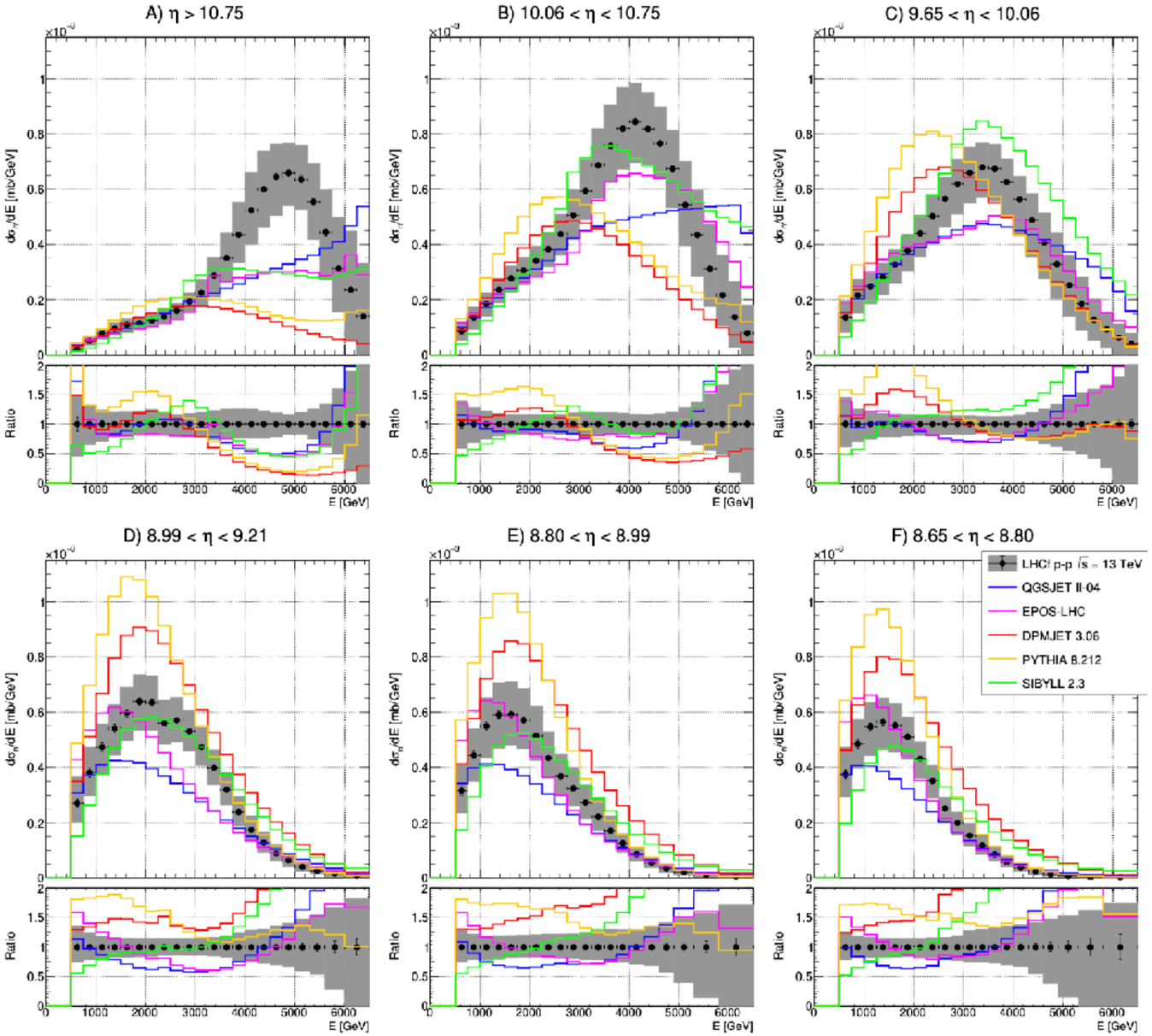
Prospects of LHCf/ATLAS and RHICf/STAR

LHCf Neutron at pp 13 TeV



Joint operation data set

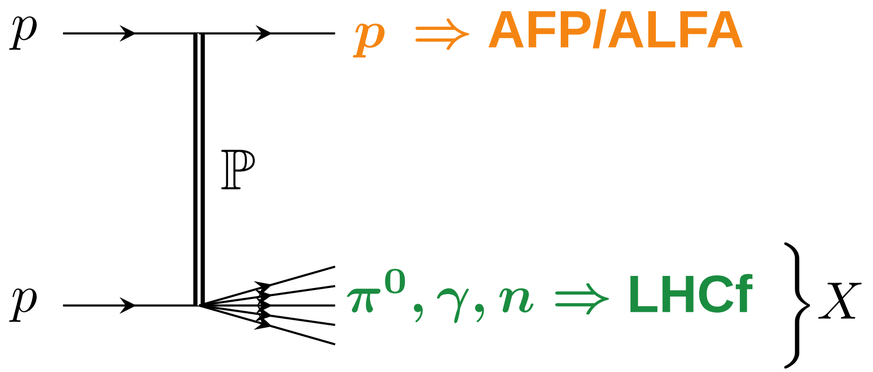
- LHCf + ATLAS
  - Op 2015: pp $\sqrt{s}$ = 13 TeV
    - Only 6 M events of common events
    - No ZDC and RPs jointed the operation
  - Op 2022: pp $\sqrt{s}$ = 13.6 TeV
    - Huge statistics of 300 M common events (all LHCf trigger events)
    - RPs (AFP and ALFA) and ZDC-HAD jointed the operation
- RHICf + STAR
  - Op 2017: pp $\sqrt{s}$ = 0.5 TeV
    - RHICf was installed in the front of ZDC
    - RPs jointed in the last fill

