CMS and fwd detectors: Status of L1 trigger studies

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FP420 meeting Aug 2005

Studies provided input to FP420 proposal for LHCC
Studies will go into CMS-TOTEM LOI and CMS Physics-TDR

Studies performed in CMS/TOTEM L1 trigger working group, meets once per week, participants:

CMS
- Antwerpen (Marek Tasevsky)
- Bristol (Richard Croft, Dave Newbold)
- Turin/Novara (Michele Arneodo, Marta Ruspa, MG)
- Wisconsin (Sridhara Dasu, Creighton Hogg, MG)

TOTEM
- CERN (Valentina Avati, Mario Deile)
- Genova (Fabrizio Ferro)
- Helsinki (Erik Bruecken, Ken Oesterberg, Fredrik Oljemark)

What happened so far ?
A quick recap

The challenge: triggering on central exclusive diffractive production of a low mass Higgs with the L1 jet trigger

Our poster-child process: **H (120 GeV, DPE prod) → b bbar**
L1 signature without fwd detectors: 2 jets in CMS Cal, each with E_T < 60GeV

→ Use rate / efficiency @ L1 jet E_T cutoff of 40 GeV as benchmark

With current software:
L1 2-jet rate for central jets (|η|<3) @ L1 jet E_T cutoff of 40 GeV for Lumi 2 x 10^{33} cm^{-2} s^{-1}: ~**50 kHz**, while considered acceptable: **O(1 kHz)**

Need additional conditions to trigger a 120 GeV Higgs with L1: Forward detectors !

Achieved so far

Answered:

A) What can be done with central CMS L1 condition alone
B) What can be won by adding T1/T2 as veto condition on L1
C) What can be done with (central CMS + RP at 220 m) L1 cond.
D) What could be achieved with RPs at 420m at HLT, if not at L1

With respect to:
1) L1 rates
2) L1 signal efficiency
3) Pile-up events

Reference luminosities:
i) No pile-up case (e.g. for L=$\mathbf{10^{32}\ cm^{-2}\ s^{-1}}$)
ii) L = $\mathbf{10^{33}\ cm^{-2}\ s^{-1}}$
iii) L = $\mathbf{2x\ 10^{33}\ cm^{-2}\ s^{-1}}$
iv) L = $\mathbf{10^{34}\ cm^{-2}\ s^{-1}}$

a) for signal:
EDDE and Exhume generators
b) for QCD background:
Pythia

Results for RP trigger: L1 2-jet rates

Luminosity $[cm^{-2}s^{-1}]$	# Pile-up events per bunch crossing	L1 2-jet rate [kHz] for $E_T > 40$GeV per jet	Total reduction needed	Reduction when requiring track in RP detectors				
				at 220 m		at 420 m	at 220 m & 420 m (asymmetric)	
					$-\xi < 0.1$			$-\xi < 0.1$
1×10^{32}	0	2.6	2	370				
1×10^{33}	3.5	26	20	7	15	27	160	380
2×10^{33}	7	52	40	4	10	14	80	190
5×10^{33}	17.5	130	100	3	5	6	32	75
1×10^{34}	35	260	200	2	3	4	17	39

Table 1: Reduction of rate from standard QCD processes for events with at least 2 central L1 jets with $E_T > 40$ GeV, achievable with requirements on tracks in RP detectors. Additional QCD rate reductions can be achieved with the $\not{H}_T$ condition and a topological condition (see text). Each of them yields, for all luminosities listed, an additional reduction by a factor 2.

From write-up in HERA-LHC proceedings

Summary: L1 rates

To trigger on L1 **H (120 GeV, DPE prod) → b bbar:** Reduce to **O(1 kHz)** L1 2-jet rate for central jets ($|\eta|<3$) @ L1 jet E_T cutoff of 40 GeV to

1) **selection on central detector quantities**
   H_T (i.e. 2 "isolated" jets): rate reduction by factor ~2

2) **T1, T2 as vetoes, to impose the presence of rapidity gaps:**
   - great to suppress the QCD background
   - kills signal as well as soon as there is pileup

3) **one-arm Roman Pot trigger at 220 m**
   - excellent suppression of QCD background in absence of pile-up
   - rejection power goes down with increasing pile-up contribution
   - improve matters by restricting ξ acceptance to diff. peak
   - another factor 2 gain by requesting 2-jets on opposite side in η of proton

