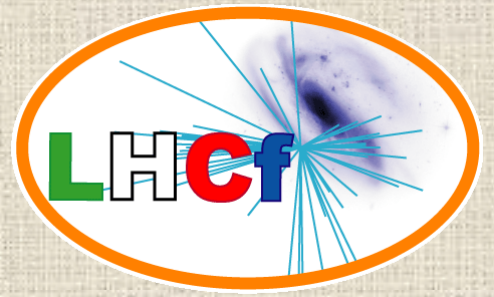



# LHCf; zero degree measurements for cosmic-ray model calibration

Takashi SAKO

(STE lab./KMI, Nagoya University)

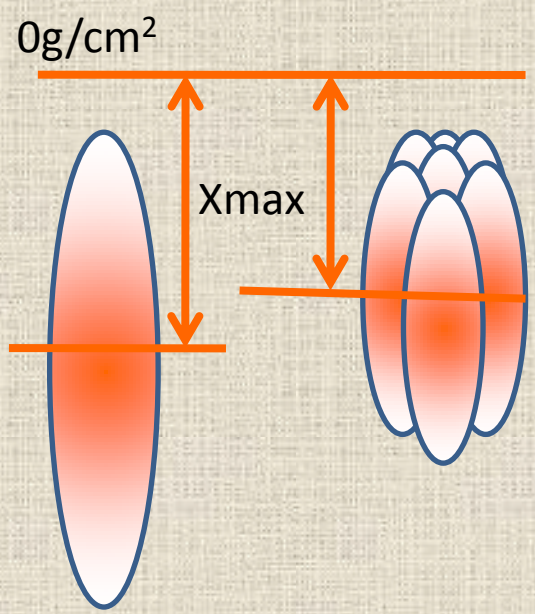
for the LHCf Collaboration

# Contents

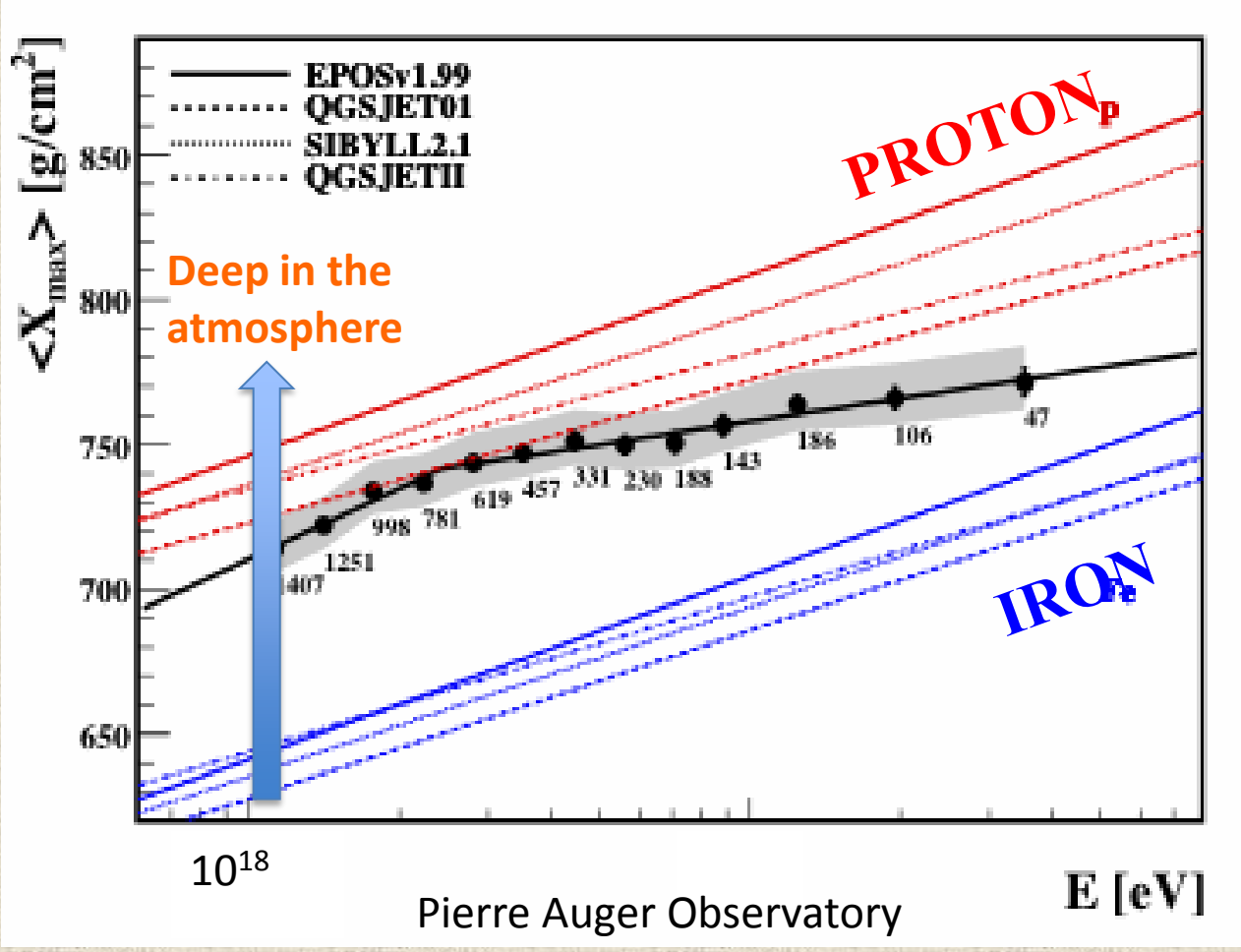
- Physics Motivation
- Experiment
- Results from 0.9 and 7TeV pp collisions
- Low luminosity operation after LS1