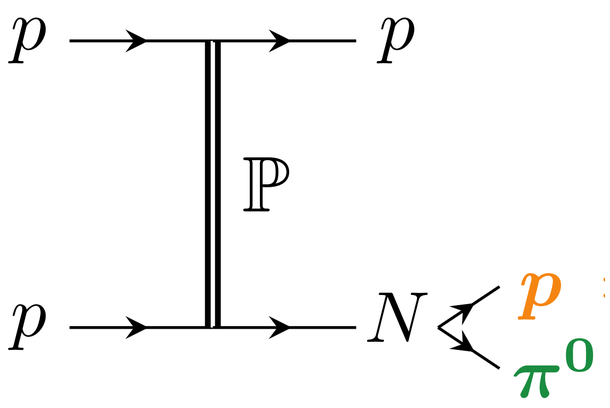
Physics cases for joint operation

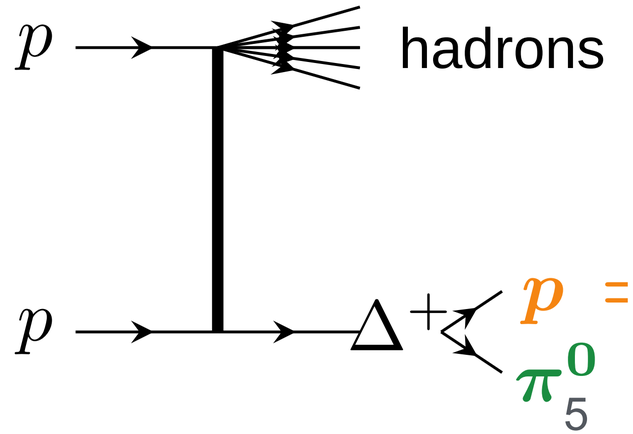
- with Central Detector
  - Measurement of diffractive collisions
  - Properties of Multi-parton interaction
- with Roman Pots
  - Single diffractive measurement
  - Measurement of N(1440) and Δ(1232)
- with ZDC
  - Improvement of energy resolution for neutrons to ~ 20%
  - Measurement of Λ ($\Lambda \rightarrow n + \pi^0$)
  - One-Pion-Exchange process

Joint operation with RPs

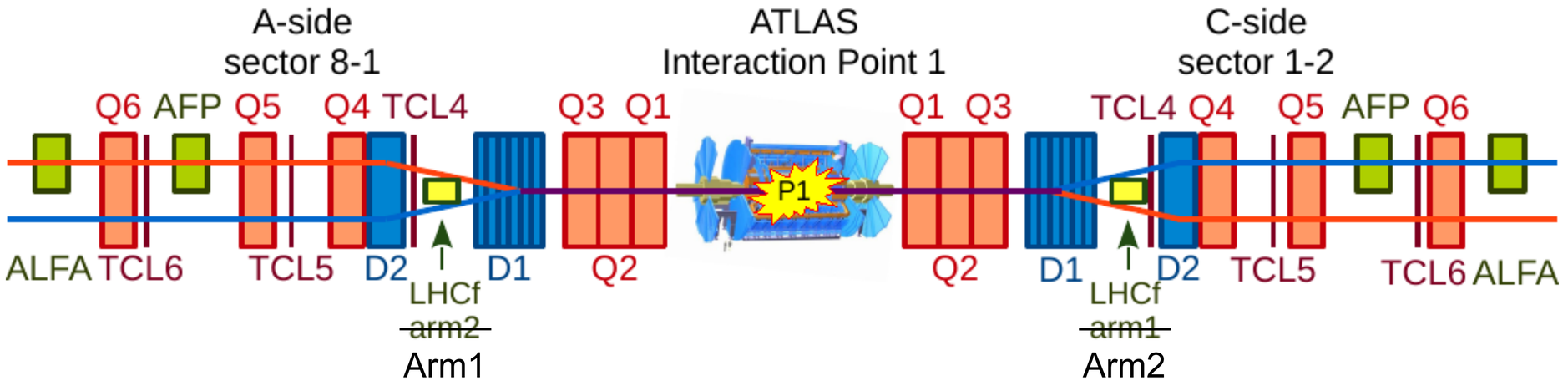
- Physics cases
  - Single diffractive measurement
    - Measuring the scattered proton,
      the diffractive mass can be estimated event-by-event.
    - Can address the hadron production from a specific mass decay.
      cross-section = (diffractive mass spectrum) x (hadron production)
  - Resonance measurement : *N* (1440) and Δ (1232)
    - N : probe the very low mass diffractive process.







