Observation of diffraction in pp-collisions at 0.9, 2.36 and 7 TeV at the LHC

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on behalf of the
CMS collaboration

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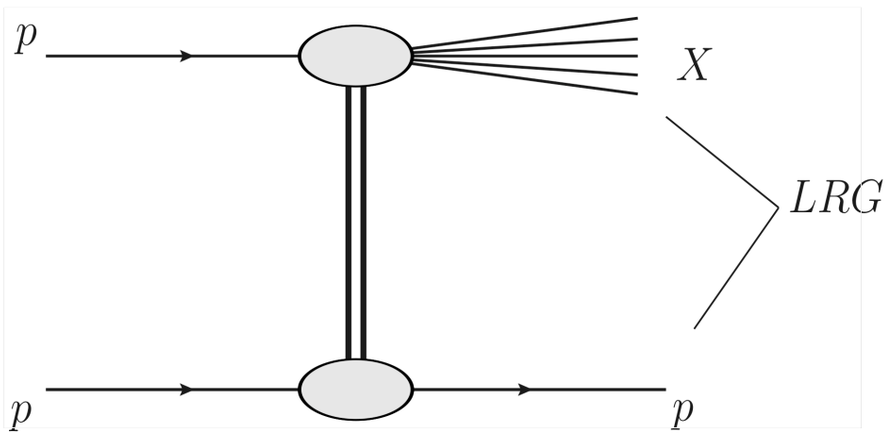
CMS

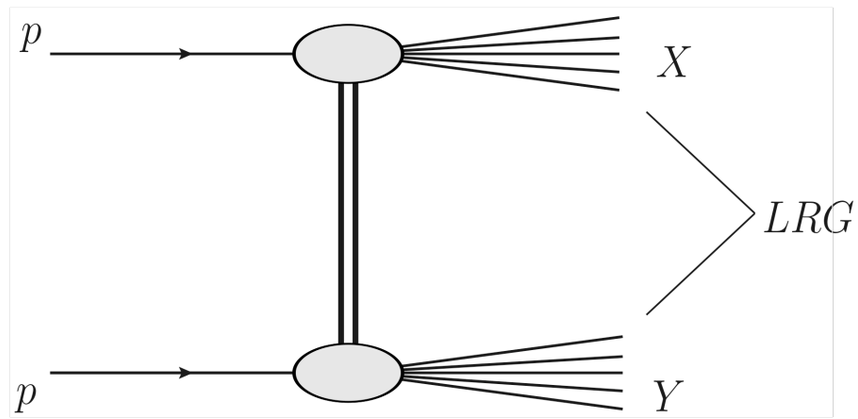
Diffraction in pp-interactions

- diffractive events correspond to a substantial fraction of the minimum-bias data-set

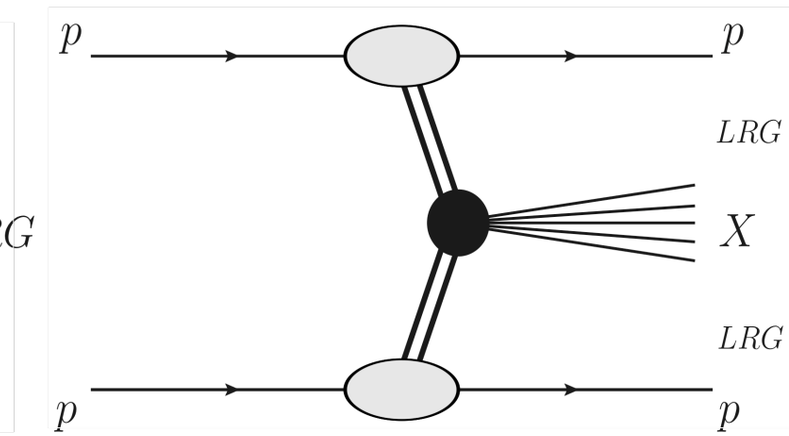
Single-diffractive dissociation (SD):



Double-diffractive dissociation (DD):

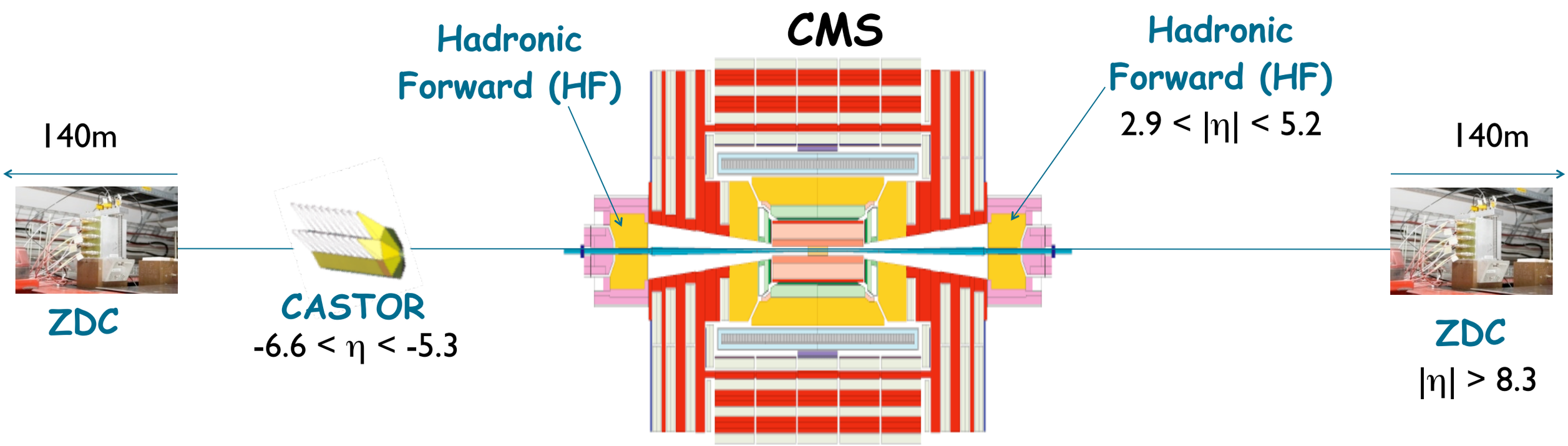


Central-diffractive dissociation (CD):



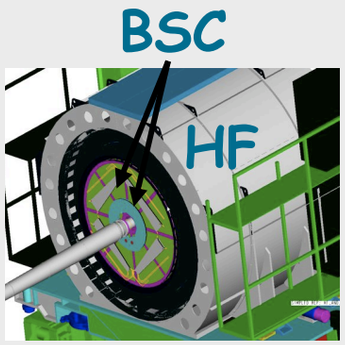
- modeling of soft diffraction is in general generator specific, process classification is often arbitrary
- defining and constraining diffractive interactions and their evolution with √s is an important ingredient in the understanding and tuning of minimum-bias at the LHC
- in this presentation: single-diffractive dissociation
  - ➡ PAS FWD-10-001: Observation of diffraction at 900 and 2360 GeV (published in June 2010)
  - ➡ PAS FWD-10-007: Observation of diffraction at 7 TeV

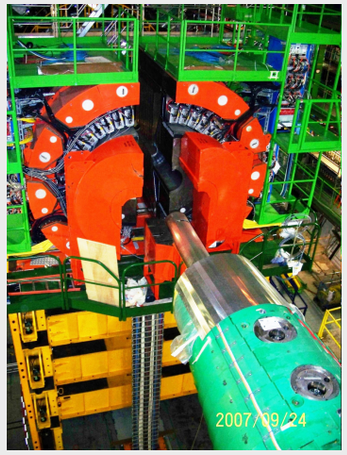
Forward detectors at CMS



Hadron Forward:

- at 11.2 m from interaction point
- rapidity coverage: 2.9 < |η| < 5.2
- steel absorbers and embedded quartz fibers

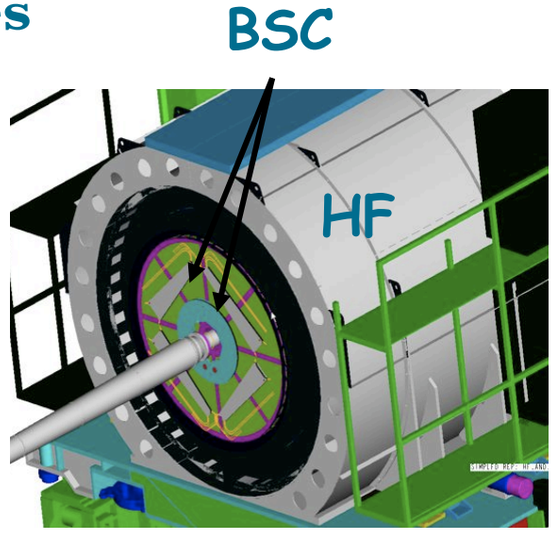




Selection of SD events

CMS data used in these analyses

- 10 μb^{-1} at $\sqrt{s}$ = 0.9 TeV
- 0.4 μb^{-1} at $\sqrt{s}$ = 2.36 TeV
- 20 μb^{-1} at $\sqrt{s}$ = 7 TeV



trigger

- signal in Beam Pickup Timing eXperiment (BPTX) from both beams passing the IP
- signal in either of the Beam Scintillator Counters (BSC) (coincidence of BSCs would suppress SD signals)

offline event selection

- high quality primary vertex
- beam halo and beam background rejection
- calorimeter noise cleaning

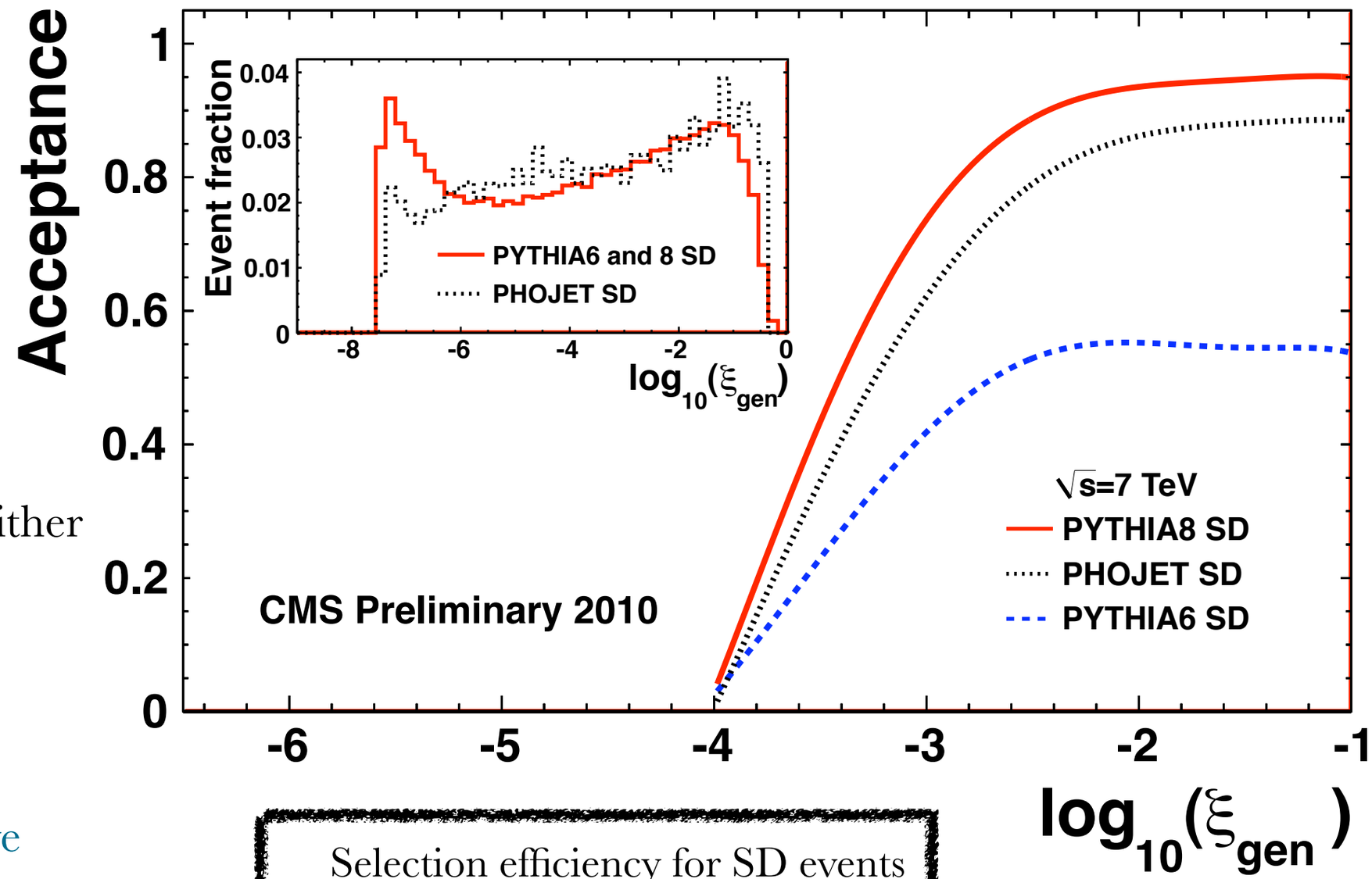
➡ largest possible acceptance for SD events with low beam related backgrounds (<1%)

Acceptance for SD events - 7 TeV

fractional energy loss of the scattered proton p in pp → pX:

$$\xi = M_X^2/s$$

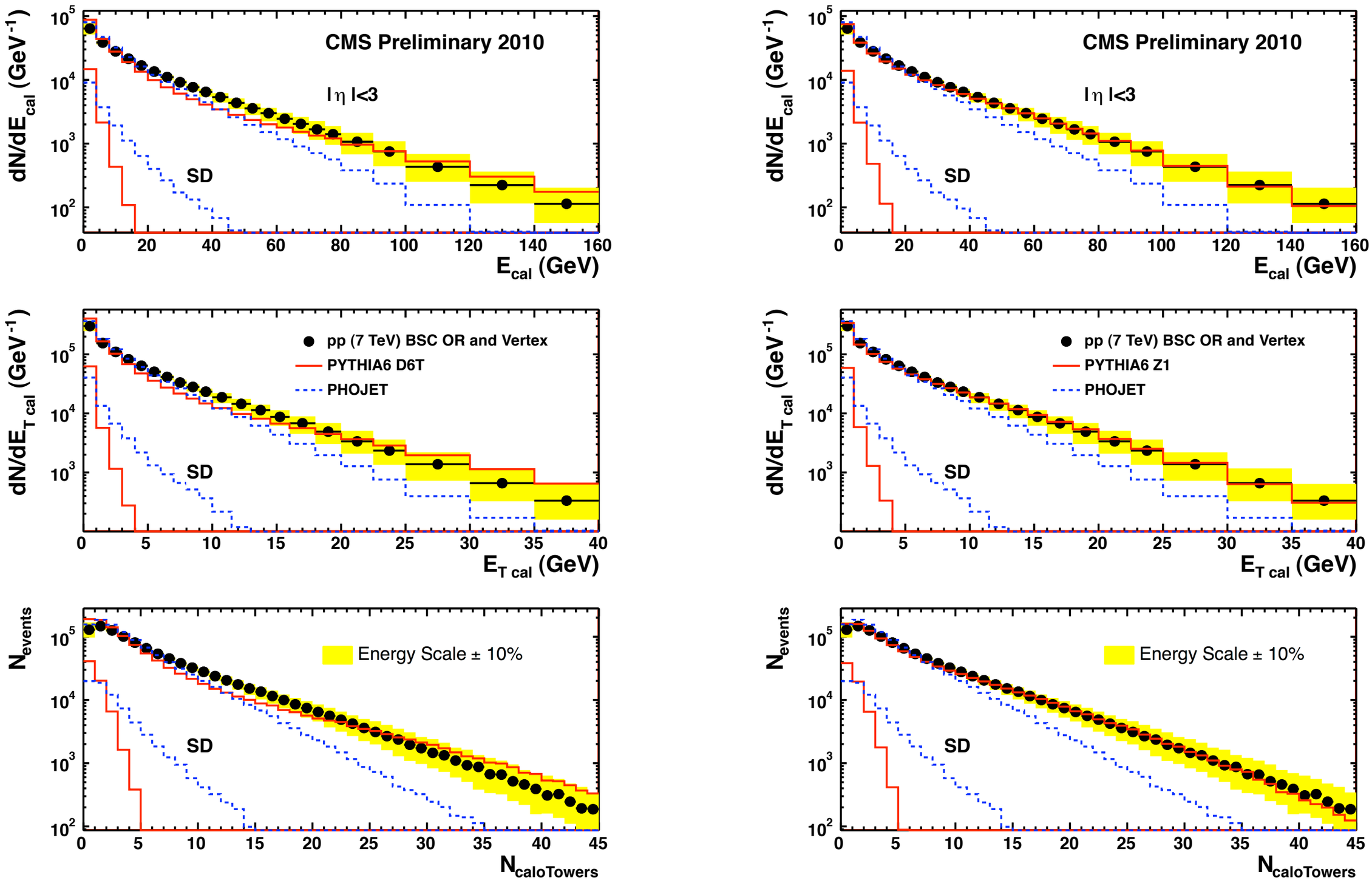
- large discrepancy between PYTHIA6 with respect to either PYTHIA8 or PHOJET
  - ➡ different simulation of diffractive system fragmentation
  - ➡ absence of hard diffractive processes in PYTHIA6
- low-ξ events are mainly rejected by vertex selection



Selection efficiency for SD events

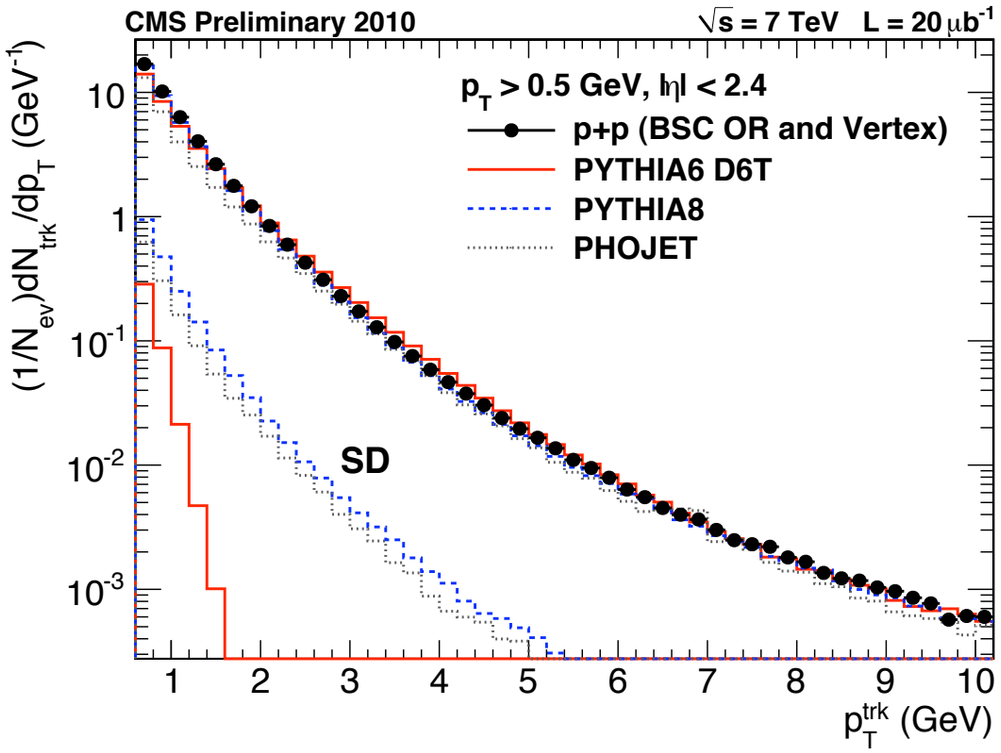
- PYTHIA6 D6T: 25%
- PYTHIA8: 43%
- PHOJET: 42%