❖ N.B: All studies use reweighting of Pythia leading proton spectrum, necessary to reproduce HERA diffractive/leading proton data

Summary: L1 rates (II)

For H (120 GeV, DPE prod) → b bbar, adding L1 conditions on the RPs at 220m is likely to provide a rate reduction sufficient to meet the CMS L1 bandwidth limits at luminosities up to 2x 10^{33} cm^{-1} s^{-1}

Asymmetric RP trigger with one proton in 220m RPs and, on the opposite side, one in the RPs at 420m

For H (120 GeV, DPE prod) → b bbar, adding L1 conditions on the RPs at 220m and 420m would provide a rate reduction sufficient to meet the CMS L1 bandwidth limits at luminosities up to 10^{34} cm^{-1} s^{-1}

Unfortunately probably not possible on L1 - cannot beat the speed of light

Summary: L1 signal efficiencies

❖ RP condition for 220m RPs reduces 2-jet L1 trigger signal efficiency by factor ~2
Result of limited acceptance of RPs in diffractive peak region

❖ Requiring 2-jet trigger threshold of ET=40 GeV and a proton be seen on one side in 220m RPs: signal efficiency for H(120 GeV) -> b bbar is of the order **25%** (Exhume)

❖ Requiring in addition that a proton be seen in the 420m RPs on the other side results in signal efficiency of about **15%**

❖ Requiring 2-jet trigger threshold of ET=40 GeV and a proton be seen on one side in 420m RPs: signal efficiency for H(120 GeV) -> b bbar is of the order **35%**

❖Muon trigger may increase the signal efficiency by up to **10%** - under study

Balls still in the air

- H (120 GeV) → b bbar:
  Under-way:
  - potential of cutting on match between RP xi measurement and xi value calculated with the 2 jets
  - muon trigger and muon+jet trigger studies

- H (140 GeV) → W W*:
  not yet addressed, but no problems with L1 trigger expected

- Single diffractive production of dijets, W's and Z's
  Production of signal MC is commencing in Wisconsin

- Trying to make accessible L1 trigger decision to offline-style analysis by recording MC run, event number and L1 yes/no decision

Balls still in the air (II)

- TOTEM is investigating possibility of making available xi measurement of their RP detectors to L1 trigger
  (N.B. TOTEM trigger workshop Sep 15/16 2005)

- Beam gas, beam halo:
  estimates in progress, need to be incorporated in trigger studies

We are writing documentation

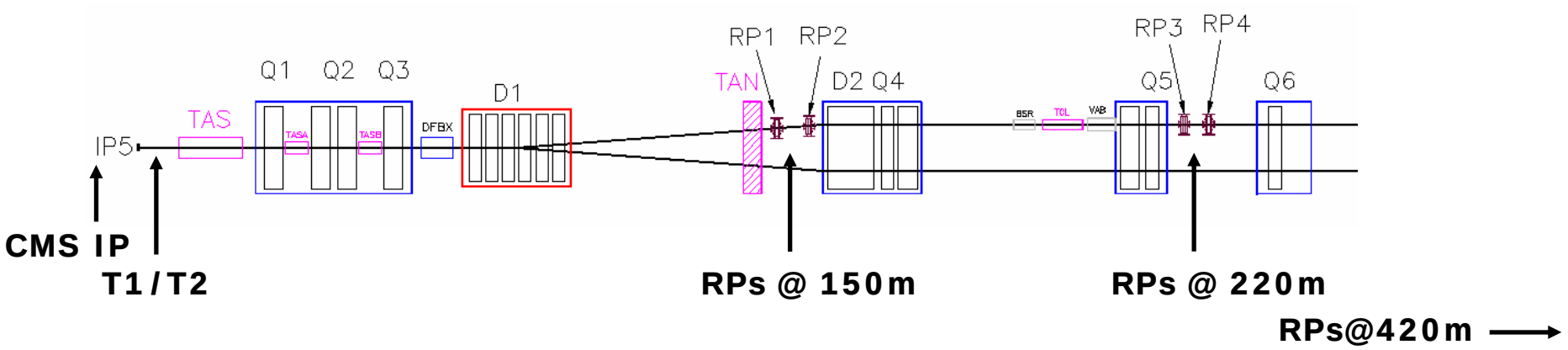
- Write-up of already available results in HERA-LHC proceedings article, almost finished

