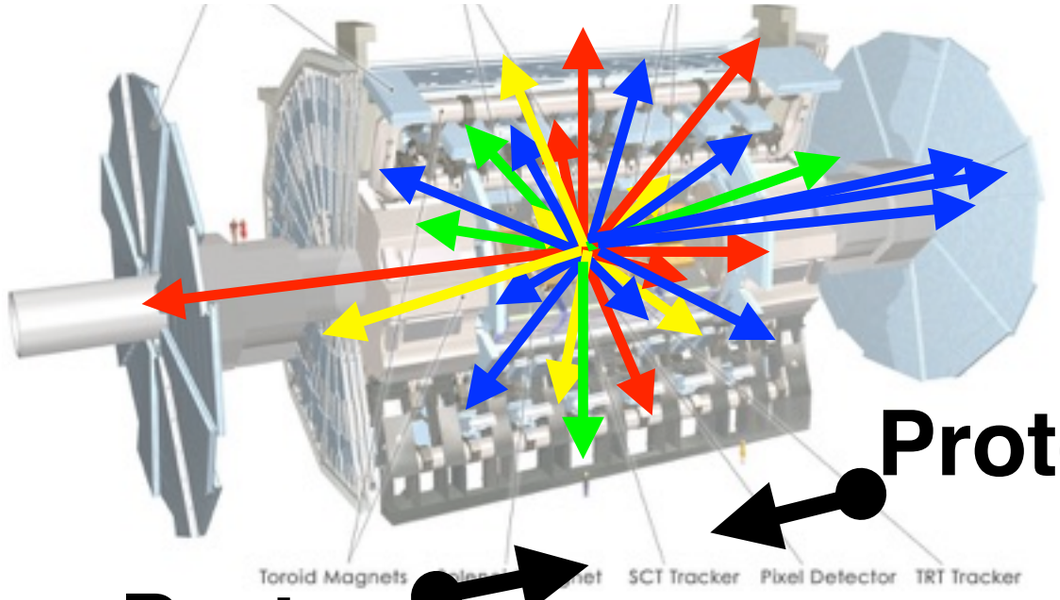
PYTHIA8205 Energy-flow





Diffraction & non-diffraction

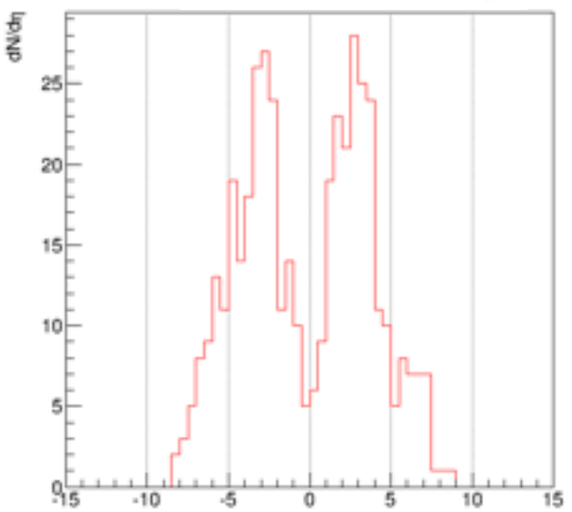
Non-diffraction



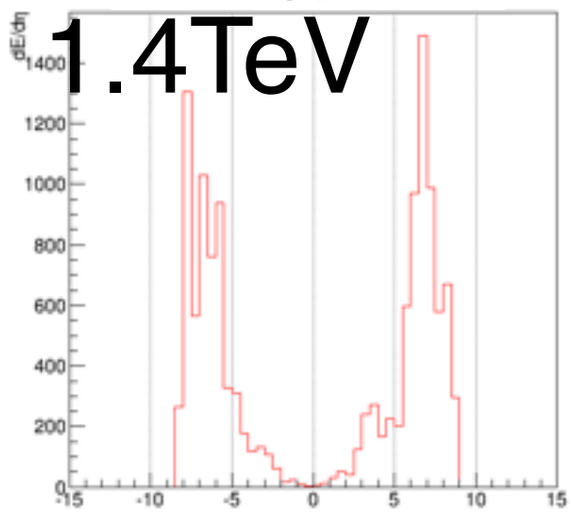
Proton

Proton

Multiplicity

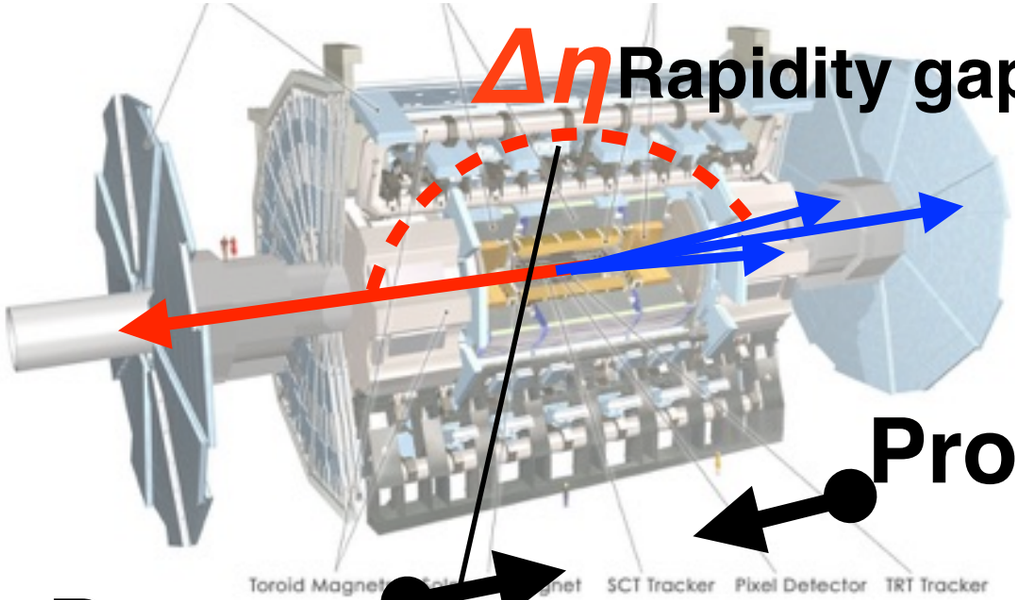


Energy-flow



Non-diffraction event view

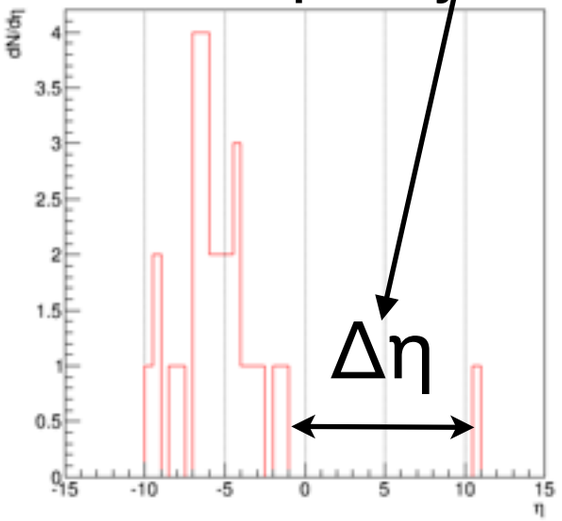
Diffraction



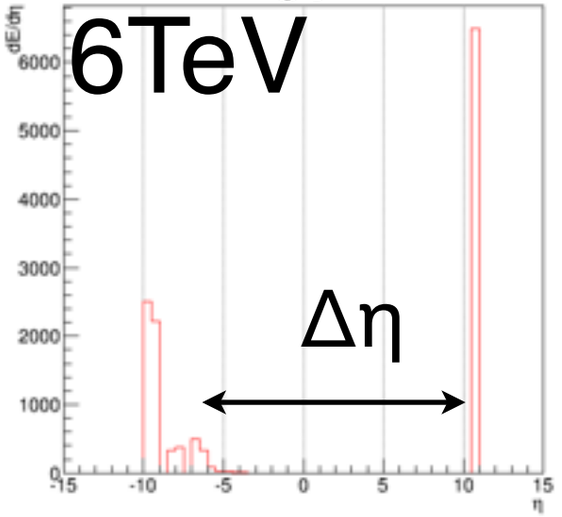
Proton

Proton

Multiplicity

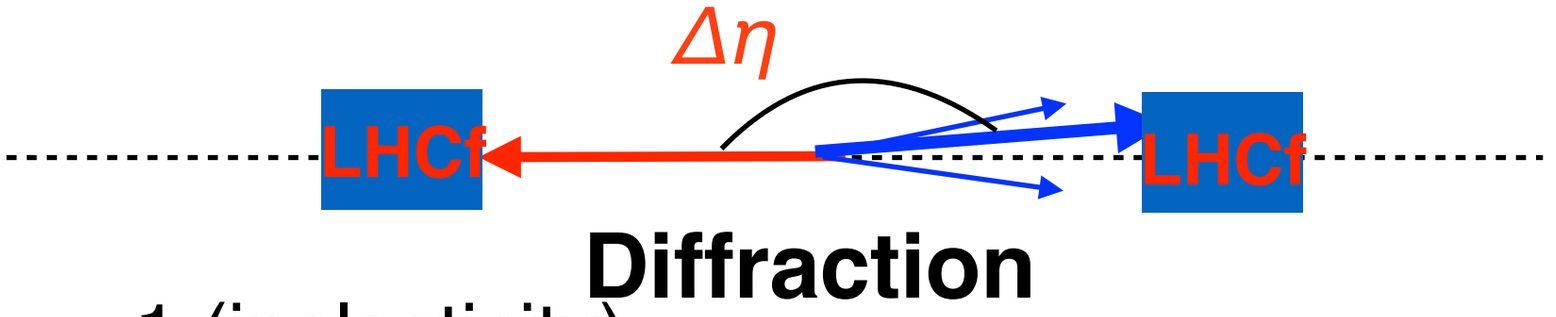


Energy-flow



Diffraction event view

Impact of diffraction collisions to X_{max}



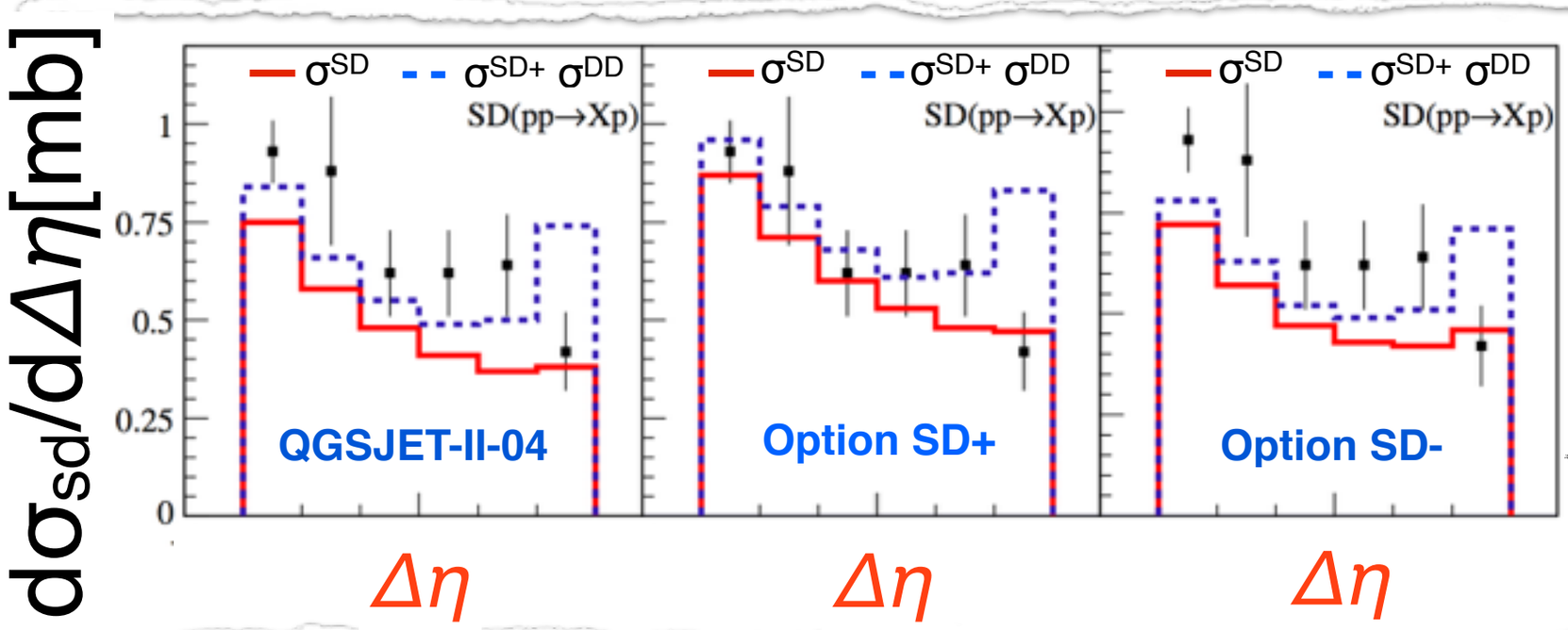
✦K_{inel}= $\Delta E/E_0$ = exp$(-\Delta\eta)$ << 1 (inelasticity)

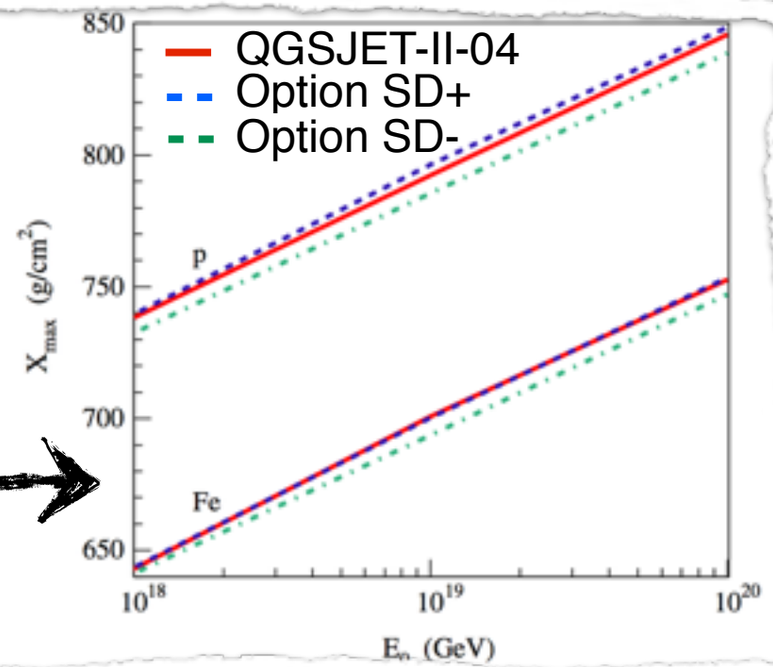
(ΔE: the energy loss of the leading secondary nucleon).