Inclusive calorimeter distributions - central region - 7 TeV

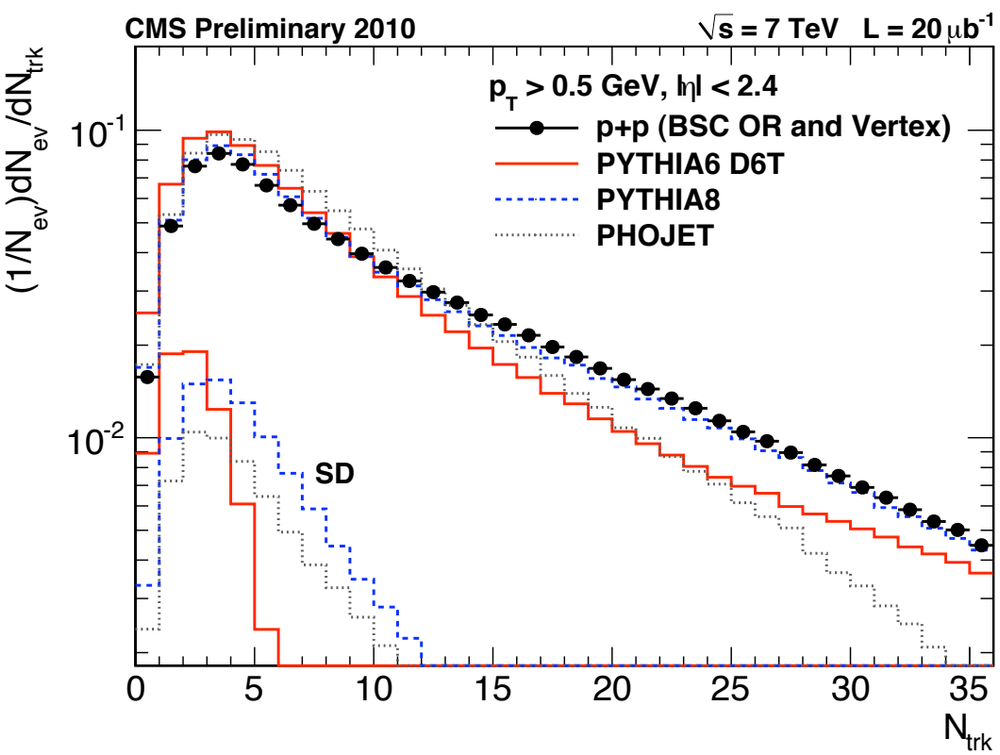


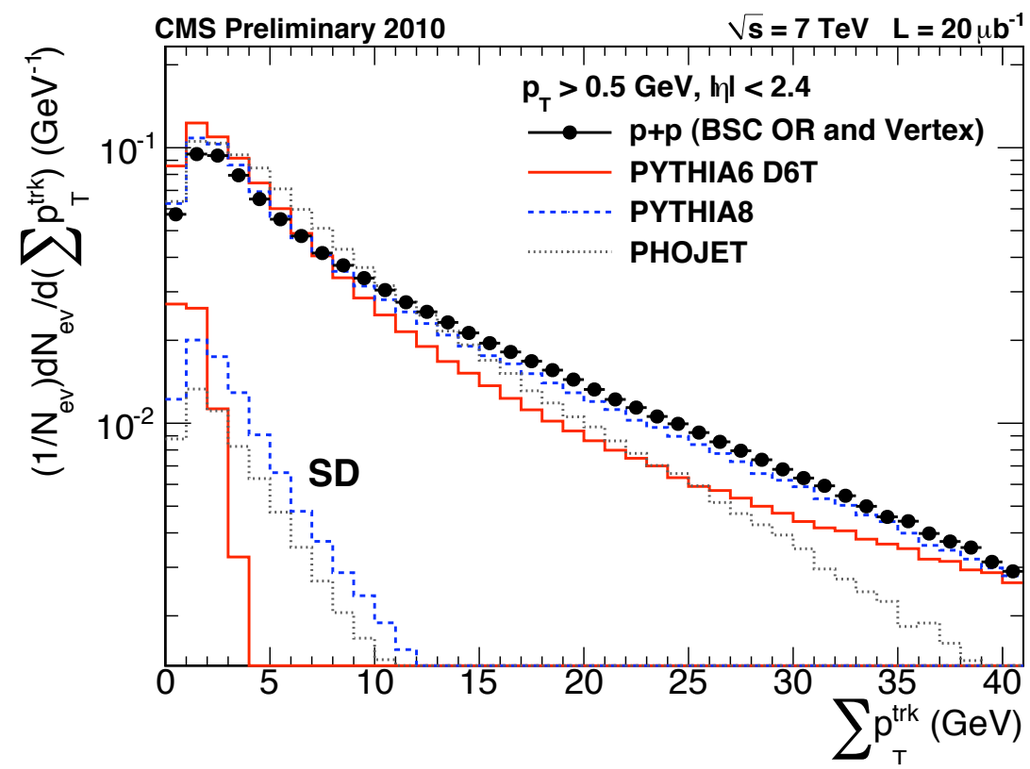
NB: all distributions in this talk are uncorrected

Inclusive tracker distributions – 7 TeV



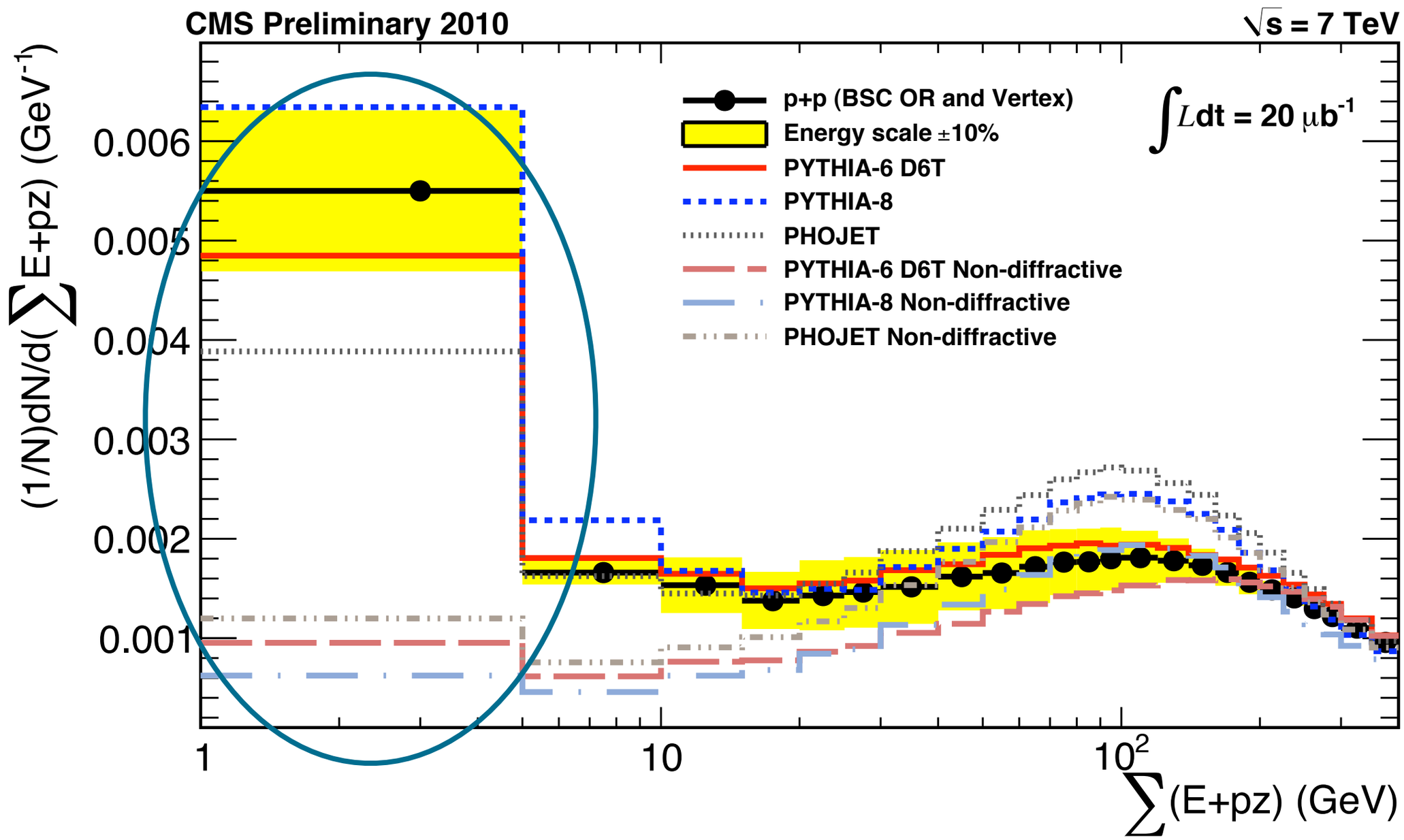
- considerably higher activity in SD events from PYTHIA8 and PHOJET
- all PYTHIA6 tunes have exactly the same description of diffractive component
- PYTHIA6 D6T and PHOJET describe poorly non-diffractive high multiplicity tails
- PYTHIA8 gives a fair description of data





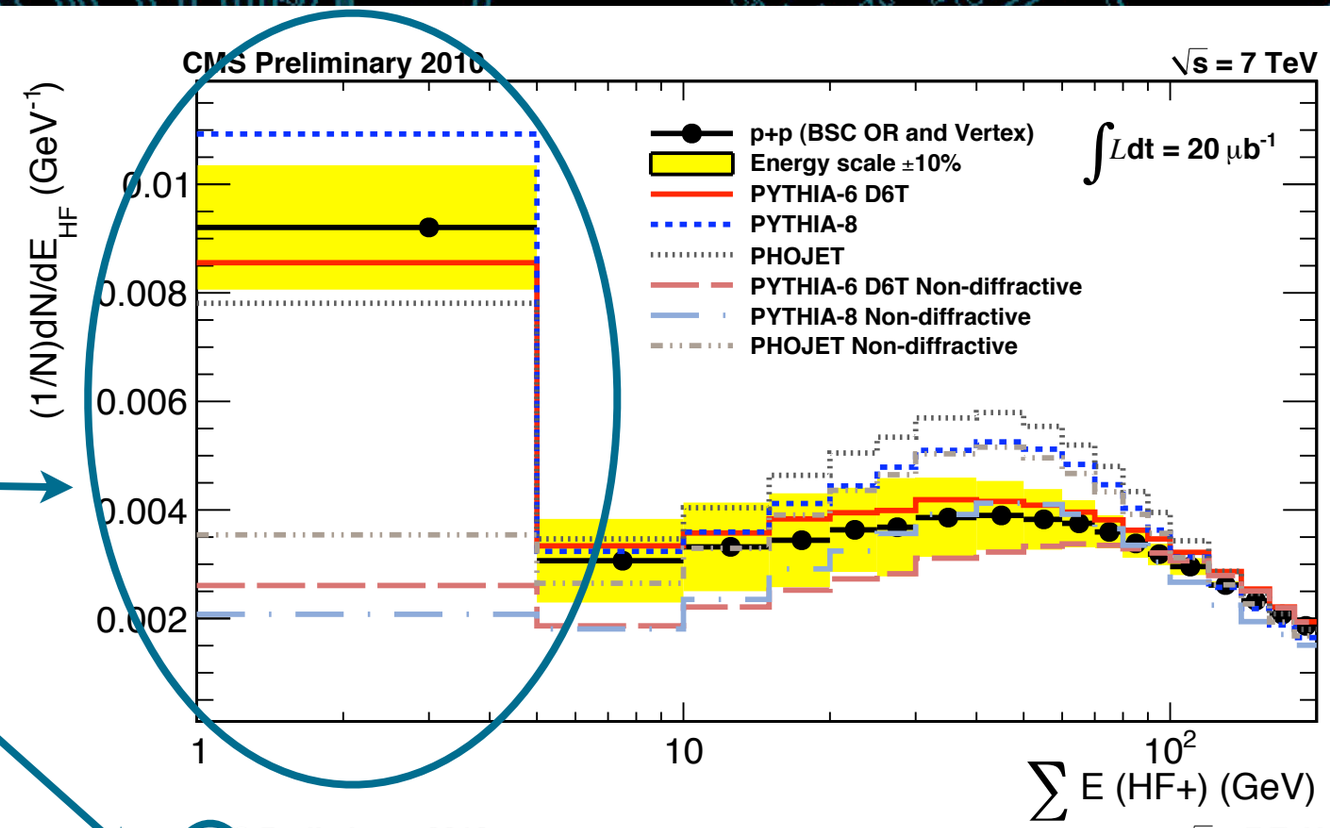
Observation of diffraction - 7 TeV

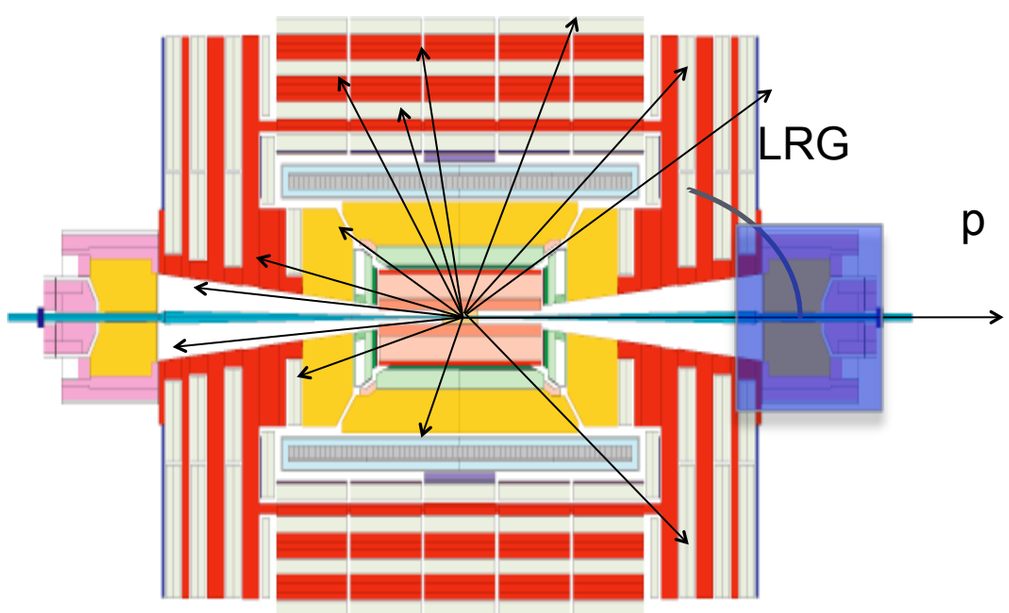
- $\xi \sim \Sigma\,(E \pm p_z)$ if the proton emitting the pomeron moves in $\pm$ z direction
- diffractive events cluster at small values of $E \pm p_z$: $\sigma \sim 1/\xi$
- observation of diffractive peak in data

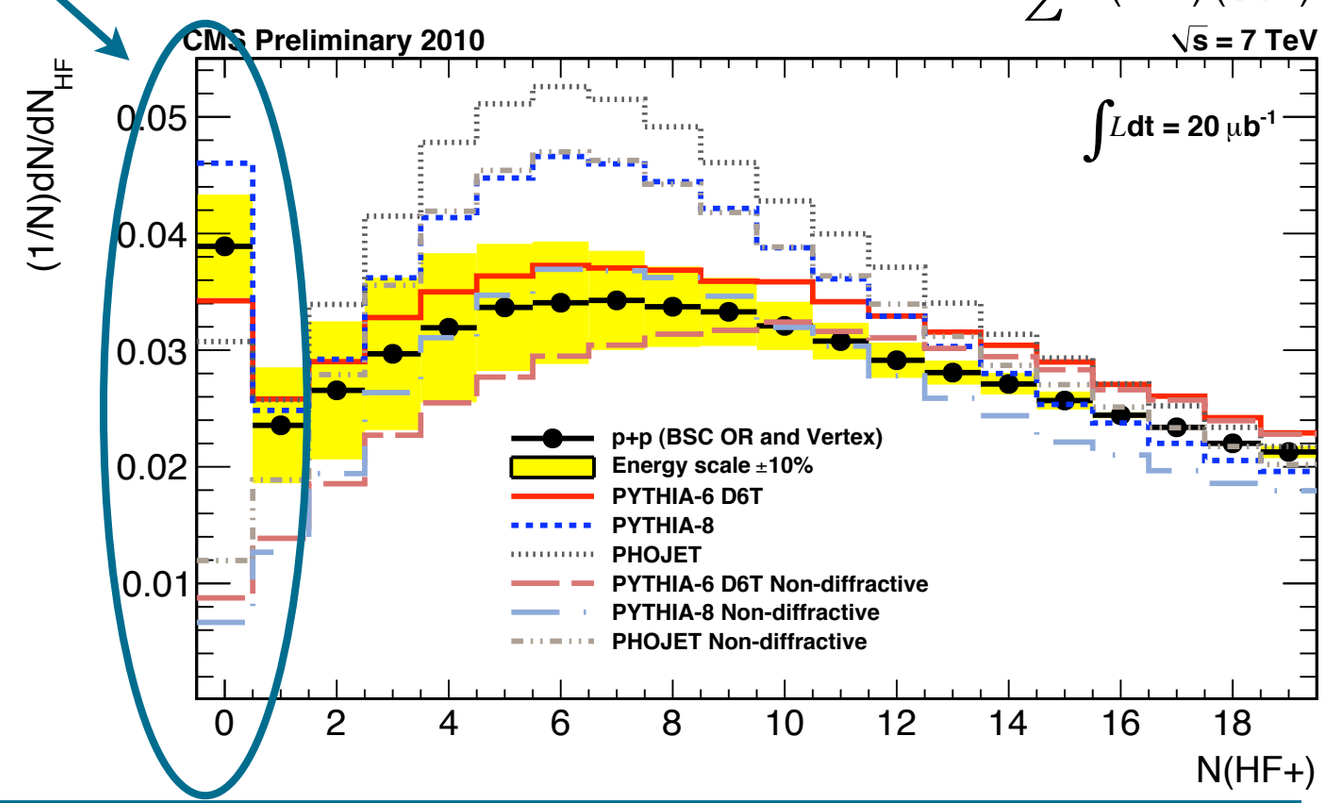


Observation of diffraction - 7 TeV

- inclusive diffraction characterized by region in rapidity devoid of hadronic activity: Large Rapidity Gap (LRG)
  - ➡ no energy deposition in HF
- gap definition at detector level

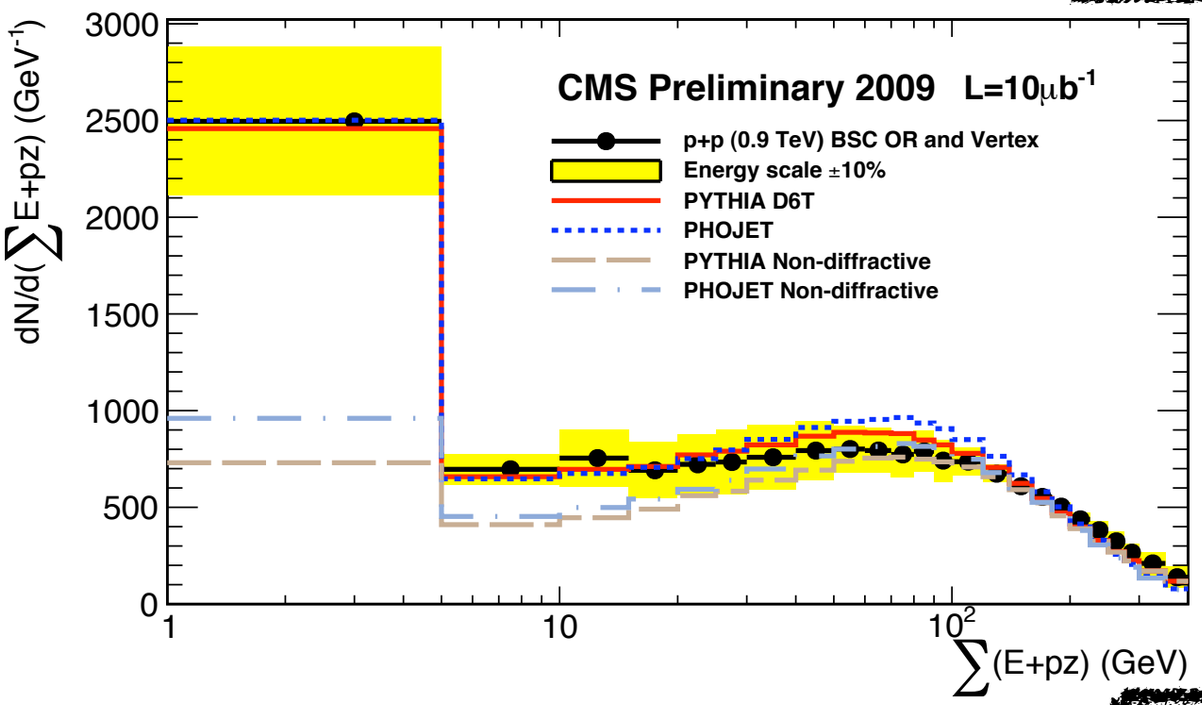


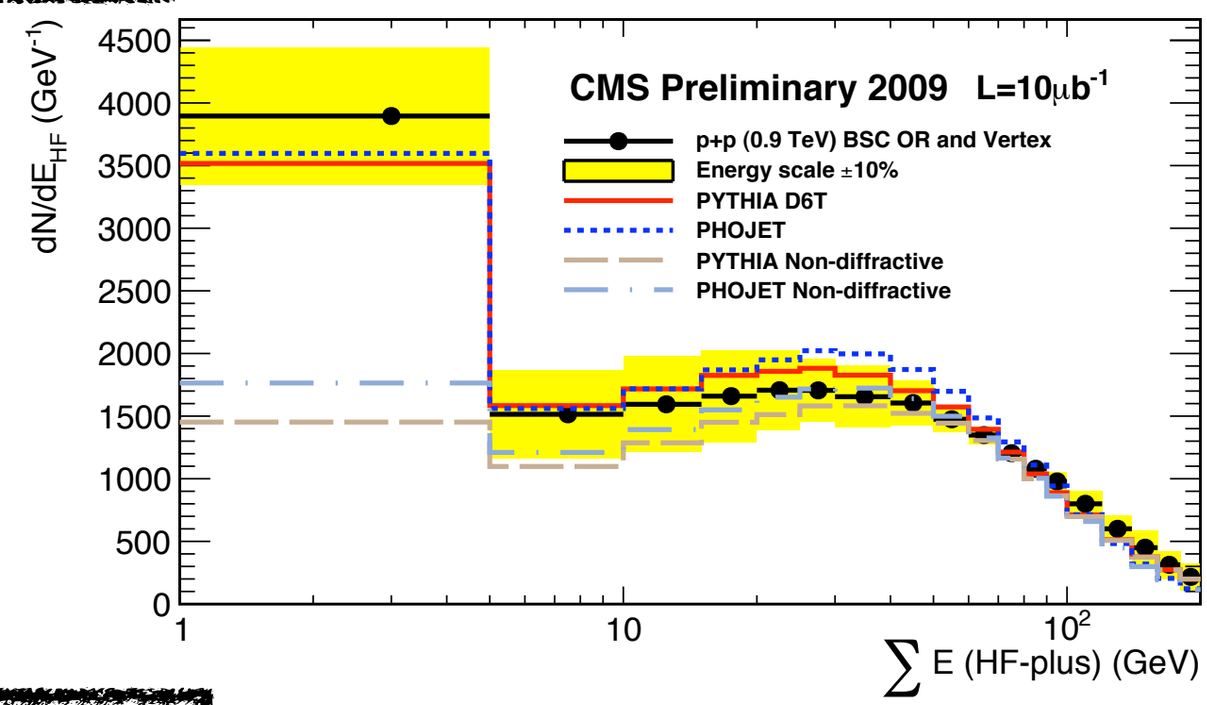




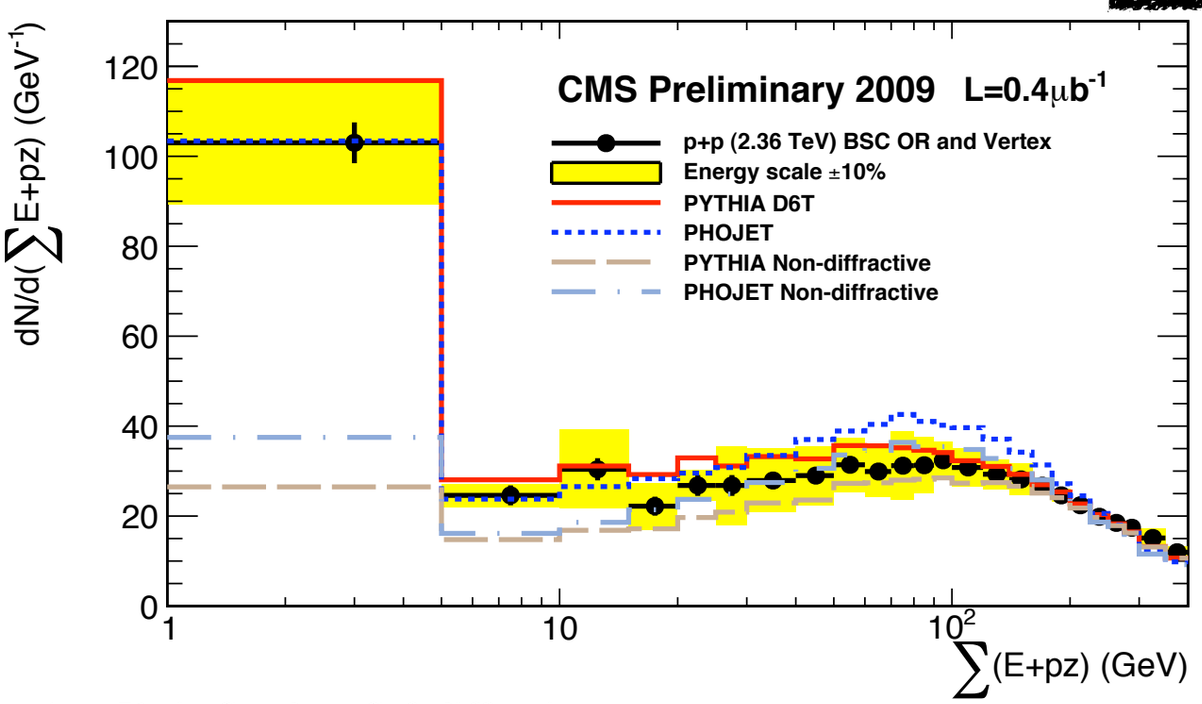
Observation of diffraction - 0.9/2.36 TeV

