A forward physics program for Atlas

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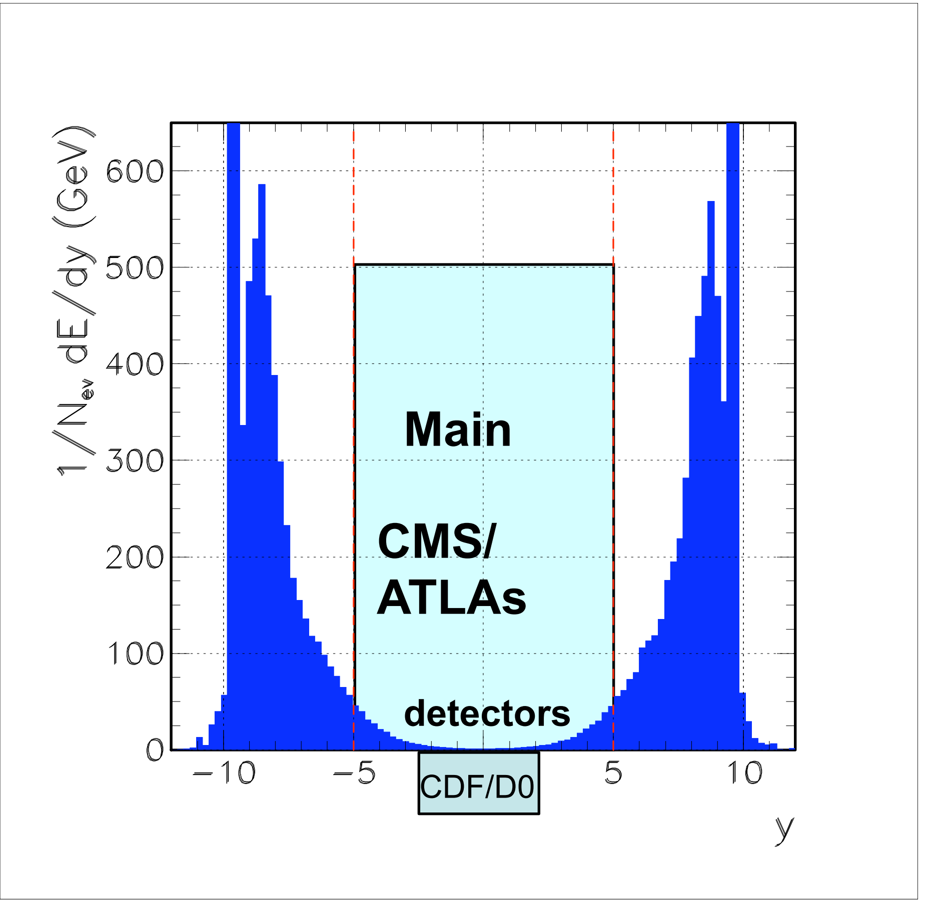
- Introduction
- First measurement:
  - Central Exclusive Diffraction
  - Gaps Between Jets
  - QCD evolution
- Two-photon physics
- Forward detectors

First data analysis

This year's data will mainly be used for commissioning and calibration, but due to the unprecedented η coverage of LHC detectors, we can say something really new on forward physics.



Still, most of the particles are produced in the very forward region, and a vast program is under way to extend the coverage as forward as a rapidity of 10 or more

Forward jets

Most of the LHC interactions will involve forward jets final states
Mainly produced by exchange of coloured objects,
-> hadronic activity in the central region
so many events that you want to set very high prescales

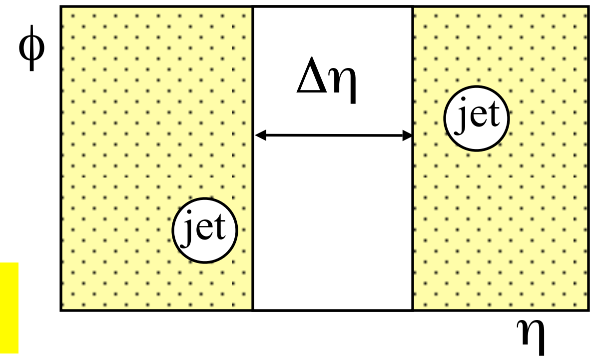
But for large $\Delta\eta$ between the two forward jets, we are entering BFKL regime, so it is interesting to compare BFKL-inspired predictions to DGLAP.