- Proceedings article will serve as core for contributions to CMS/TOTEM LOI and CMS Physics TDR

- Supporting notes in preparation:
  - R. Croft (CMS) on efficiency and rate studies for the diffractive Higgs
  - V. Avati, K. Oesterberg (Totem) on the RP acceptance calculations
  - F. Oljemark (Totem) on L1 jet calibration and diffractive Higgs Muon trigger studies - will be his Master's thesis
  - F. Ferro (Totem) on T1/T2 track reco and trigger generation

RESERVE

Forward detectors

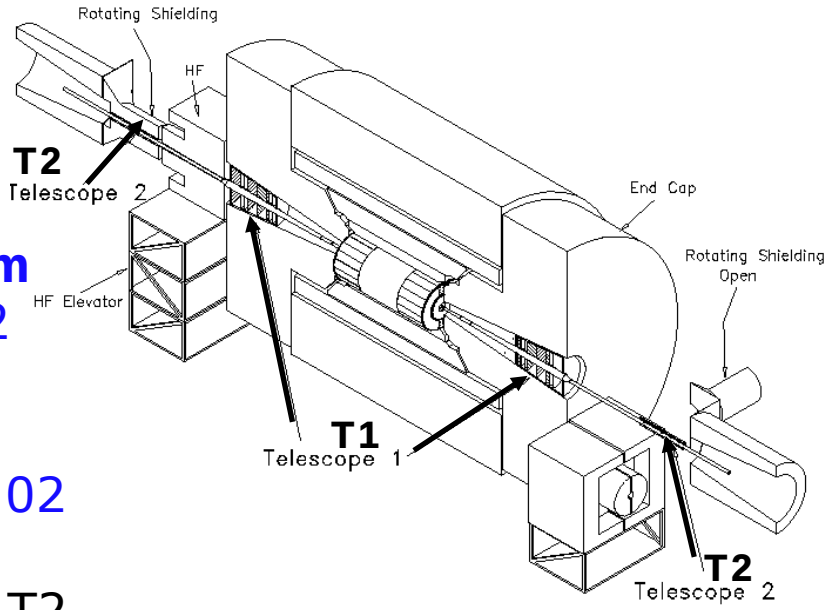


TOTEM detectors:
T1 (CSC) in CMS endcaps
T2 (GEM) in shielding behind HF
T1 + T2: $3 \leq |\eta| \leq 6.8$

Roman pots (Si) on 2 sides at up to **220 m**
Acc. for nominal LHC optics: $0.02 < \xi < 0.2$

Under discussion: **RPs at 420 m**
Acc. for nominal LHC optics: $0.002 < \xi < 0.02$