# Physics Motivation

# Hadronic interaction model and CR



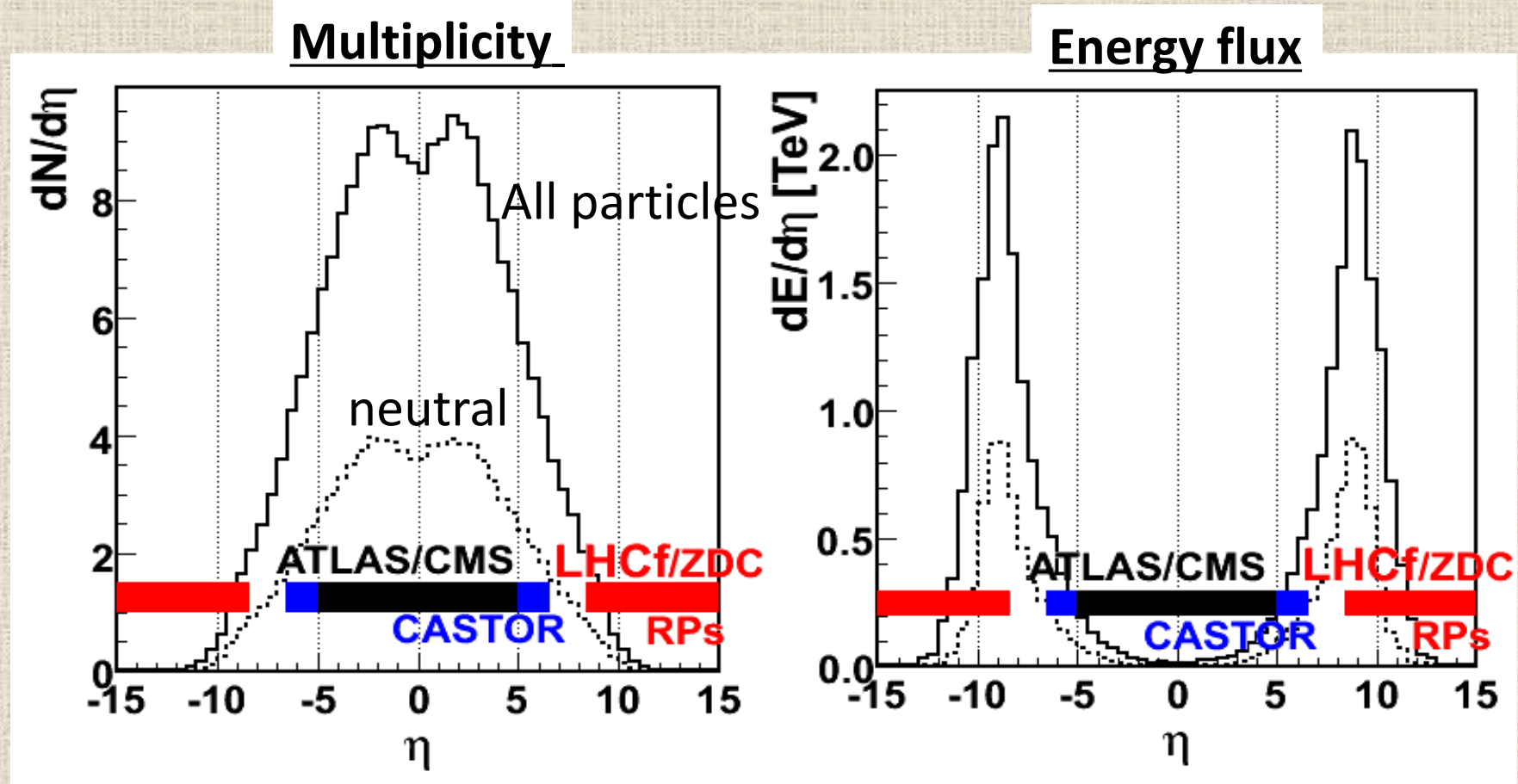

Proton shower and nuclear shower of same total energy




- CRs up to $10^{20}$eV are observed
- Source, nature of the spectral shape, chemical composition (Fig) are unknown
- Players: EPOS, QGSJET, SIBYLL, DPMJET models

# Where to be measured at colliders?

multiplicity and energy flux at LHC 14TeV collisions

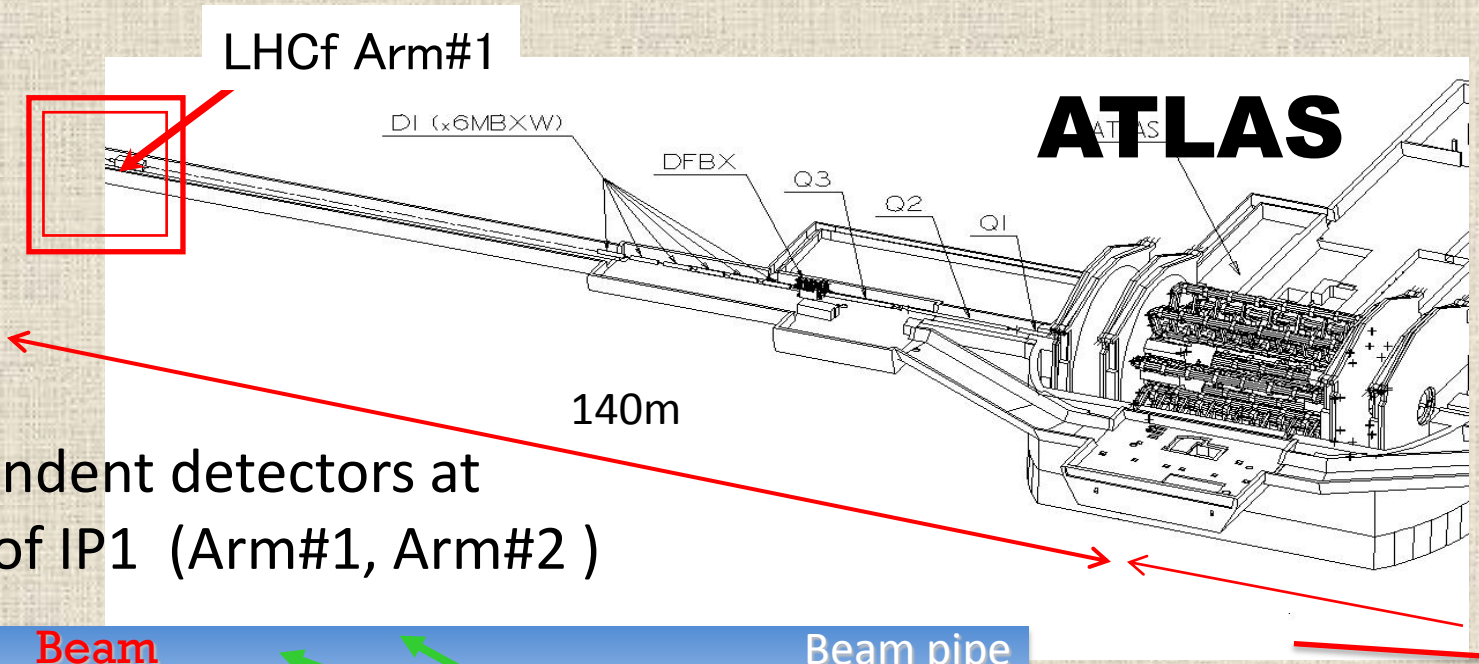



Most of the particles produced into central,

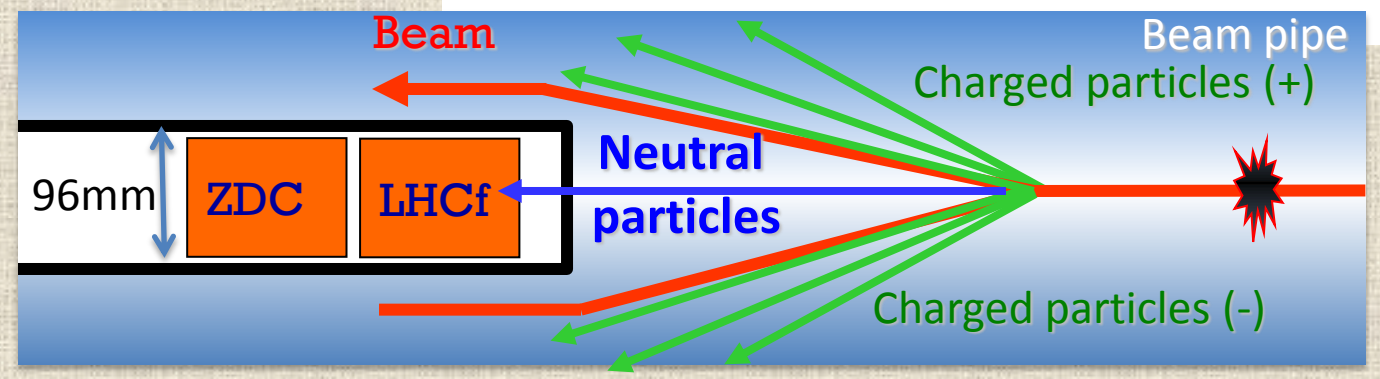
Most of the energy flows into **forward**

# Experiment

# The LHC forward experiment



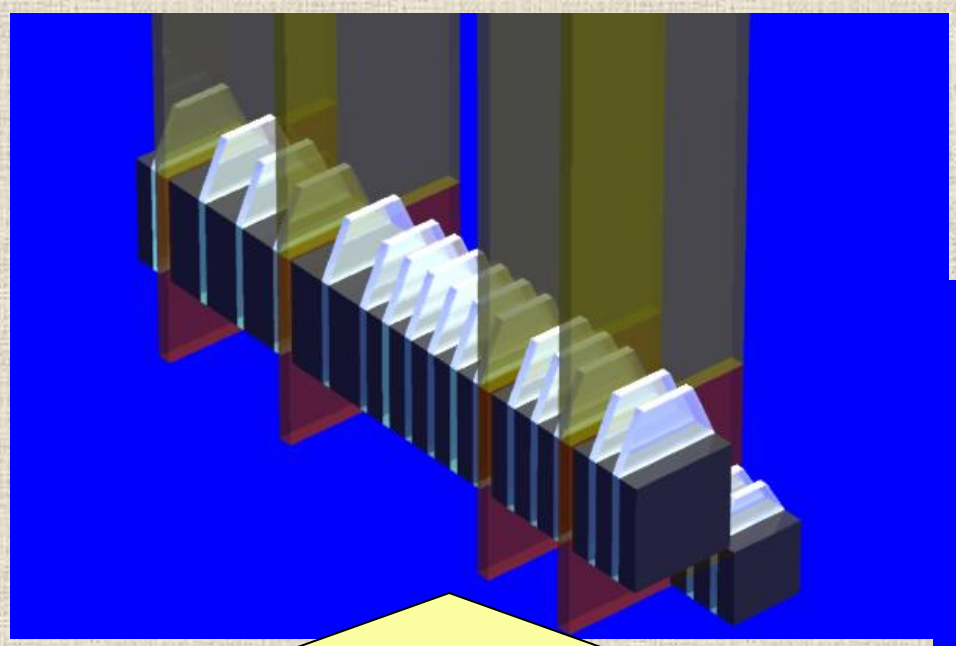

Two independent detectors at either side of IP1 (Arm#1, Arm#2 )