Enhancement of events with large rapidity gaps already observed at Tevatron, Hera, test extrapolation to LHC

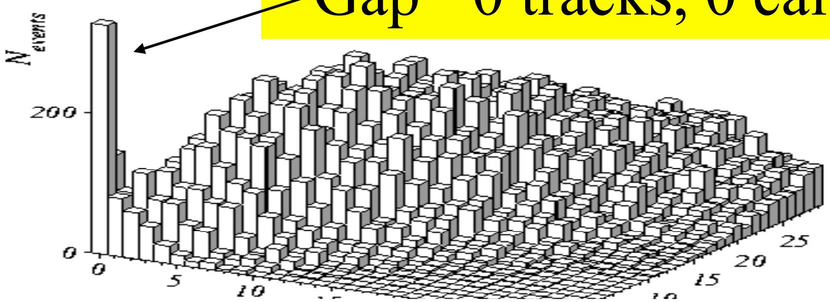
Experimentally, a good starting ground for VBF physics and diffractive studies

Previous Hard Color-Singlet Mesurements

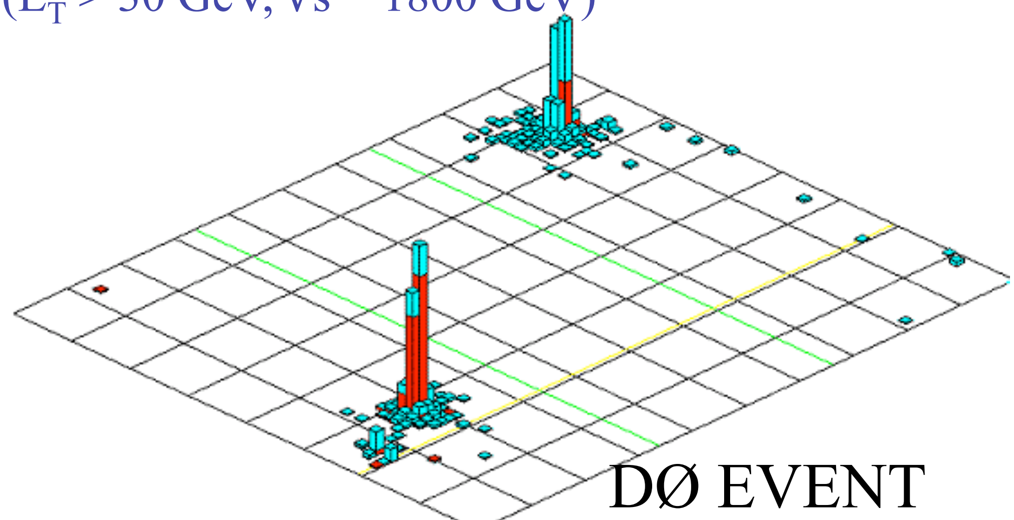
QCD color-singlet signal observed in ~ 1 % opposite-side events (ppbar)



Gap= 0 tracks, 0 cal. towers



(E_T > 30 GeV, $\sqrt{s}$ = 1800 GeV)