→diffraction collision is relate to the X_{max}

✦ The higher rate of Diffractive collision, the deeper X_{max}

S. Ostapchenko, et al., Phy. Rev. D 89, 074009 (2014)





LHCf-ATLAS common experiment

140m 140m

Neutron

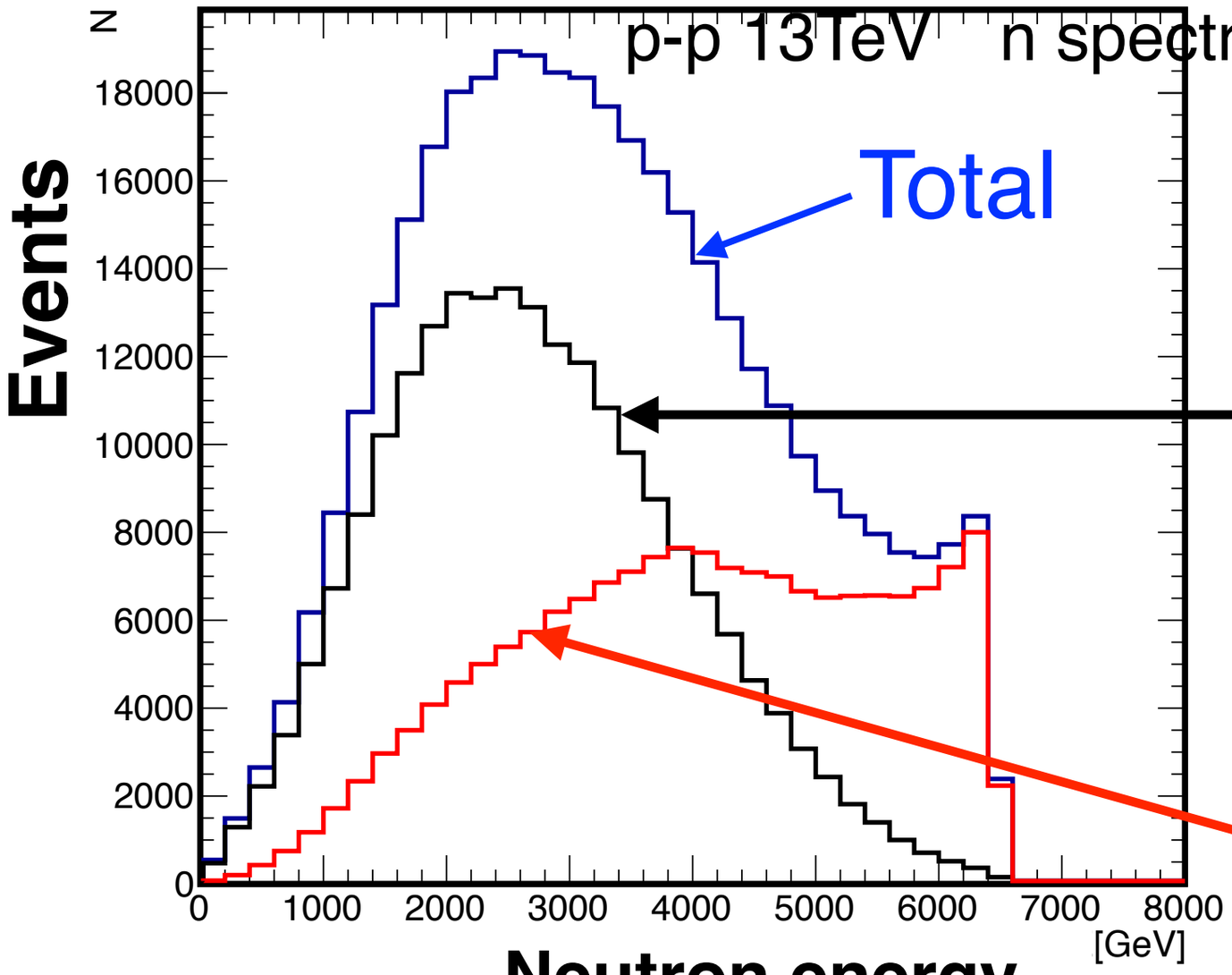
Gamma

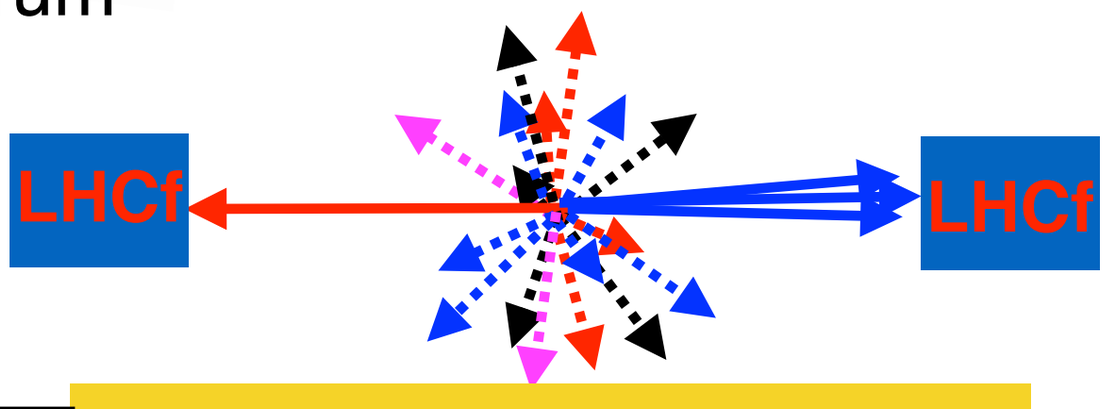
Collision

LHCf Arm1

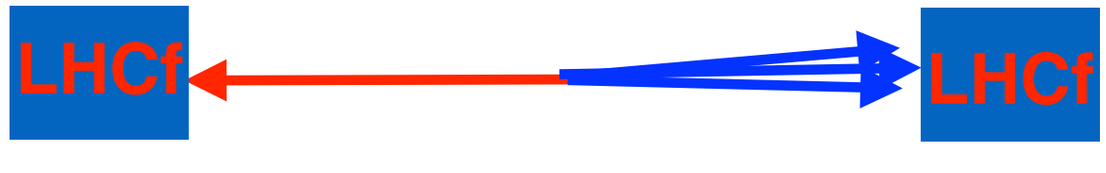
LHCf Arm2

PYTHIA8.2
p-p 13TeV n spectrum





Non-Diffraction



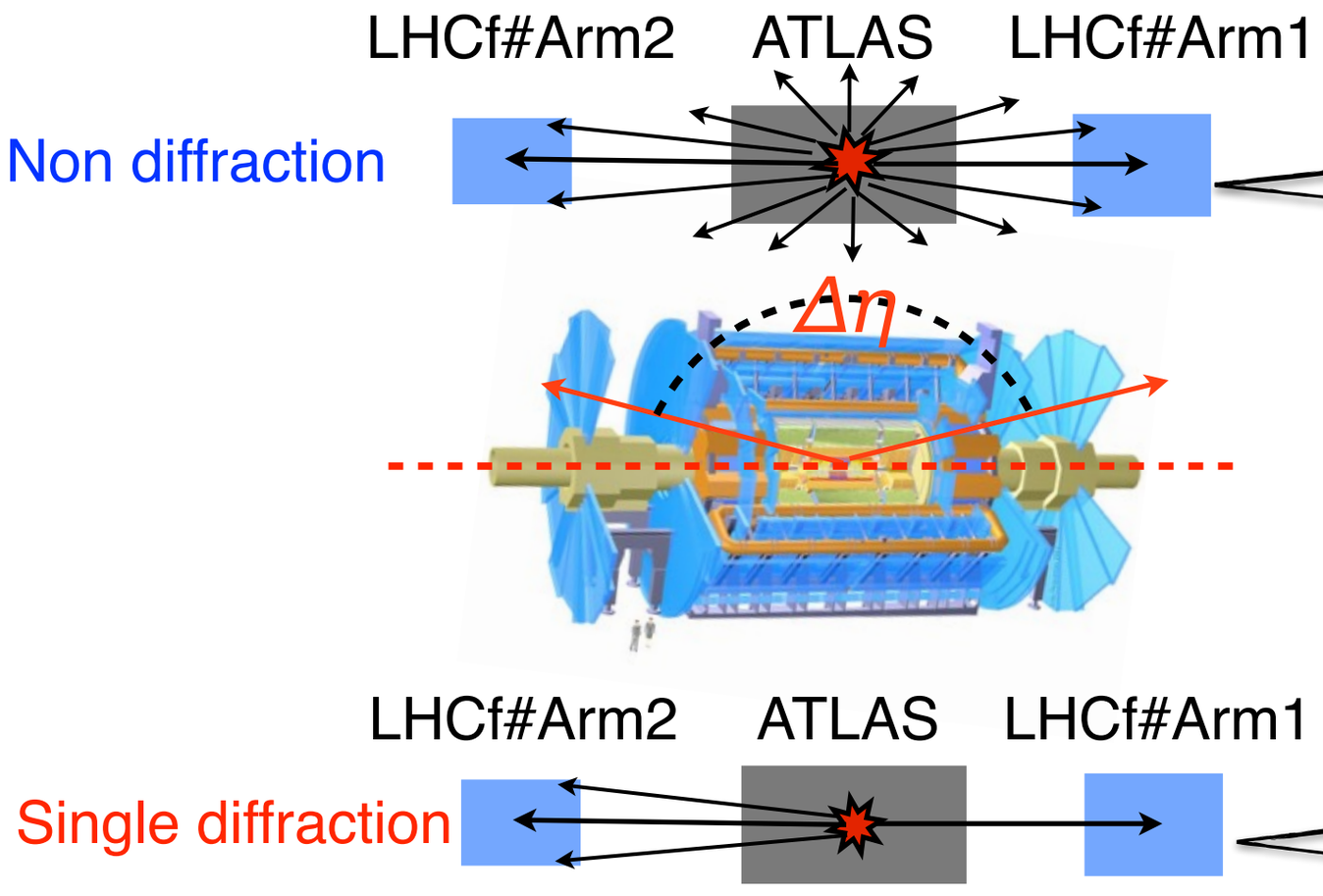
Diffraction

A Simulation Study for the LHCf-ATLAS Common Experiment

Simulation setting & event selection

✦Simulation setting

- PYTHIA8205
- 10^7 inelastic proton-proton collisions ($\sqrt{s}$=13TeV).



✦Event selection

In the angle range of Δη:

- Condition: $|\eta|<2.5, N_{ch}>=2$, $P_T>100$MeV
- ATLAS identifies >= 2 charged particles,

→Non Diffraction(ND)

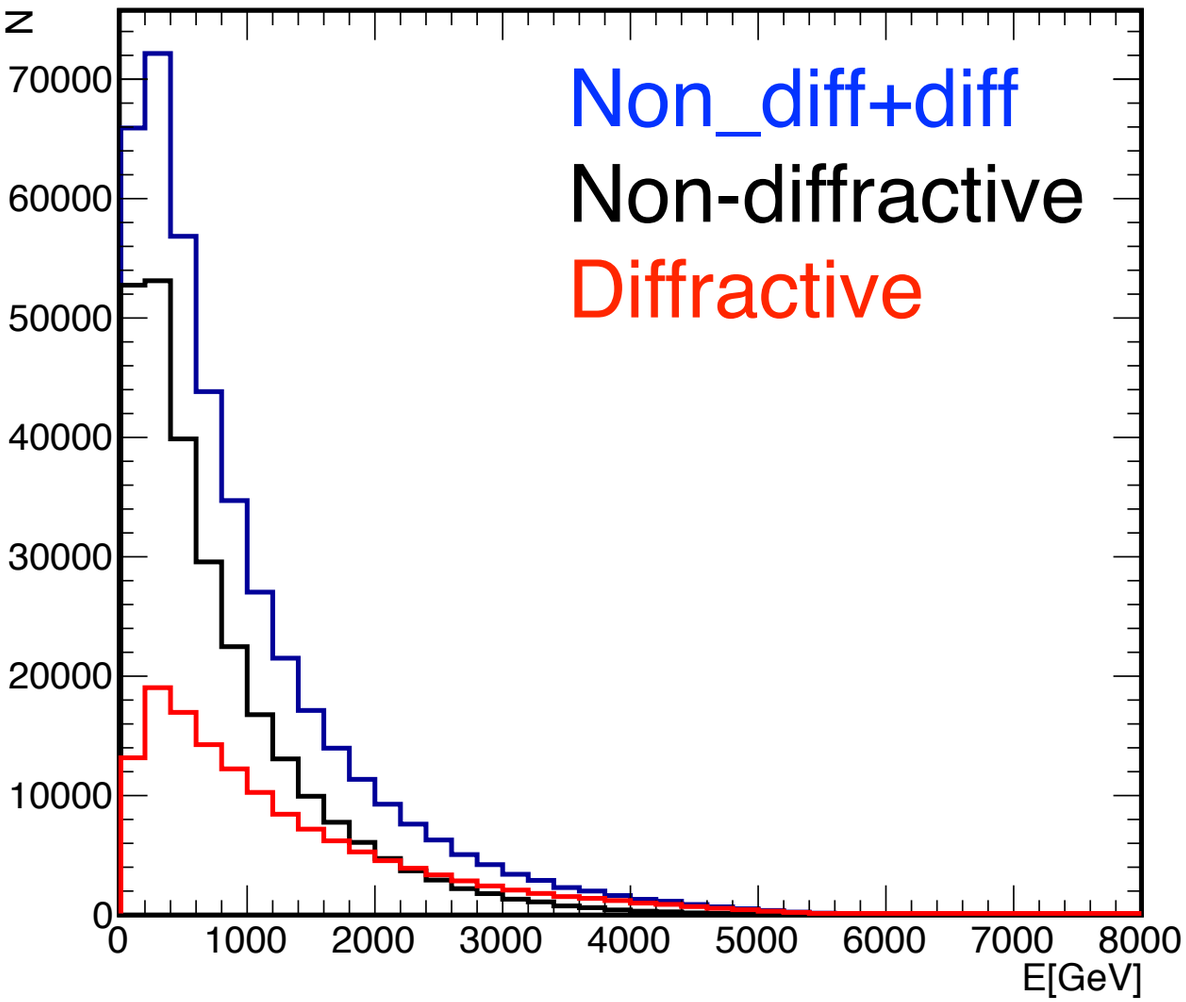
- Condition: $|\eta|<2.5$, not ND event
- ATLAS identifies 0 or 1
- charged particles,

→Diffractive like ($\overline{ND}$)

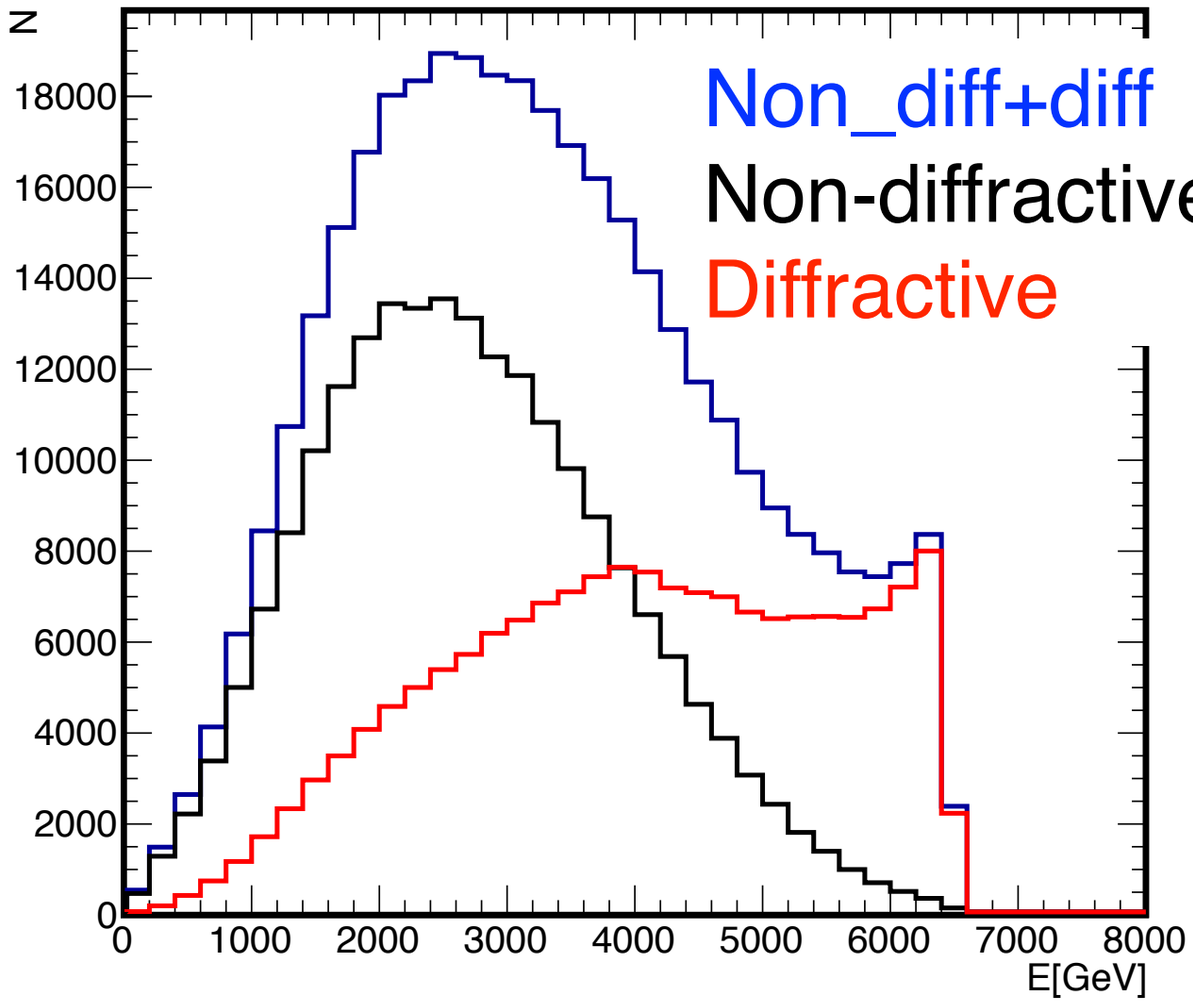
Evaluate the diffractive-like selection method

LHCf spectra (PYTHIA prediction)