- All charged particles are swept by dipole magnet
- Neutral particles (photons and neutrons) arrive at LHCf
- 0 degree is covered

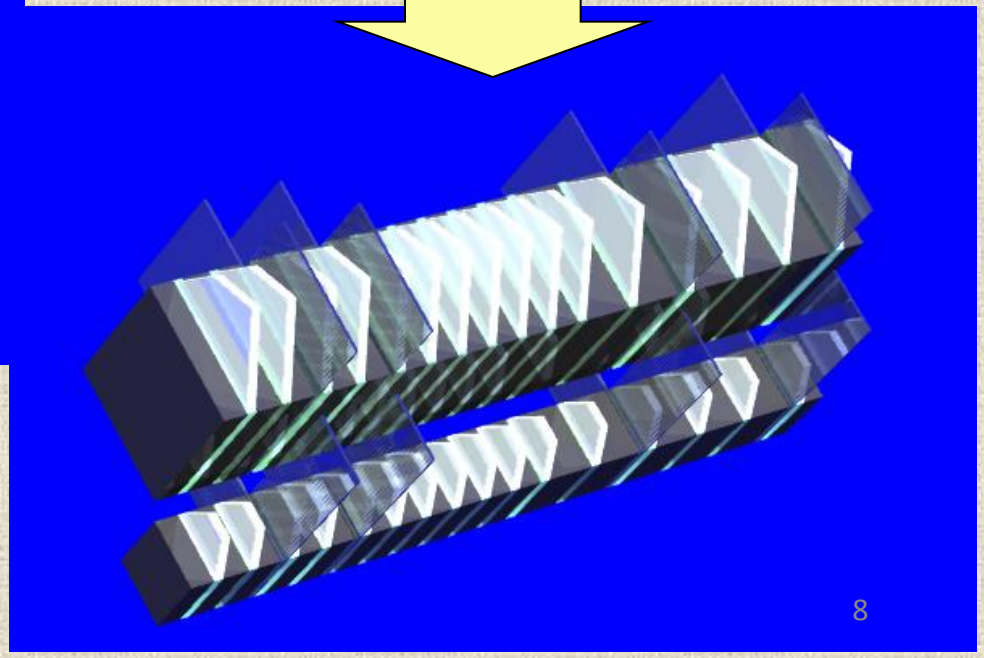
# LHCf Detectors

- ✓ Imaging sampling shower calorimeters
- ✓ Two calorimeter towers in each of Arm1 and Arm2
- ✓ Each tower has 44 r.l. of Tungsten,16 sampling scintillator and 4 position sensitive layers



Arm#2 Detector
25mmx25mm+32mmx32mm
4 XY Silicon strip detectors

Arm#1 Detector
20mmx20mm+40mmx40mm
4 XY SciFi+MAPMT



# LHCf Detectors

- ✓ **Imaging sampling shower calorimeters**
- ✓ **Two calorimeter towers in each of Arm1 and Arm2**
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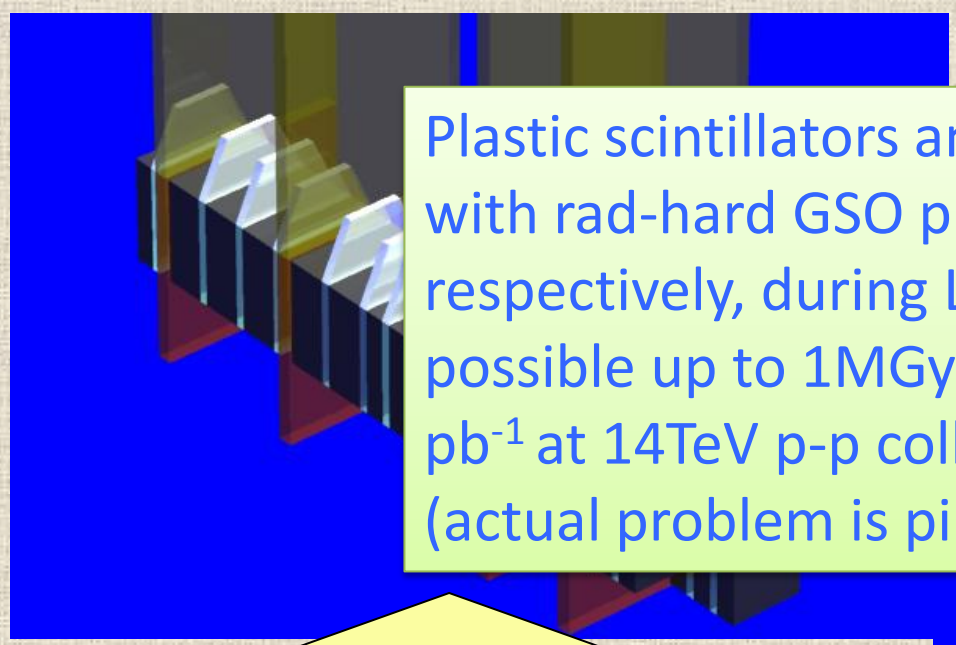


**Arm#1 Detector**
**40mm**

Plastic scintillators and SciFi are replaced with rad-hard GSO plates and GSO bars, respectively, during LS1. Operation is possible up to 1MGy corresponding to 500 $pb^{-1}$ at 14TeV p-p collisions.
(actual problem is pile-up; discuss later)