ATLAS AFP and ALFA



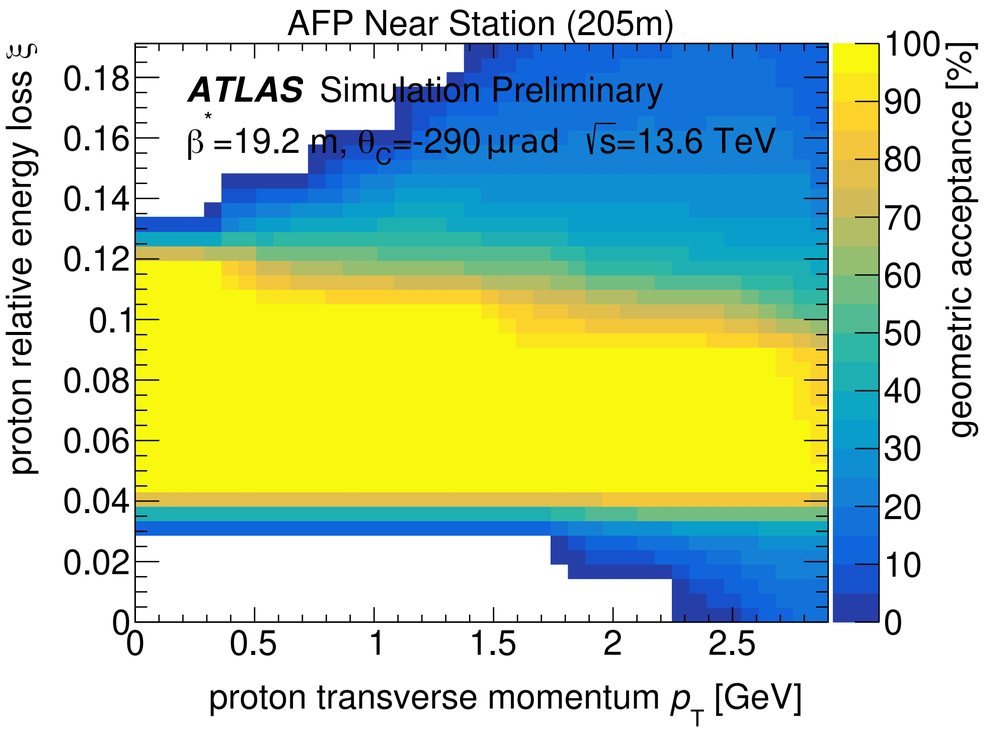
- ALFA : optimized for high-β* operation
- AFP : designed for operation in nominal pp runs
- Both the detectors were operated during the 2022 operation

→ Feasibility study of LHCf + ATLAS RPs was done by an ATLAS PhD. student.