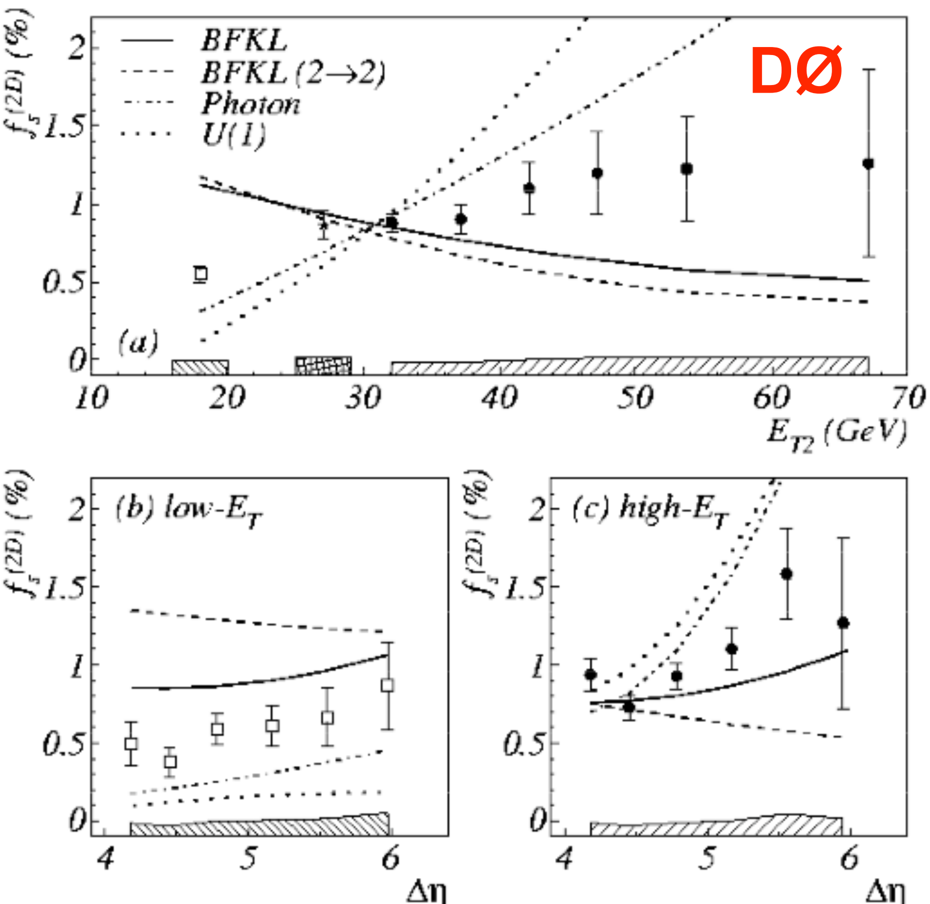
DØ EVENT

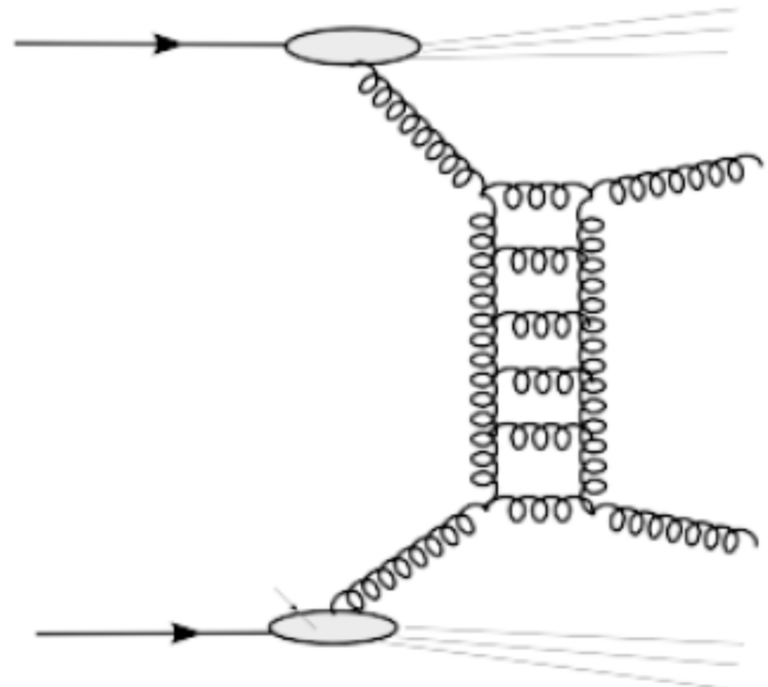
Publications

DØ: PRL 72, 2332(1994)
CDF: PRL 74, 885 (1995)
DØ: PRL 76, 734 (1996)
Zeus: PLB369, 55 (1996)
CDF: PRL 80, 1156 (1998)
DØ: PLB 440, 189 (1998)
CDF: PRL 81, 5278 (1998)
H1: Eur.Phys.J. C24 517 (2002)

Gap fraction evolution

- QCD production believed to be dominated by hard color singlet exchange (BFKL).
- Single gluon exchange (i.e. normal QCD) radiates and populates the interval between jets. Lack of activity (gap) formation is exponentially suppressed with interval size.