**Arm#2 Detector**
**25mmx25mm+32mmx32mm**
**4 XY Silicon strip detectors**

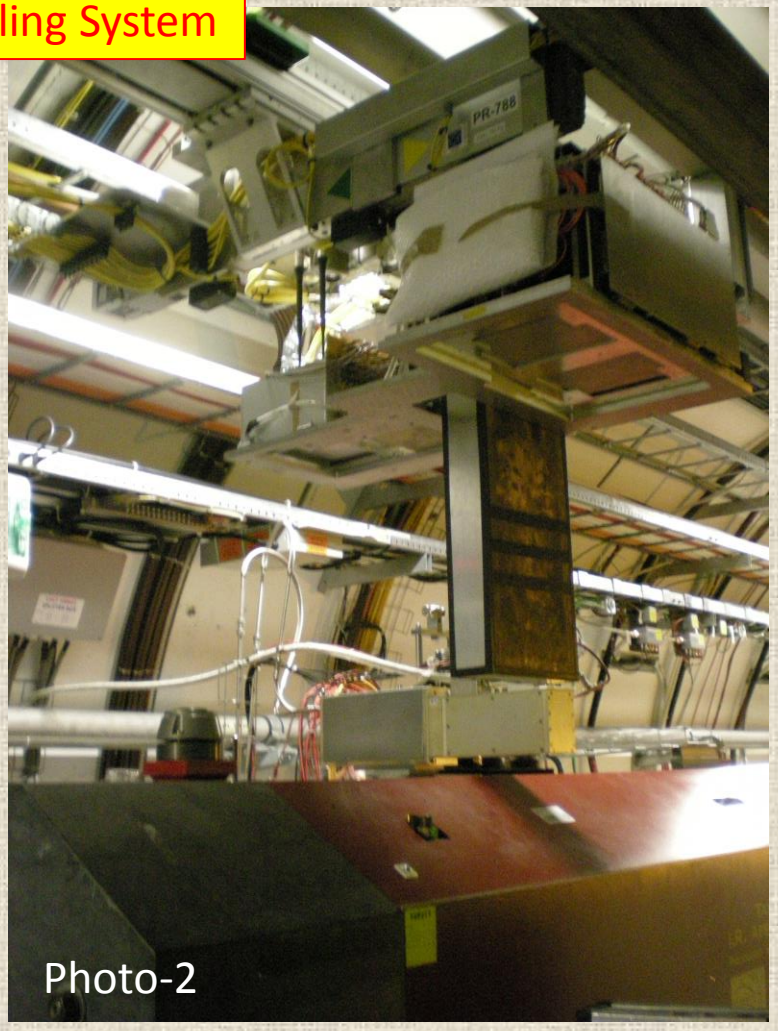
Photo-1

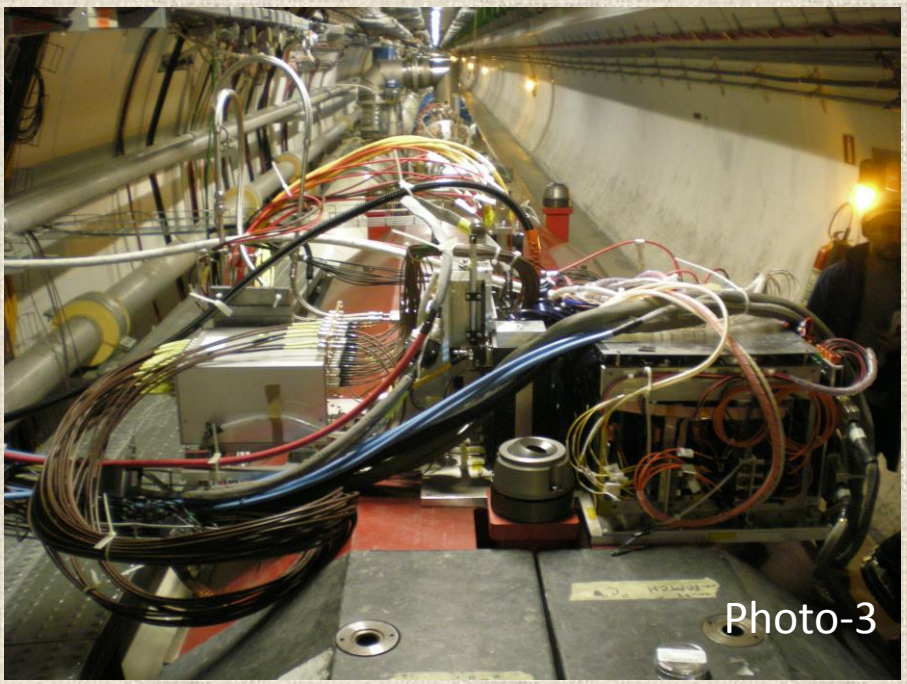
Remote Handling System

LHCf frontend electronics

TAN

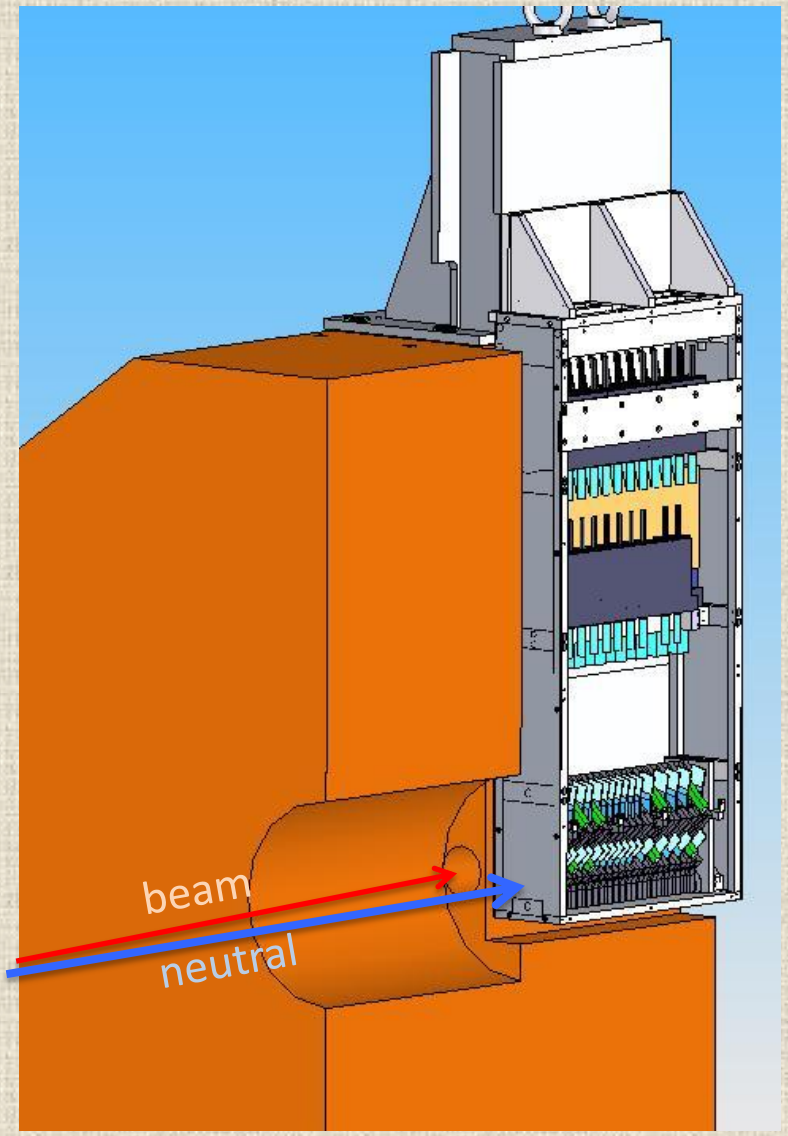
LHCf calorimeter



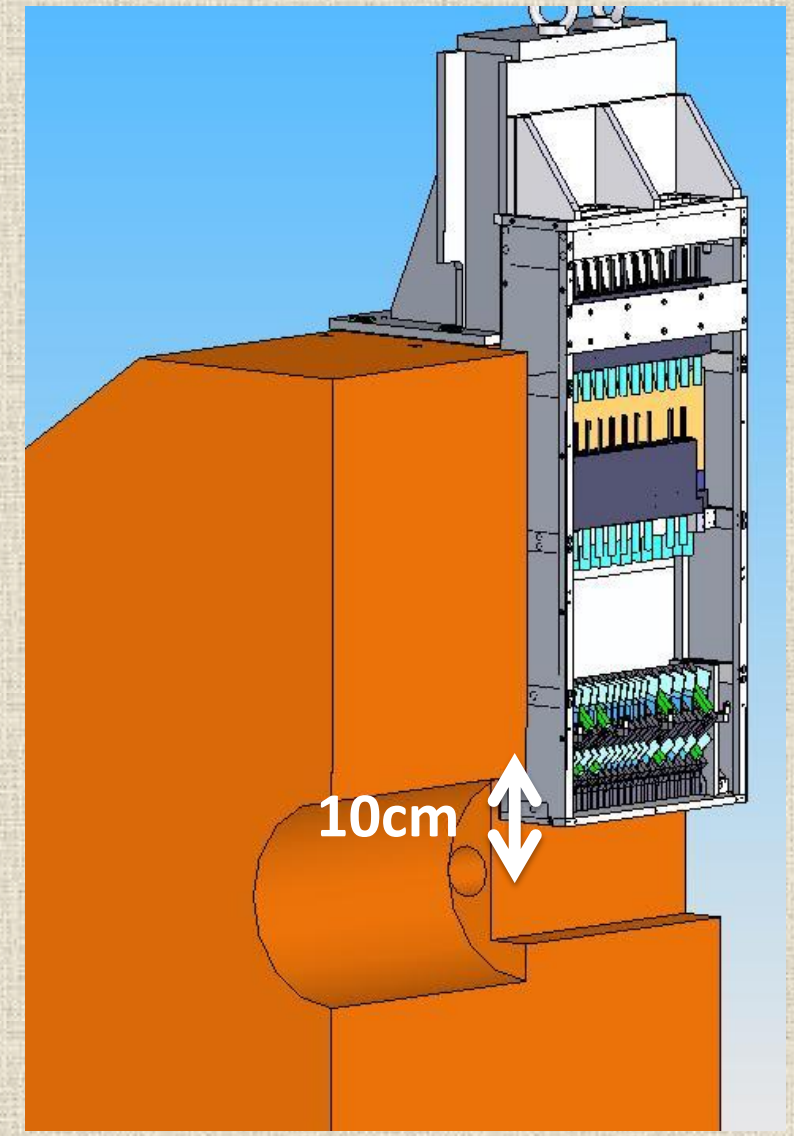