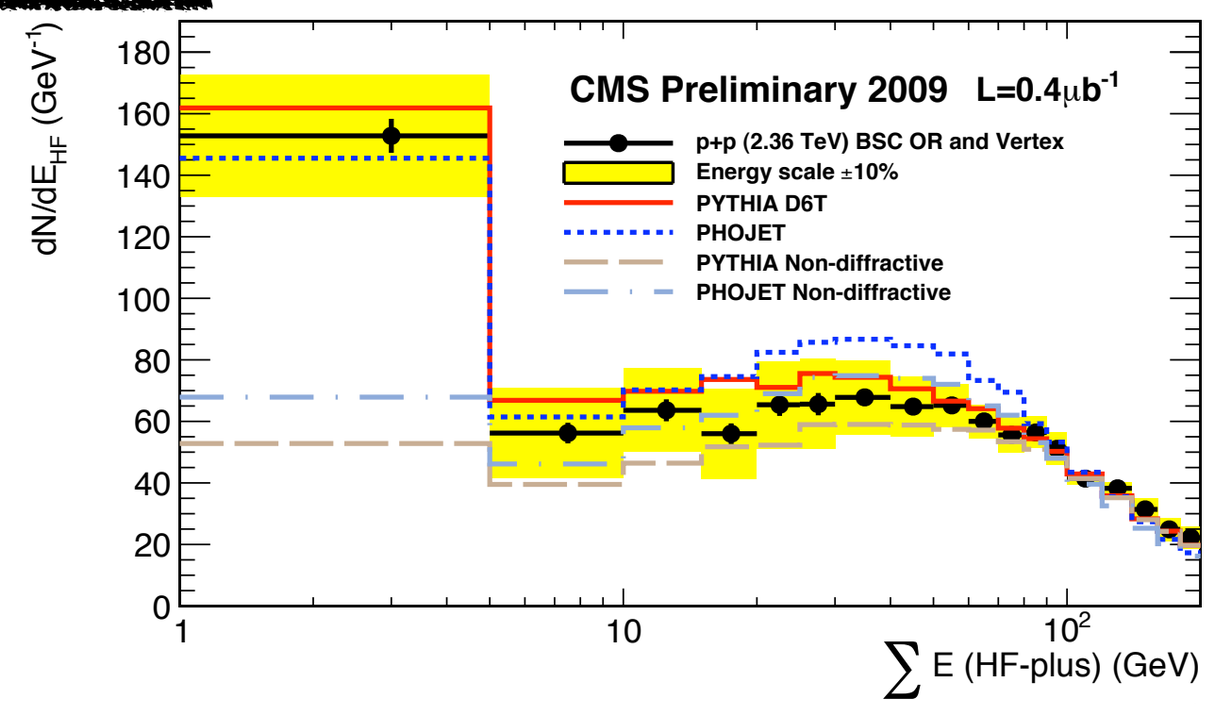
0.9 TeV



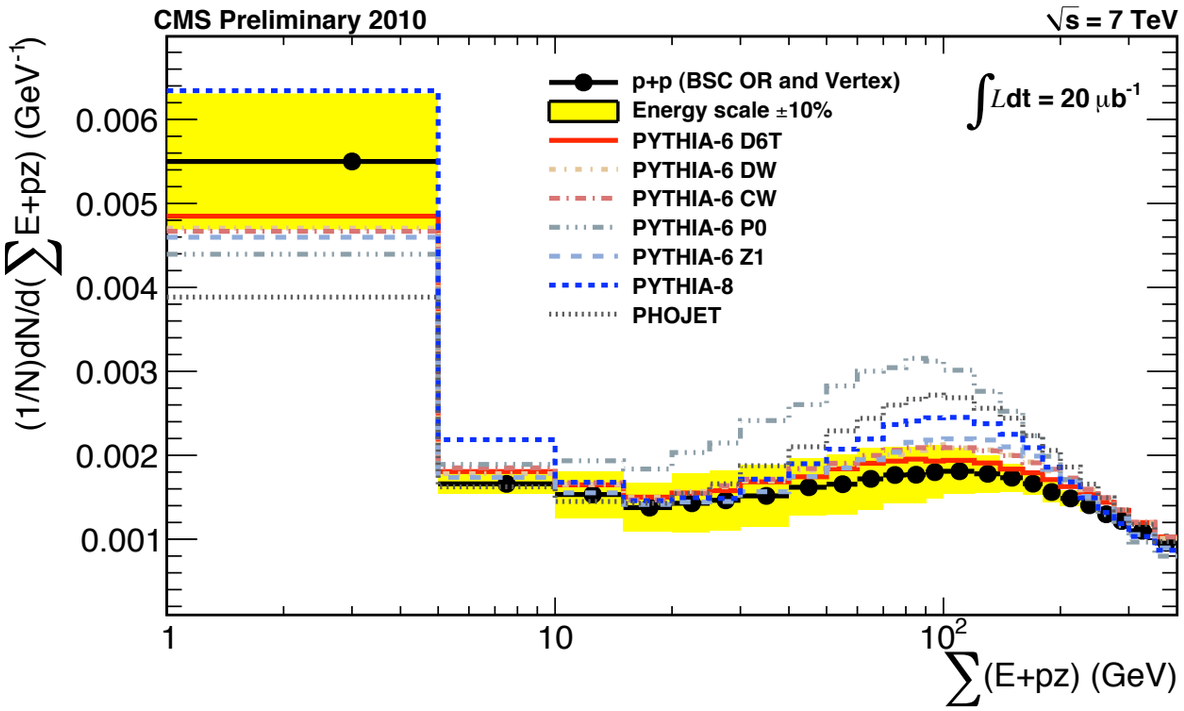


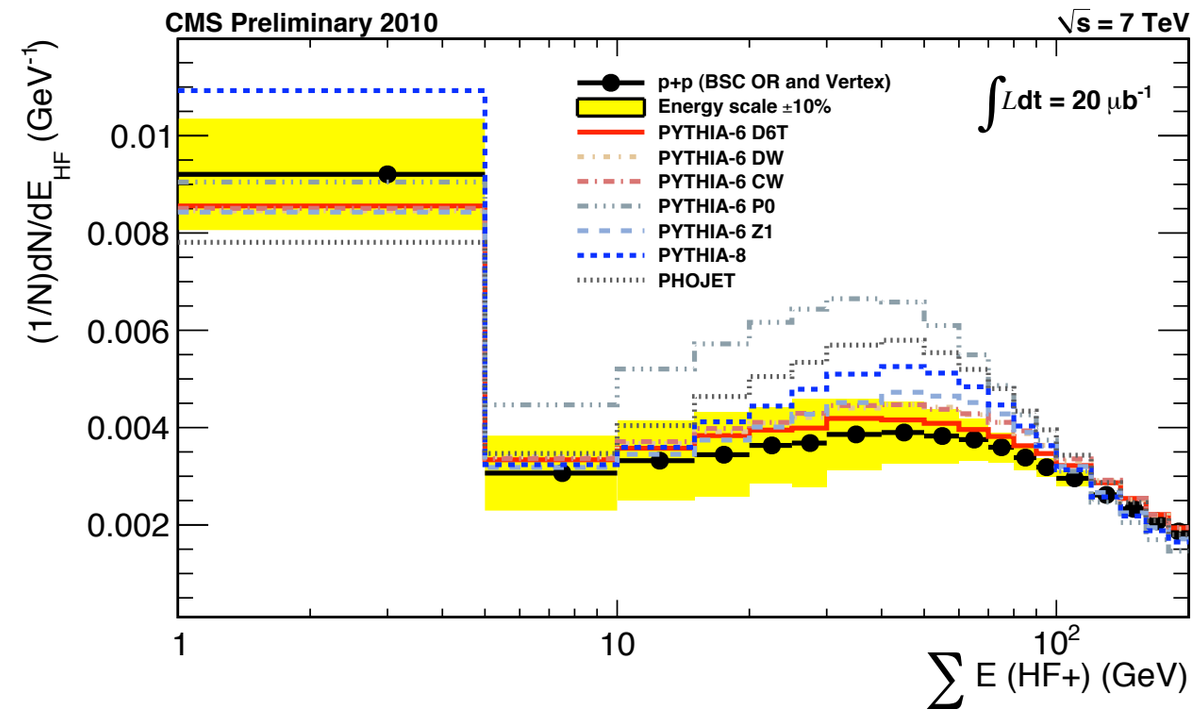
2.36 TeV



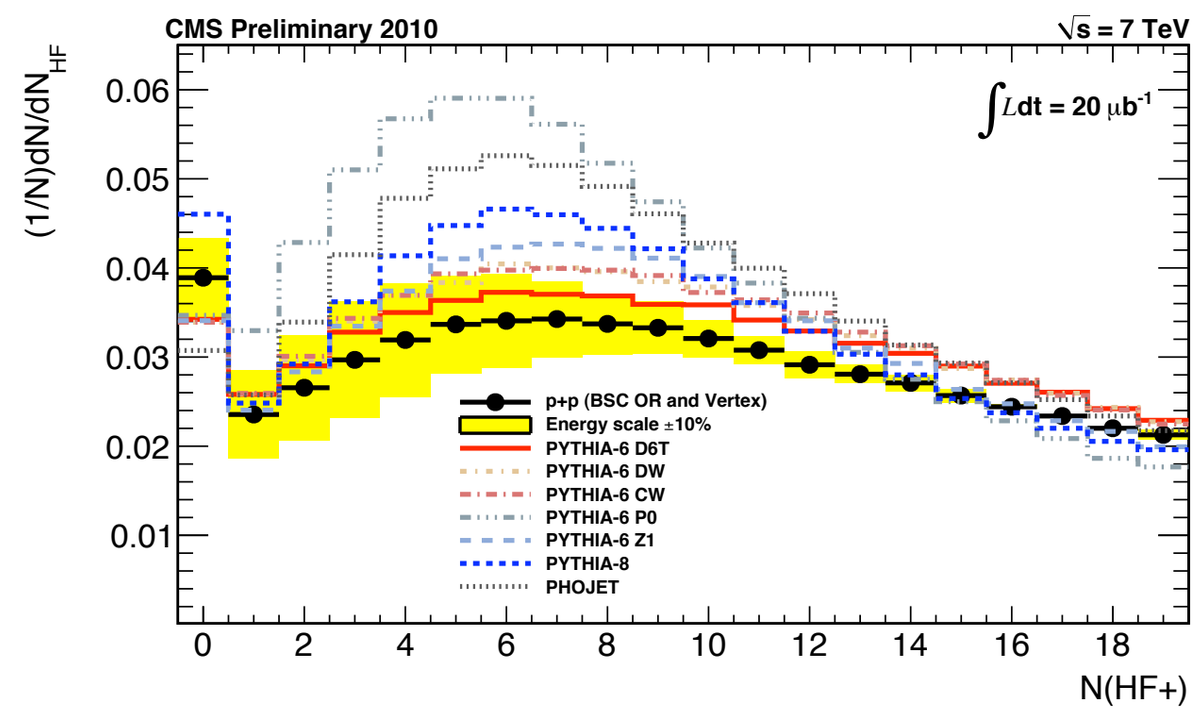


Data and MC comparison - 7 TeV



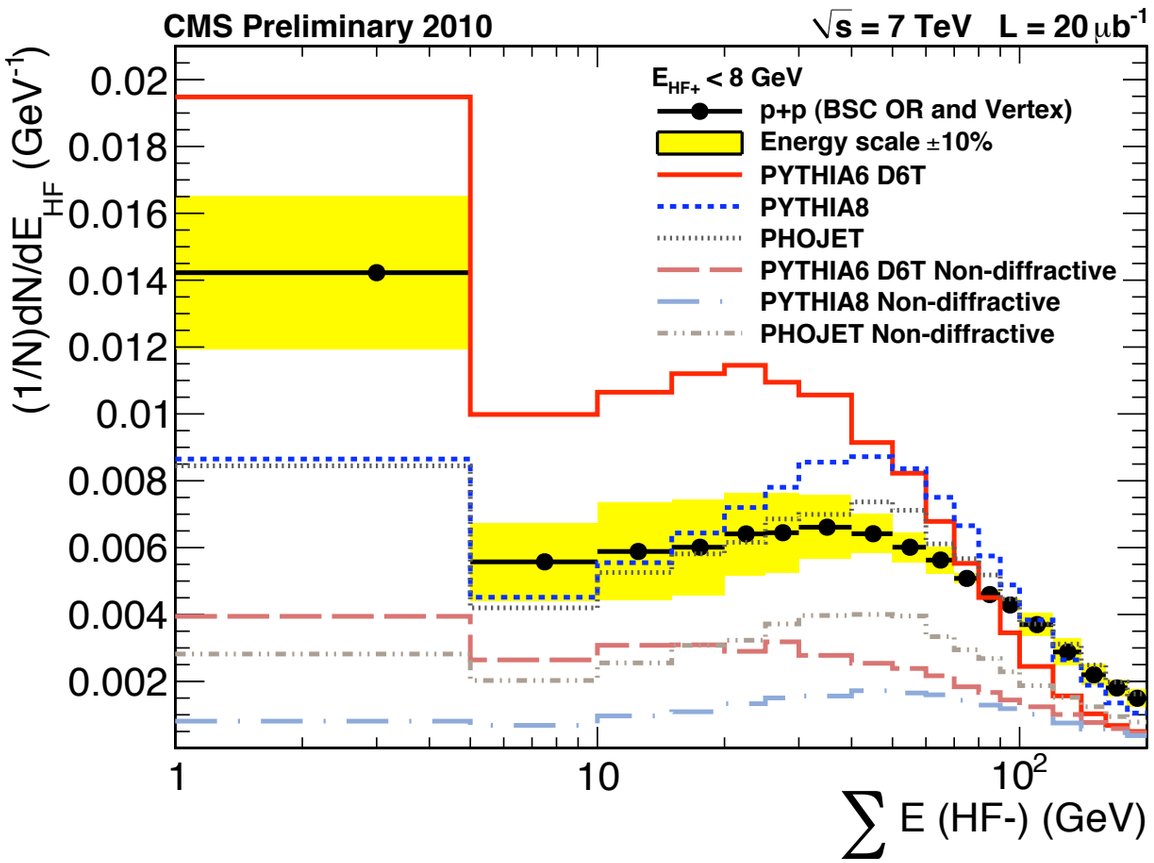


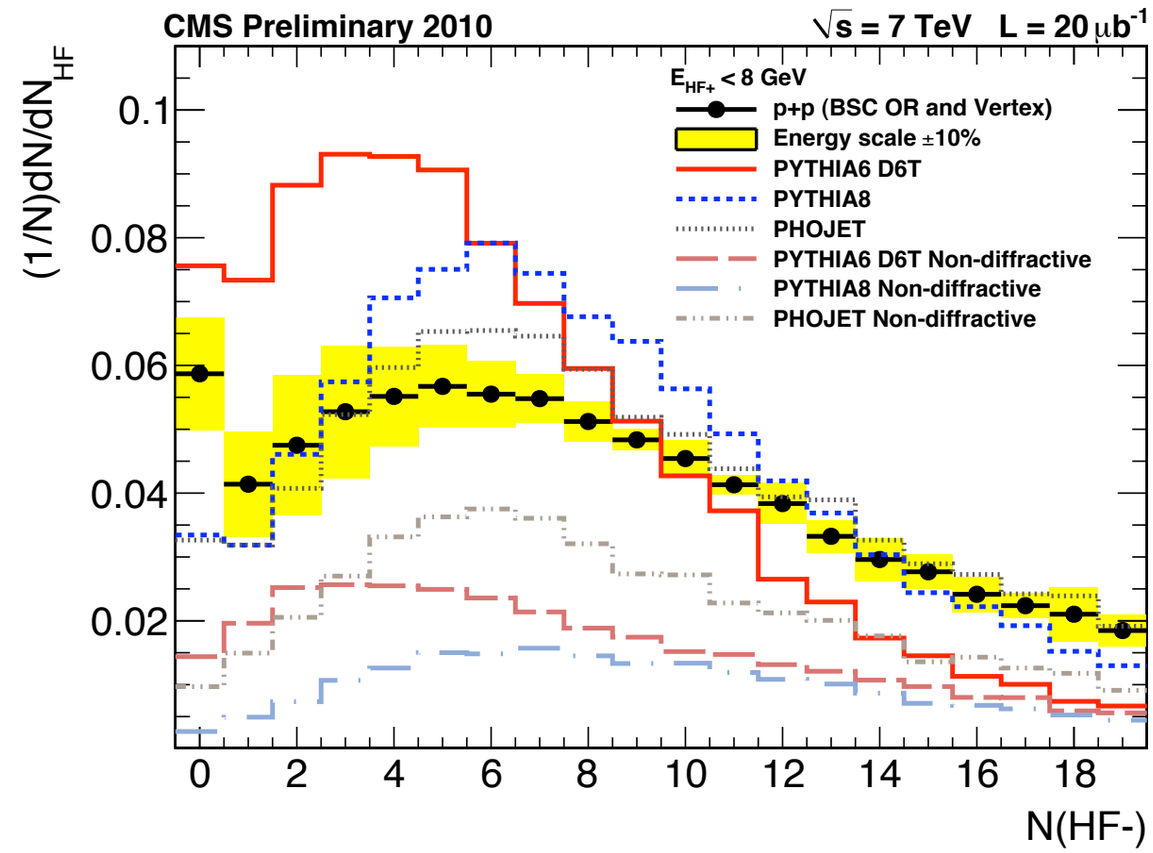
- reasonable agreement with PYTHIA6 tune D6T and fair with tunes DW, CW and Z1
- disagreement with PYTHIA8, PYTHIA6 tune P0 and PHOJET