Gamma



Neutron

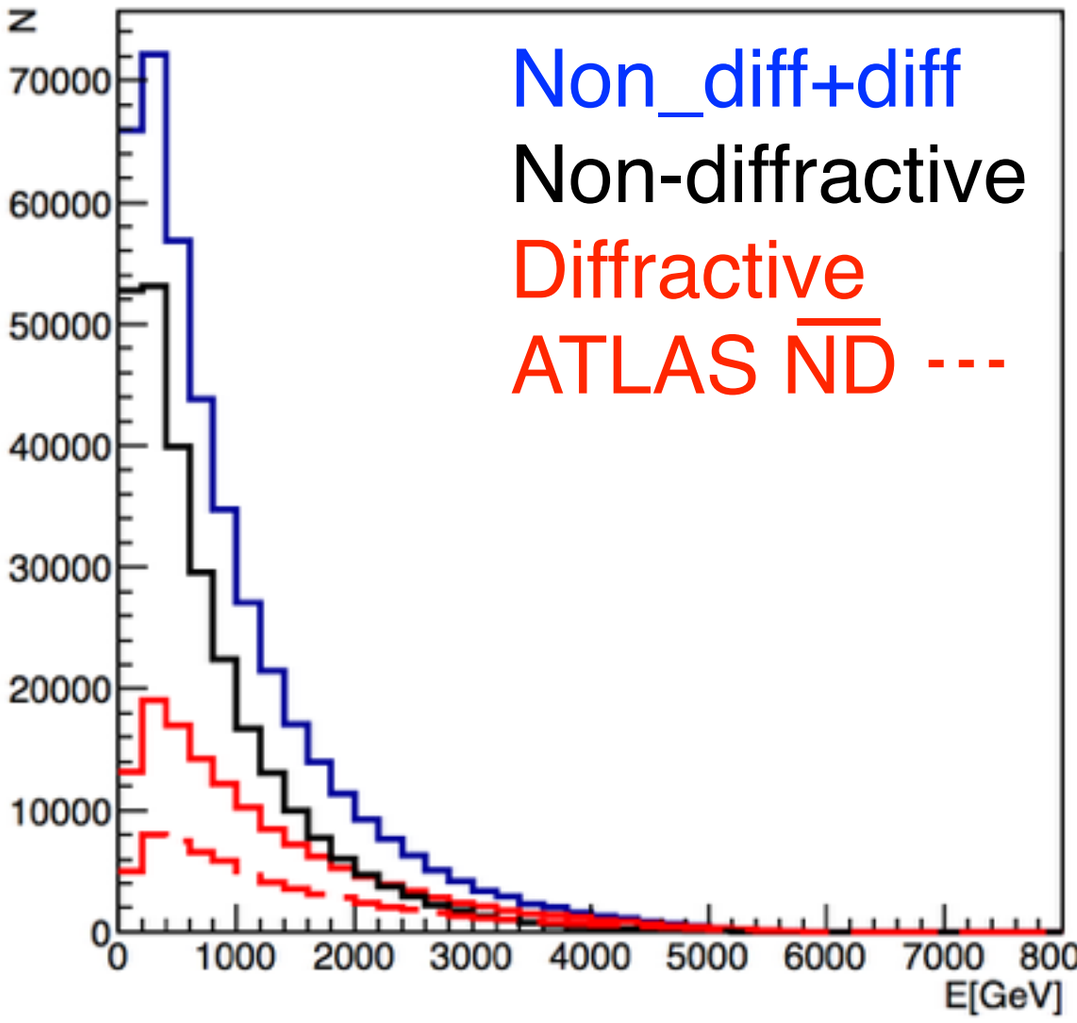


MC true: Non Diffractive

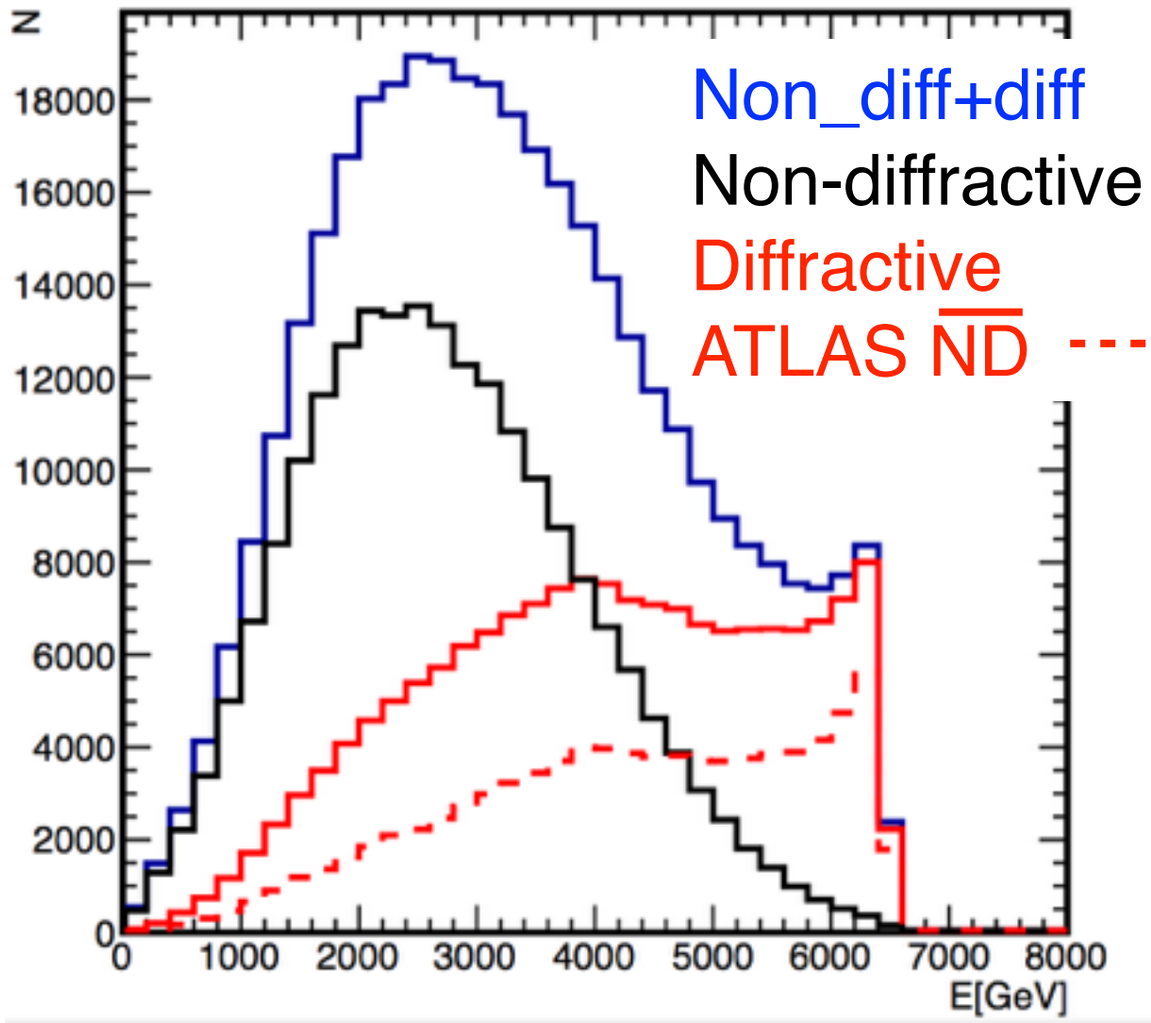
Diffractive

LHCf spectra (PYTHIA prediction)

Gamma



Neutron



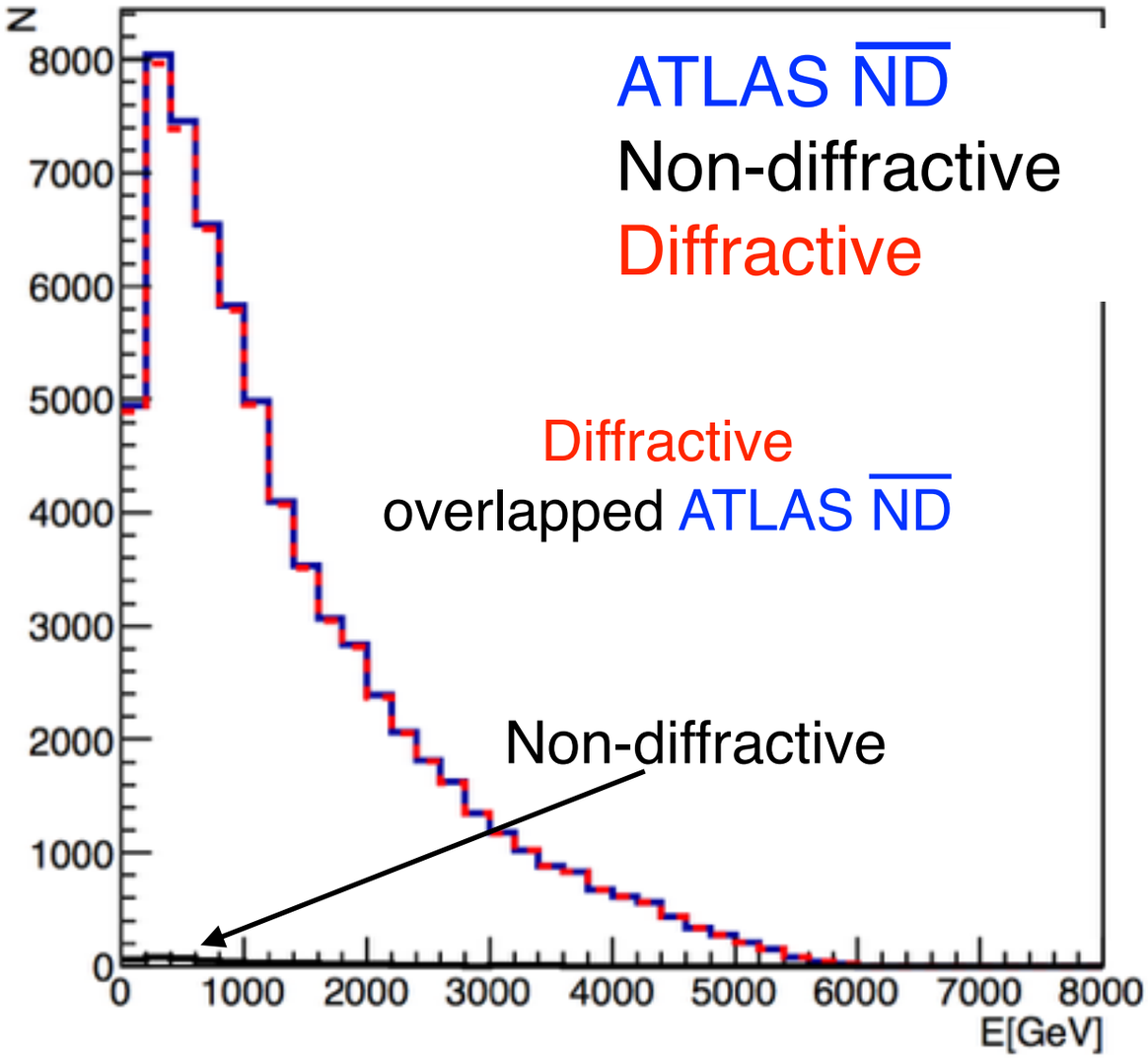
ND: according to ATLAS Diff-like selection

Diff-like events in the LHCf trigger (ATLAS ND/Total) is about **11.8%**

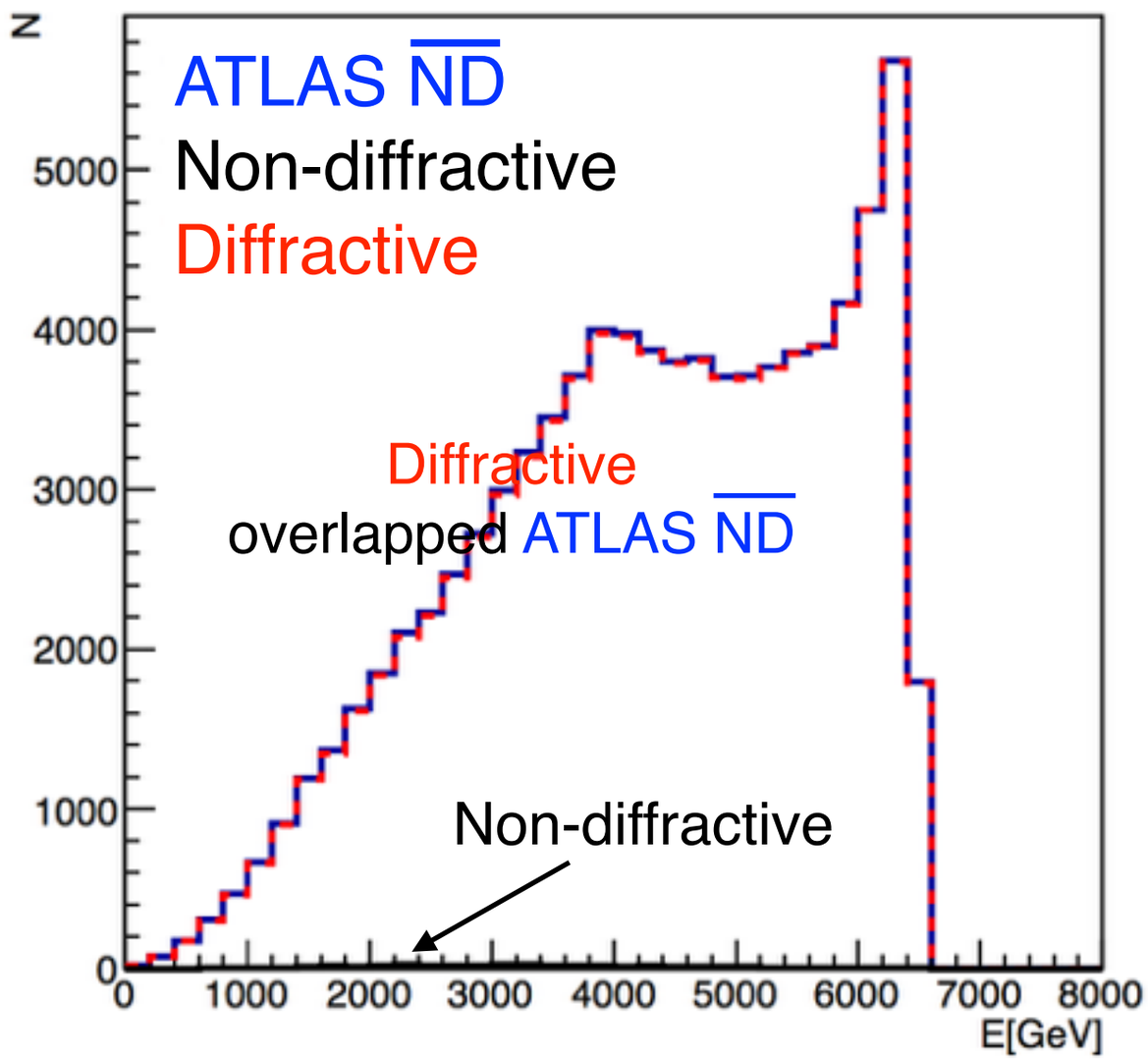
Efficiency of diffraction identification using ATLAS information is (ATLAS ND / Diffractive) **~40%**

Purity of event selection

Gamma



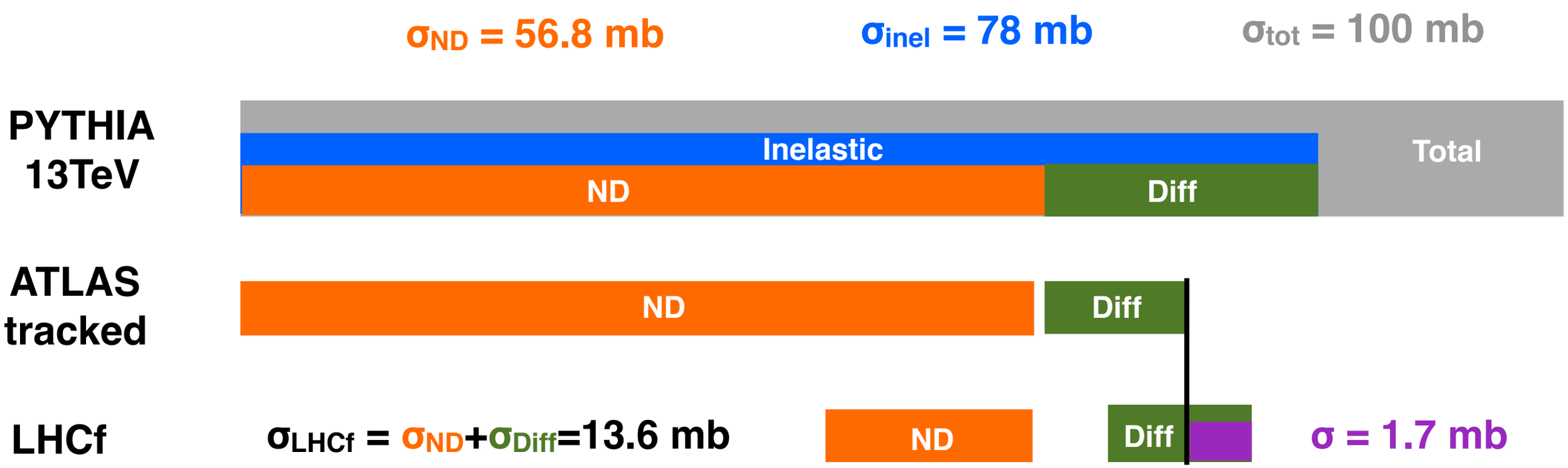
Neutron



ND: According to ATLAS Diff-like selection

Purity of diffraction identification using ATLAS information (Diffractive / ATLAS ND) **~99%**

Event of LHCf trigger



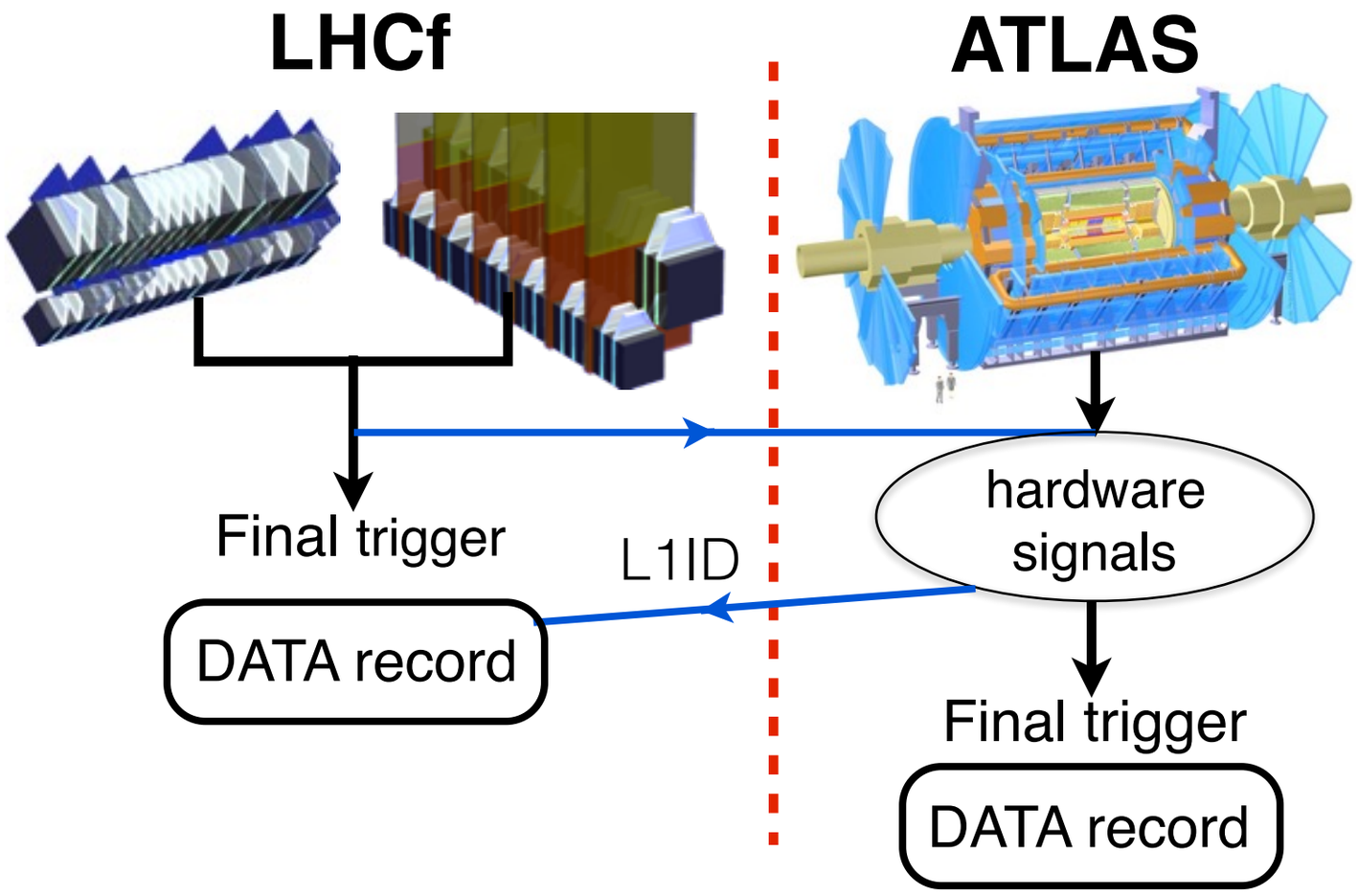
✦ATLAS trigger can not take a part of diffractive events

✦LHCf trigger: 13.6mb

✦ LHCf trigger without ATLAS track in |η|<2.5 is 1.5 mb, respectively.