# Vertical movement and scan

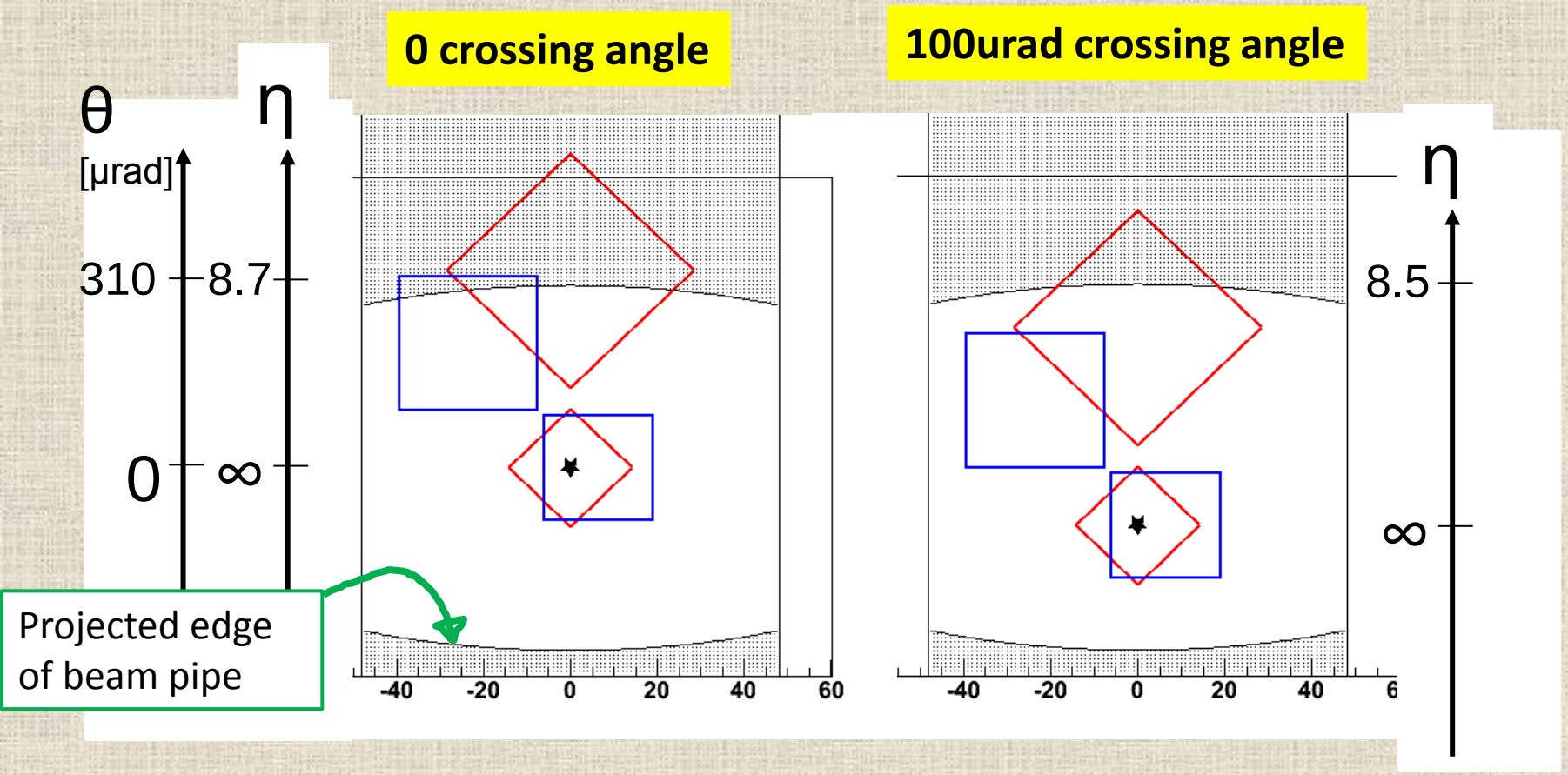
Run position




Garage position to wait stable beams



# Calorimeters viewed from IP

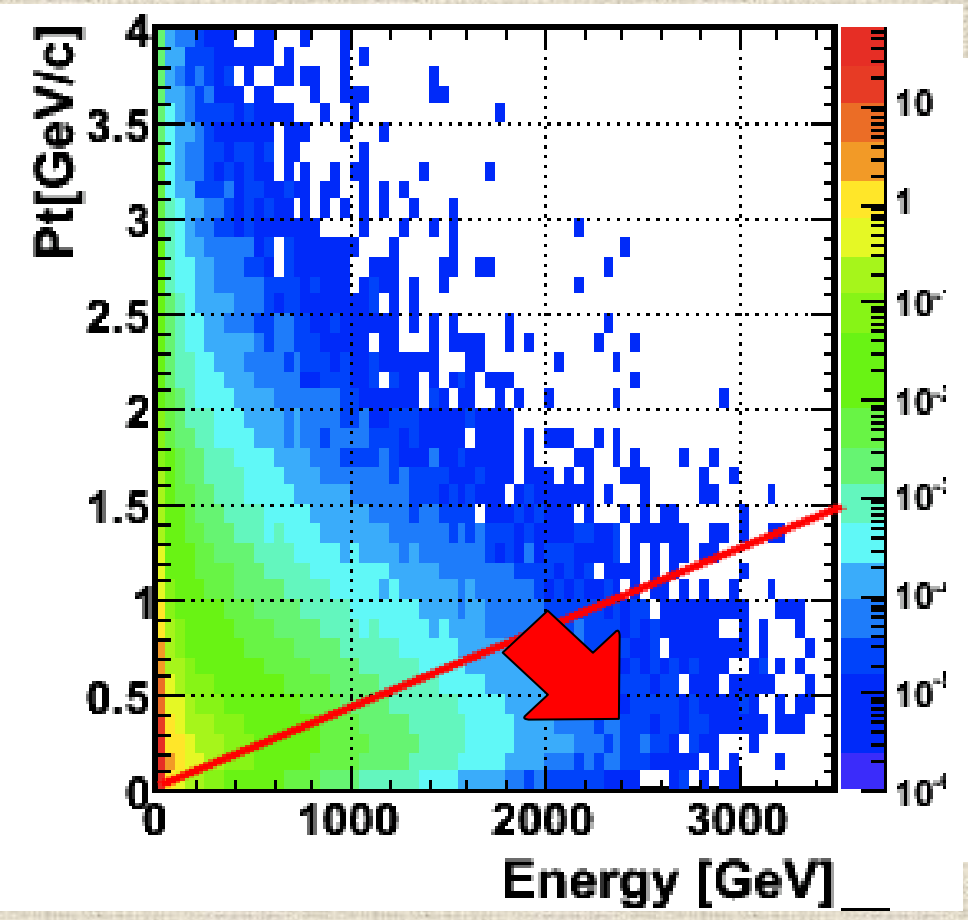



- ✓ Geometrical acceptance of Arm1 and Arm2
- ✓ Crossing angle operation enhances the acceptance