Enhancing diffractive component - 7 TeV

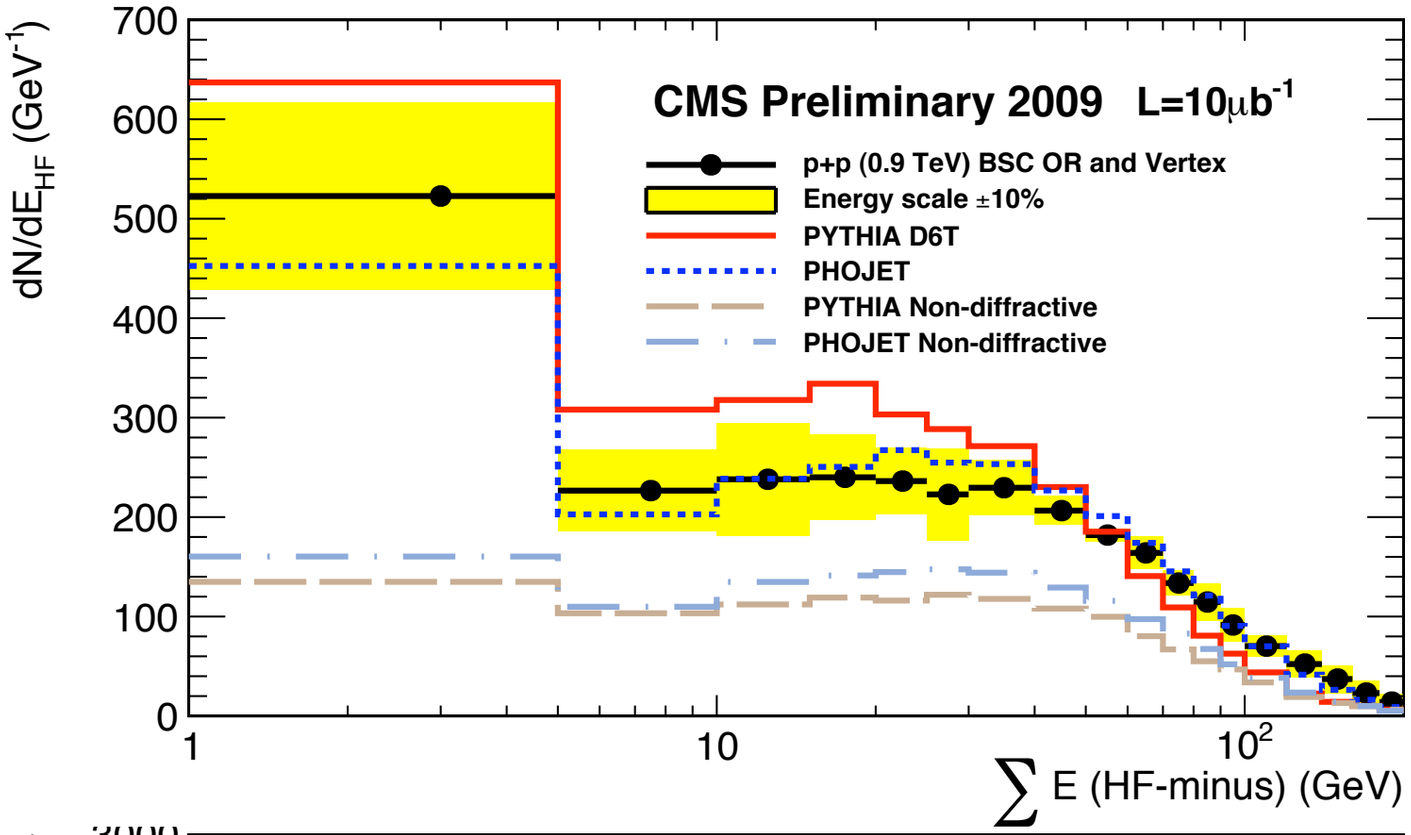
- to test description of diffraction select events with a LRG on one side: $E_{HF+} < 8$ GeV
  - ➡ suppressed non-diffractive contribution

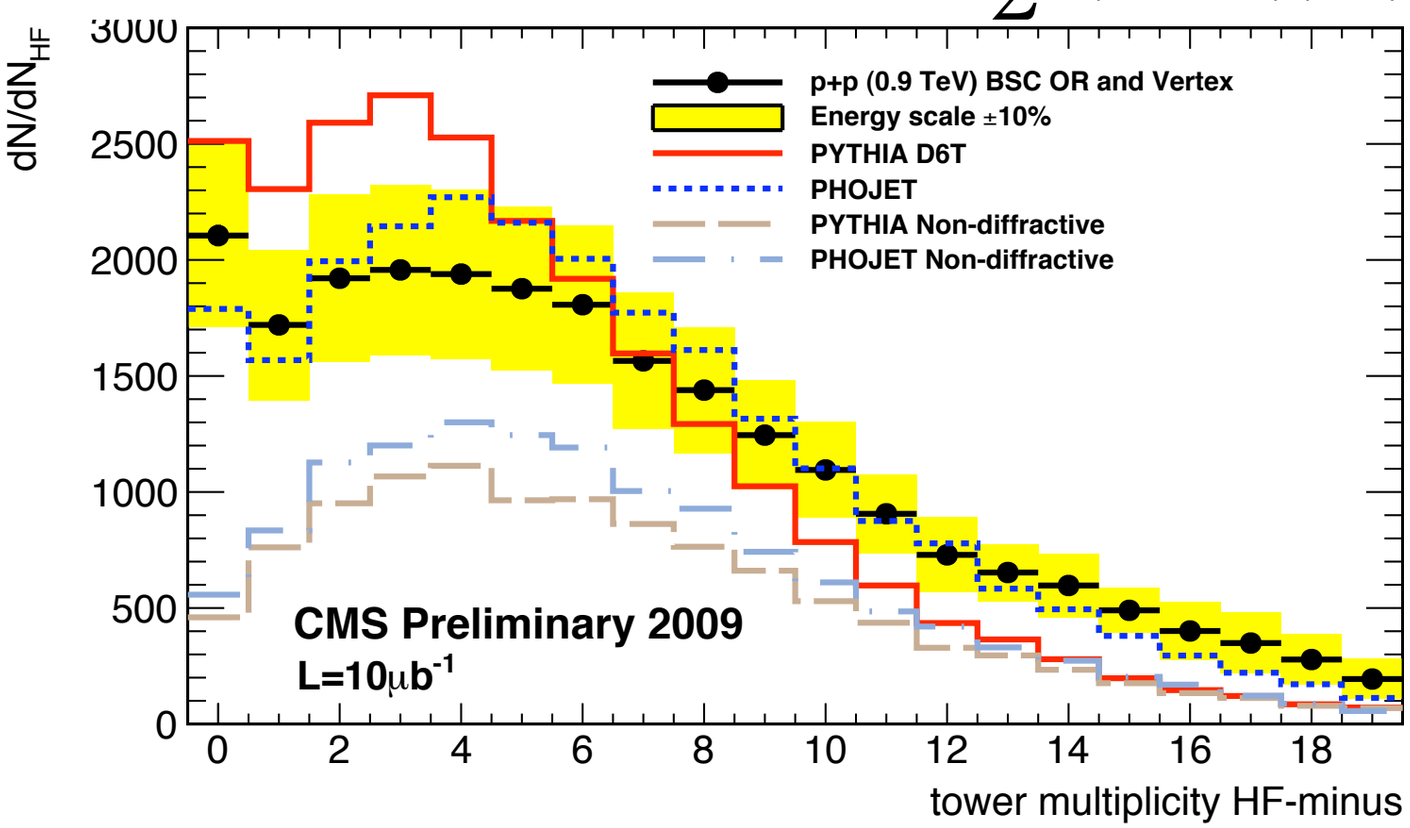




- PYTHIA6 describes well inclusive spectrum shown before, but not diffractive enriched sample
- PYTHIA8 and PHOJET describe better the tails of the distribution, however not the lower energy/multiplicity region

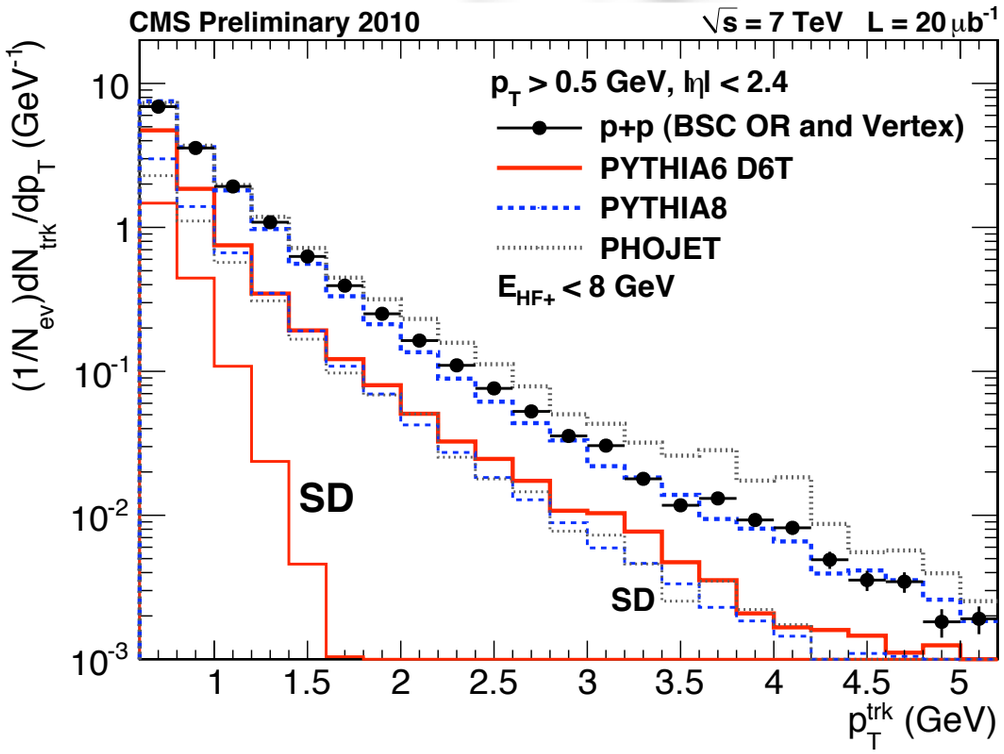
Enhancing diffractive component - 0.9 TeV



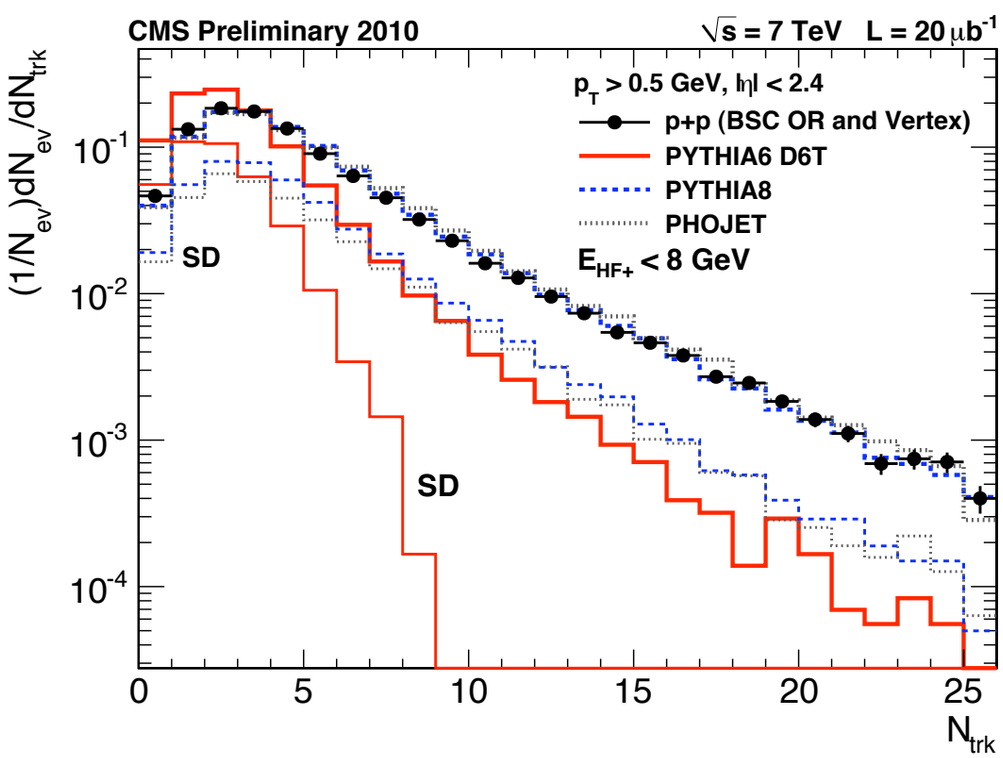


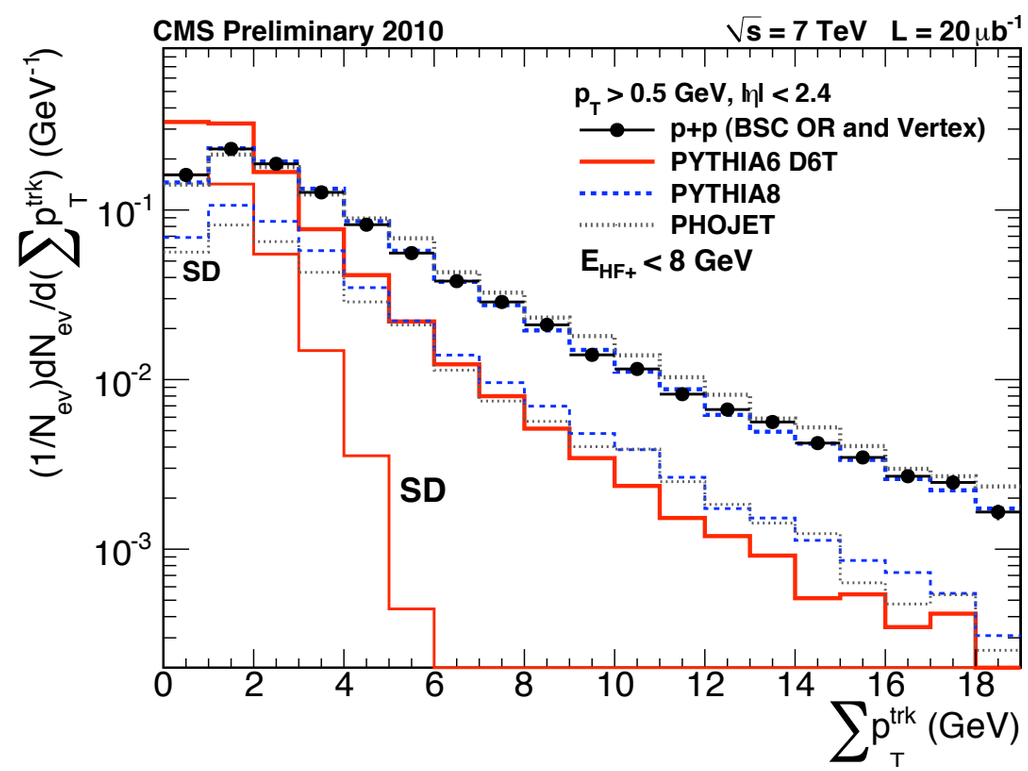
- PYTHIA6 shows in general a softer spectrum for the diffractive system
- PHOJET agrees better with data, in particular the high-mass region

Enhancing diffractive component



- SD activity is higher in PYTHIA8 and PHOJET
- PYTHIA8 and PHOJET describe data fairly well
- PYTHIA6 D6T has a considerably softer spectrum than data





Summary

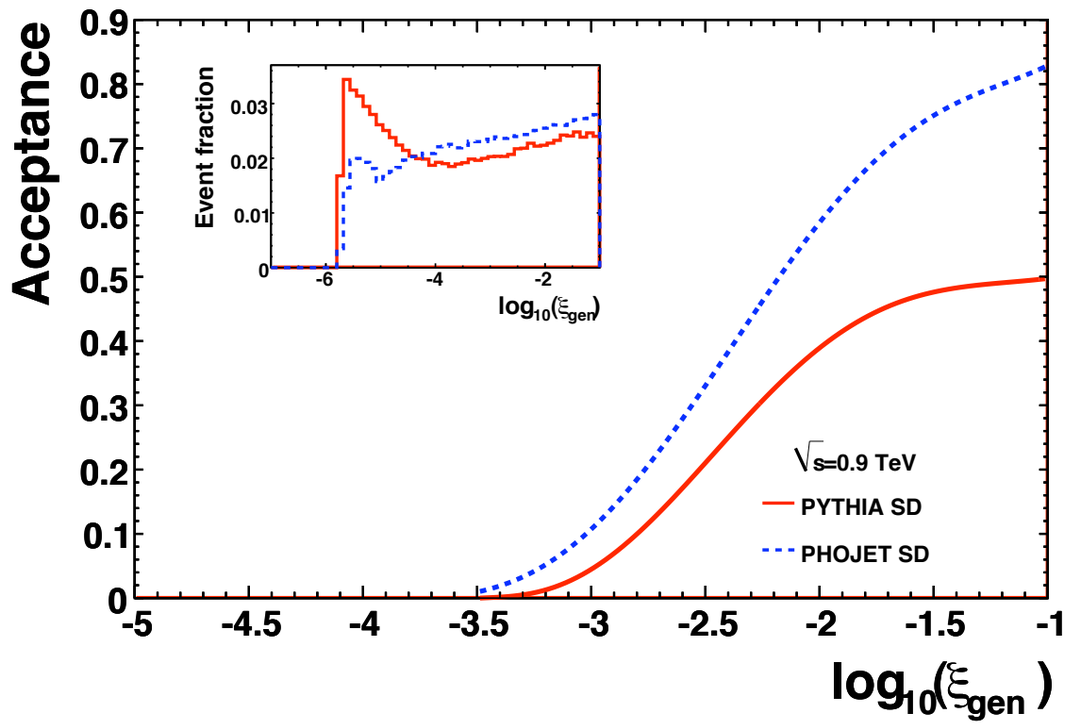
- evidence of single-diffraction observation at the LHC at 0.9, 2.36 and 7 TeV centre-of-mass energy has been presented
- SD events appear as a peak at small values of $\Sigma\,(E \pm p_z)$, reflecting the $1/\xi$ behavior of the diffractive cross section
- SD events also appear as a peak in the energy and multiplicity distributions of the forward calorimeter HF, reflecting the presence of a rapidity gap over HF
- the uncorrected data have been compared to PYTHIA6, PYTHIA8 and PHOJET after simulation of the detector response

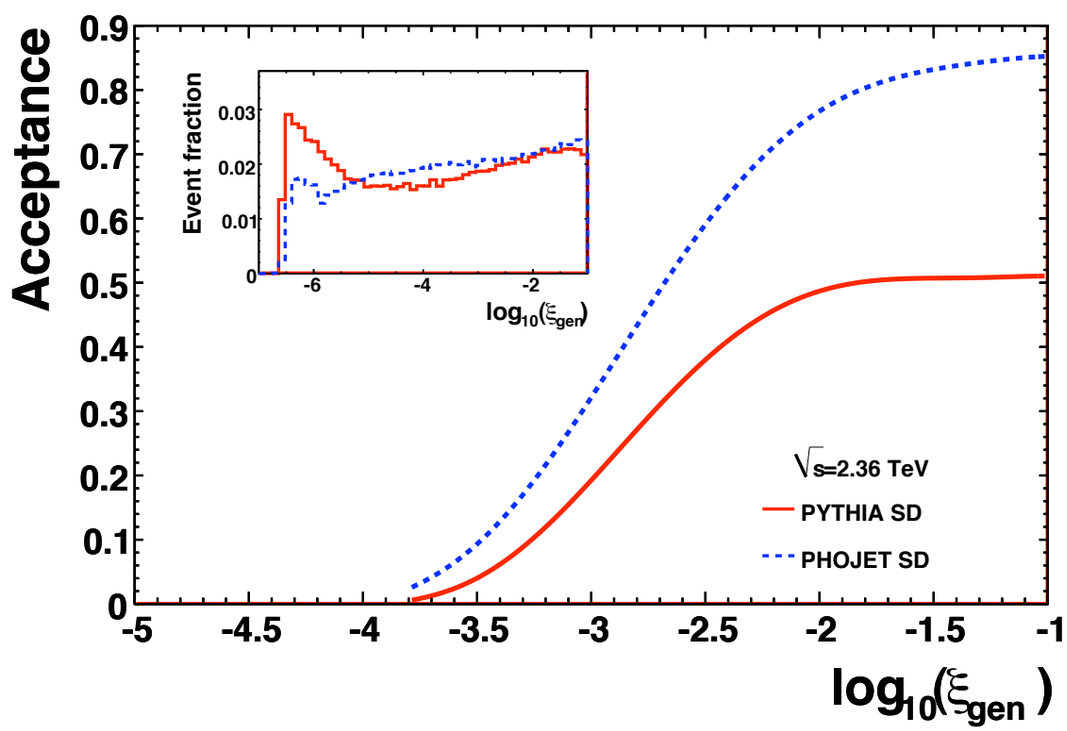
	Pythia 6 D6T	DW	CW	P0	Z1	Pythia 8	Phojet
distributions without diffractive enhancement							
Cal $\lvert\eta\rvert < 3$	fair	fair	fair	bad	ok	fair	very bad
Tracking	bad	bad	bad	fair	fair	ok	bad
Forward	ok	fair	fair	bad	fair	bad	bad
distributions with diffractive enhancement							
Tracking	bad	bad	bad	fair	fair	ok	fair
Forward	bad	bad	bad	bad	bad	bad	fair

- the diffractive component is best reproduced by PYTHIA8 in the central region and by PHOJET
- the inclusive distributions are well described by PYTHIA6 Z1 and PYTHIA8 in the central region and by PYTHIA6 D6T in the forward region
- none of the simulations considered describes all features of the data