Trigger system on LHCf side for the LHCf-ATLAS common experiment

Outline of common trigger system

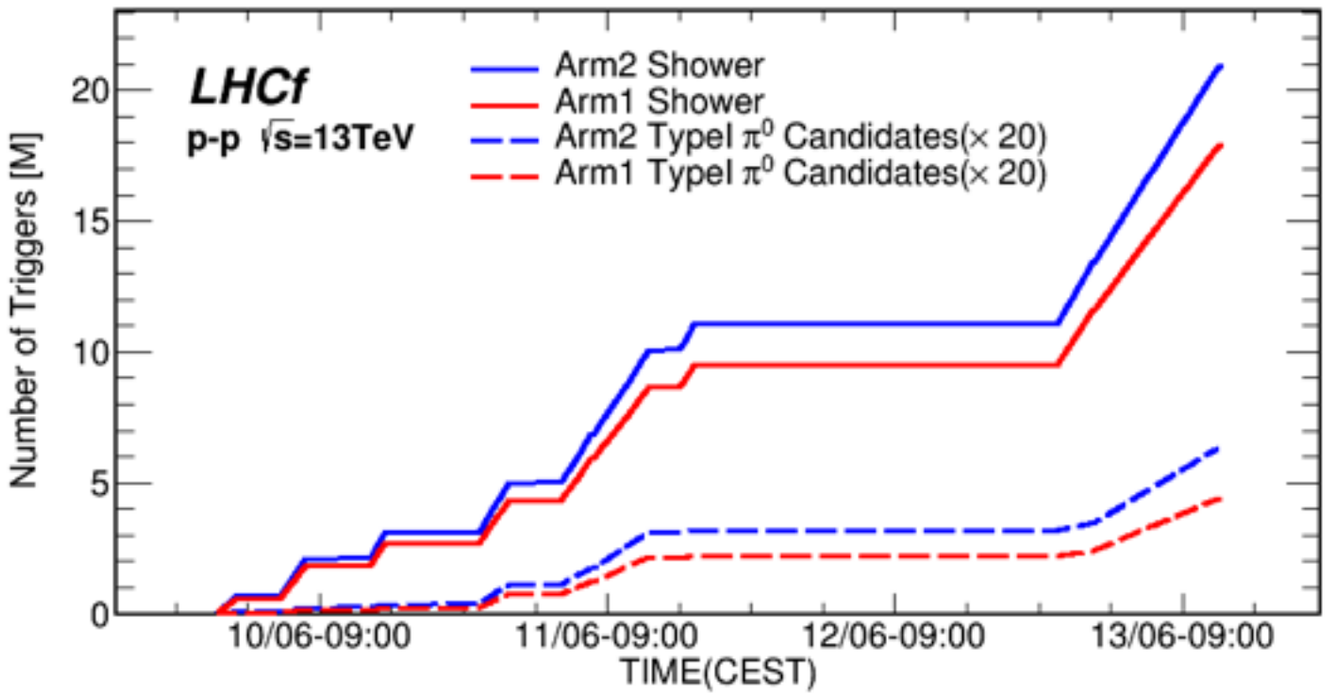


✦LHCf is treated as a part of ATLAS.
✦LHCf triggers ATLAS.

- LHCf has to send the final trigger to ATLAS within a limit time(~**1.6μs)**,
- ATLAS will receive LHCf final trigger to issue the common trigger.

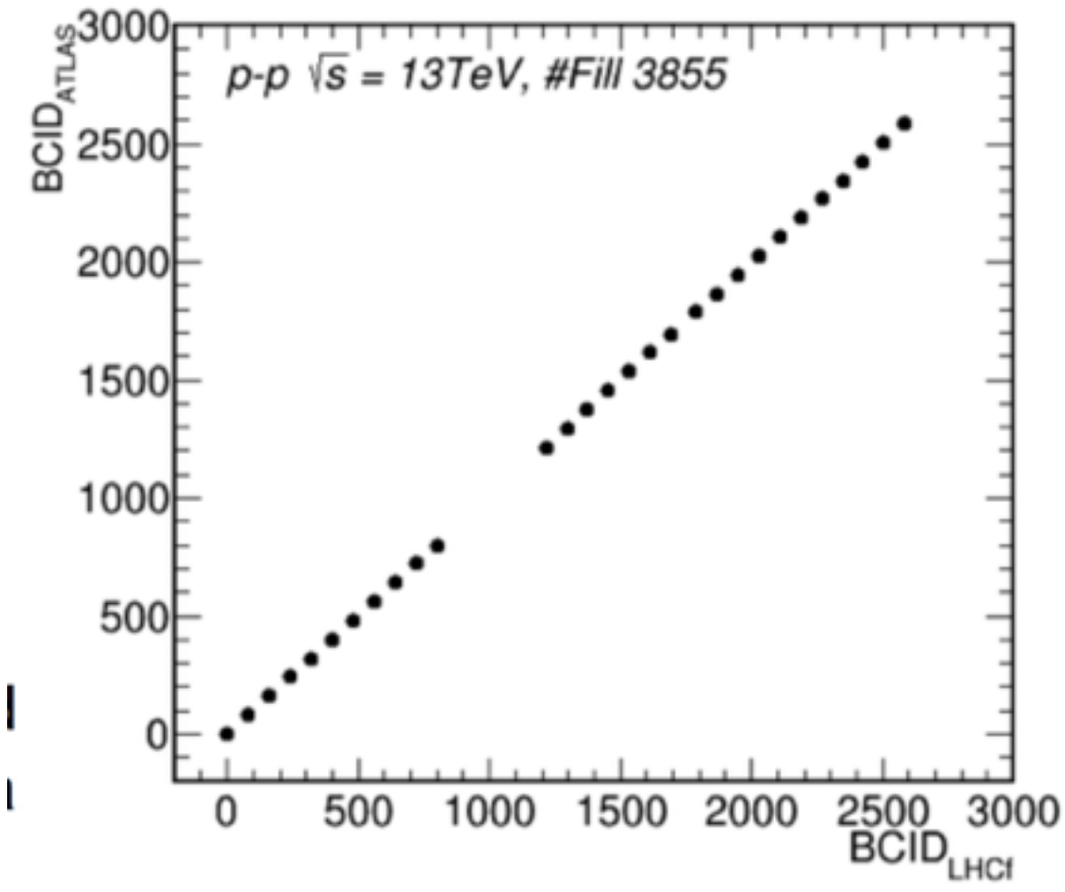
Statistics of 13TeV p-p operation

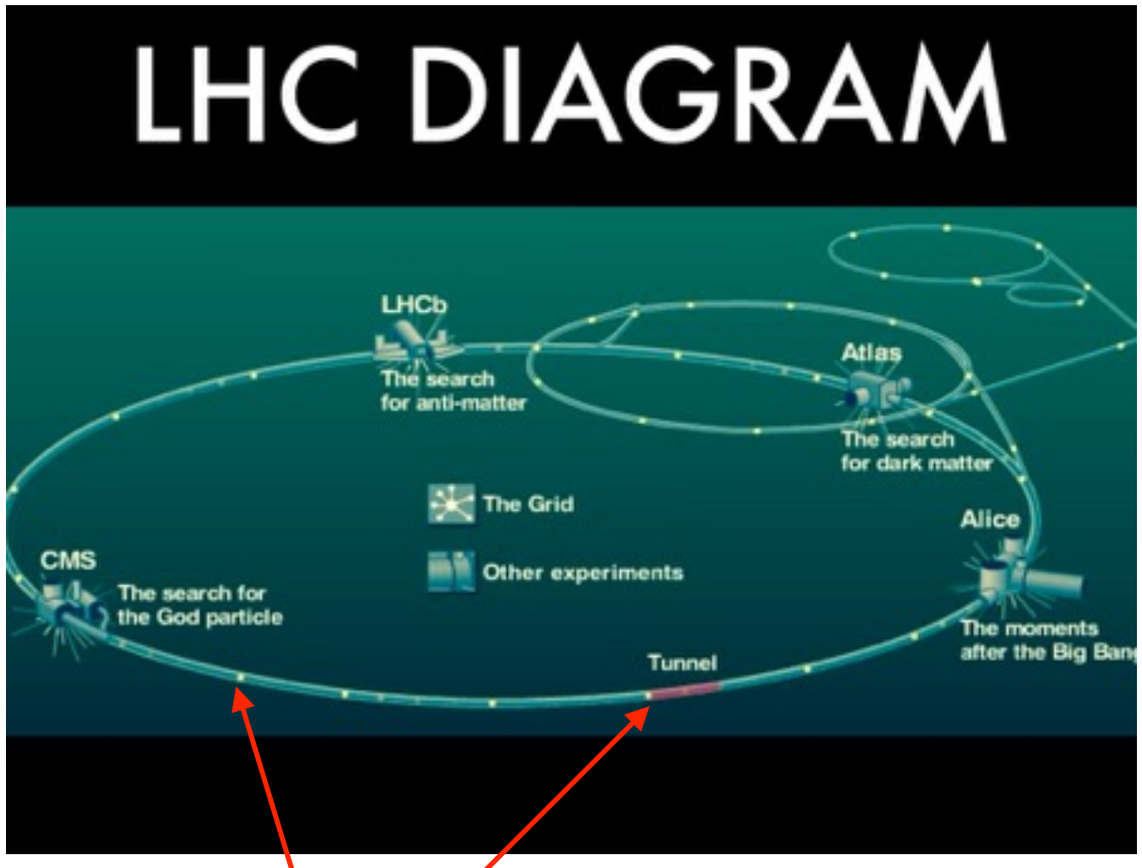
LHCf detector	Arm1	Arm2
Operation time[h]	26.6	26.6
Collected luminosities[nb^{-1}]	5.15	5.15
Number of recorded shower events[M]	17.94	20.98
Number of typeI Pi0 candidates[M]	0.22	0.31



- In 13TeV operation、Arm1,Arm2 have recorded 17.94M and 20.98M shower events.
  - It's enough compare to the data set in 7TeV analysis with serval M.
  - According to MC PYTHIA study, Arm1,Arm2 can identify 1.97M and 2.31M diffraction-like events, it's enough for LHCf-ATLAS common analyses.

LHCf-ATLAS Event matching

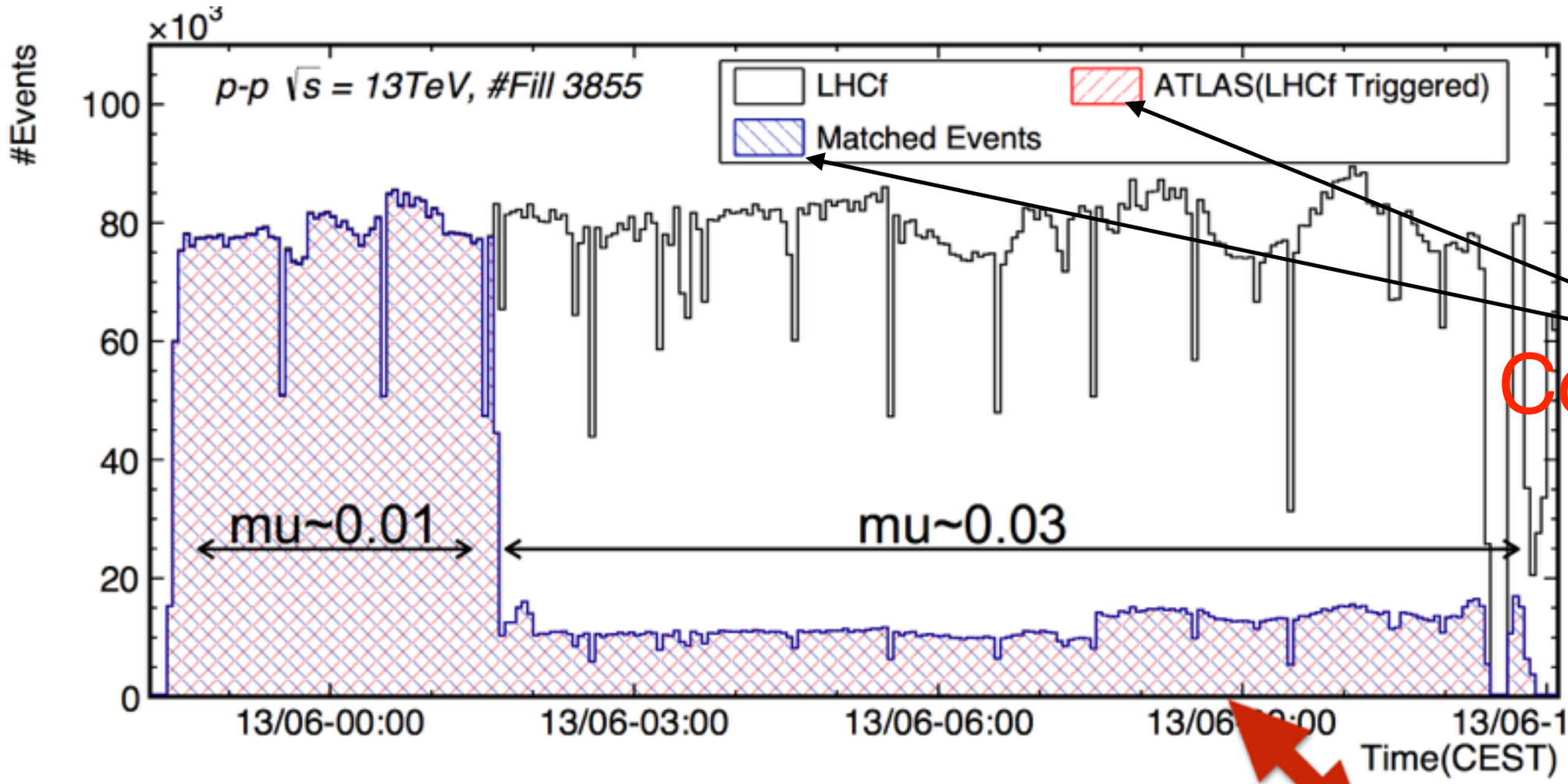




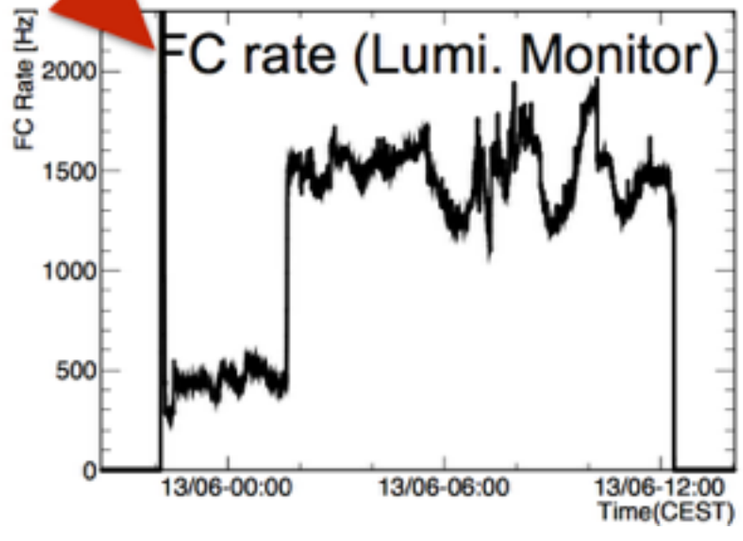
Bunches

- **LHCf-ATLAS common operation has succeeded**
- The event matching was done by using ATLAS L1ID with offline. and confirmed by using BCID(Bunch Crossing ID)

LHCf-ATLAS Event matching

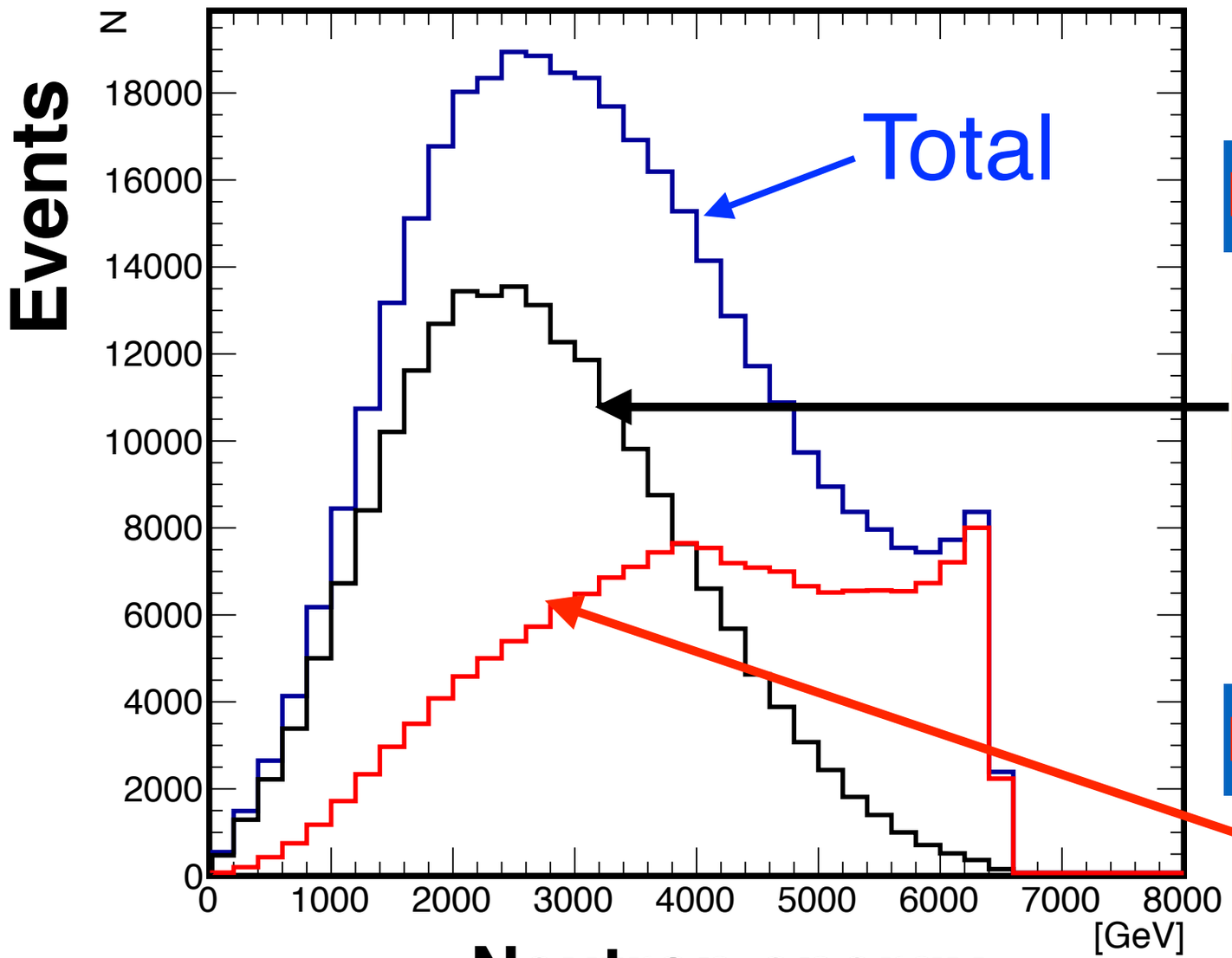


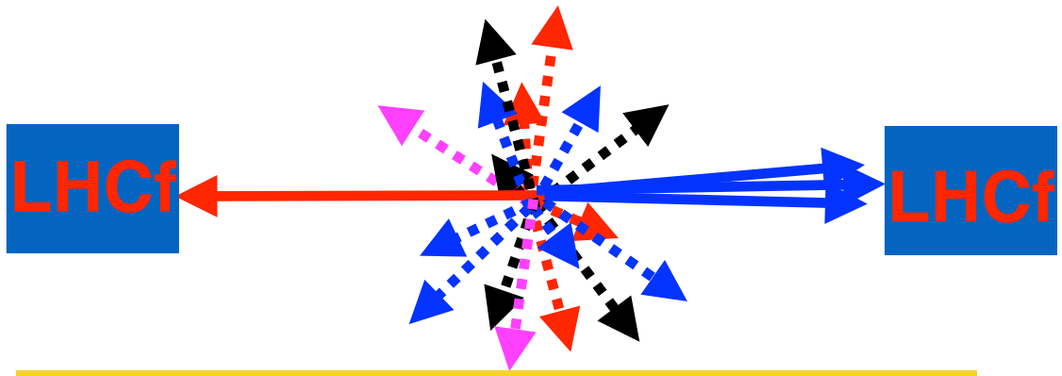
Consistent



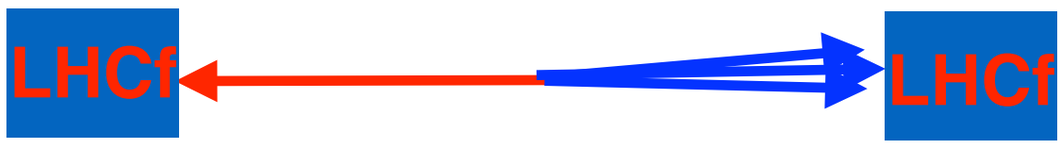
	mu=0.01 (run 44299-44472)	mu=0.03 (run44482-45106)
LHCf events	4.168 M	14.194M
Matched events	4.158 M	2.121 M

Future plan





Non-Diffraction



Diffraction

Identify the LHCf detected particles were created by diffraction or non-diffraction collision. make the plot as above, experimentally.