# Which E-$p_T$ range LHCf sees ?

πηοτονσ

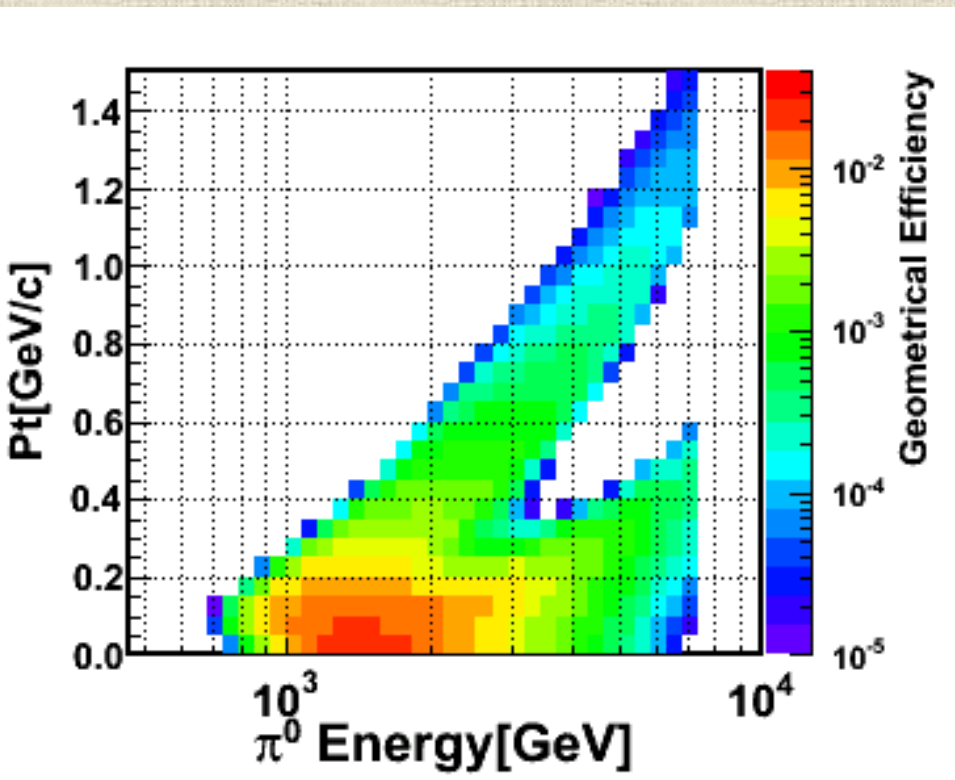
(αχχεπτανχε νοτ χονσιδερεδ)




(pp 7TeV, EPOS)

□⁰ (Αρμ1)

(αχχεπτανχε χονσιδερεδ)



# Results from 900GeV and 7TeV pp collisions

# Summary of LHCf data taking

900 GeV p-p collisions (2009-2010)

- Total of 42 hours for physics (0.3 $nb^{-1}$ delivered)
- About $10^5$ shower events in Arm1+Arm2
- Photon spectra published (2012)

7 TeV p-p collisions (2010) (detectors were removed in Jul. 2010)

- Total of 150 hours for physics with different setups (350 $nb^{-1}$ delivered)
  - ✓ Different vertical position to increase the accessible kinematical range
  - ✓ Runs with or without beam crossing angle
- ~ $4x10^8$ shower events in Arm1+Arm2
- ~ $10^6$ $\pi^0$ events in Arm1 and Arm2
- Photon spectra (2011) and $\pi^0$ spectra (2012) published

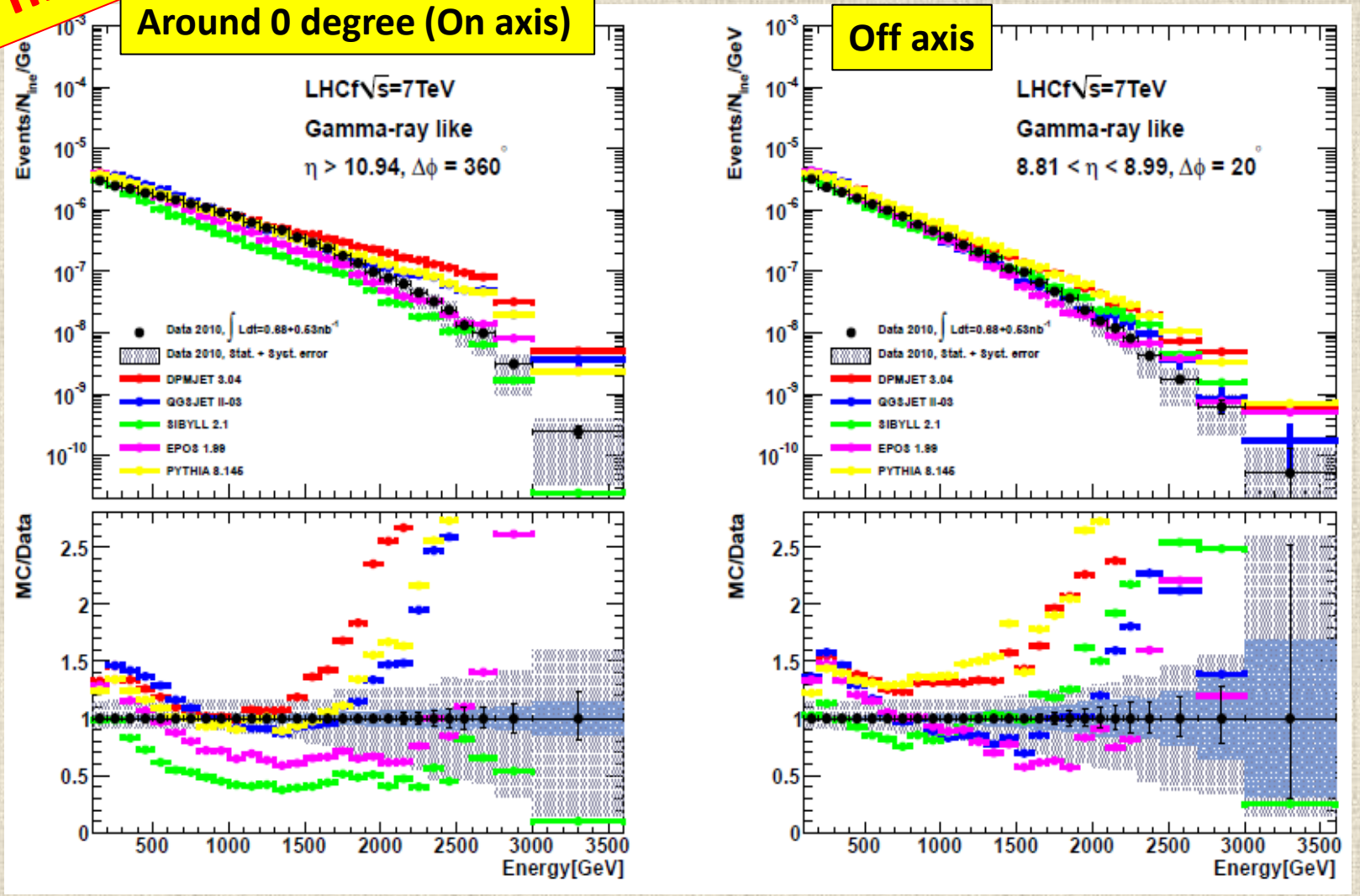
5 TeV ($\sqrt{s_{NN}}$) p-Pb and 2.76 TeV p-p collisions (2013) (only Arm2 reinstalled)

- $1.6x10^8$ shower events in p-Pb
- $5x10^6$ shower events in p-p
- ATLAS was triggered by LHCf at 20-40 Hz
- 0.8m $\beta^*$ in p-Pb made a wide beam dispersion ☹