BACKUP

Acceptance SD events - 0.9/2.36 TeV



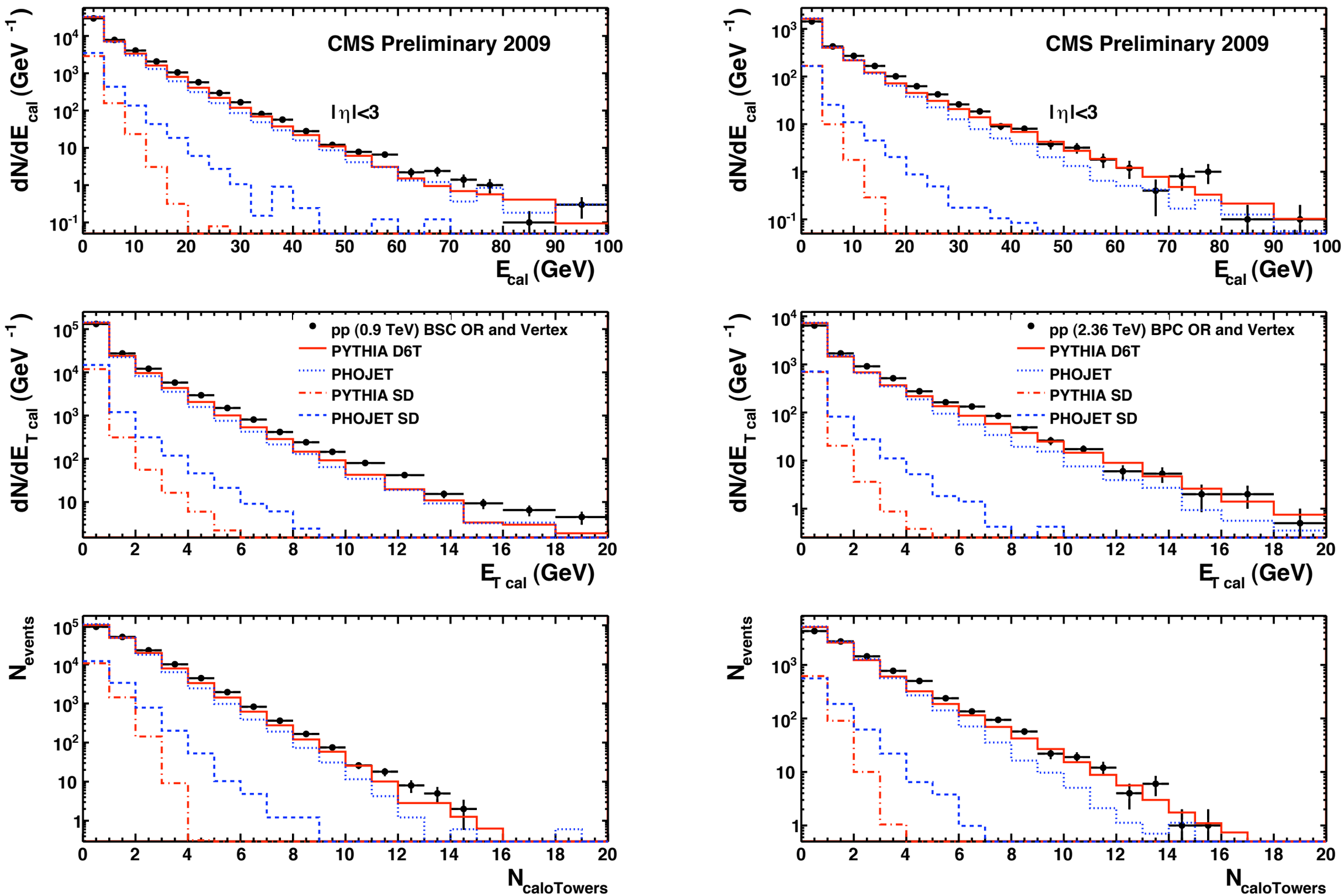


- large discrepancy between PYTHIA6 with respect to PHOJET due to different modeling
- small acceptance for low-ξ events due to undetected system X at low M_X

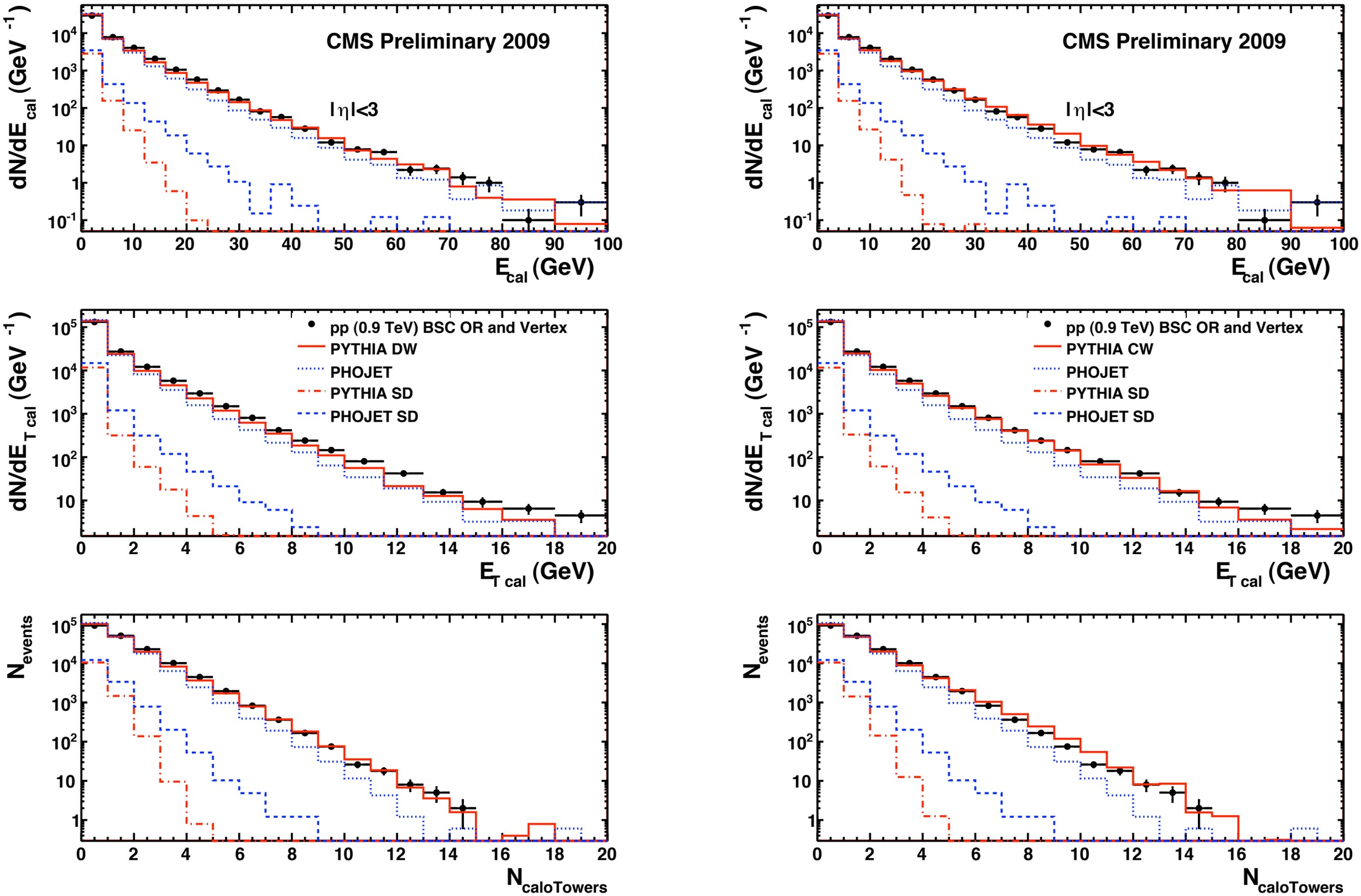
Selection efficiency for SD events

- PYTHIA6 D6T: 20%
- PHOJET: 35%

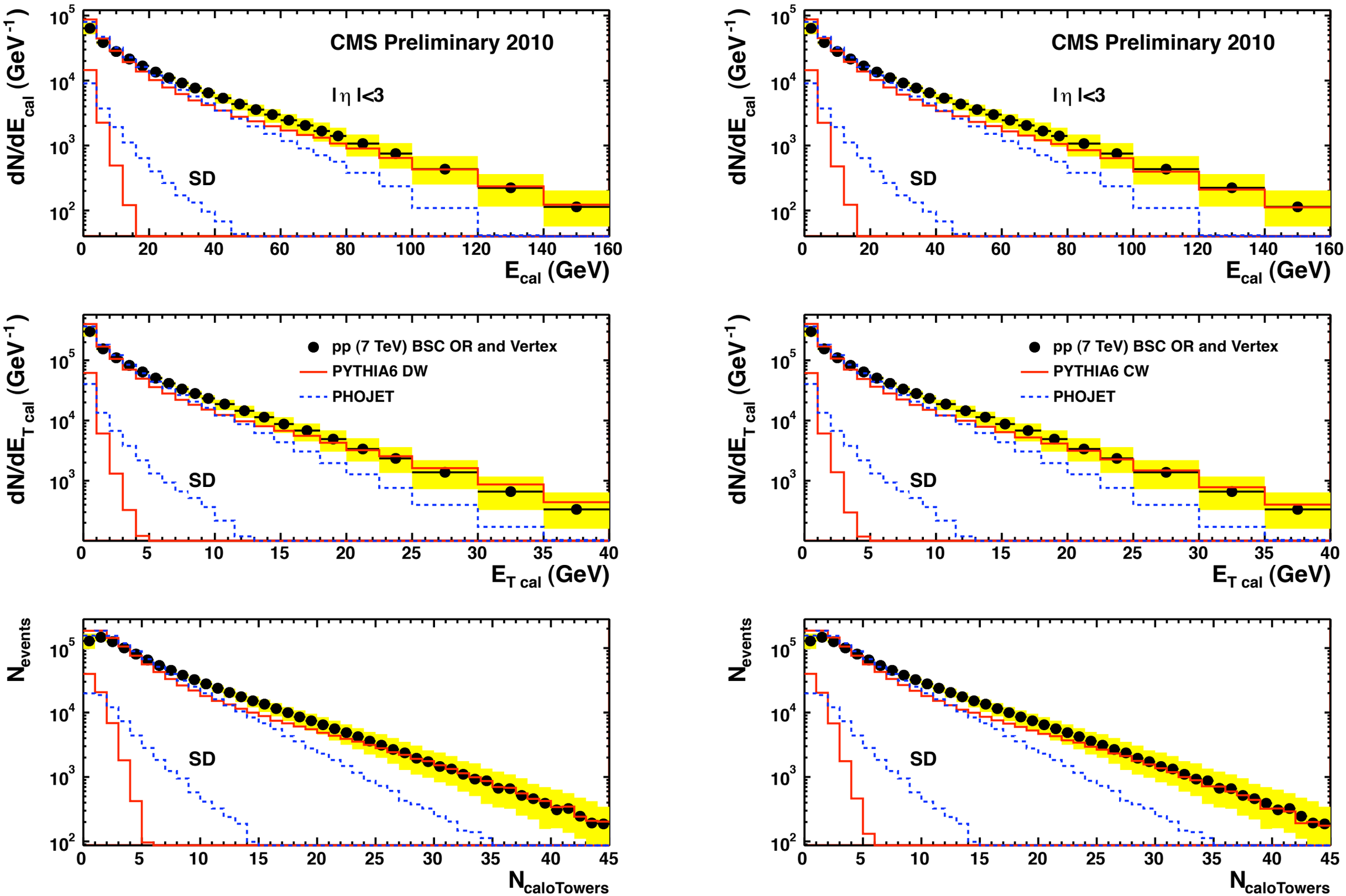
Calorimeter distributions - central region - 0.9/2.36 TeV



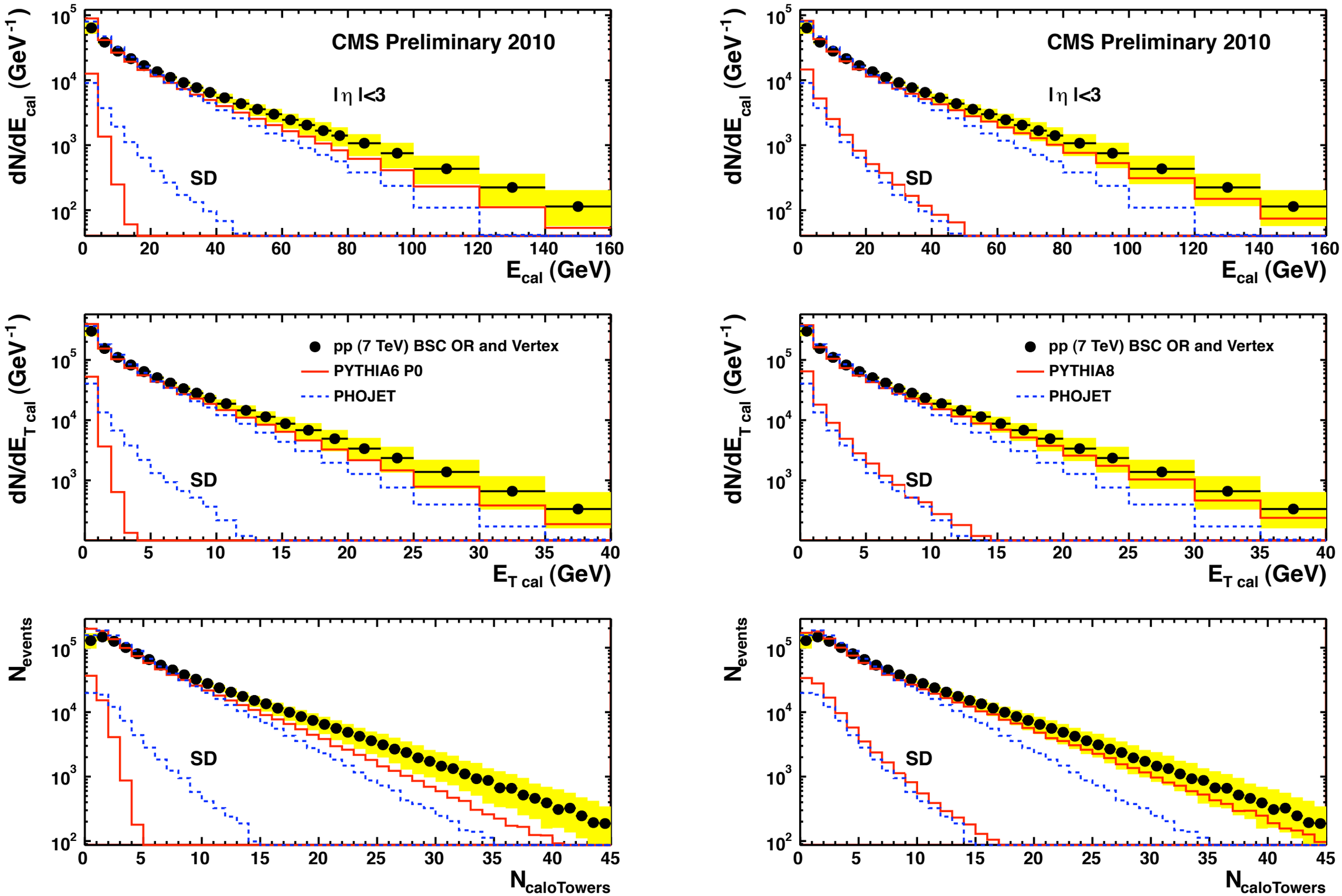
Calorimeter distributions - central region - 0.9 TeV



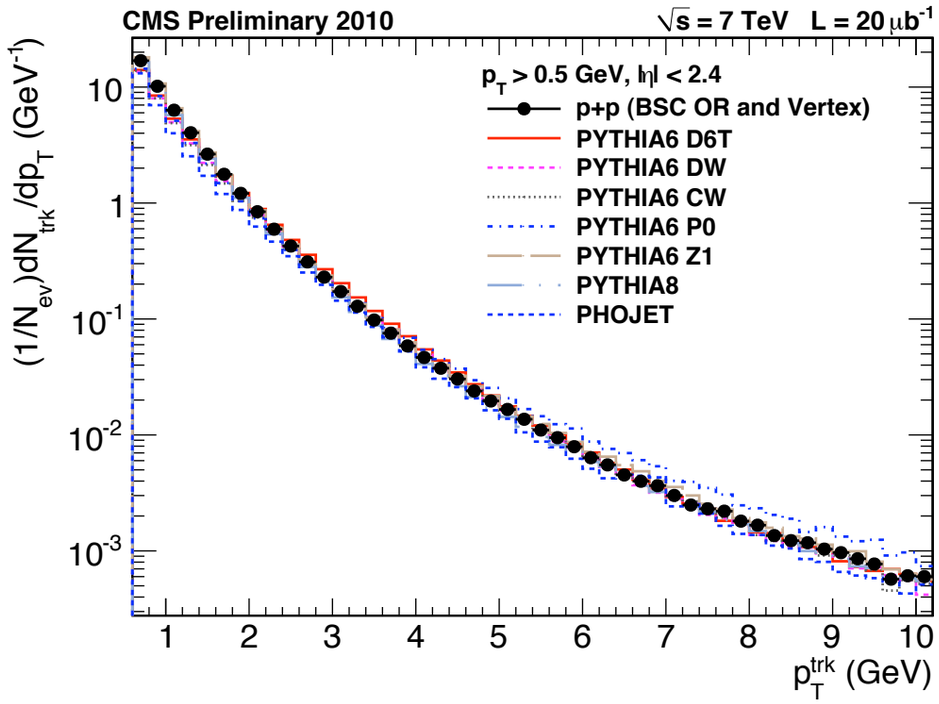
Calorimeter distributions - central region - 7 TeV

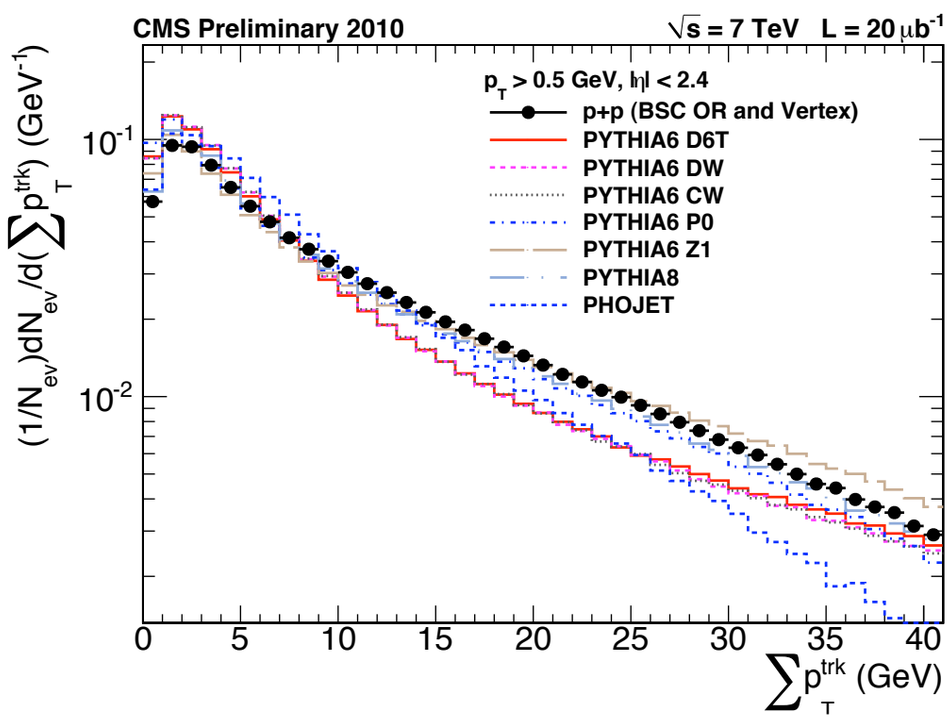


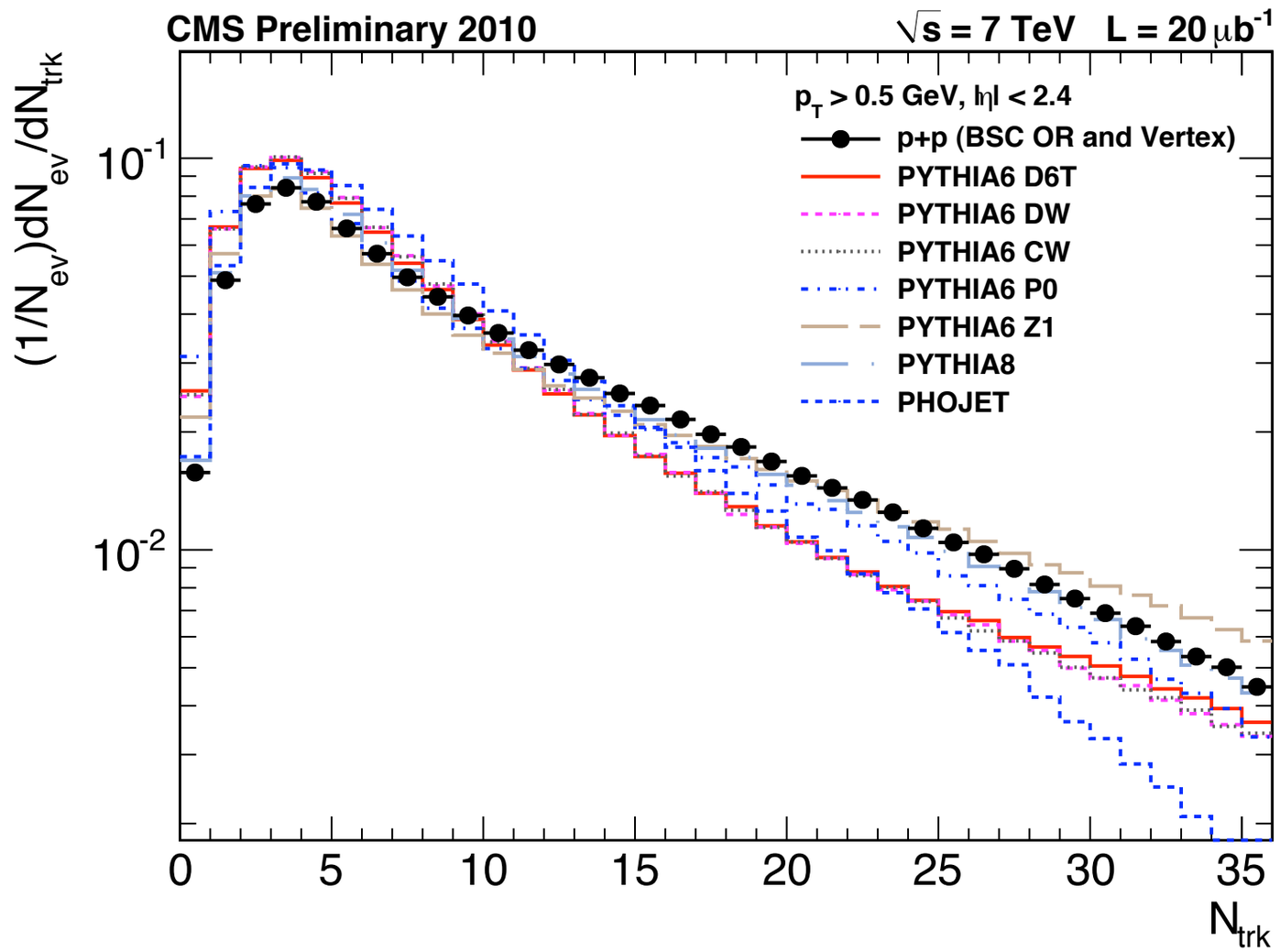
Calorimeter distributions - central region - 7 TeV