CMS: **Castor calorimeter**, downstream of T2



Current MC situation

Available at U Wisconsin

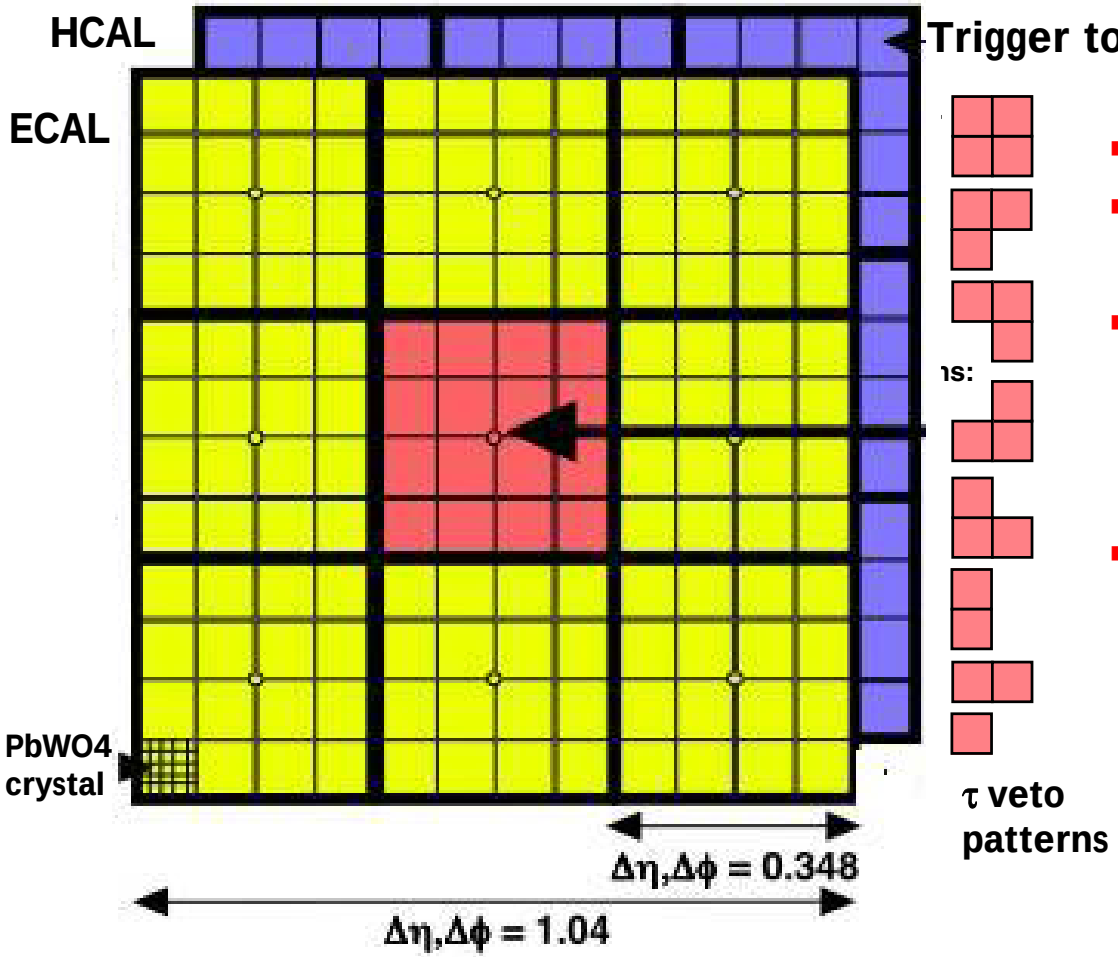
All MC available for no pile-up and for $1x10^{33}$, $2x10^{33}$, $1x10^{34}$
For all MC L1 ntuple available

- 100k EDDE H (120) decaying to b bbar
- 100k Exhume H (120) decaying to b bbar
- 100k Exhume H (140) decaying to WW

- 500k full pile-up events (i.e. include diff and elastics)