# Photon spectra @ 7TeV (Data vs. Models)

Adriani et al., PLB, 703 (2011) 128-134

**0.7 nb$^{-1}$**

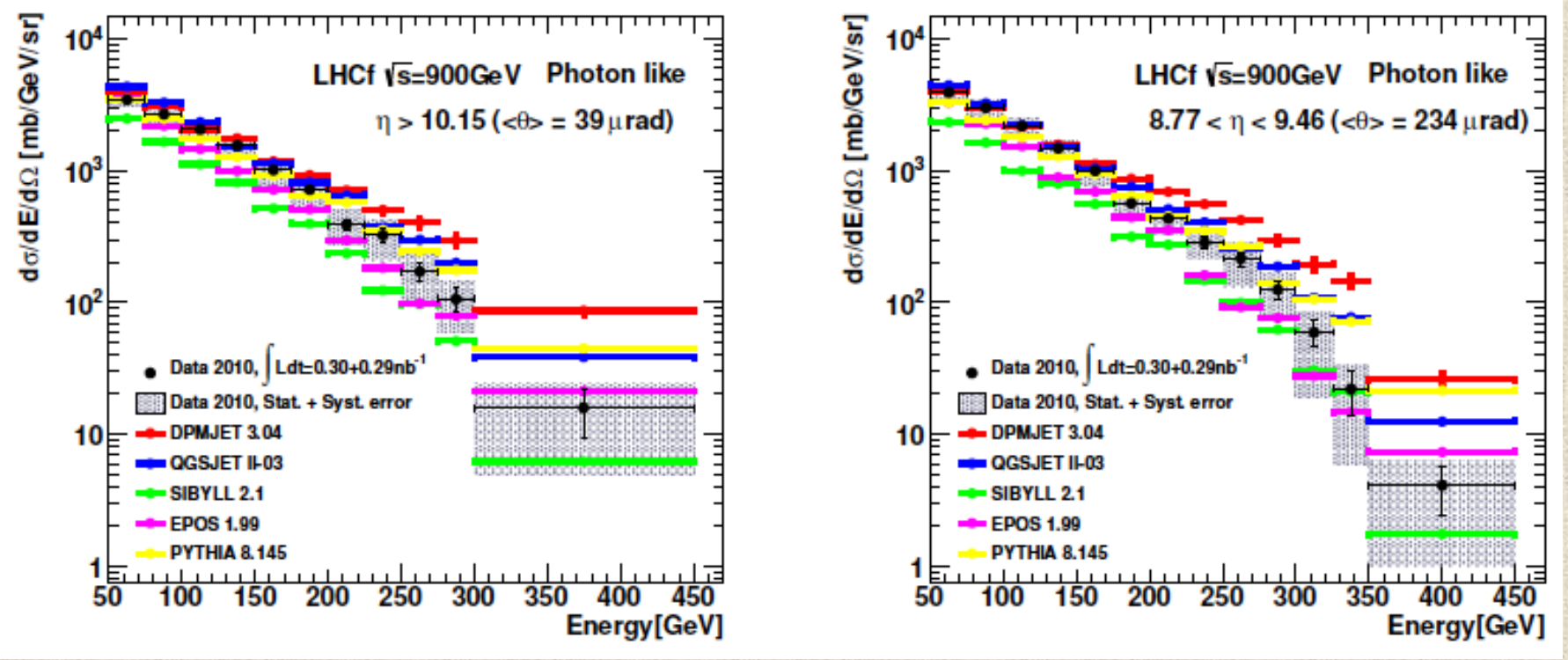



DPMJET 3.04 QGSJET II-03 SIBYLL 2.1 EPOS 1.99 PYTHIA 8.145

# Photon spectra @ 900GeV

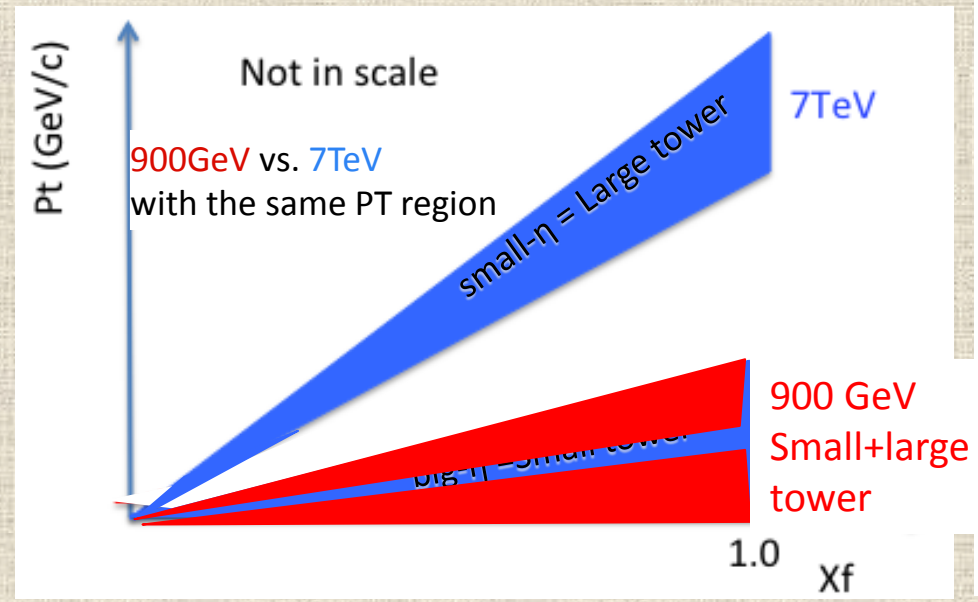
0.3 nb$^{-1}$

Adriani et al., PLB, 715 (2012) 298-303

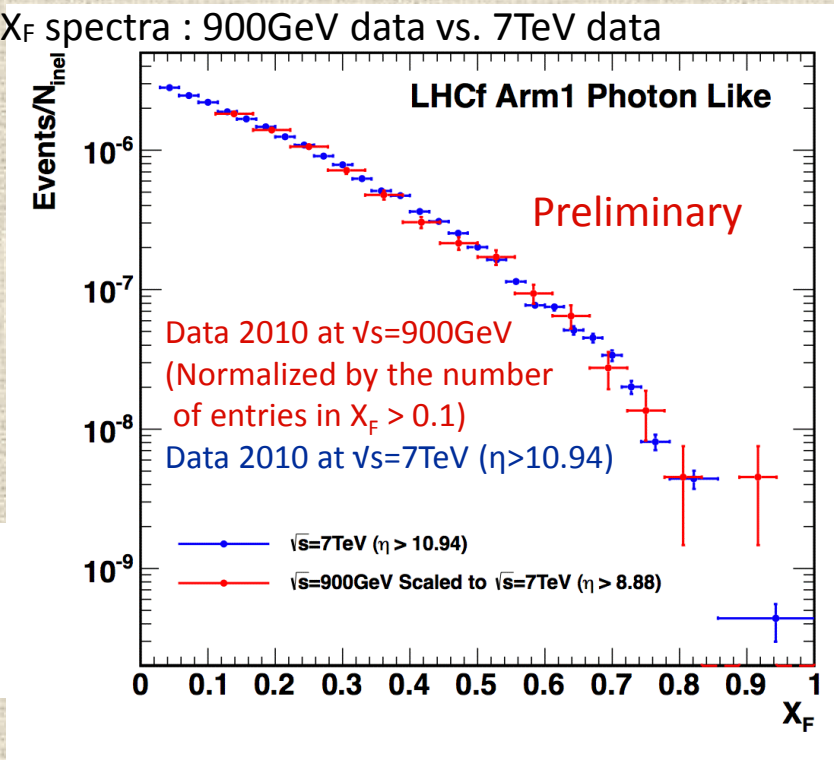


# 900GeV vs. 7TeV

*LHCf coverage in $X_F$-$p_T$ plane*
*($X_F = E/E_{beam}$)*




$X_F$ spectra : 900GeV data vs. 7TeV data



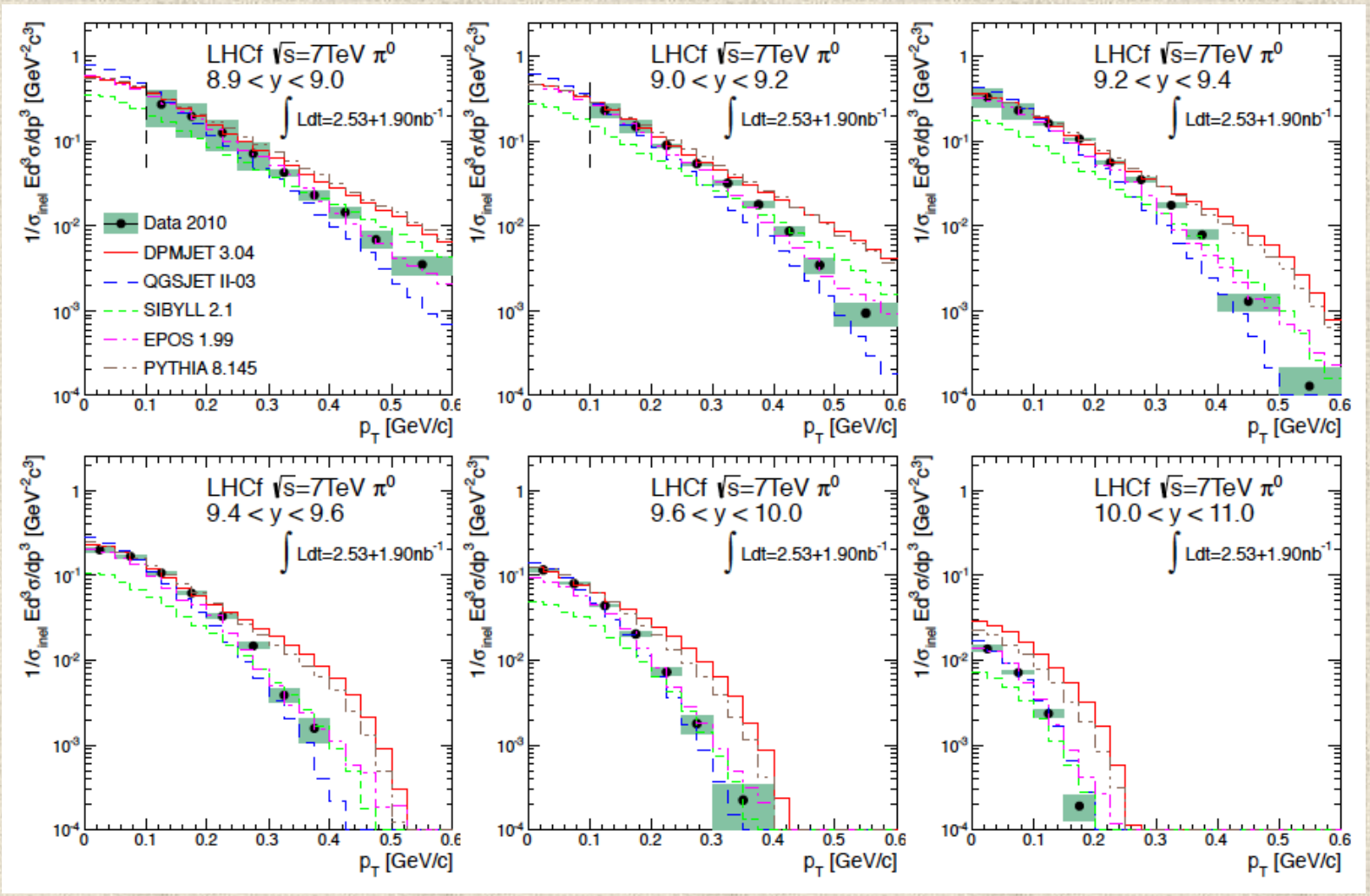

- ✓ Normalized by # of evnets$X_F > 0.1$
- ✓ Statistical error only

Good agreement of $X_F$ spectrum shape between 900 GeV and 7 TeV.
What will happen at 13 TeV and beyond?

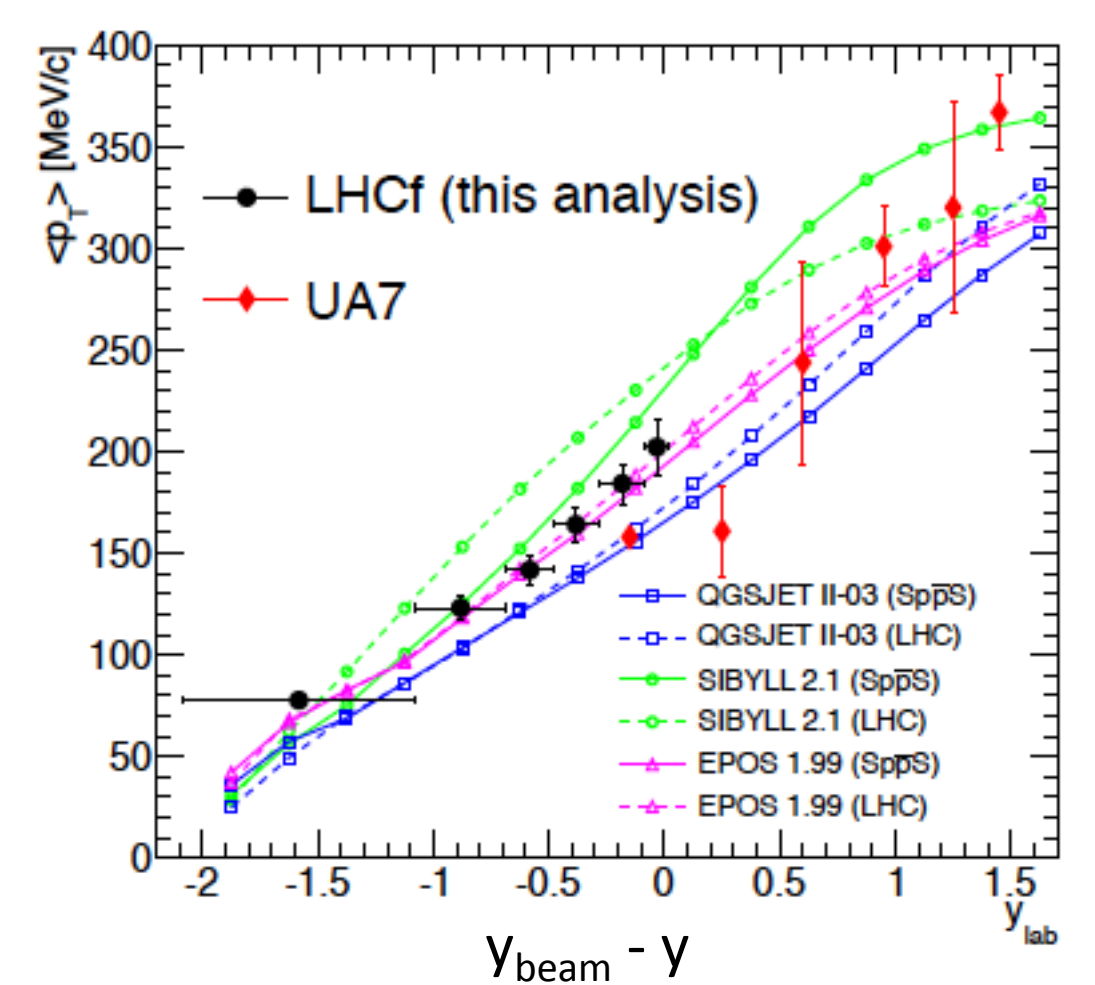
# $\pi^0$ $p_T$ distribution in different rapidity (y) ranges

2.5 nb$^{-1}$

Adriani et al., PRD, 86, 092001 (2012)



# $\pi^0$ <$P_T$>




<$p_T$> comparison with UA7 at 630GeV
(Pare et al., PLB, 242, 531 (1990))

# Low luminosity operation after LS1

# Operation at 13 TeV p-p

- **Physics**
  - Highest possible accelerator energy ($E_{lab}$=$10^{17}$eV) to approach CR region