Summary

✦The LHCf and ATLAS had a common operation at 13TeV collision, dedicated to the measurement of diffractive events.

✦The identification of diffraction can verify and improve the hadronic interaction models.

✦To estimated the efficiency and purity of diffractive event identification in the common experiment by simulation.

- The efficiency of diffraction identification is approximately 40%, with 99% purity.

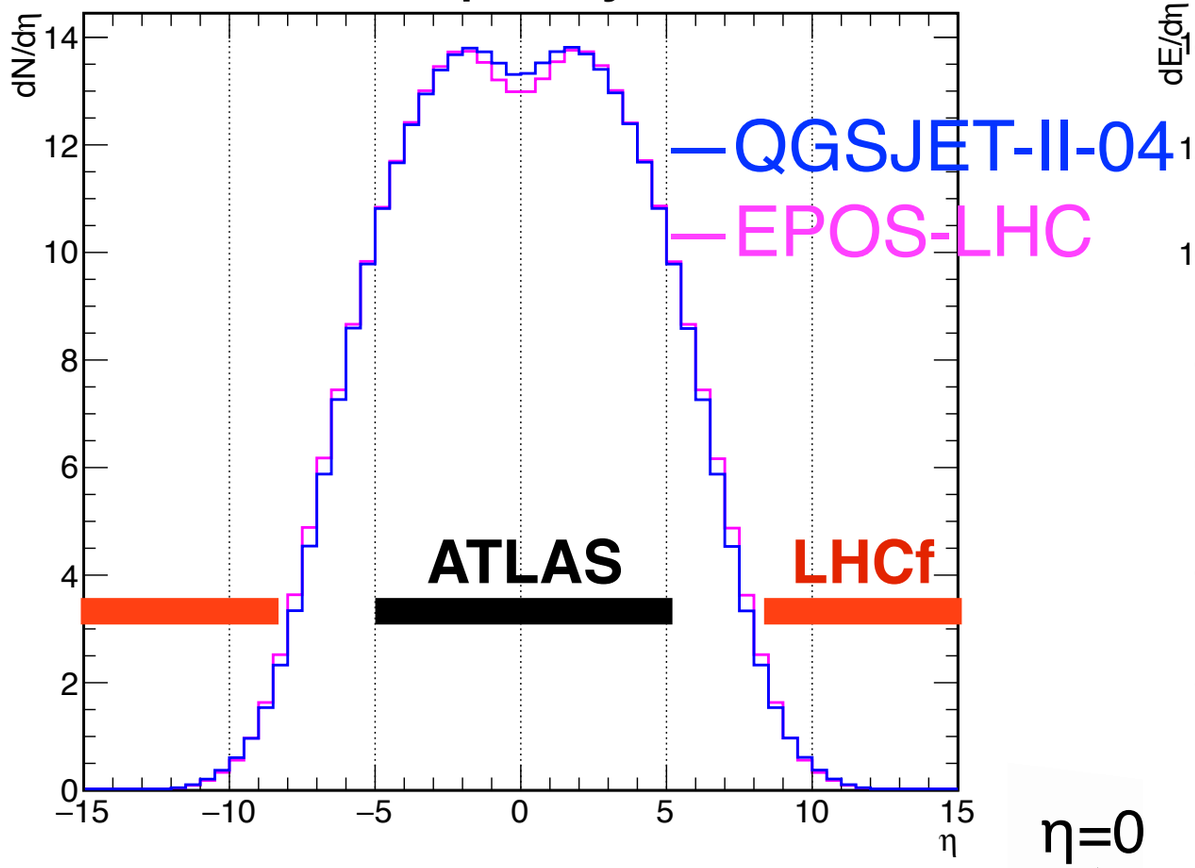
✦The common trigger works well, the event matching have been confirmed, we toke the meaningful data for diffractive events study.

Back up

Particle density and energy flow for 13TeV p-p

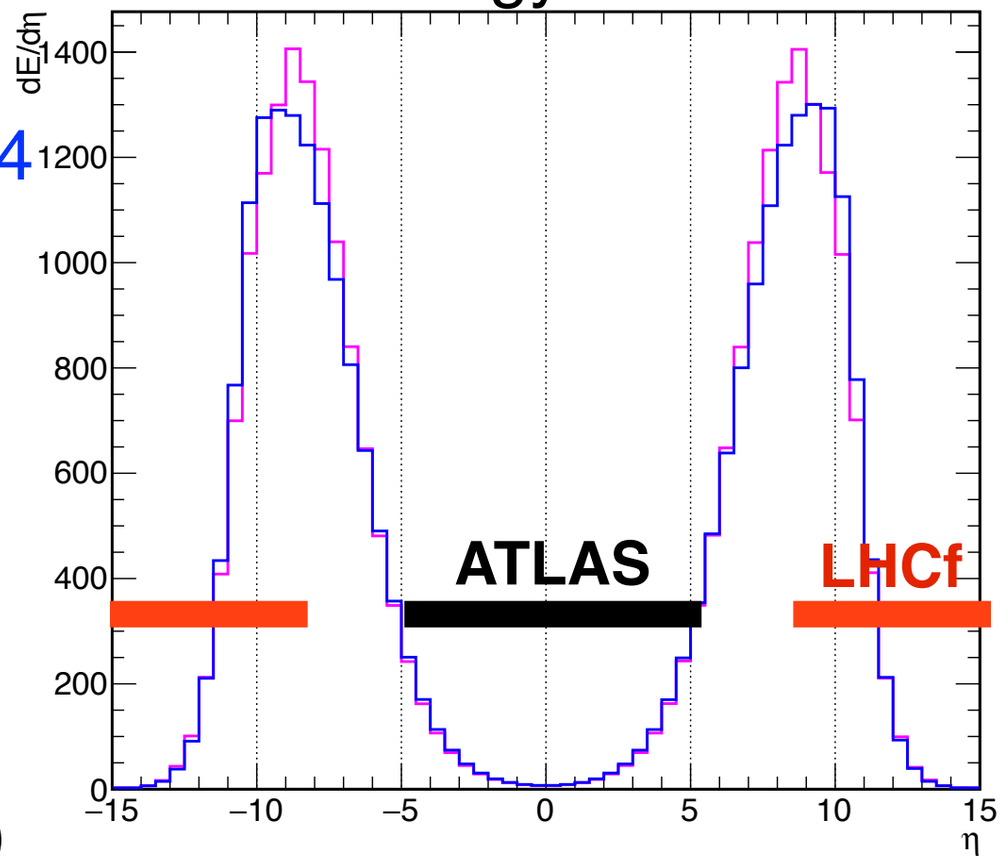
Most of secondary particles concentrate to the center

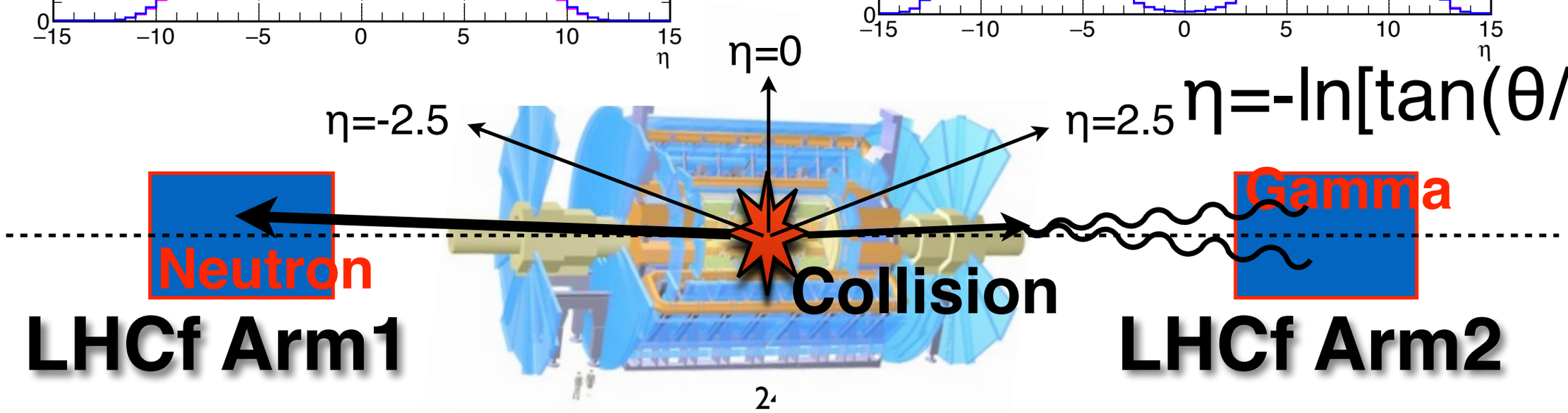
Multiplicity



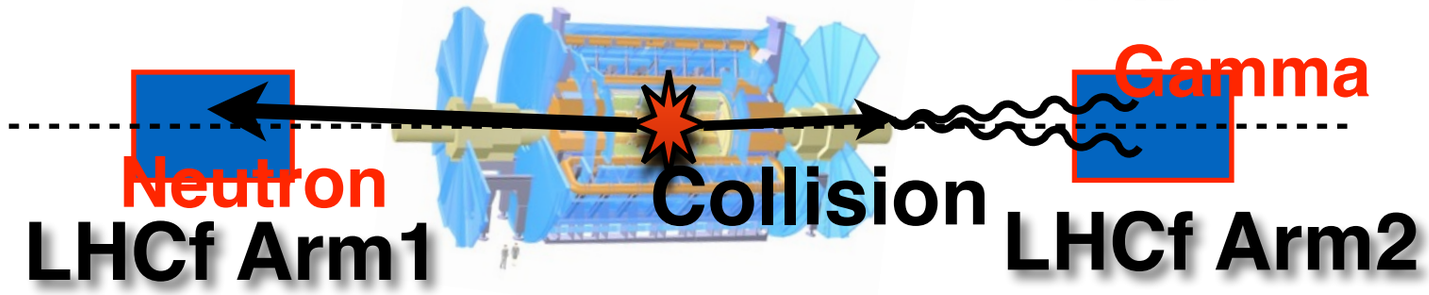
The most energetic secondary particles emitted to the very forward region (LHCf sensitive region)

Energy-flow





Impact of diffraction collisions to X^{u}_{max}

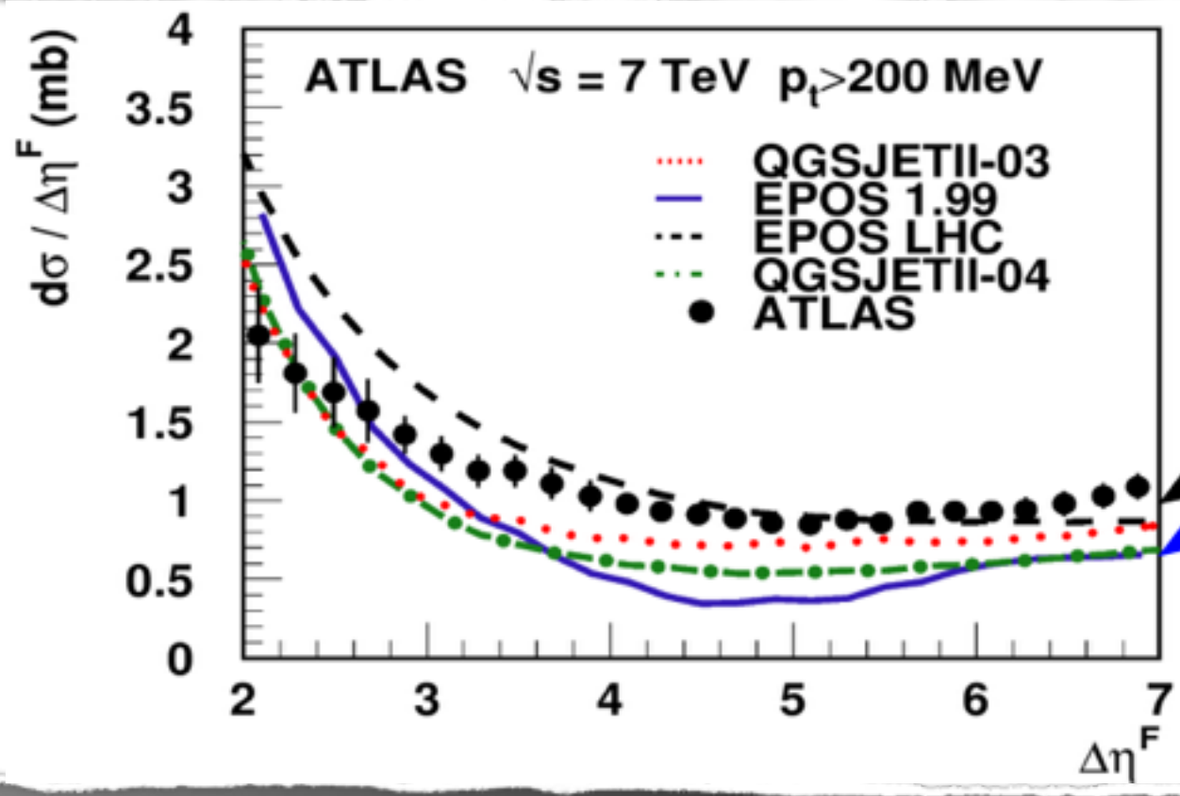


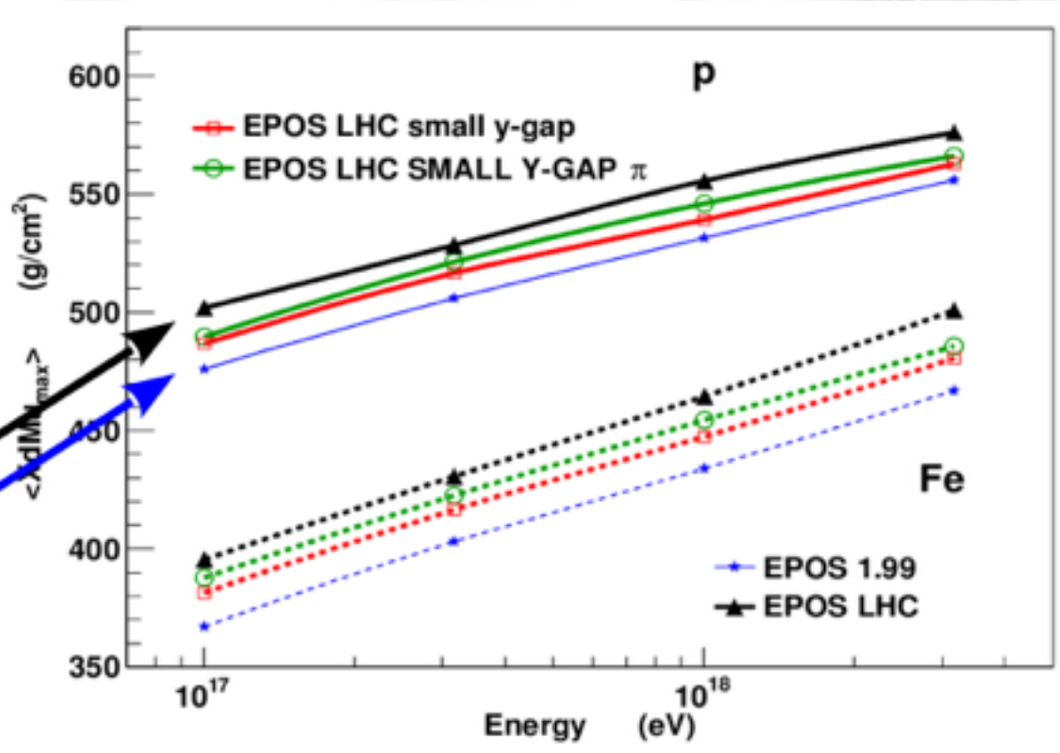
✦Weak influence on EM Xmas

✦Cumulative effect for X^{u}_{max}

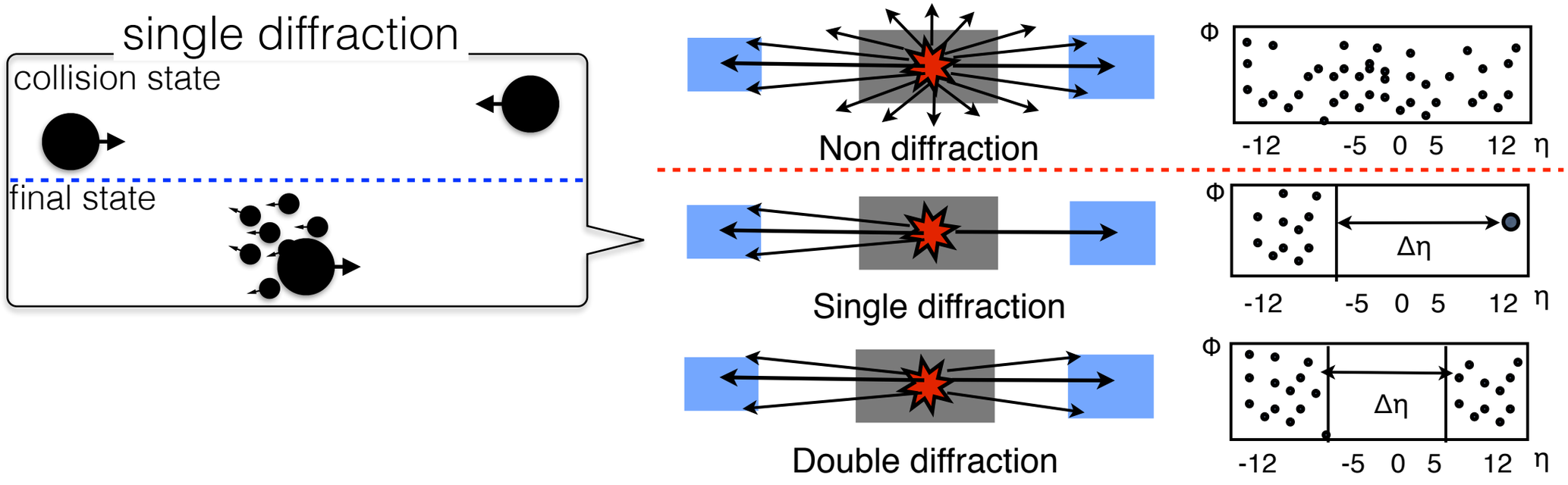
✦ Neutron (baryon) and gamma (pair production from π meson) are detectable for LHCf detectors

T. Pieorg, HESZ 2015





Diffractive event



- ✦The inelastic collisions: classified by diffraction and non-diffraction.
  - The diffraction and non-diffraction are very different mechanisms in hadronic collisions.
  - The diffraction contributes ~28% of the inelastic cross section in proton-proton collisions.
- ✦Diffractive reaction is characterized by a rapidity gap (Δη) in the final state. the rapidity gap is defined as no particle is produced at a rapidity region.
- ✦The measurements of diffractive events require the instruments with large pseudo-rapidity acceptance.