- 1 M QCD background events, pythia

Reminder: Level-1 Jets



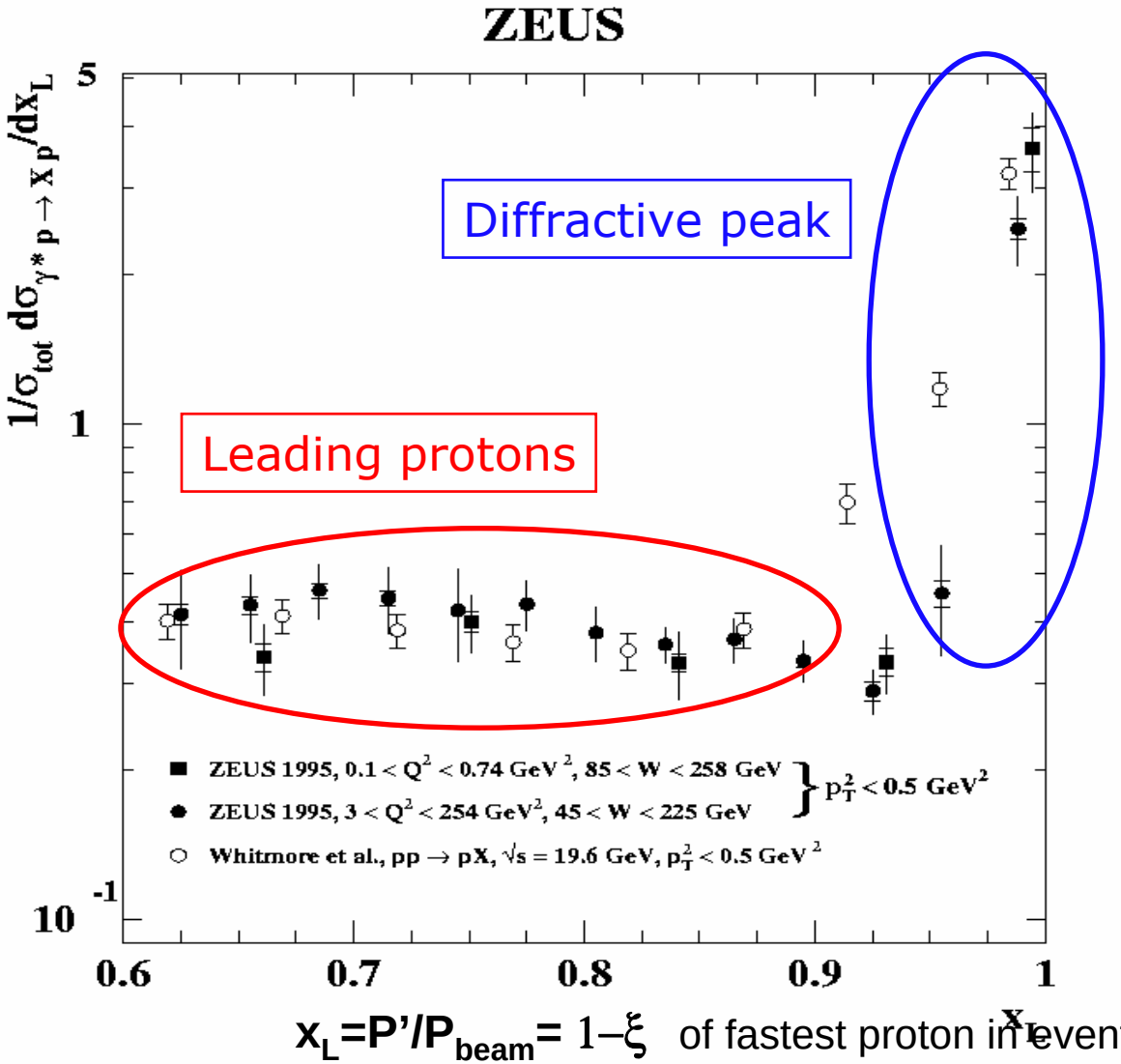
- 4x4 trigger towers = **region**
- Search for jets with a **sliding 3x3 regions window**
- **Jet** = 3x3 region where E_T in central region is above some threshold and larger than E_T in any of the 8 outer regions
- Reconstructed L1 jet E_T on average ~ 60% of real jet E_T, thus need for jet E_T calibration

A jet = 144 trigger towers, with typical tower dimensions $\Delta\eta \times \Delta\phi = 0.09 \times 0.09$
Hence typical jet dimensions: $\Delta\eta \times \Delta\phi = 1 \times 1$

Pile-up studies

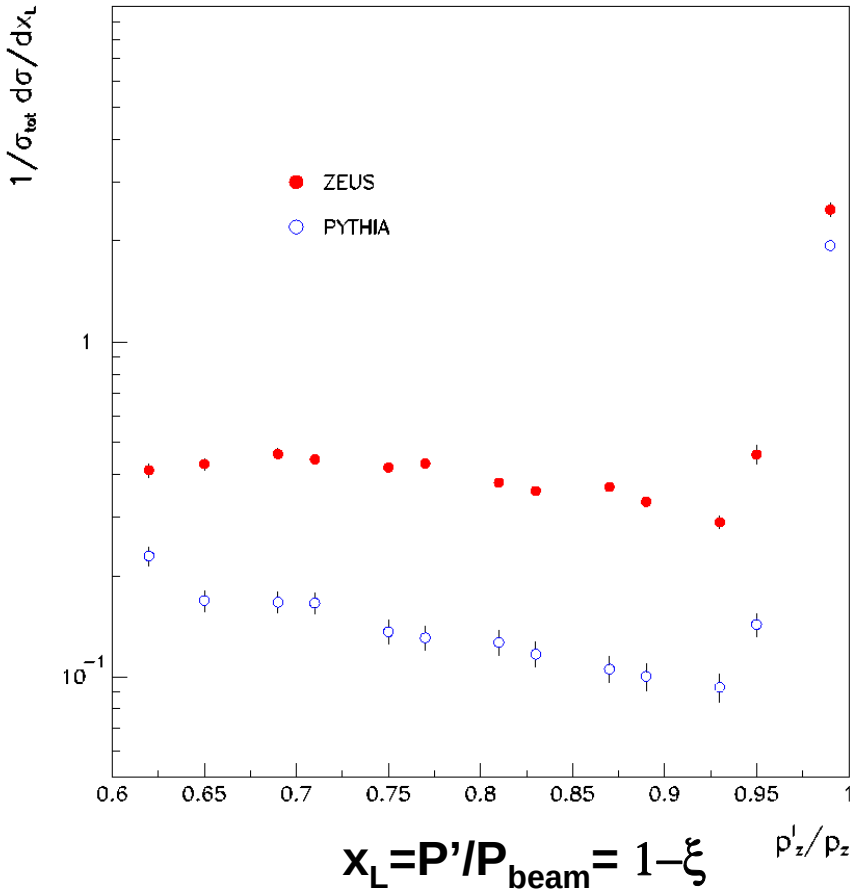
Soft diffractive & elastic events contribute substantially to pile-up
Crucial to study impact of pile-up on RP L1 condition