  - Test √s scaling (or dependence) from 900GeV to extrapolate over 13 TeV
- **(minimum) Statistics**
  - Several sets of 1nb$^{-1}$ collision data in early period (even during machine commissioning)
- **Constraints**
  - DAQ limits >2us event interval
  - DAQ speed <1kHz
  - Negligible pile-up => O(0.01)
  - Small collision angle dispersion <10urad; high $\beta^*$
- **Ideal beam requirements**
  - $N_b$=43, L=5x$10^{28}$ cm$^{-2}$ s$^{-1}$ => 1nb$^{-1}$/5h (UNIT)
  - $\beta^*$>≈5m ; just unsqueezed collision
- **Operation requirements**
  - Several sets of UNIT operation
  - Two operation periods (pilot and main) separated by a week

# Summary

- **LHCf is**
  - Motivated to improve CR simulations
  - A kind of ZDCs installed in the TANs at IP1
  - Capable to test models with ≈ $nb^{-1}$ of data
  - Upgrading the detectors to be rad-hard during LS1, enabling operation up to 500 $pb^{-1}$
  - Hoping 0(10$nb^{-1}$) of low luminosity (<$10^{29}$) operation after LS1
  - Interested in joining the discussion for p-Pb after LS1
  - Interested in future light ion collisions for CR physics

# To classify various requests…

## (No machine duty cycle considered)