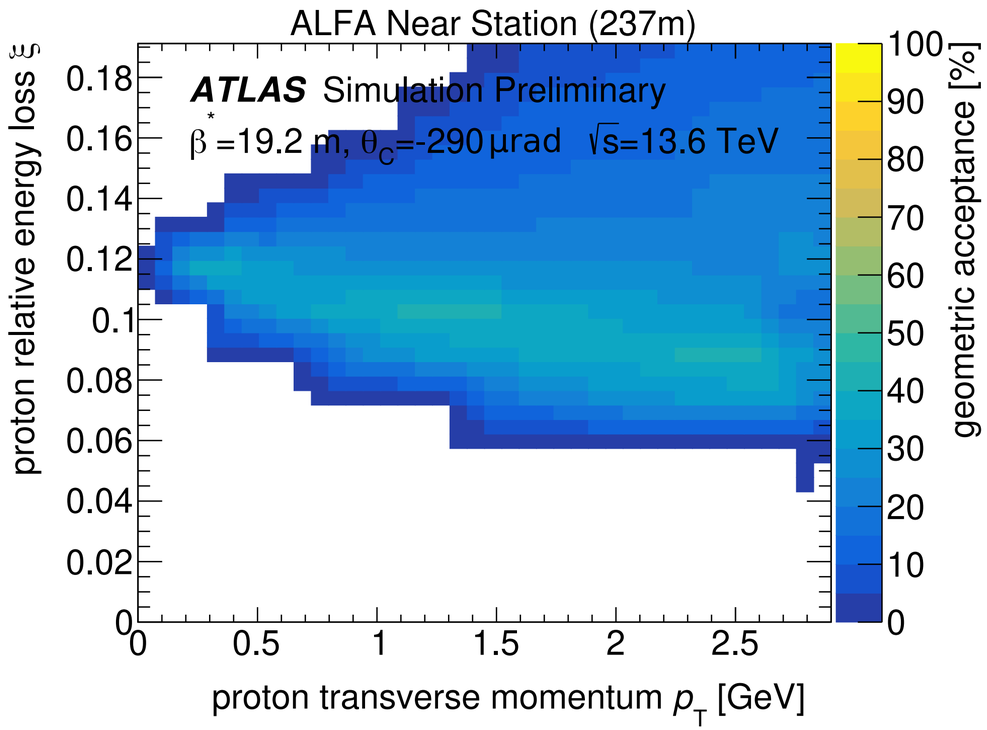
Acceptance of RPs

- Study the acceptance for protons using the MC simulation

AFP near station: $5.2\,\text{mm} \rightarrow 6.5\,\text{mm}$



ALFA near station: $3.9\,\text{mm} \rightarrow 6.1\,\text{mm}$

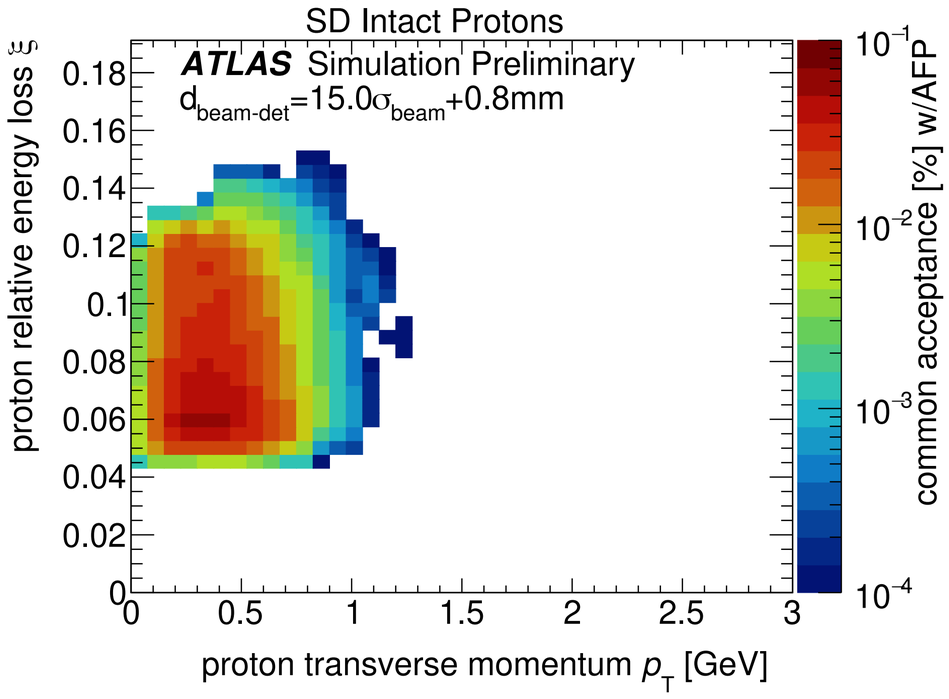


Acceptance for single-diffractive process

-

LHCf+AFP

Single diffraction



event rate [Hz]	# events (2 d)
46.5 ± 1.3	8.0 ± 0.3 million

scattered proton in AFP

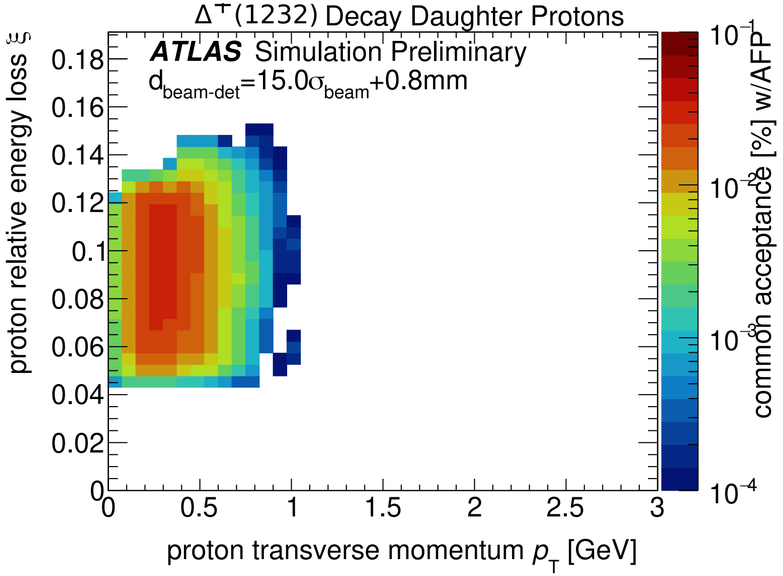
+

Any particle with > 200 GeV in LHCf