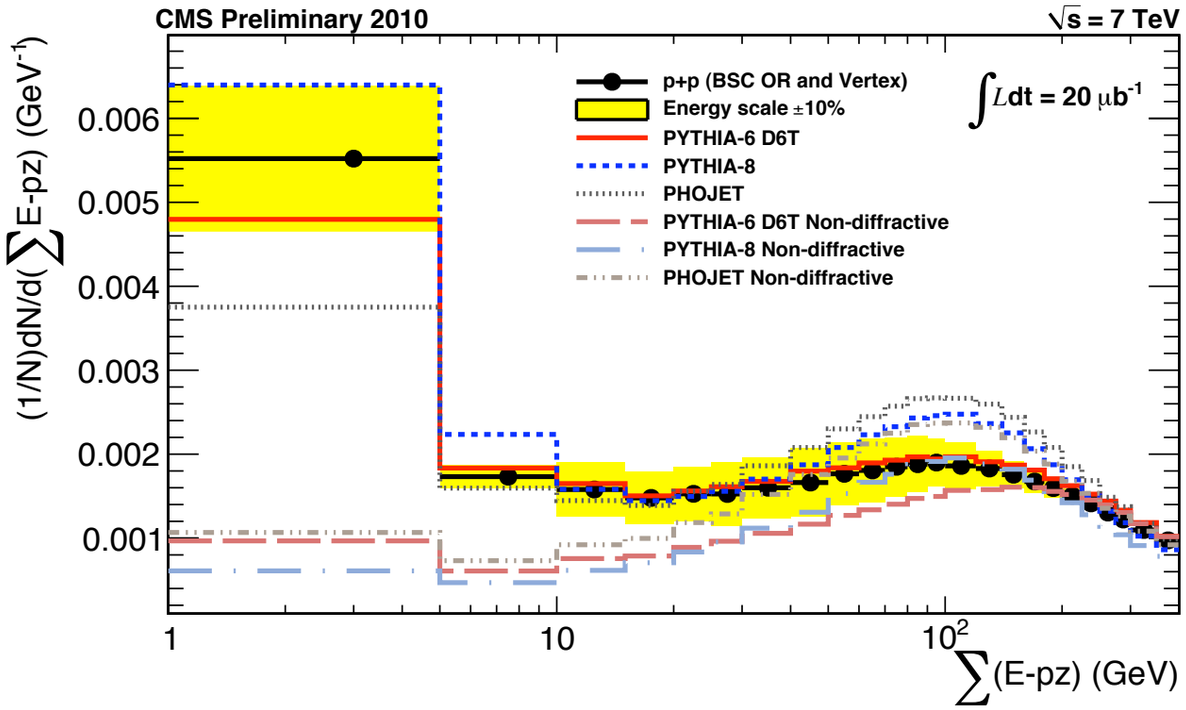
Tracker distributions – 7 TeV



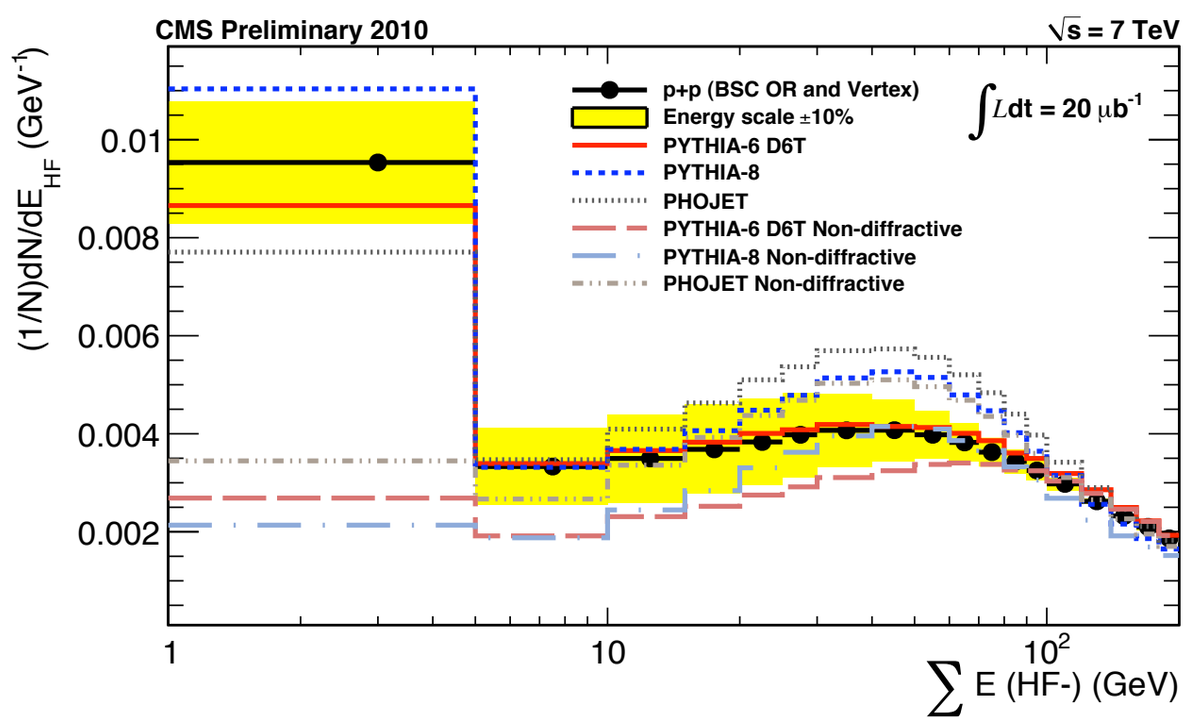


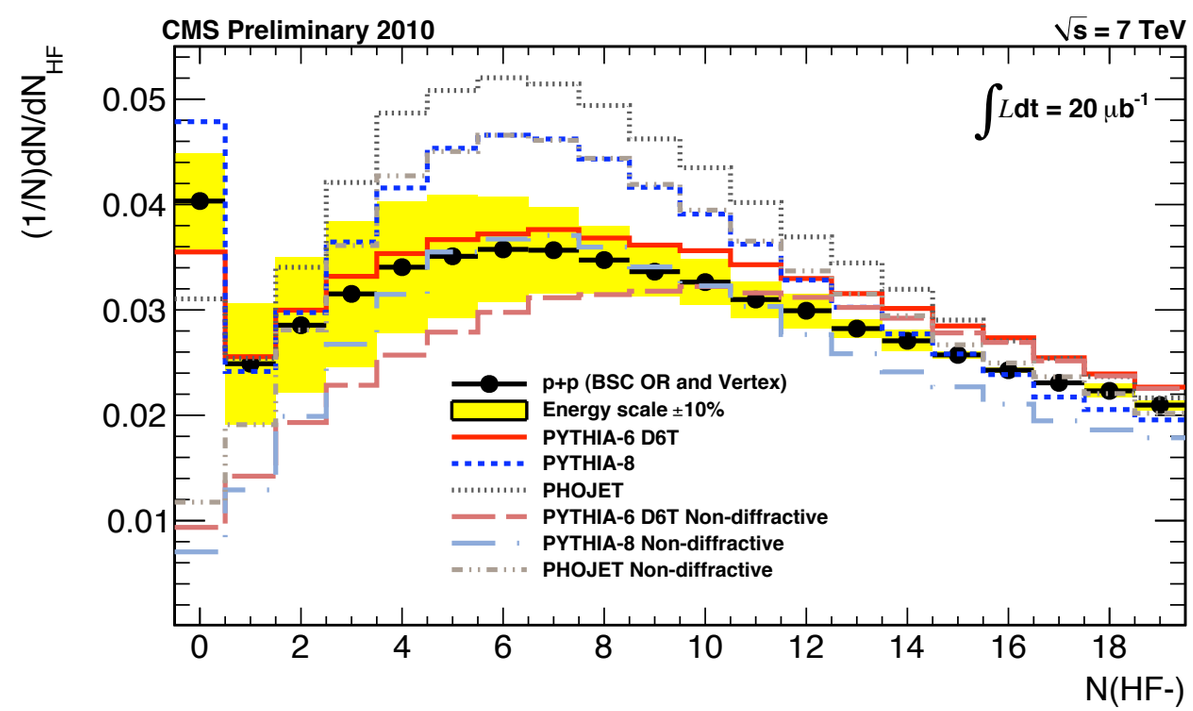


Observation of diffraction - 7 TeV

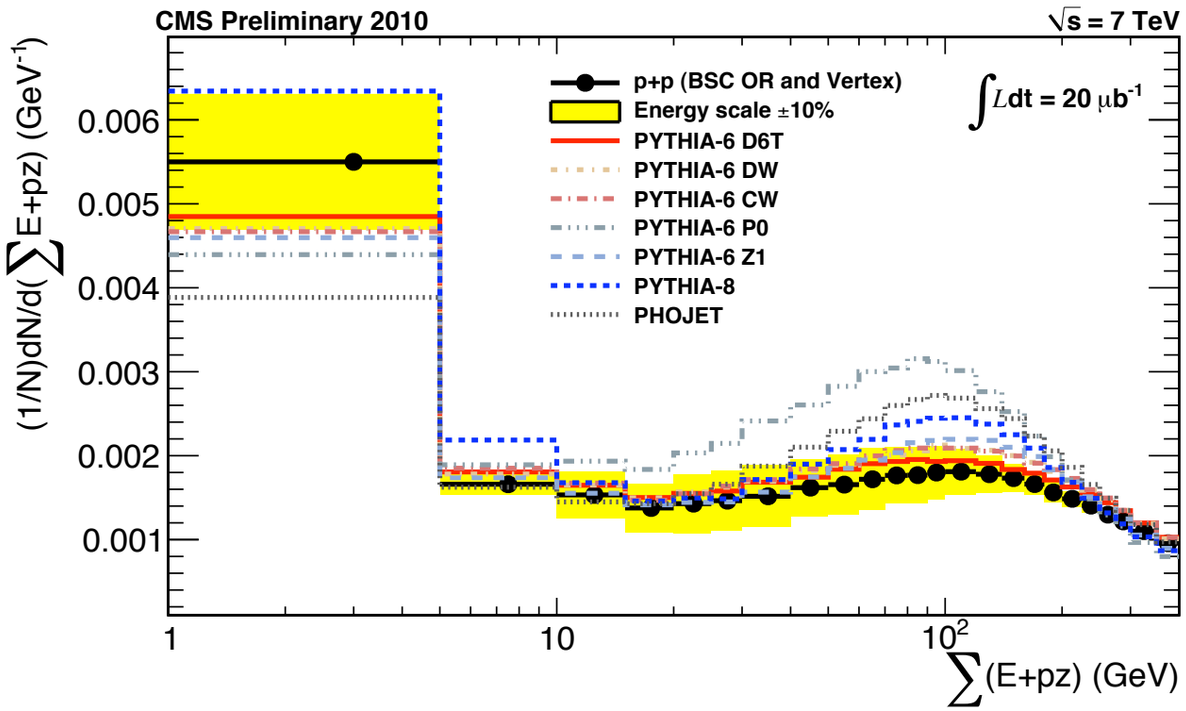


- Σ (E-p_z), energy and tower multiplicity in HF-
- observation of diffractive peak in data
- comparison to different MC tunes

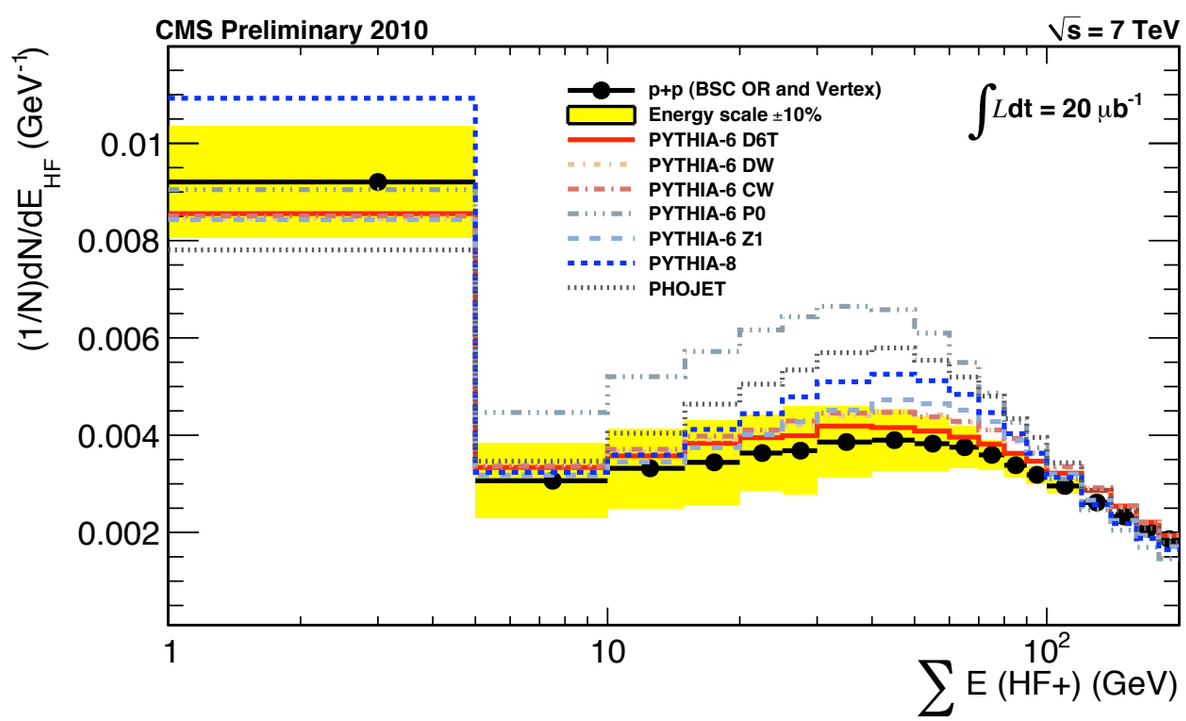


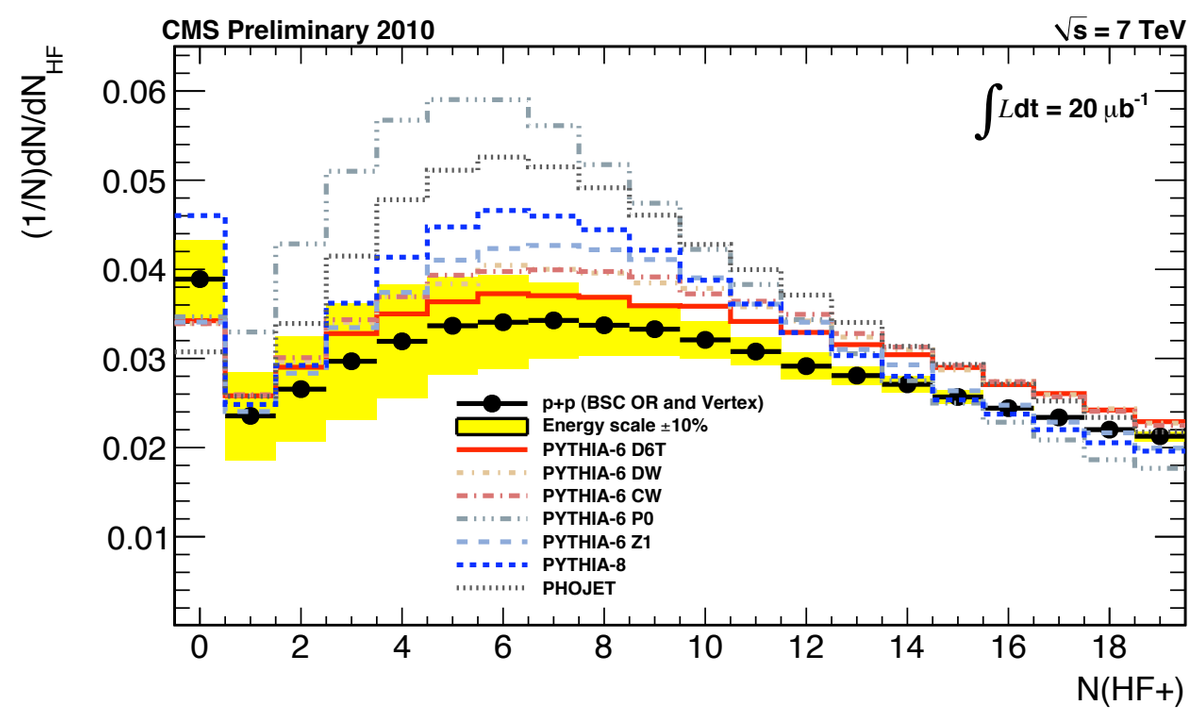


Observation of diffraction - 7 TeV

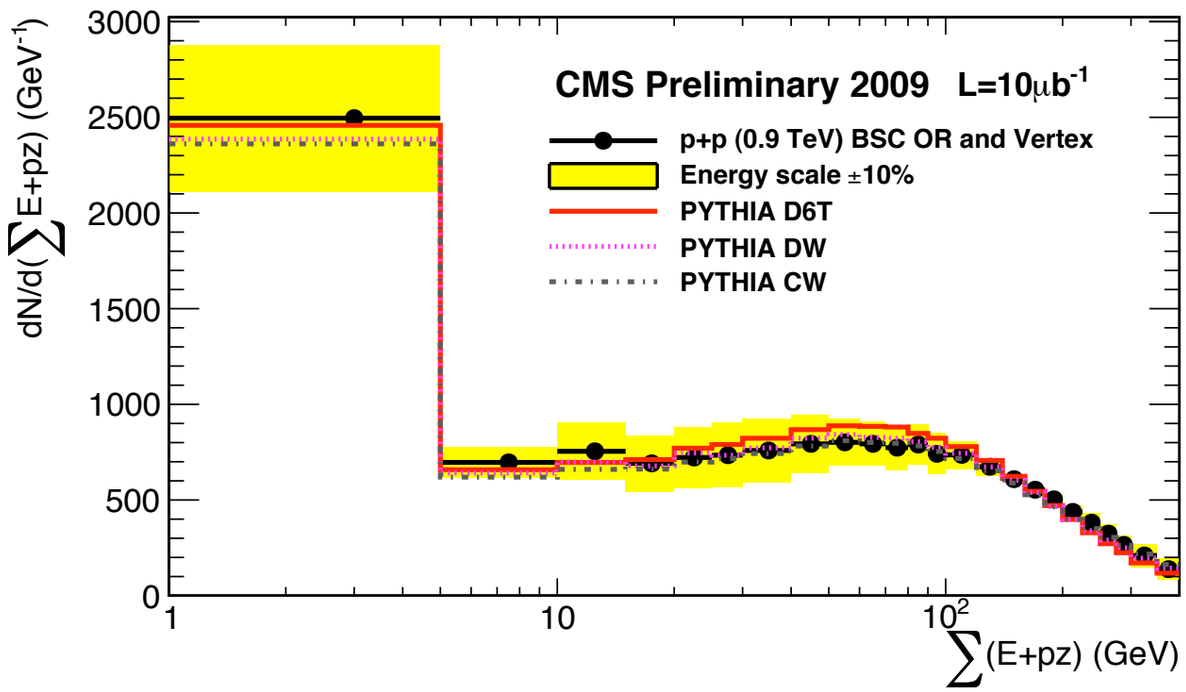


- Σ (E+p_z), energy and tower multiplicity in HF+
- observation of diffractive peak in data
- comparison to different MC tunes