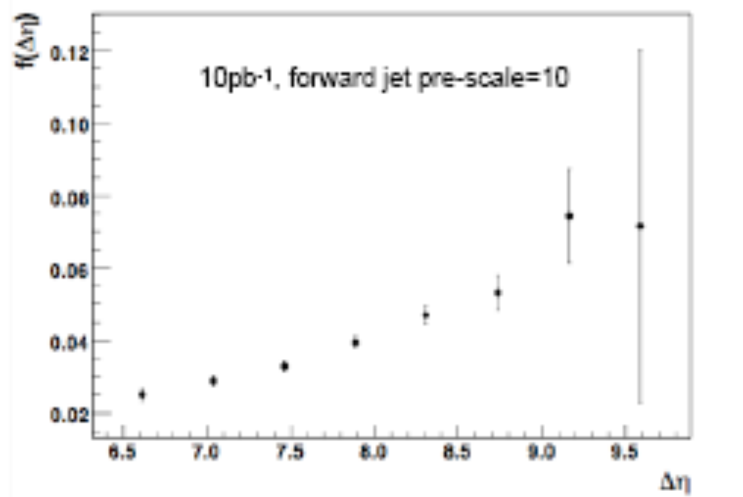


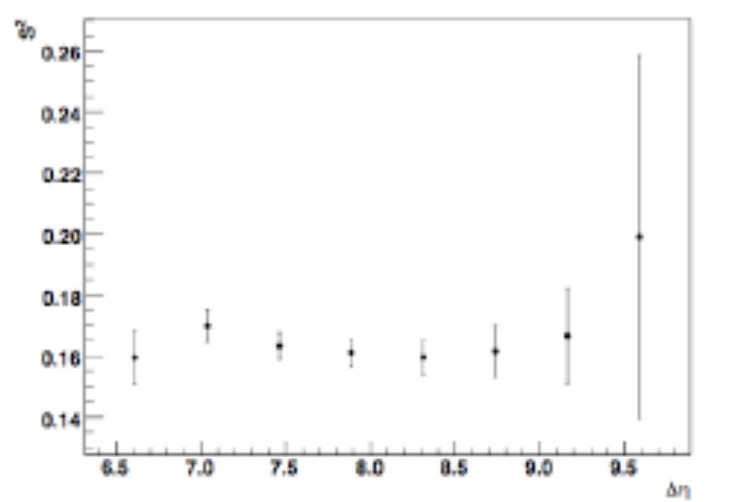
BFKL did not describe observed DØ E_T dependence but BFKL model later modified B. Cox et al JHEP9910:023,

Need more precise data, larger Δη coverage

Rise of the Gap Fraction - Hadron Level Prediction for the LHC

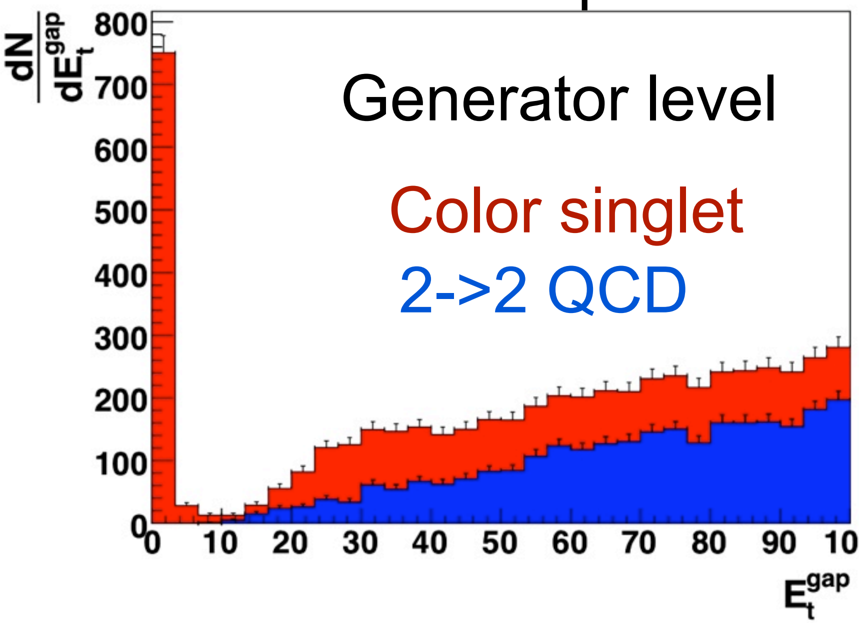
- Hadron level feasibility study performed using HERWIG+JIMMY for QCD and CSE events.
- Stable particles restricted to calorimeter coverage ($|\eta|<4.9$). Basic smearing of particle energy given by ATLAS parameters.
- Forward jet trigger approximated for particles in forward calorimeters. Events kept if 2 jets with $E_T>30$GeV. Assume jet prescale=10.
- Analysis defines gap by using KT algorithm, sum transverse energy of mini-jets in the interval between the two leading jets. Define CSE to have $\Sigma E_T<10$GeV.