Diffractive event

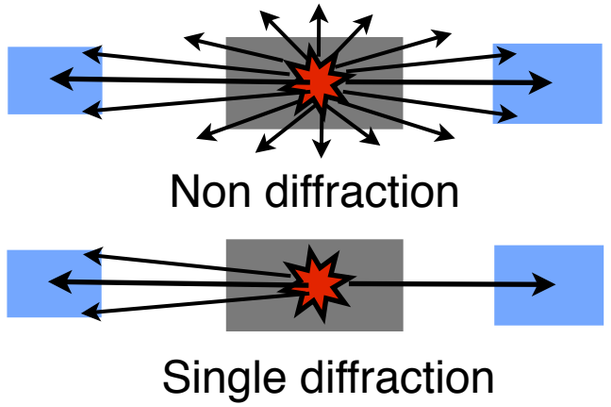
✦Hadron collision

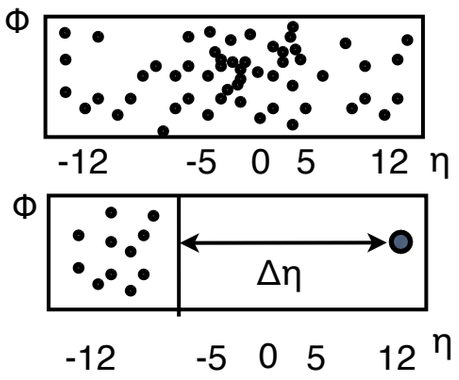
Secondly particles emit in wide angle(pseudo rapidity η)range (non diffraction),
Secondly particles concentrate on forward region (diffraction)

✦Detection of Diffractive event

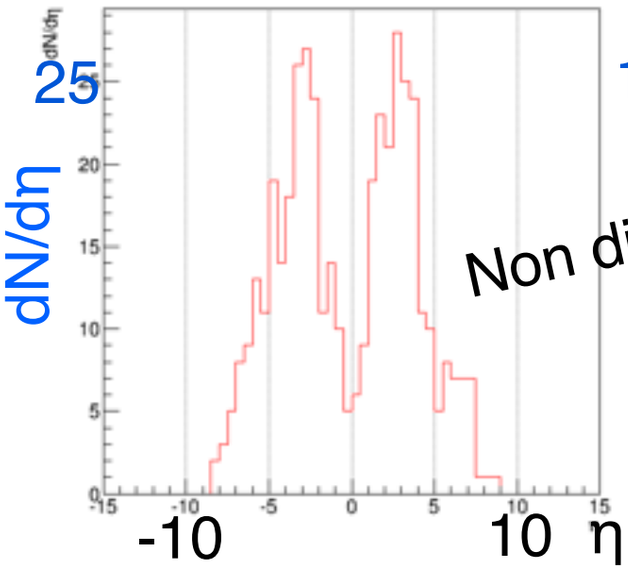
Using the characteristic which is no particles in wide rapidity range(rapidity gap Δη)
A part of diffractive events could not be detected by Central detector(ATLAS,CMS)

→LHCf-ATLAS common experiment

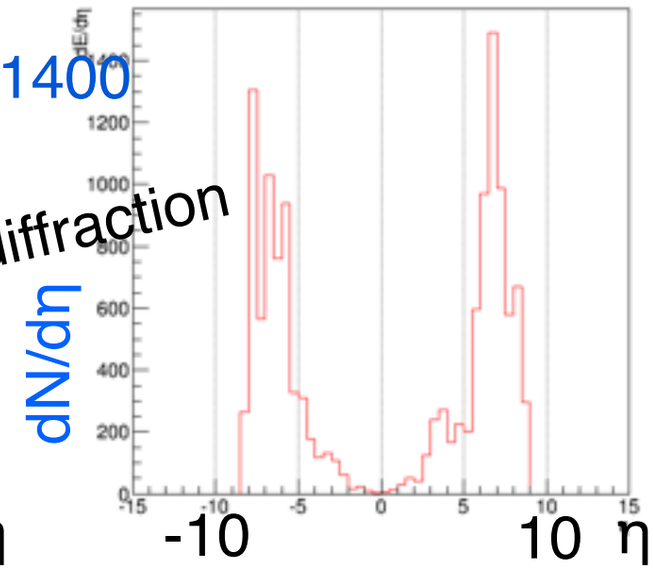


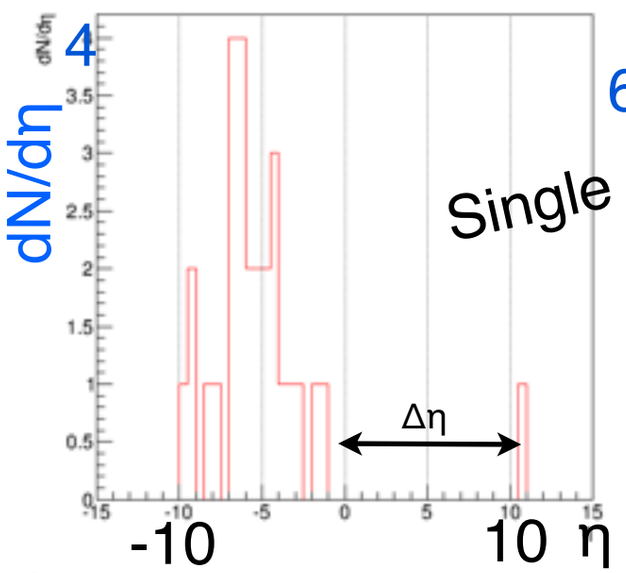


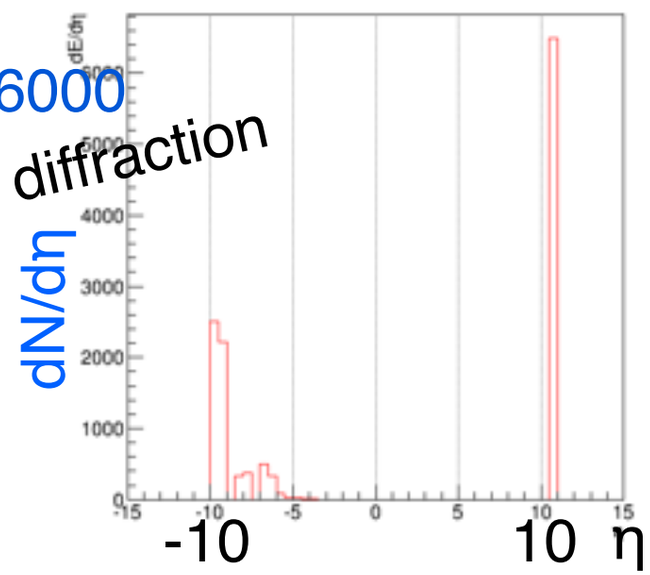
Particle density



Energy flow

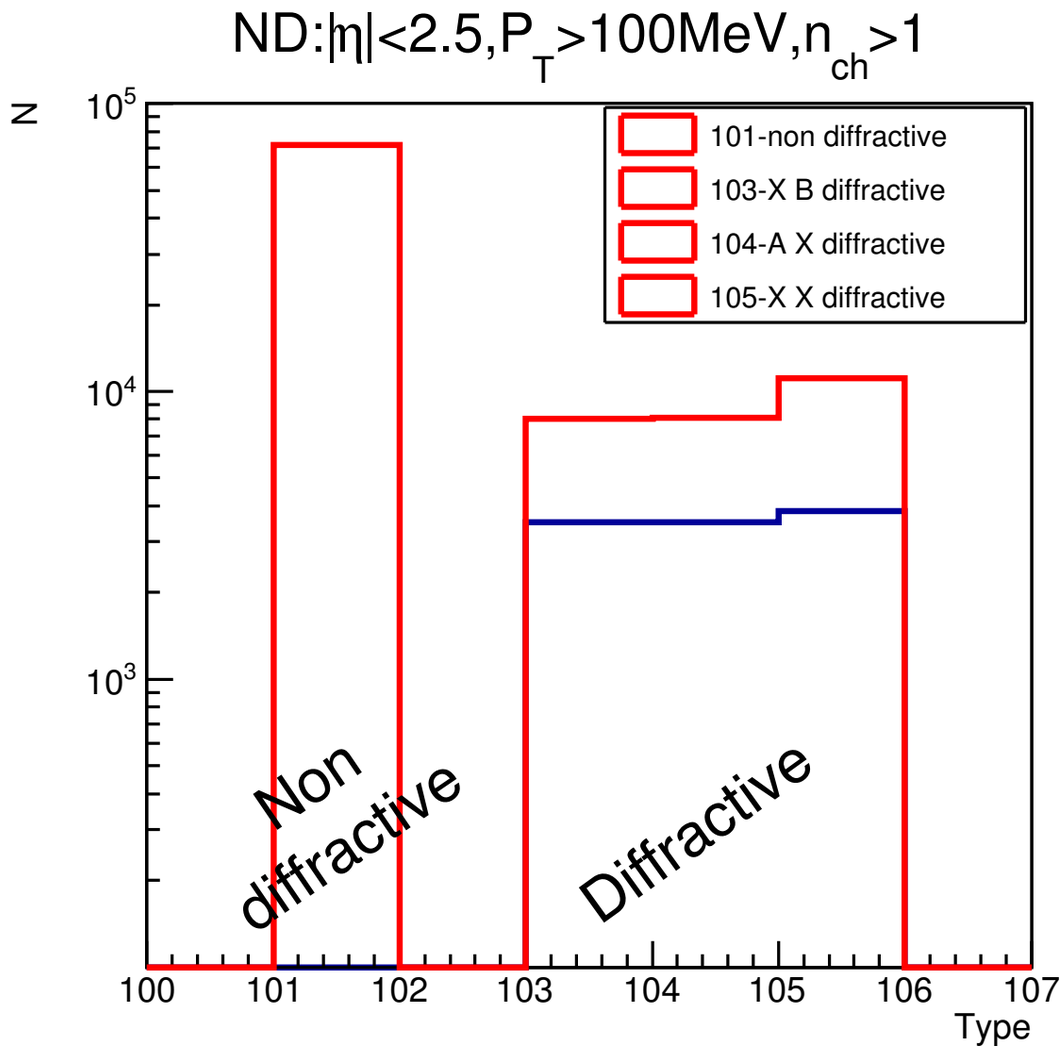


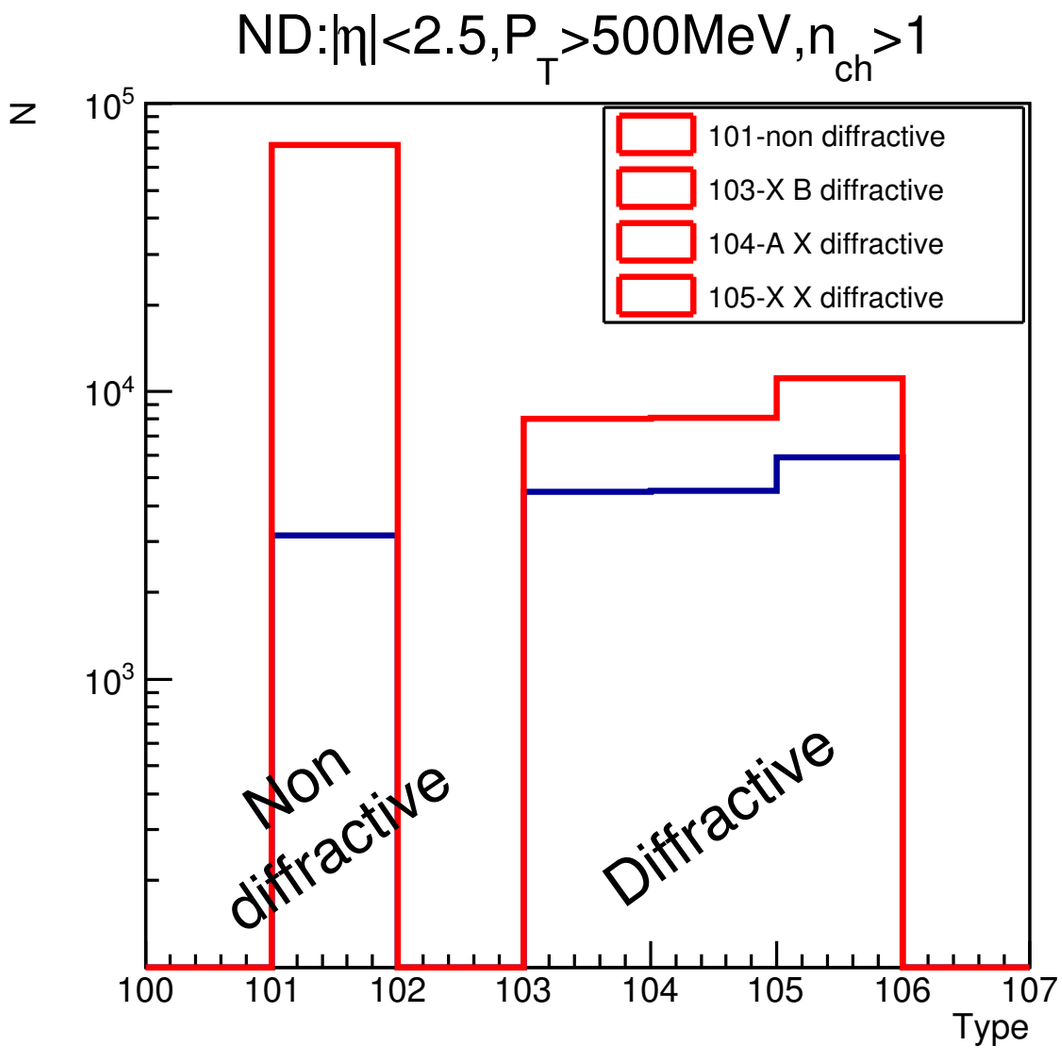




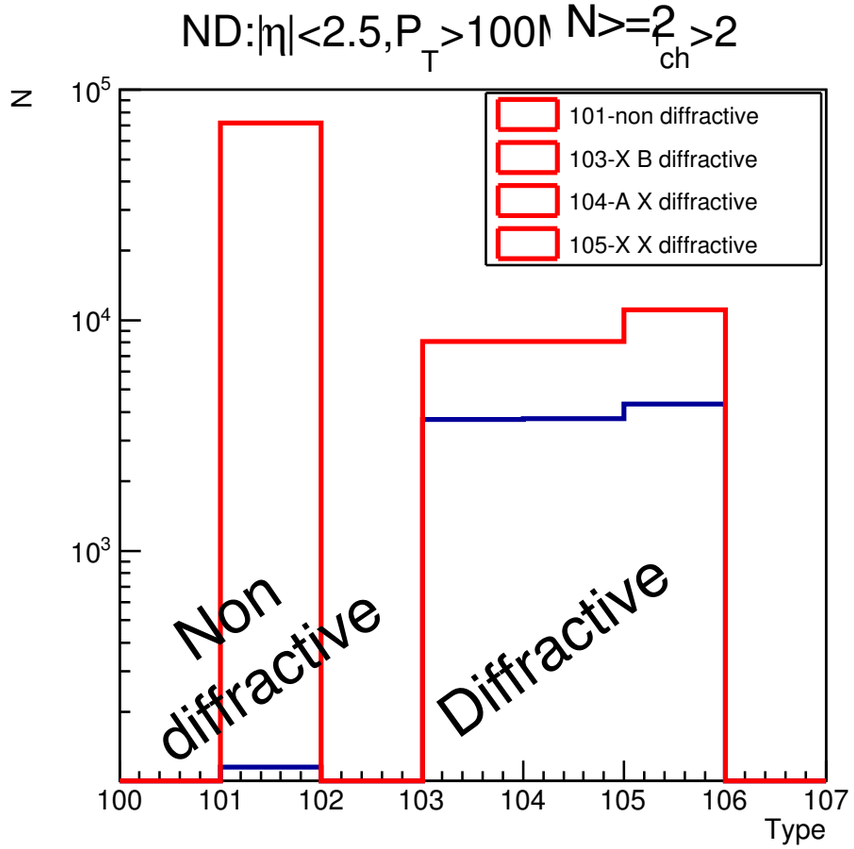
$\overline{ND}$ event selection purity 1