Prerequisite:
Realistic MC simulation of diffractive events in pile-up
Pile-up in CMS generated with Pythia, compare to HERA and pp leading proton data



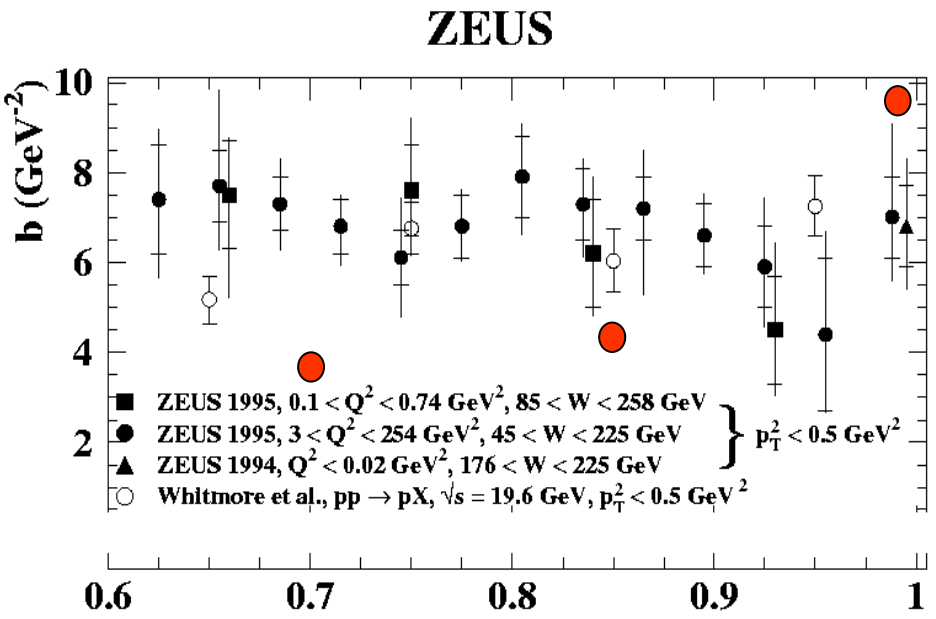
$x_L = P'/P_{beam} = 1-\xi$ of fastest proton in event

Pile-up studies (II)



$x_L = P'/P_{beam} = 1-\xi$

- Pythia wrong in shape & normal. outside diff peak (~ factor 2-3)
- Pythia approx ok in diffractive peak



$x_L = P'/P_{beam} = 1-\xi$

- Pythia too low outside diff peak
- Pythia approx ok in diff peak after taking shrinkage ($b = b_0 + 4\,\alpha'^{I} \ln s$) into account

Plots Marta Ruspa

Beam halo background in RPs

Very preliminary estimates available (M. Deile) for
L = 0.5x 10^{33}, 1.2x 10^{33} and 2x 10^{33}

Example: Beam halo at L = 2x 10^{33}
Estimates valid for RPs at 220 m and 420 m

a) 2808 bunches with 0.52 x 10^{11} p/bunch
single-arm rate: 0.7 MHz = 0.02/bunch
double-arm coincidence: 16 kHz = 0.0005/BX

b) 936 bunches with 0.90 x 10^{11} p/bunch
single-arm rate: 0.4 MHz = 0.04/bunch
double-arm coincidence: 18kHz = 0.0018/BX