Large statistics events can be expected

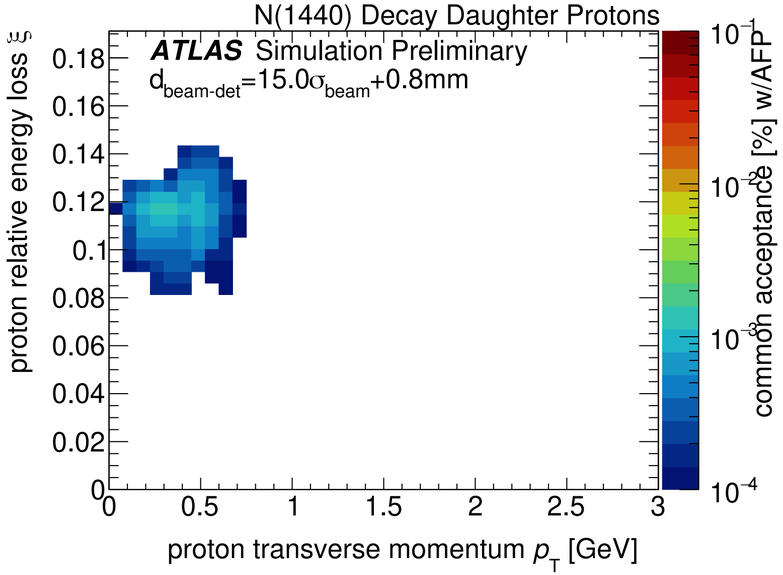
Acceptance for N and Δ resonances

$\Delta^+(1232)$ production



event rate [mHz]	# events (2 d)
17.7 ± 0.6	3050 ± 100

$N(1440)$ production



event rate [mHz]	# events (2 d)
13.6 ± 1.3	2350 ± 220

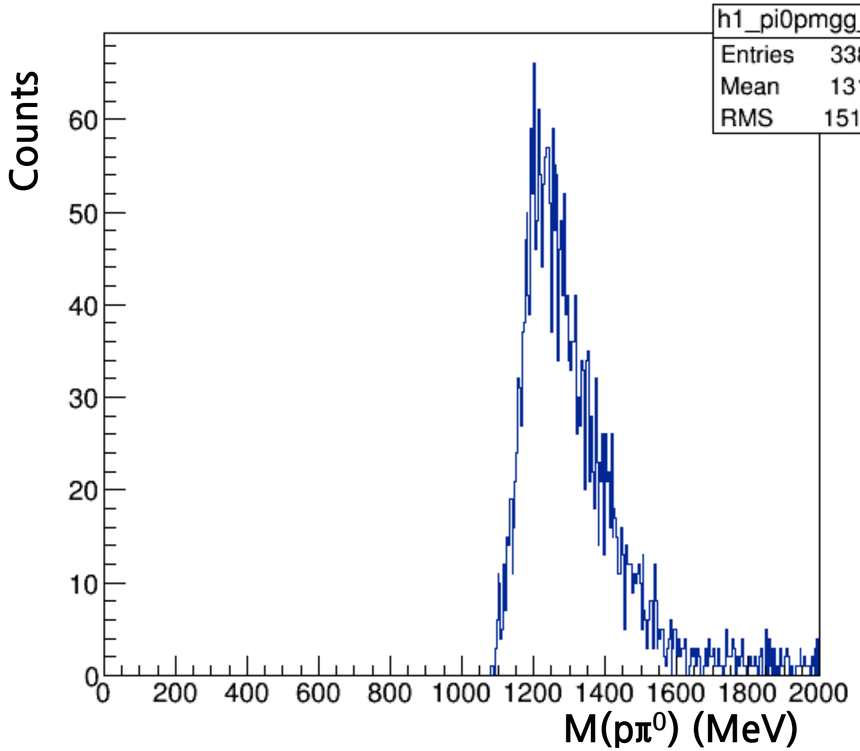
scattered proton in AFP
+
pi0 in LHCf

These event numbers are estimated assuming 100% DAQ efficiency

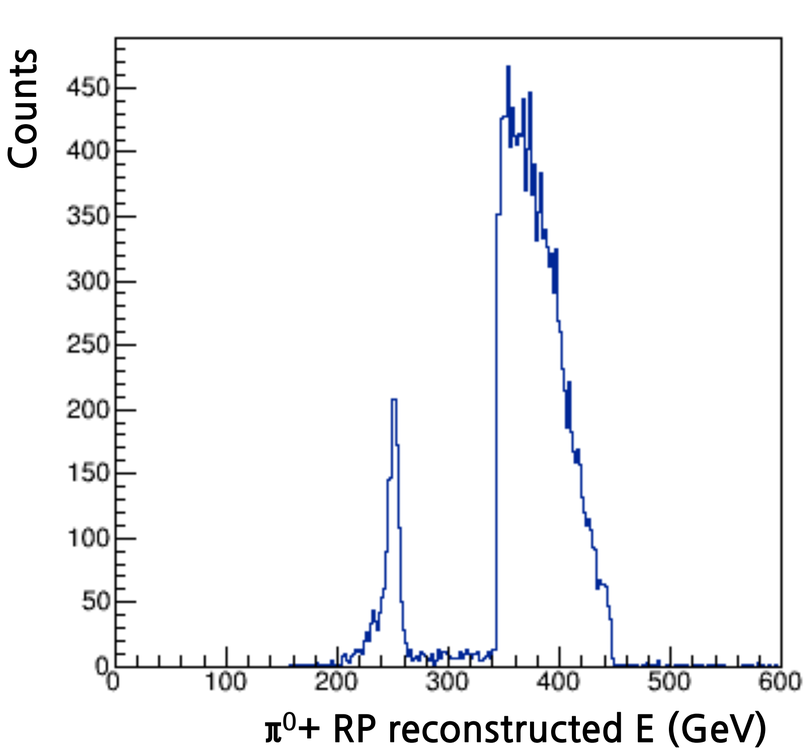
→ Statistics may be limited