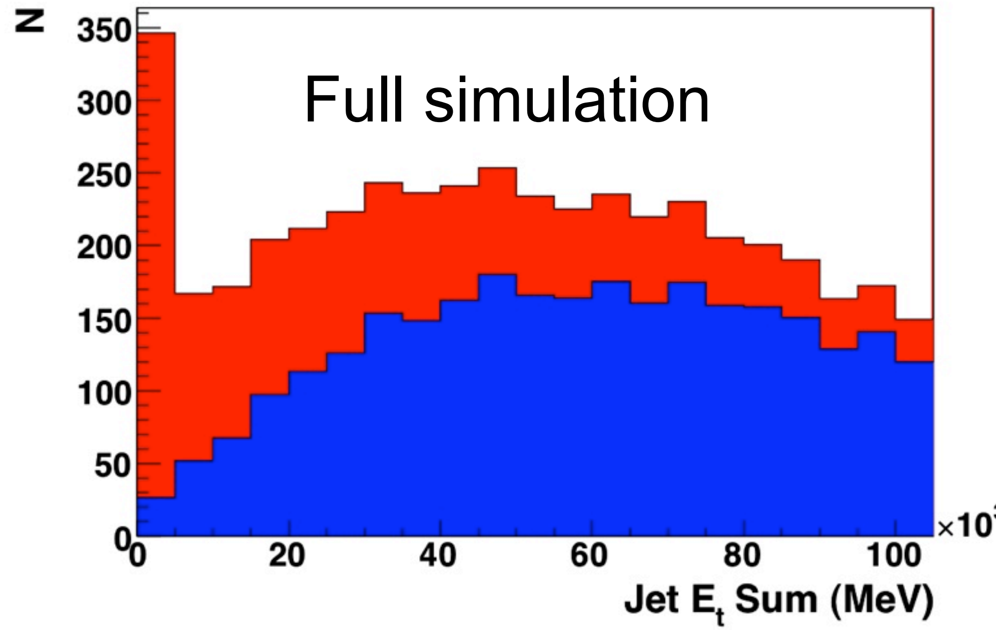




Jet-gap-jet in Atlas (very preliminary)

1 pb-1





- Hadron level analysis defined CSE as less than 10 GeV of transverse energy in the interval between the jets. (Basic smearing of particle energy applied)
  - How does noise and real detector affect this?
  - How does the crack region affect this?
  - Can tracking information improve gap definition (a la D0)?