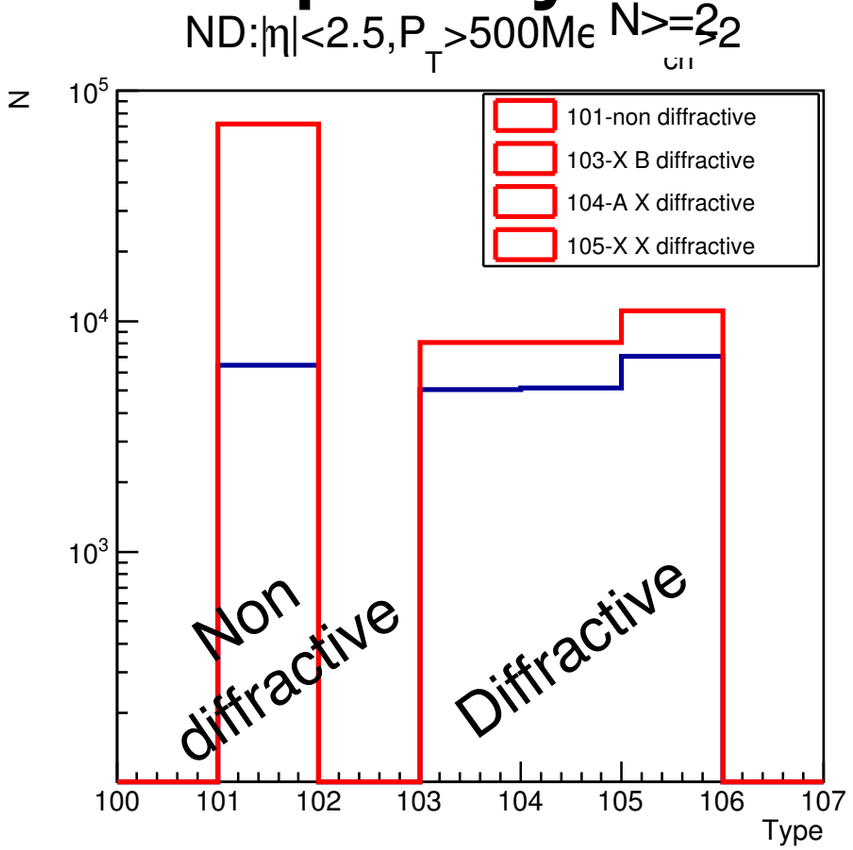
- Histogram of different type diffractive events identified by simulation true(101 non diffractive not been plot).
- Histogram of the selected $\overline{ND}$ events which are classified by event type according to simulation true. (Non Diffractive(ND) events identified by η, Pt, N($n_{,Pt}$)conditions).
  - Non Diffractive(ND) event：conditions on the top of figure
  - $\overline{ND}$ = Total-ND