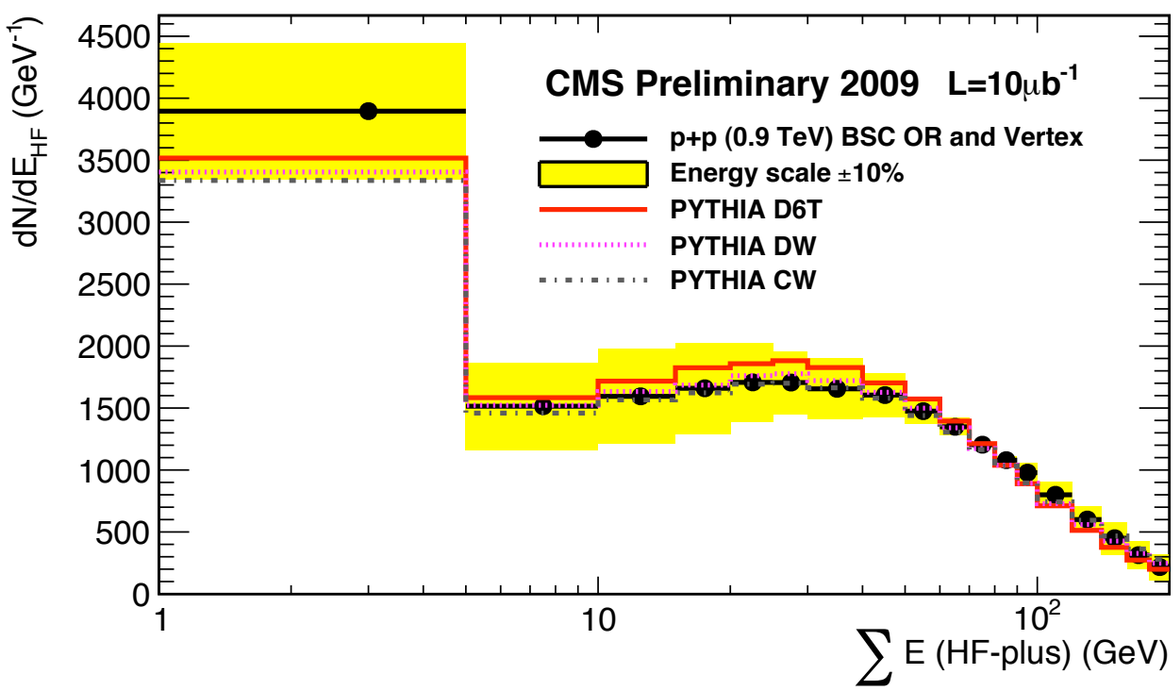


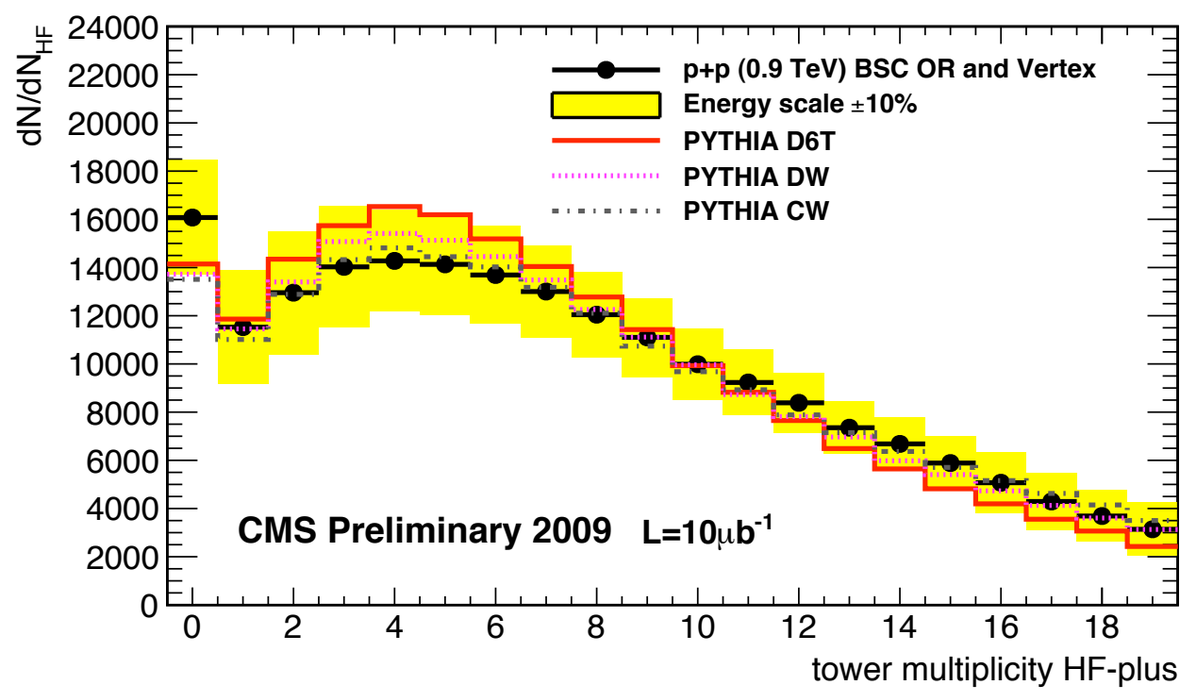


Observation of diffraction - 0.9 TeV

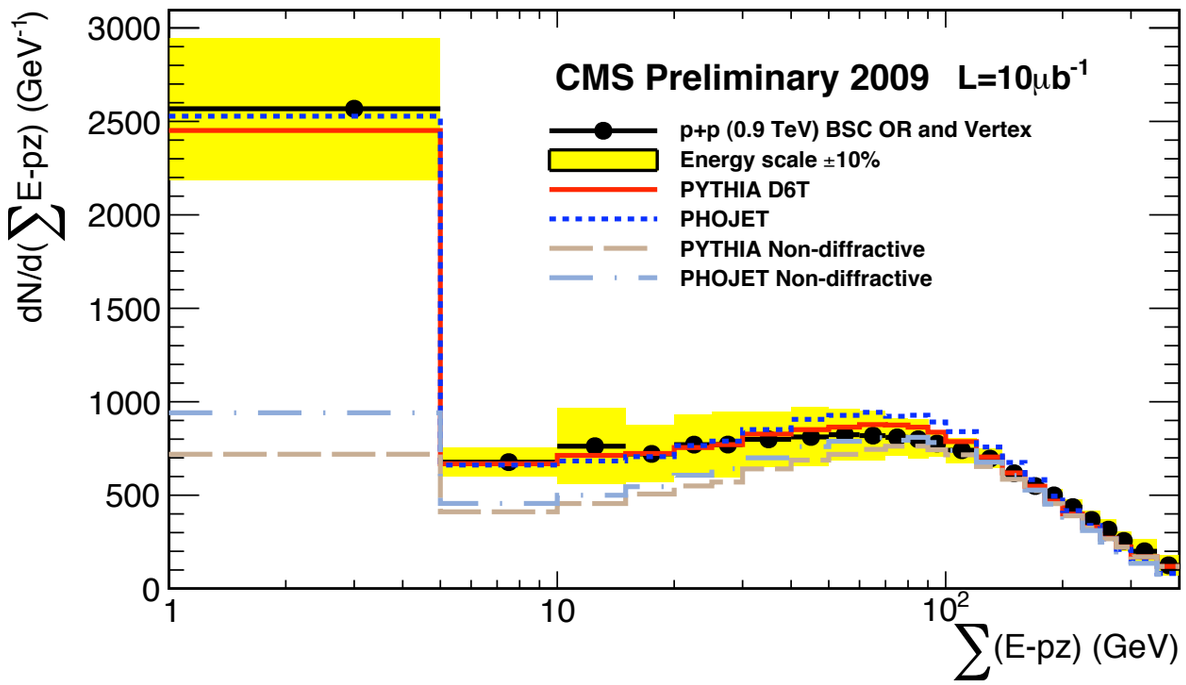


- Σ (E+p_z), energy and tower multiplicity in HF+
- observation of diffractive peak in data
- comparison to different MC tunes

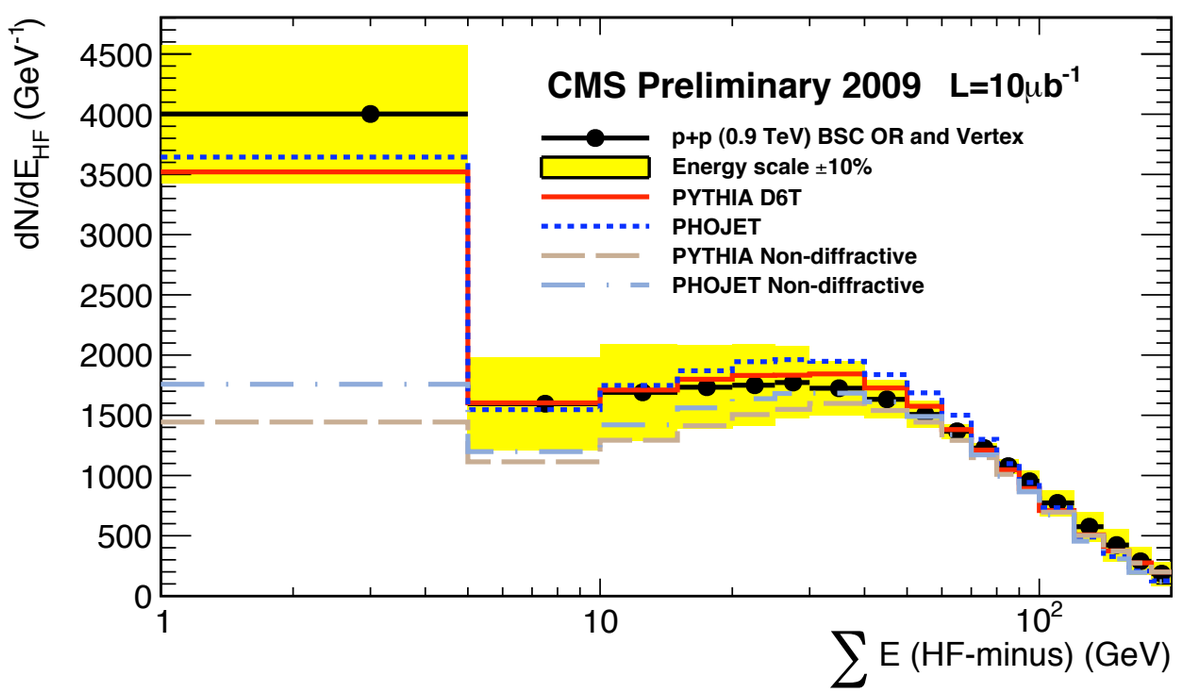


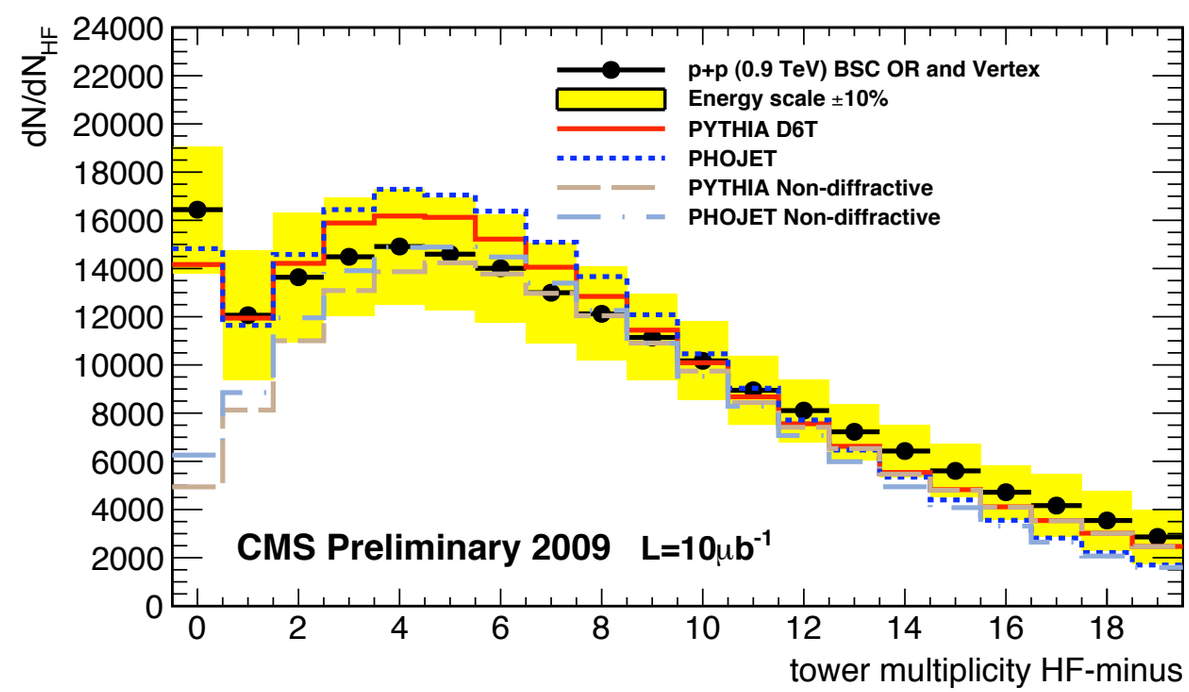


Observation of diffraction - 0.9 TeV

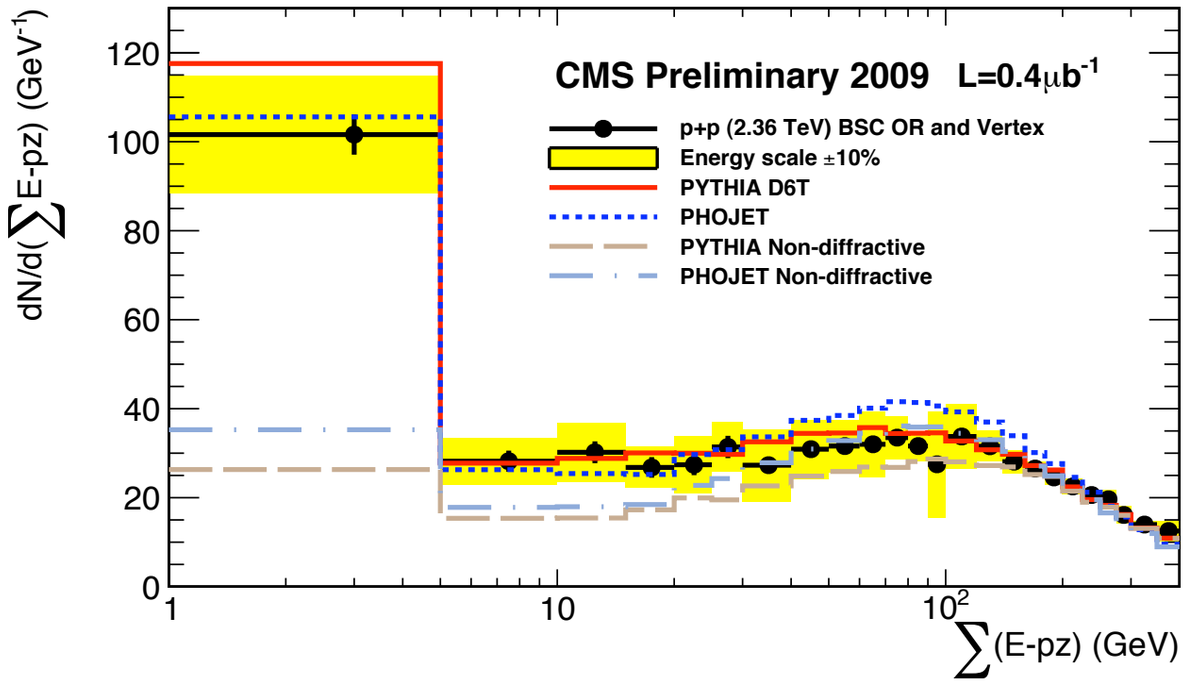


- Σ (E-p_z), energy and tower multiplicity in HF-
- observation of diffractive peak in data
- comparison to different MC tunes

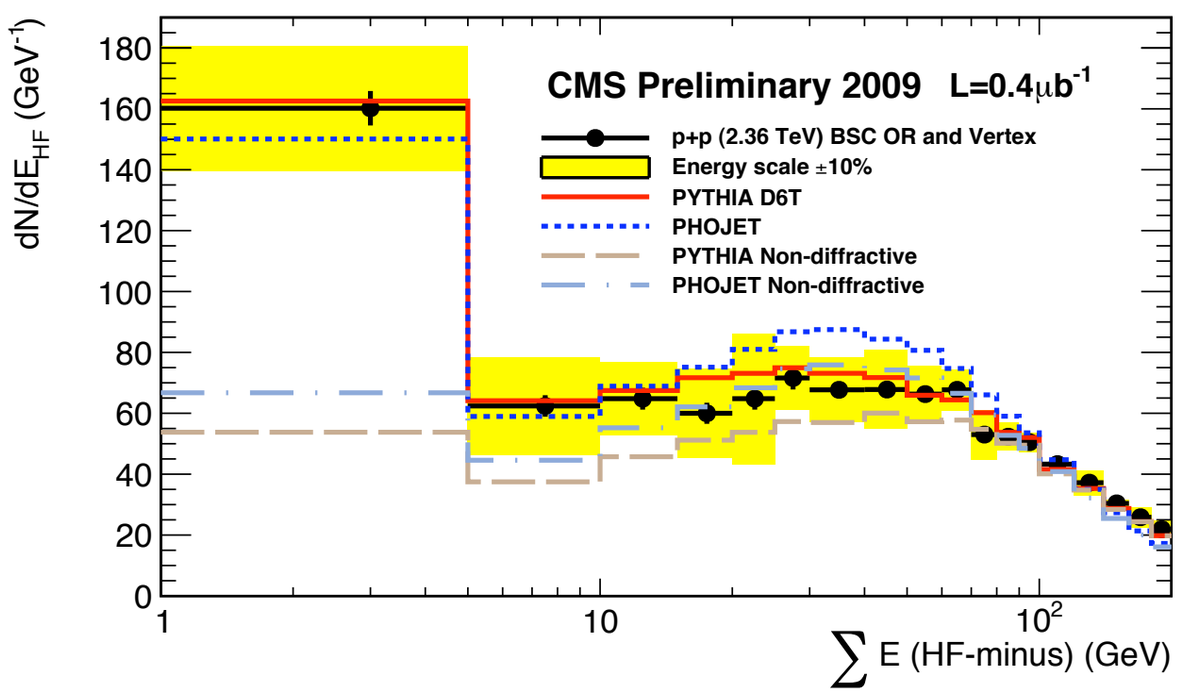


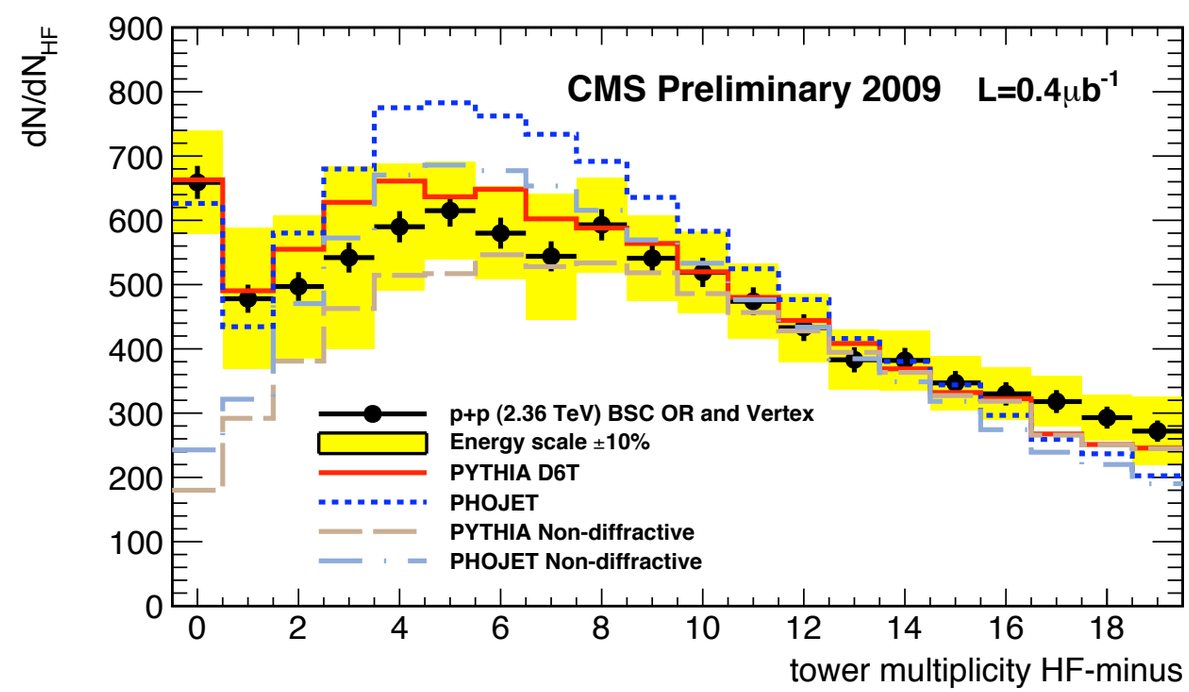


Observation of diffraction - 2.36 TeV

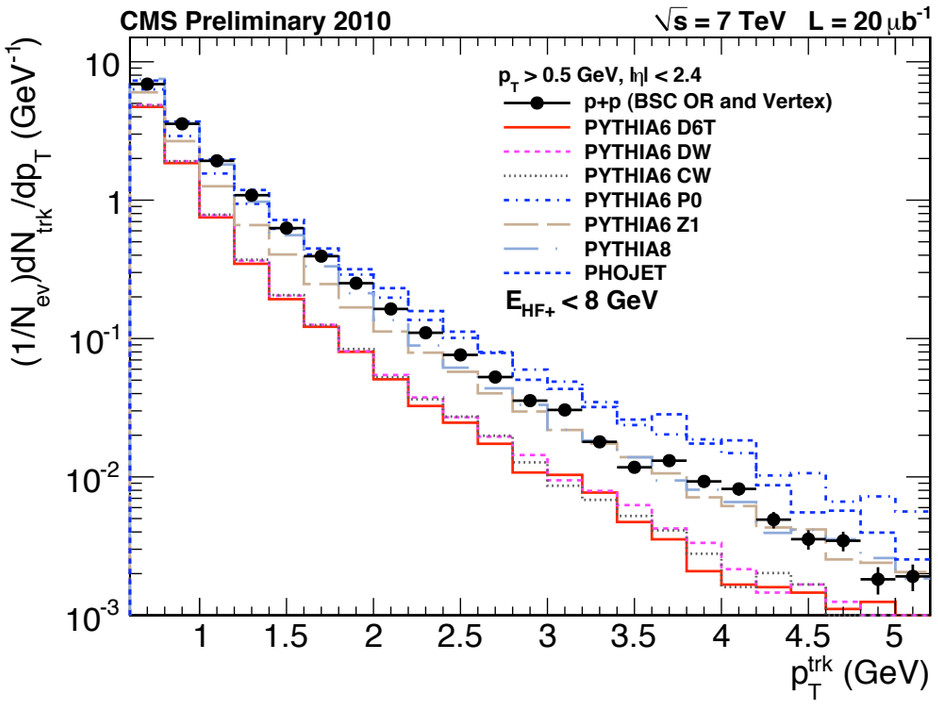


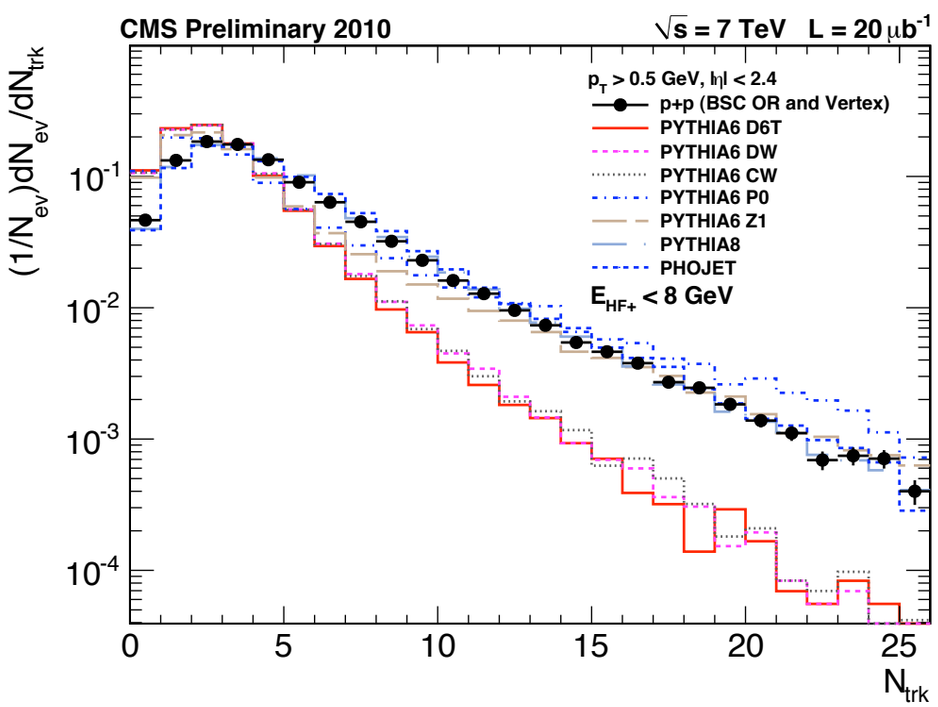
- Σ (E-p_z), energy and tower multiplicity in HF-
- observation of diffractive peak in data
- comparison to different MC tunes