In addition, the combinatorial background may be a problem for this analysis.

Other topics (pp → pπ^{0}X)

RHICf + RP at 510 GeV



RHICf + RP at 510 GeV

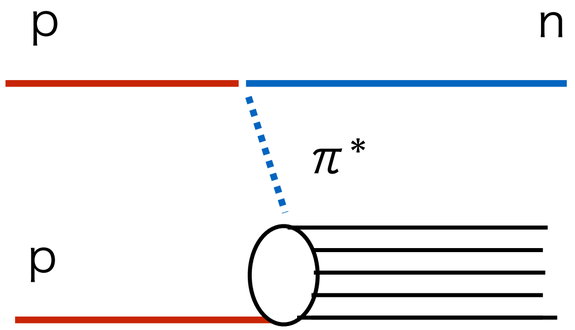


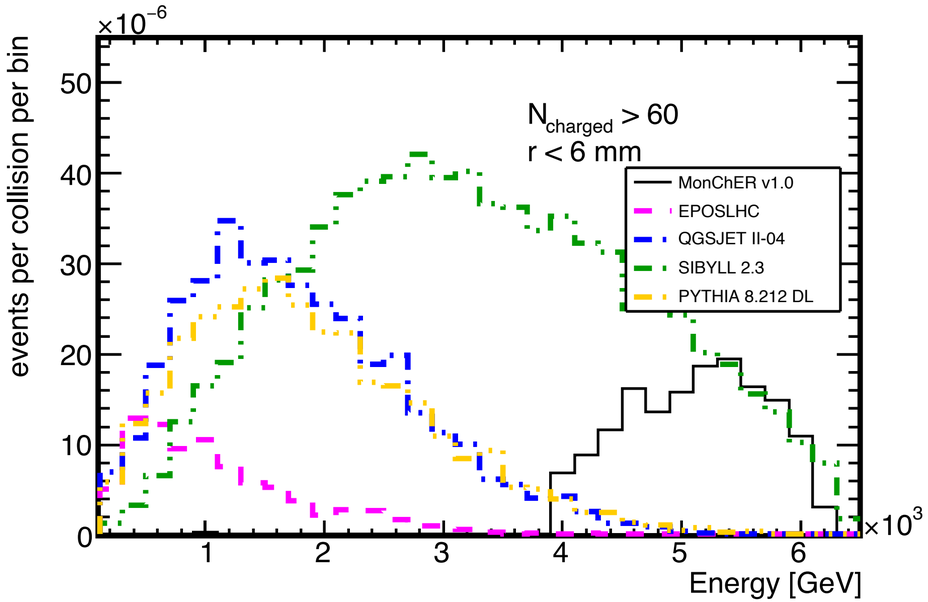
Quick study
of RHICf + STAR RPs
by Minho

- We can study the diffractive pπ^0 channel using Roman pot.
- It was once studied for forward π^0 at STAR and a similar study is currently being proceeded with the diffractive EM jet analysis.
- It will also be interesting if we study the pπ^0 channel with the very forward π^0 production.