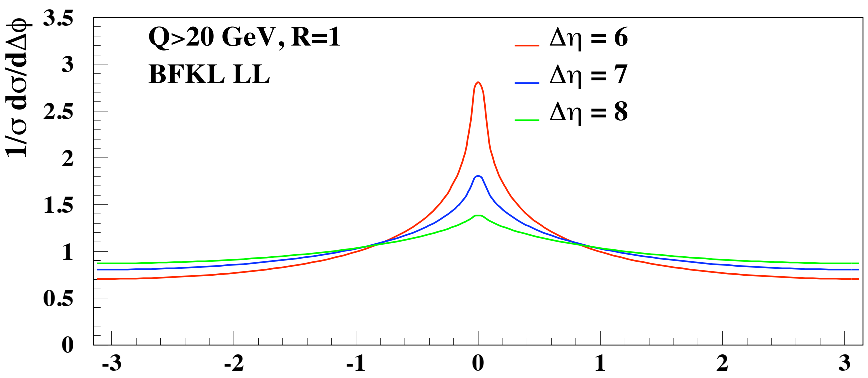
Not only gaps

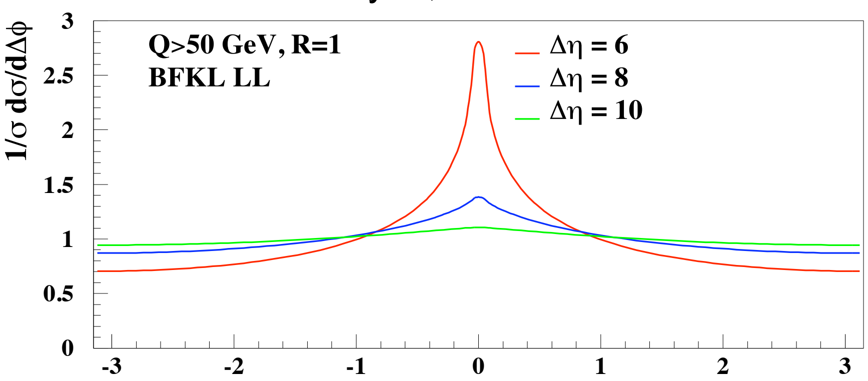
The BFKL ladder does not only predict an increase of events with large rapidity gaps.

In fact, a diagram where the ladder is cut in half leads to an enhancement of jets in the central region of similar Et to the forward-backward ones (~one per two rapidity units), and de-correlation of the ΔΦ between the jets (Mueller-Navelet jets).

ΔΦ dependence on Δη is another indicator of BFKL behaviour:

Ch. Royon, low-x 2008

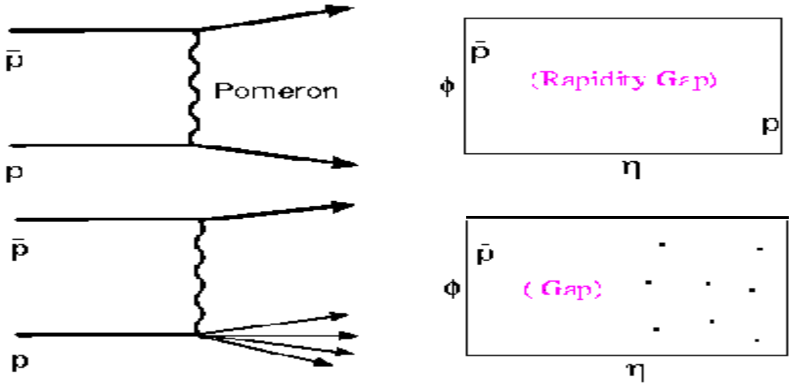




Other observables, depending on ket energies, may not be available from day 0 due to calibration, but certainly for the 2009 analysis

More Diffractive Topologies

Soft Processes:



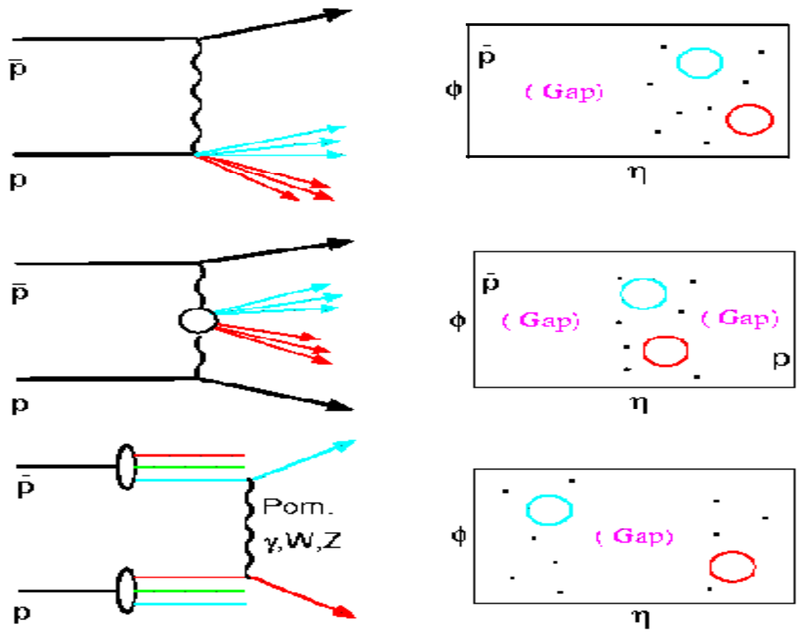
Elastic Scattering

$$p\,\bar{p} \to p\,\bar{p}$$

Single Diffraction

$$p\,\bar{p} \to p\,(\bar{p}) + X$$

Hard Processes (jet production):