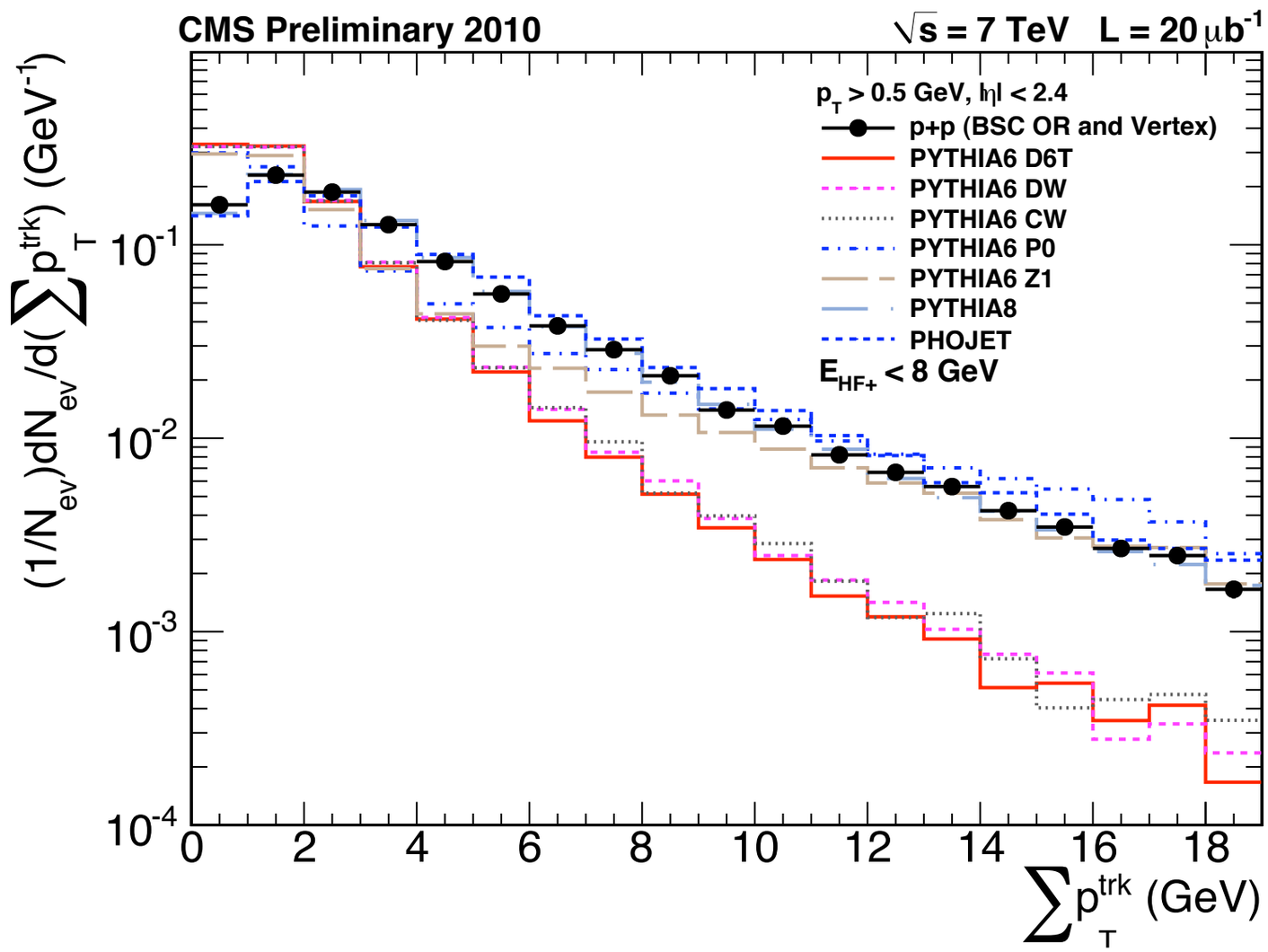




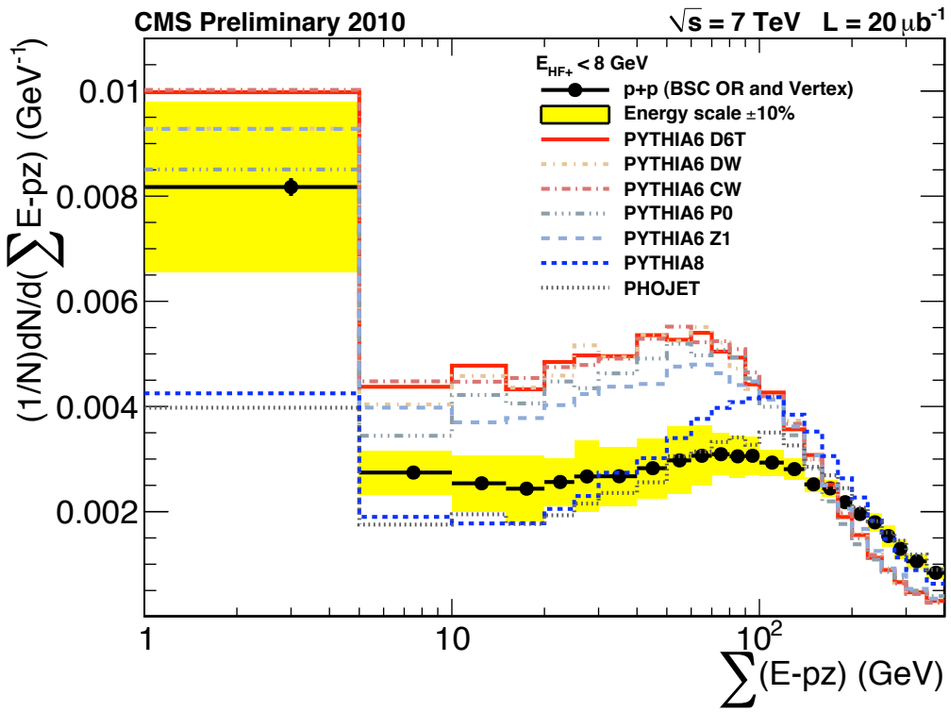
Tracker distributions – $E_{HF+} < 8$ GeV – 7 TeV



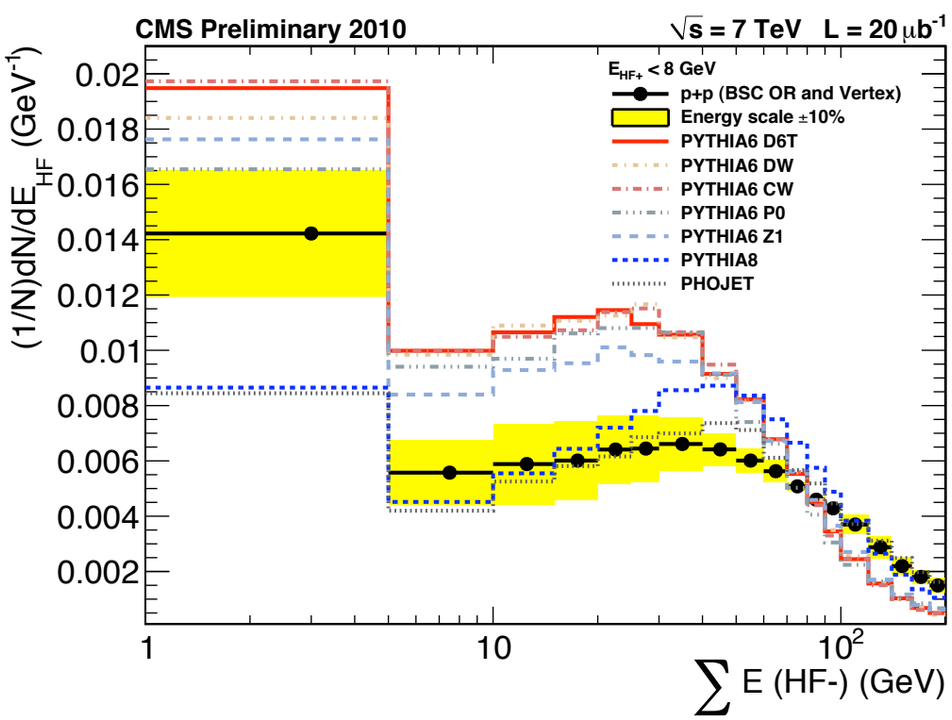


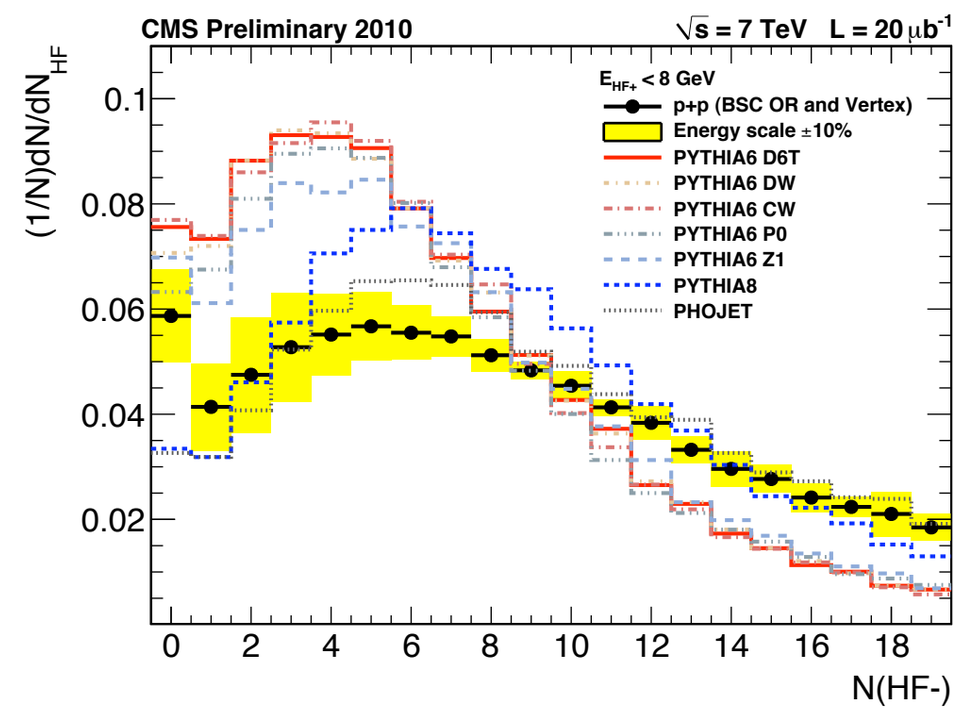


Diffraction – $E_{HF+} < 8$ GeV – 7 TeV

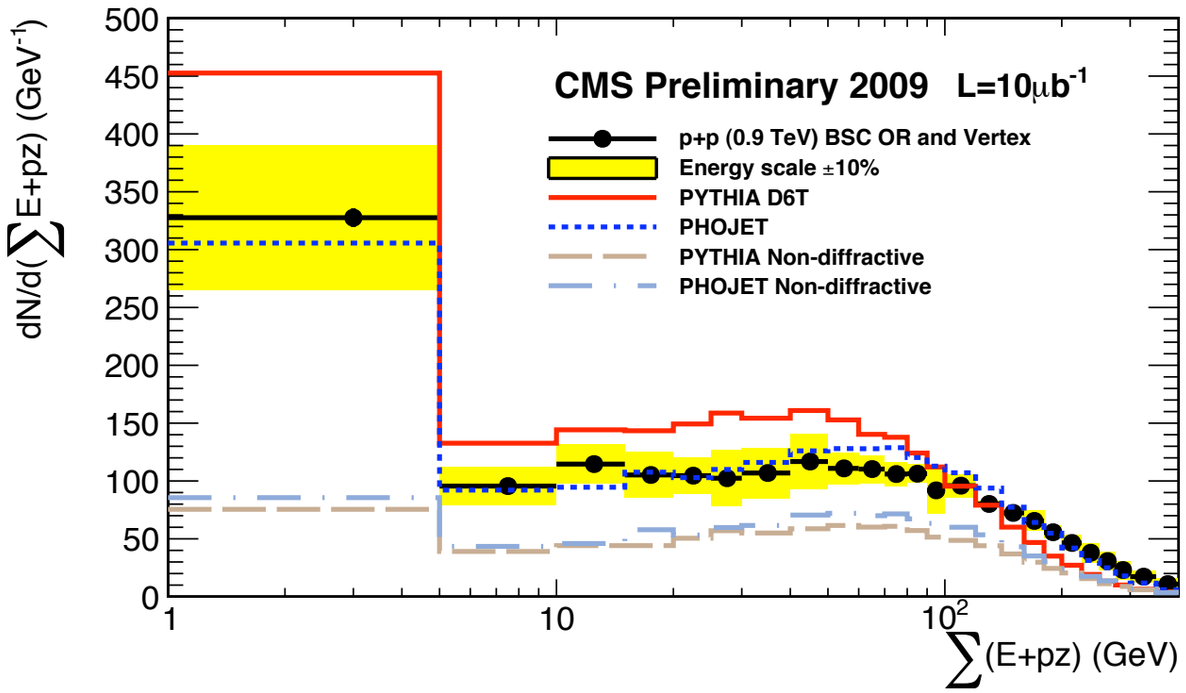
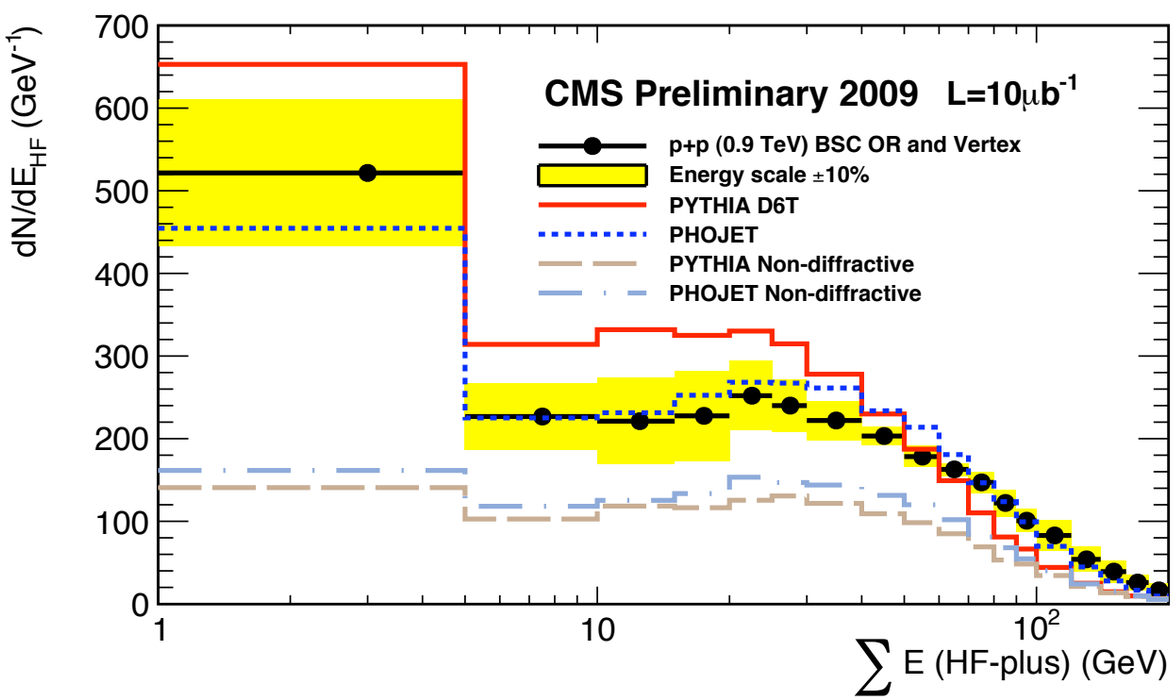
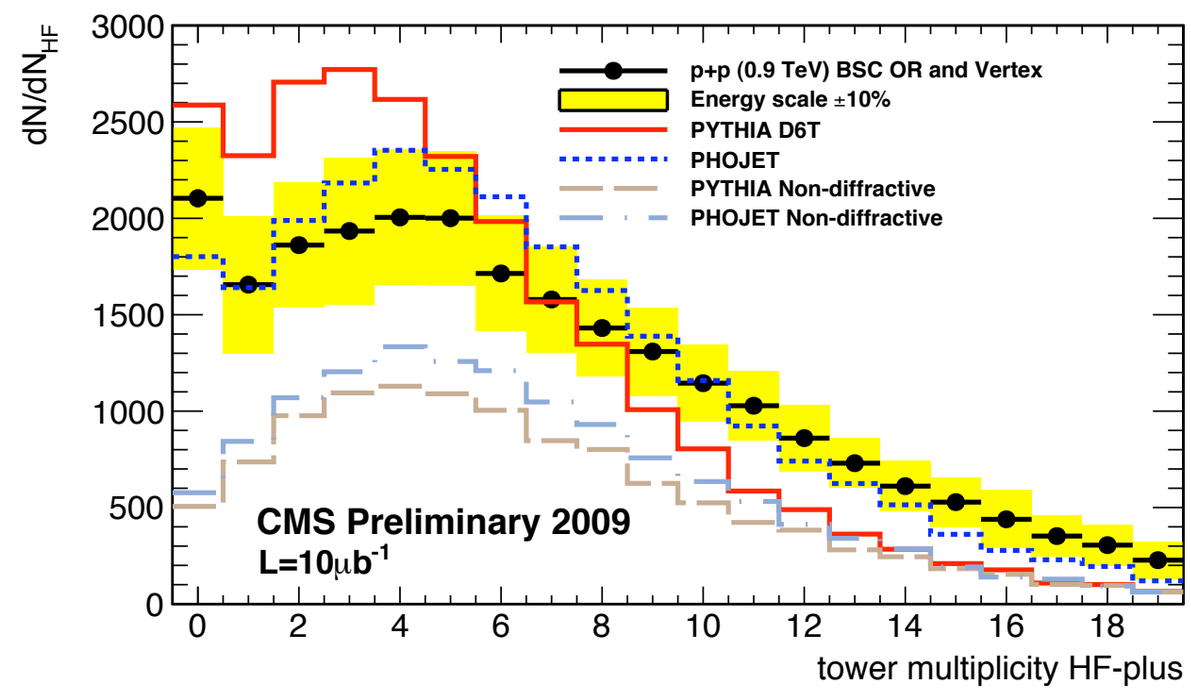


- Σ (E-p_z), energy and tower multiplicity in HF- when $E_{HF+} < 8$ GeV
- observation of diffractive peak in data
- comparison to different MC tunes





Diffraction – $E_{HF-} < 8$ GeV – 7 TeV



- Σ (E+p_z), energy and tower multiplicity in HF+ when $E_{HF-} < 8$ GeV
- observation of diffractive peak in data
- comparison to different MC tunes