Physics case with ZDC

- Improvement of energy resolution for neutrons to 20%
  - ↔ LHCf/RHICf alone : ~40%, (~30% with event selection)
  - General improvement of neutron diff. cross-section measurements
- Measurement of Λ
  - Λ can be a good probe of strange baryon production
  - Detection : $\Lambda \rightarrow n + \pi^0$
- One-Pion-Exchange measurement to study the p-π interaction

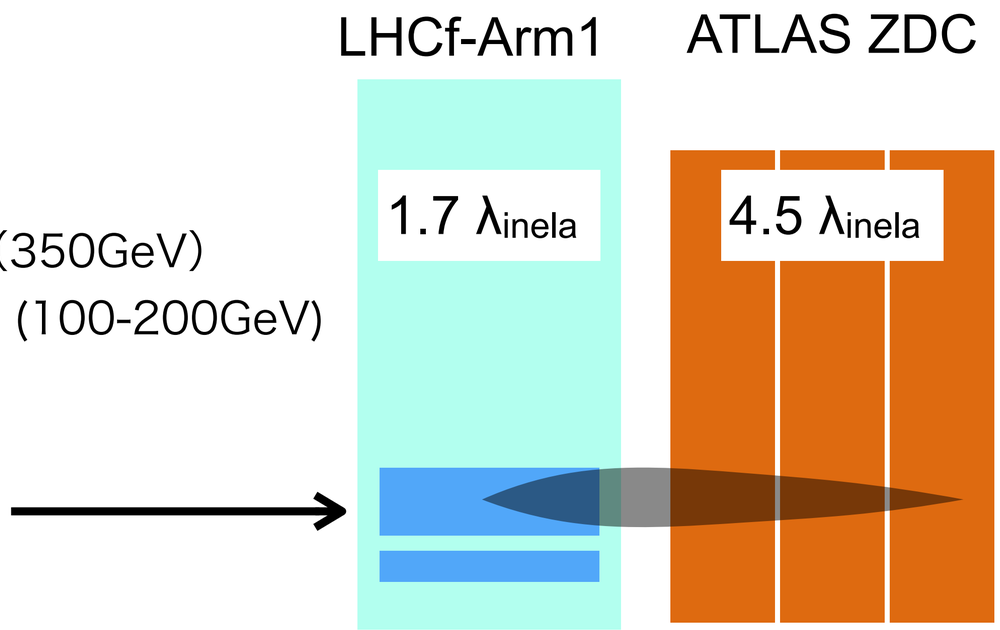


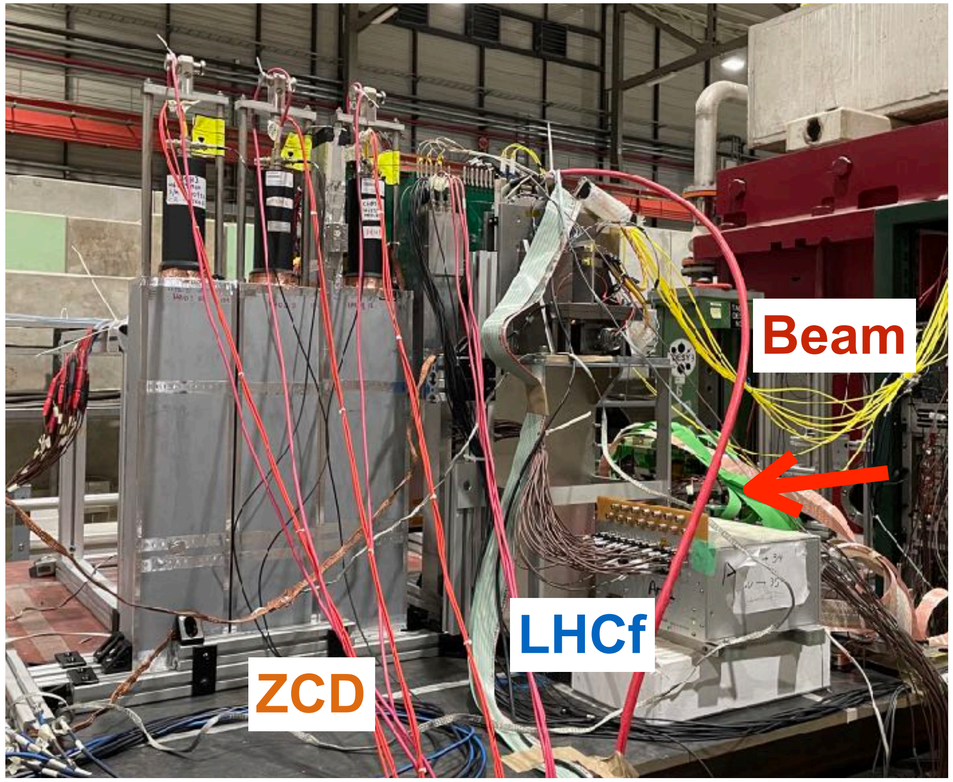


Performance study using SPS

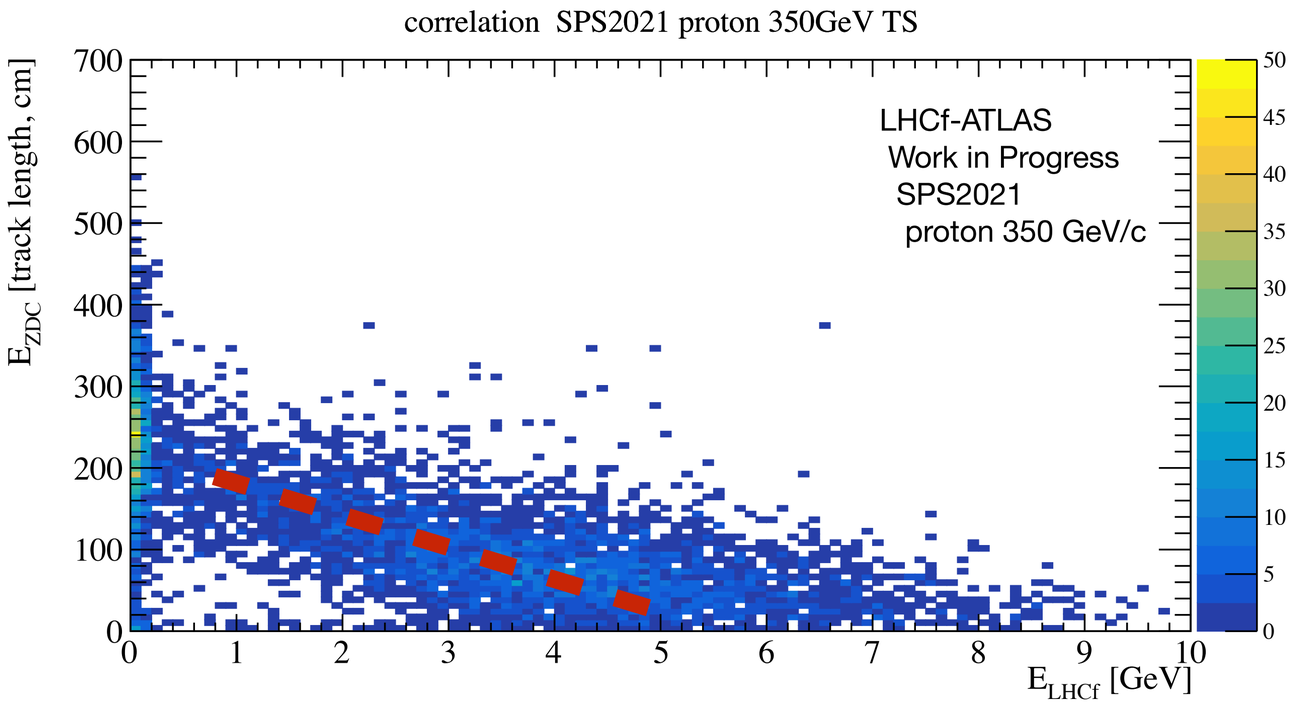
- Joint beam test of LHCf Arm1 + ZDC was performed in 2021.
- Kondo-san confirmed the improvement of resolution to < 20%
  → Kobayashi-san will present a study of the uniformity.

@Beam Test：
Proton beam（350GeV）
Electron beam (100-200GeV)