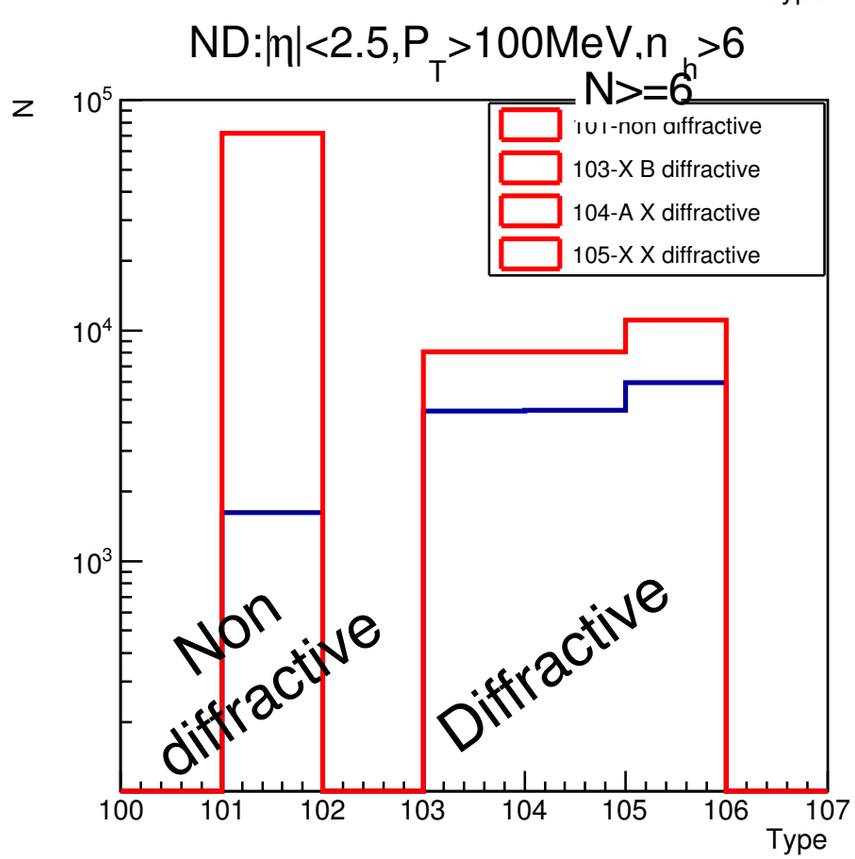


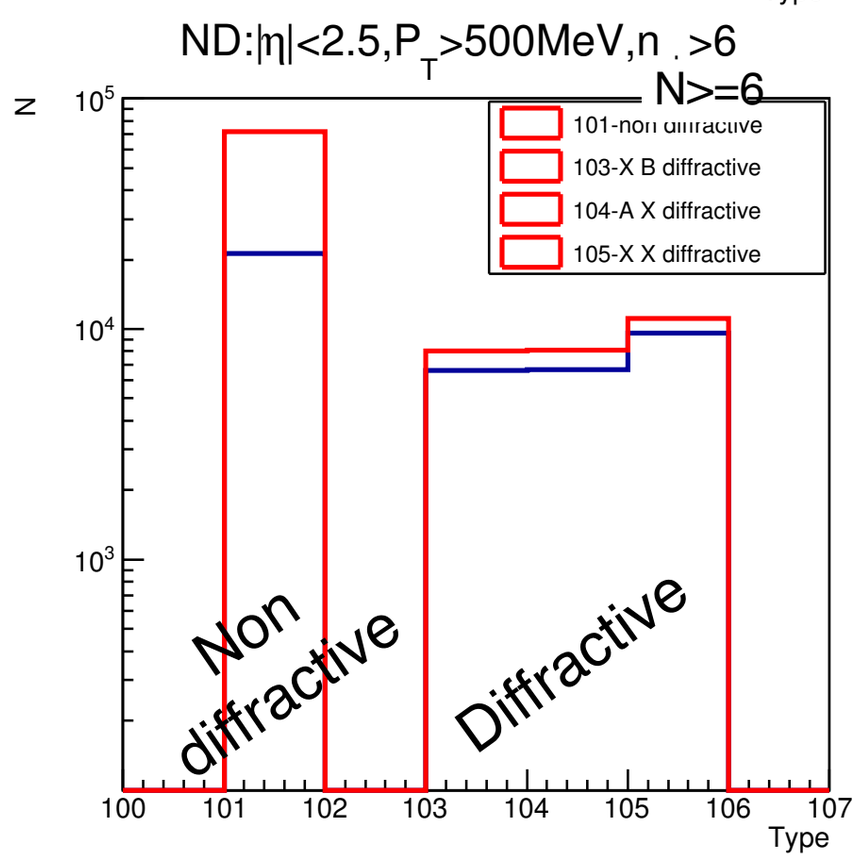


ND event selection purity 2

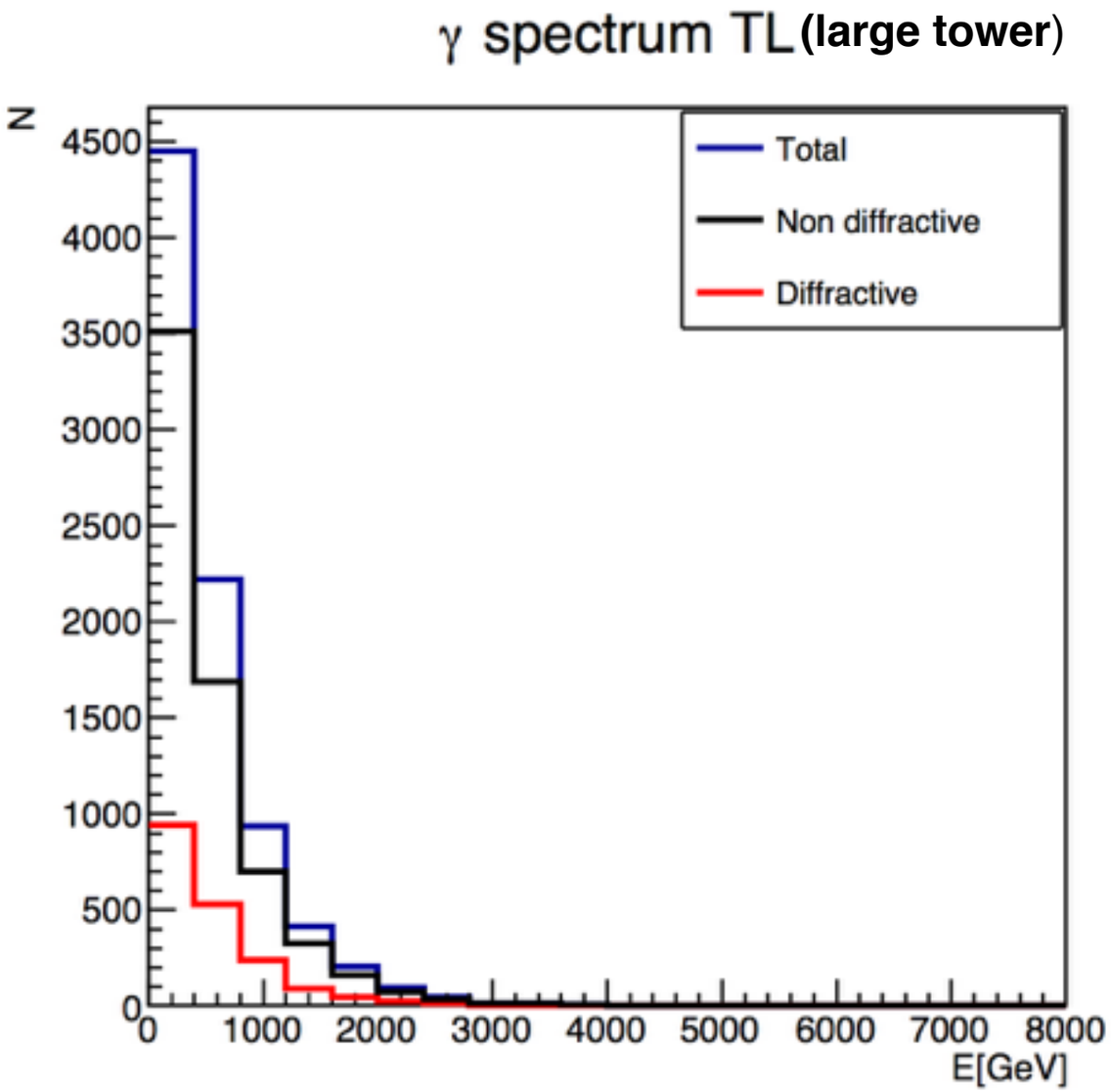


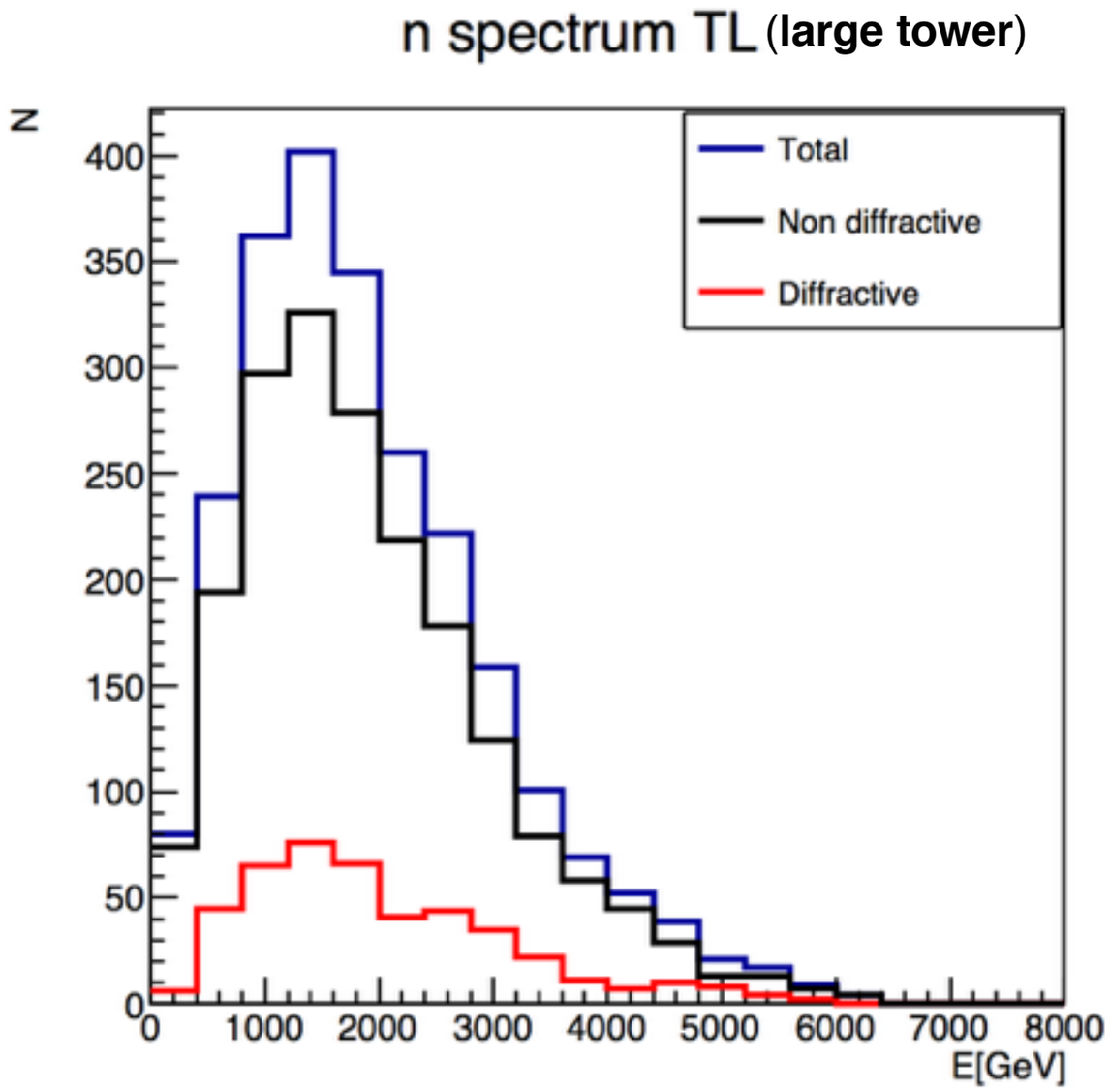






LHCf spectrum - Arm1 LargeTower

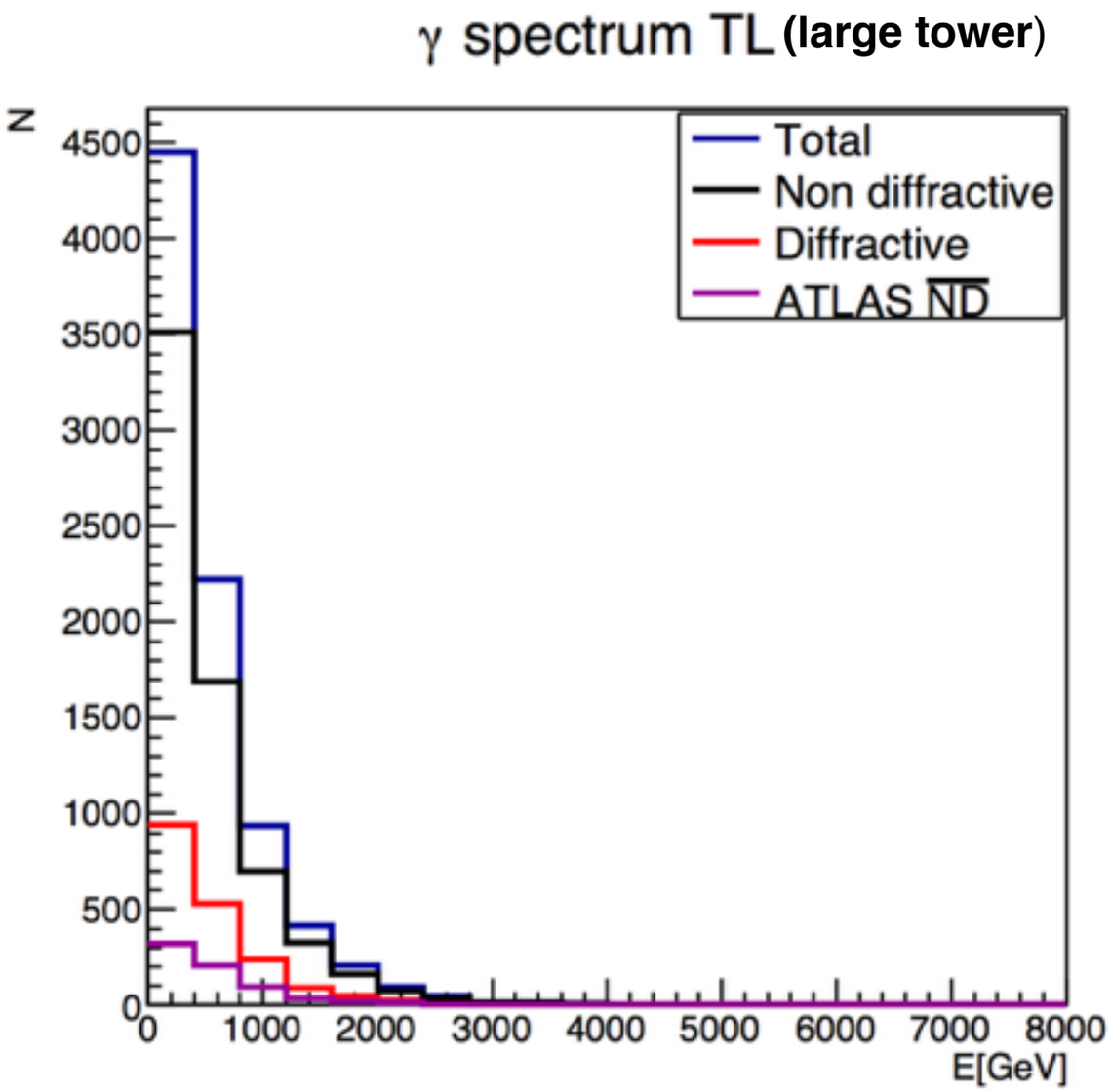


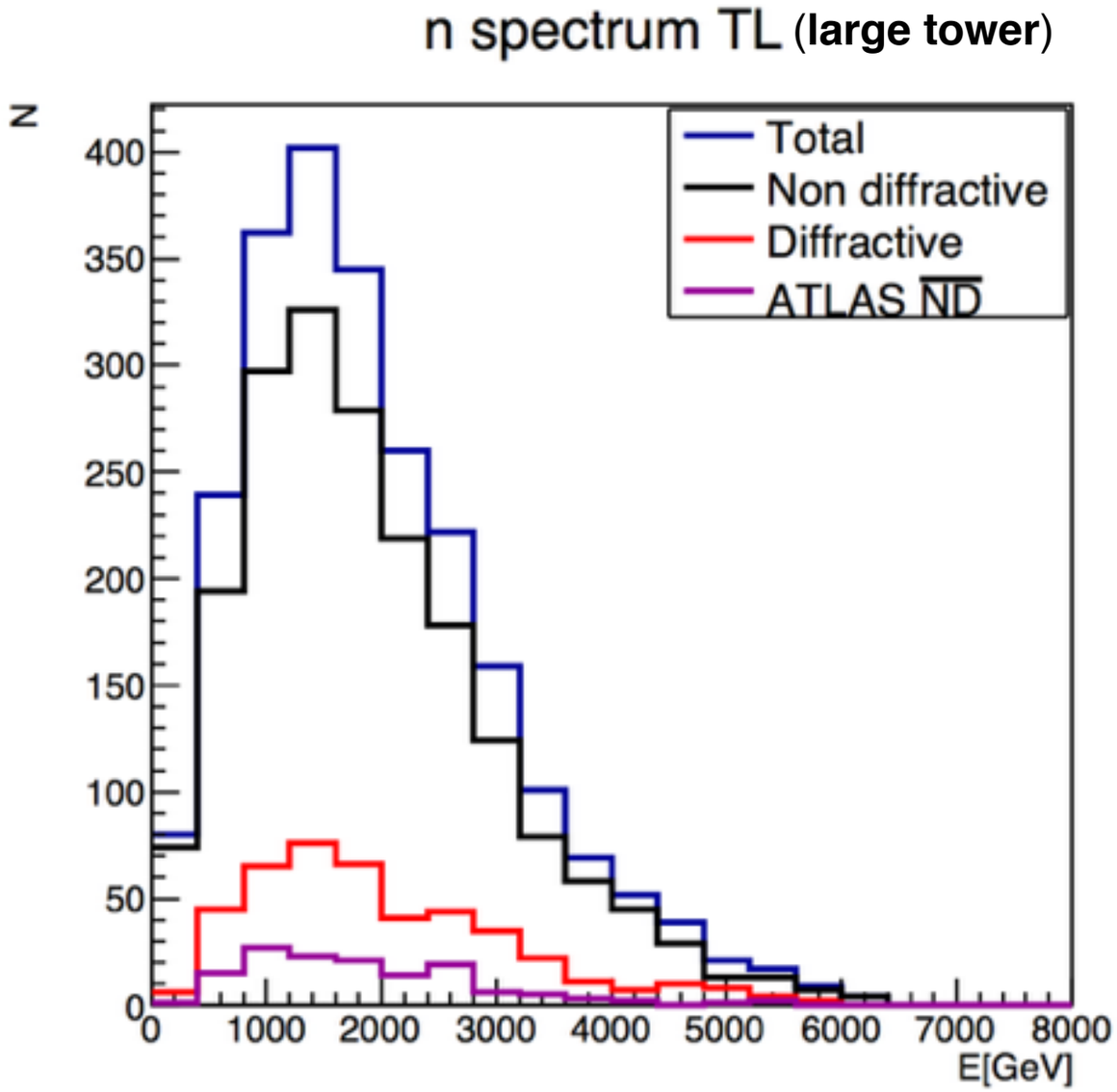


MC:Non Diffractive

Diffractive

LHCf spectrum - Arm1 LargeTower





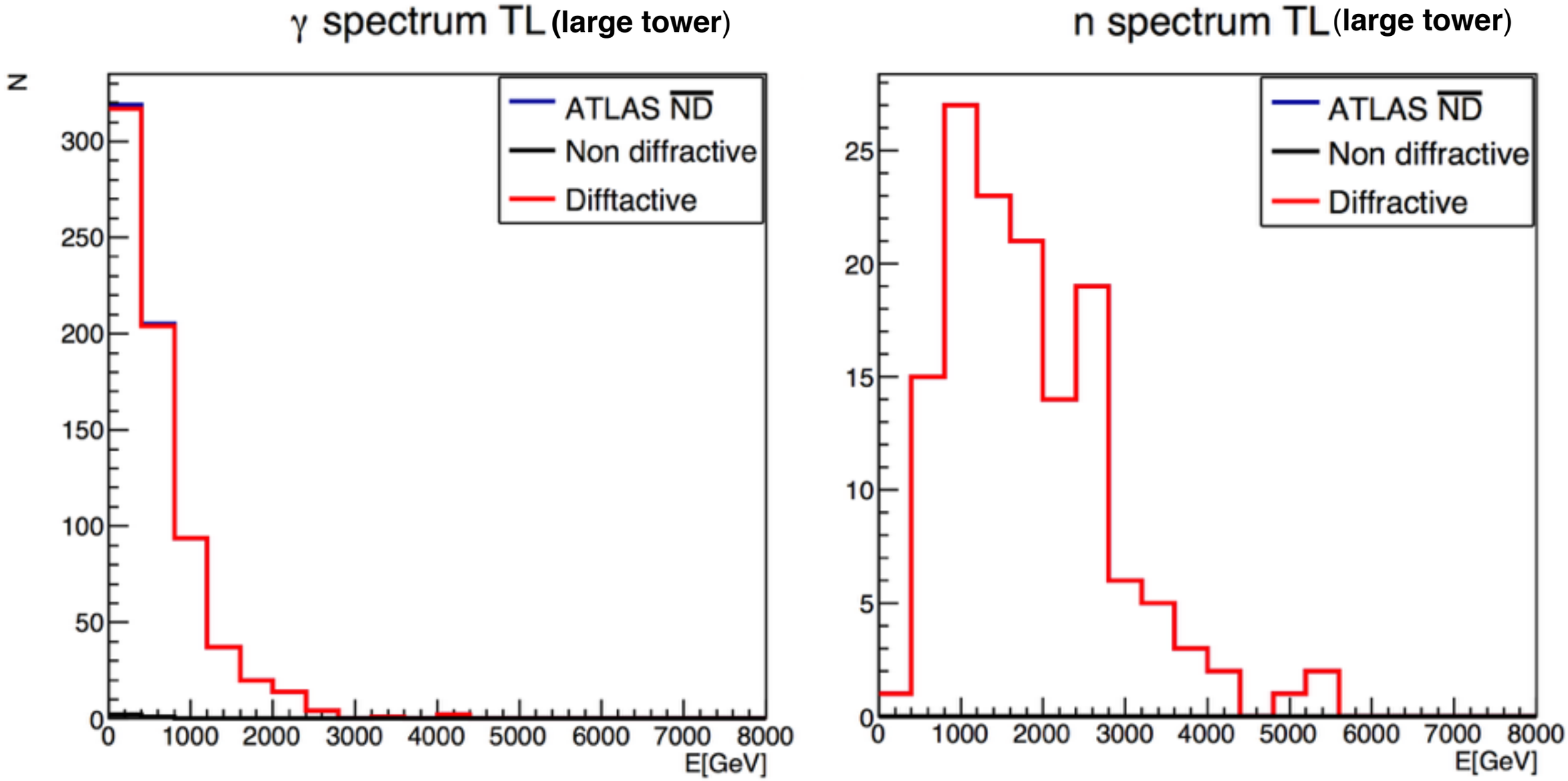
MC:Non Diffractive

Diffractive

$\overline{\text{ND}}$: according to ATLAS Diff-like selection

Diff-like events of LHCf trigger is about 11.8%
Diff-like selection efficiency 35~40%

Selected diffraction purity - Arm1 LargeTower



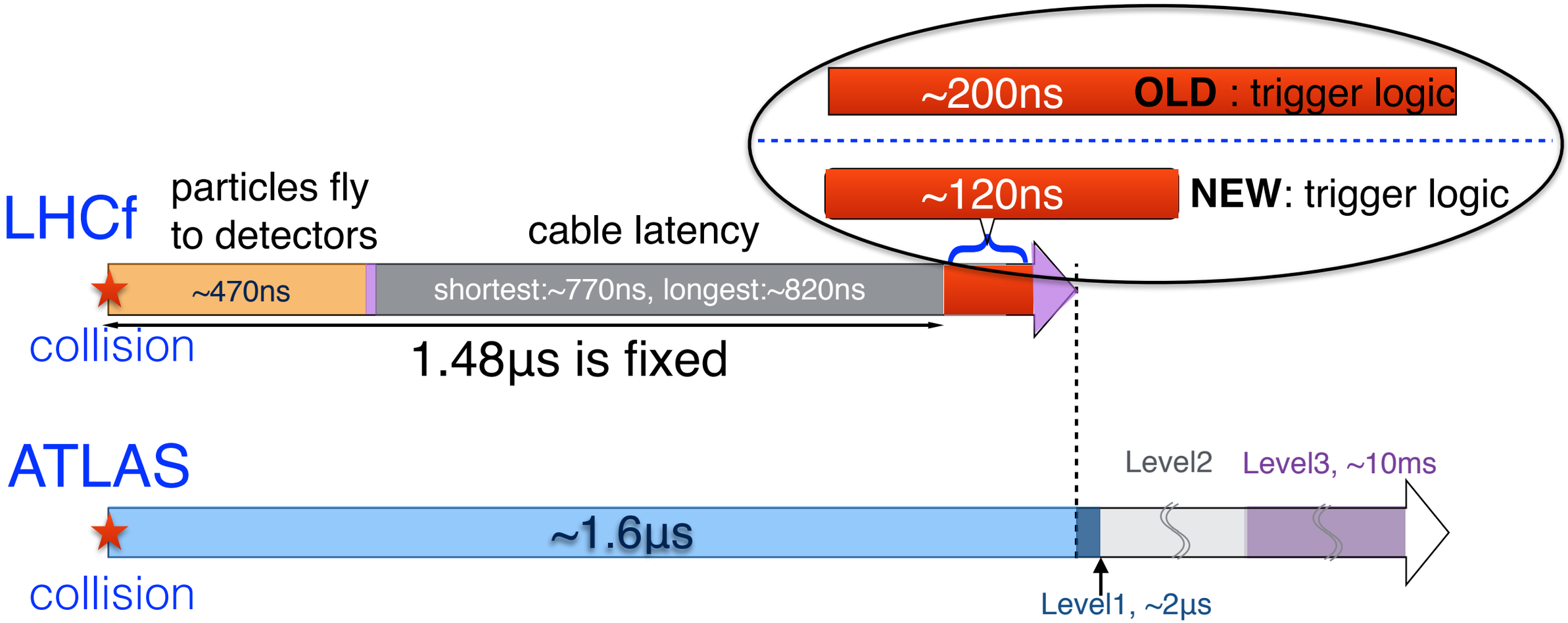
MC:Non Diffractive

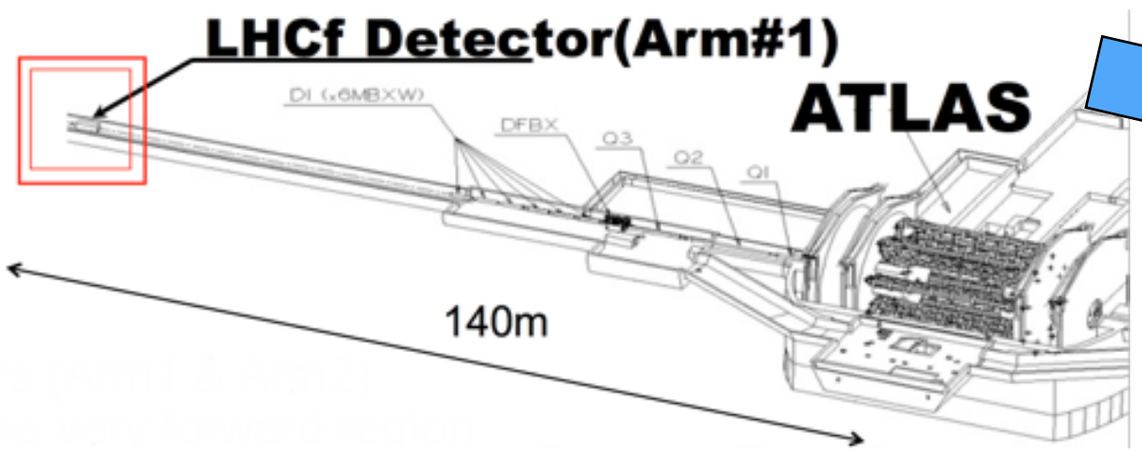
Diffractive

$\overline{ND}$: according to ATLAS Diff-like selection

Diff-like selection purity ~99%

Issues of the new LHCf trigger system



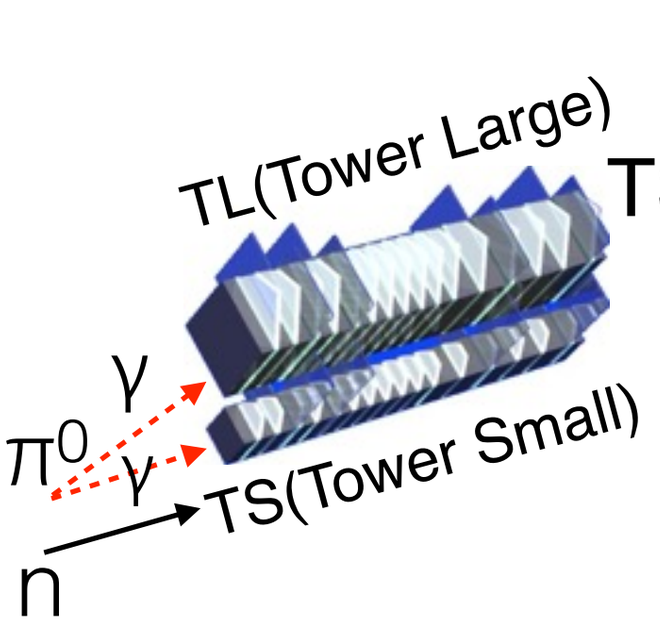


The counting room:
the LHCf trigger logic board placed

The time limit requirement for the new LHCf trigger logic

< 120ns

LHCf Trigger Diagram



3 consecutive layers with signal

TS or TL → shower trigger

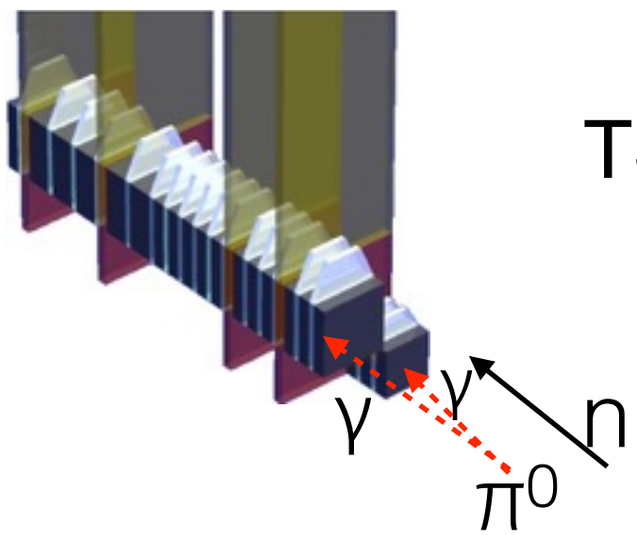
Arm1side

Arm2 side

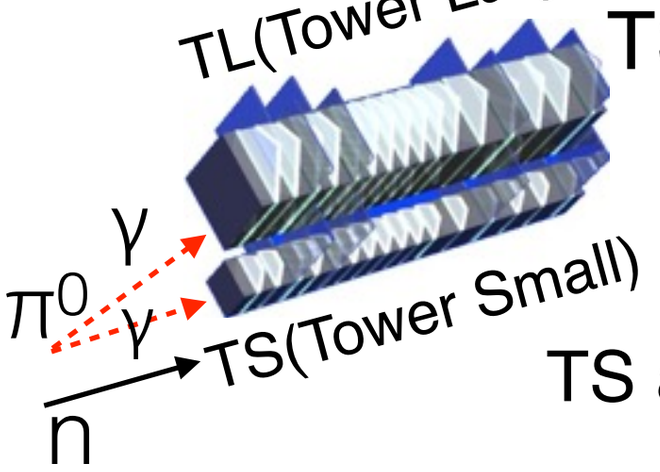
3 consecutive layers with signal

TS or TL → shower trigger

OR → Final Trigger (Trigger to ATLAS)



LHCf Trigger Diagram



TS or TL

3層連続で信号の検出

shower trigger 204Hz

pre-scale

TS and TL

前7層のうちに3層連続で信号の検出

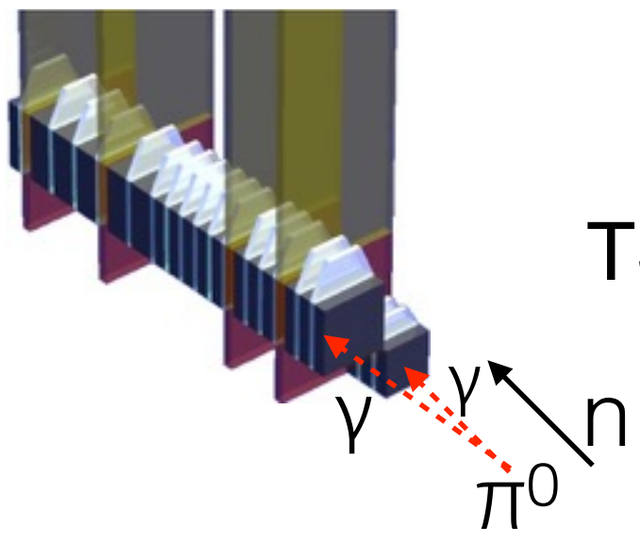
special shower trigger 7Hz

Arm1側

OR

Final Trigger (Trigger to ATLAS)

Arm2側



TS or TL

3層連続で信号の検出

shower trigger 230Hz

pre-scale

TS and TL

前7層のうちに3層連続で信号の検出

special shower trigger 12Hz

DAQ Rate & DAQ Efficiency

- DAQ rate is limited by the dead time of LHCf DAQ
  The up limit is about 500Hz.