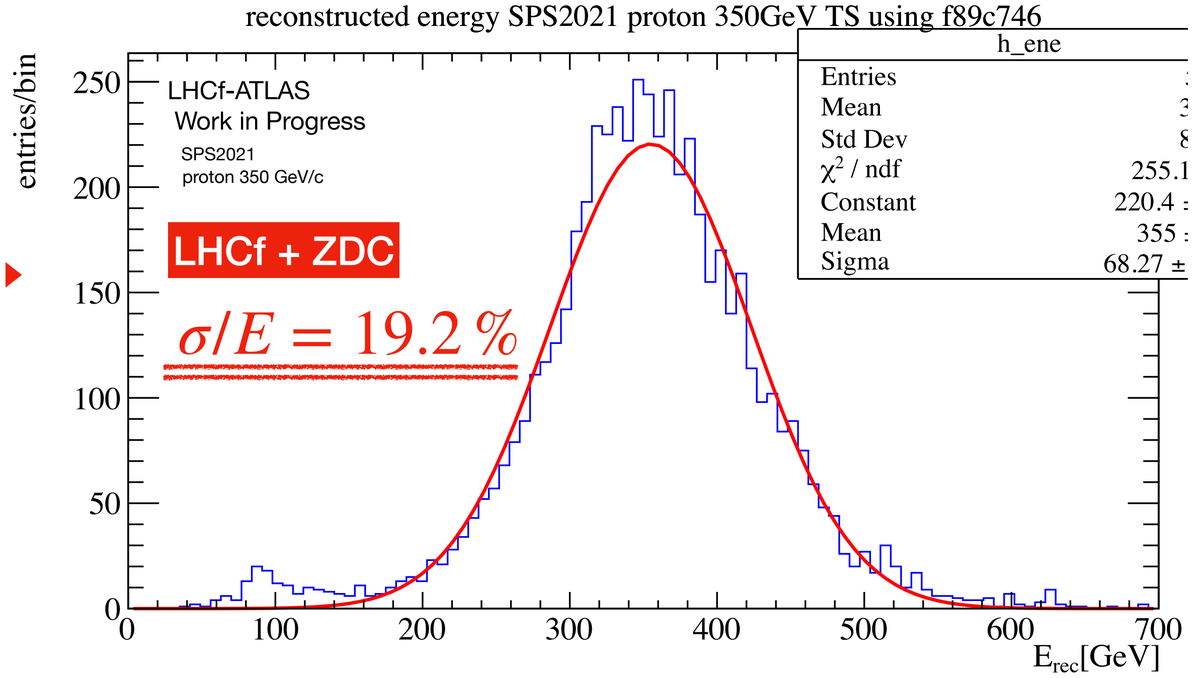




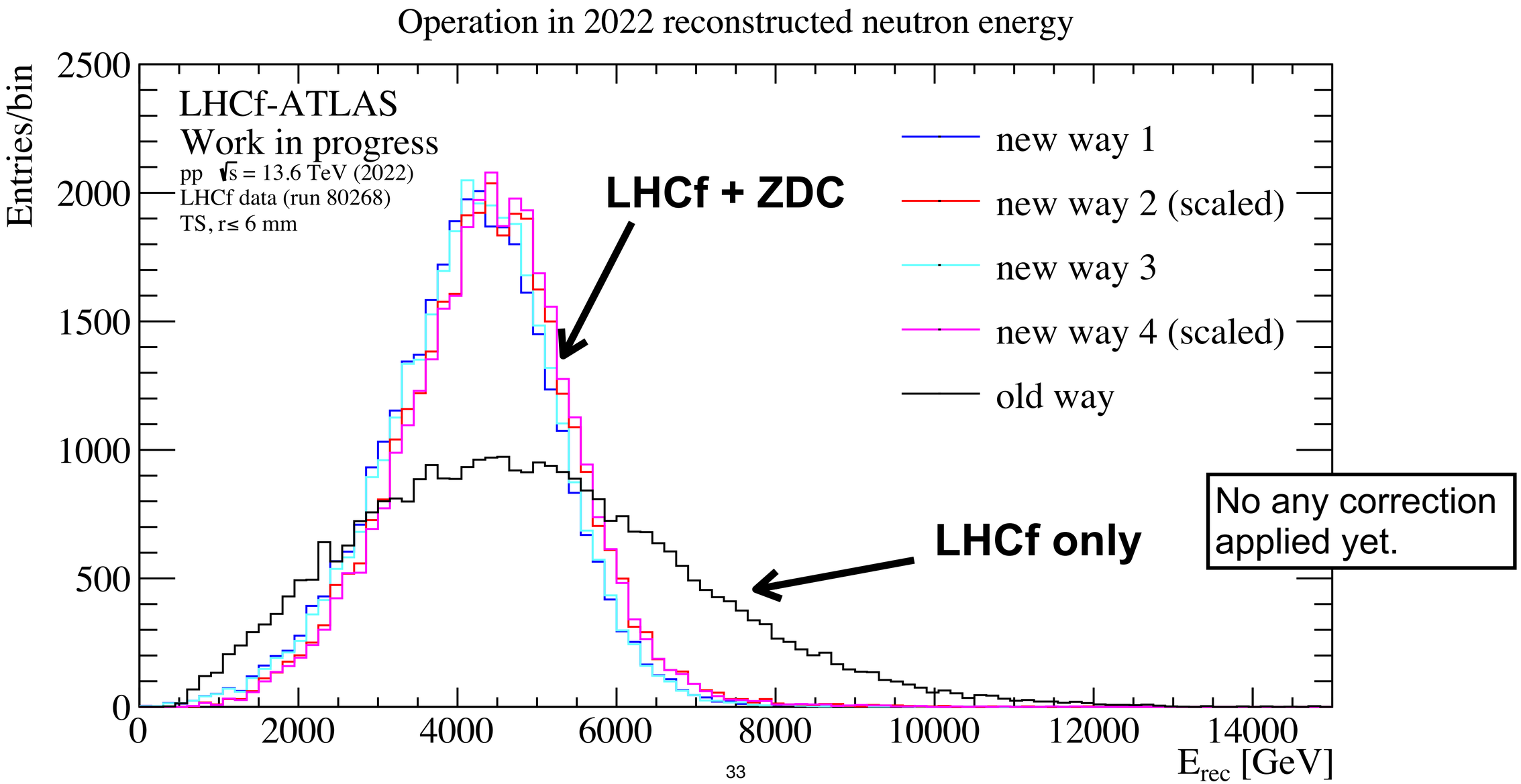
Energy reconstruction of LHCf + ZDC



$E_{est} = E_{LHCf} + \alpha E_{ZDC}$



Quick analysis of LHC data



Backup

$N(1440)\ 1/2^+$

$I(J^P) = \frac{1}{2}(\frac{1}{2}^+)$

Re(pole position) = 1360 to 1380 ($\approx$ 1370) MeV
-2Im(pole position) = 160 to 190 ($\approx$ 175) MeV
Breit-Wigner mass = 1410 to 1470 ($\approx$ 1440) MeV
Breit-Wigner full width = 250 to 450 ($\approx$ 350) MeV

***N*(1440) DECAY MODES**	Fraction (Γ_i/Γ)	p (MeV/c)
$N\pi$	55–75 %	398
$N\eta$	<1 %	†
$N\pi\pi$	17–50 %	347
$\Delta(1232)\pi$, P-wave	6–27 %	147
$N\sigma$	11–23 %	–
$p\gamma$, helicity=1/2	0.035–0.048 %	414
$n\gamma$, helicity=1/2	0.02–0.04 %	413

$\Delta(1232)\ 3/2^+$

$I(J^P) = \frac{3}{2}(\frac{3}{2}^+)$

Re(pole position) = 1209 to 1211 ($\approx$ 1210) MeV
-2Im(pole position) = 98 to 102 ($\approx$ 100) MeV
Breit-Wigner mass (mixed charges) = 1230 to 1234 ($\approx$ 1232) MeV
Breit-Wigner full width (mixed charges) = 114 to 120 ($\approx$ 117) MeV

Δ(1232) DECAY MODES	Fraction (Γ_i/Γ)	p (MeV/c)
$N\pi$	99.4 %	229
$N\gamma$	0.55–0.65 %	259
$N\gamma$, helicity=1/2	0.11–0.13 %	259
$N\gamma$, helicity=3/2	0.44–0.52 %	259
pe^+e^-	$(4.2\pm0.7)\times10^{-5}$	259