Hard Single Diffraction

$$p\,\bar{p} \to p\,(\bar{p}) + j\,j$$

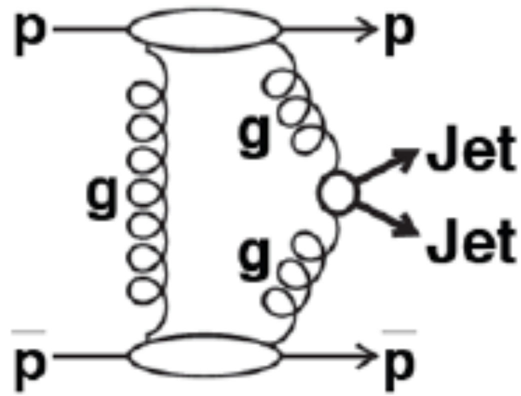
Hard Double Pomeron

$$p\,\bar{p} \to p\;\;\bar{p} + j\,j$$

Hard Color Singlet

Triggering: diffraction has gap(s) and/or protons; high cross section hard diffraction has jets too

Central Exclusive Di-jet Production

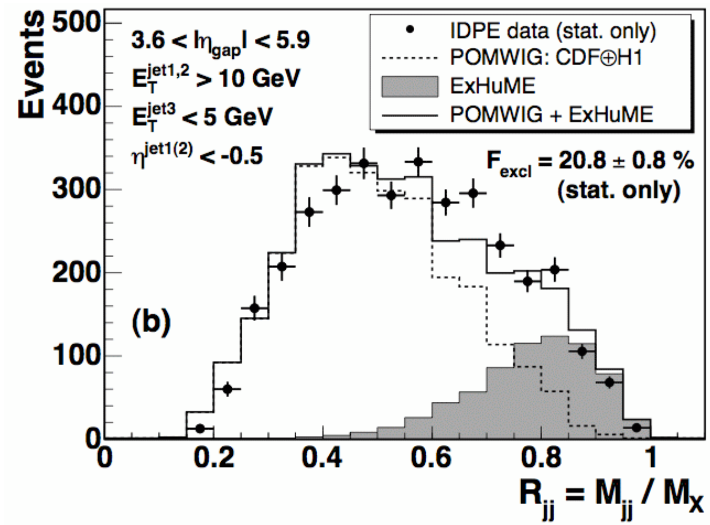


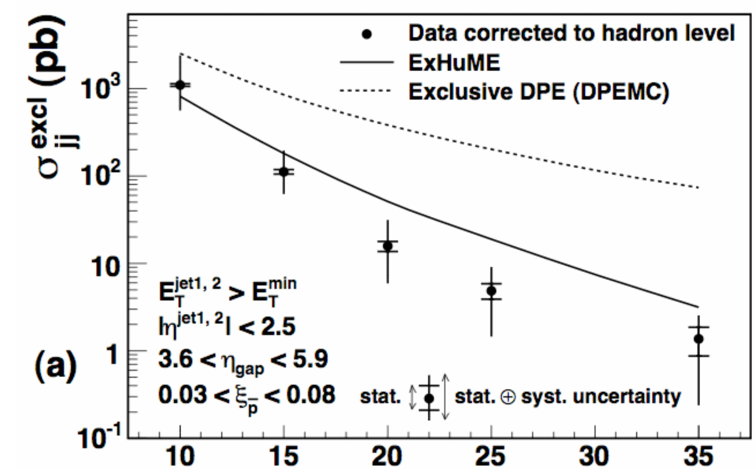
- Protons remain intact.
- All of the energy lost by protons goes into the production of central system.
  (for protons losing 1% of momentum, effective center-of-mass energy is 140 GeV—Higgs measurements possible with proton spectrometers)
  - Measure central jets and no activity in forward region
- Fraction of b-jets in di-jet sample is reduced with respect to standard production.
- Measuring CEP dijet rate allows us to test the theoretical framework - generalised parton distributions, sudakov suppression, soft-survival.
  - Constrains model, important for proposed forward proton detector upgrade.

CEP observation at CDF

- **Di-jets:**
  - **CDF observed an excess of events at high values of the dijet mass fraction (mass of dijets / mass in calorimeter)**
  - **6σ deviation from background.**
  - **Excess is consistent with CEP theory predictions.**

- **Di-photons:**
  - **Observed 3 candidate γγ events.**
  - **Cross section consistent with theory (within theoretical error of factor 2-3)**





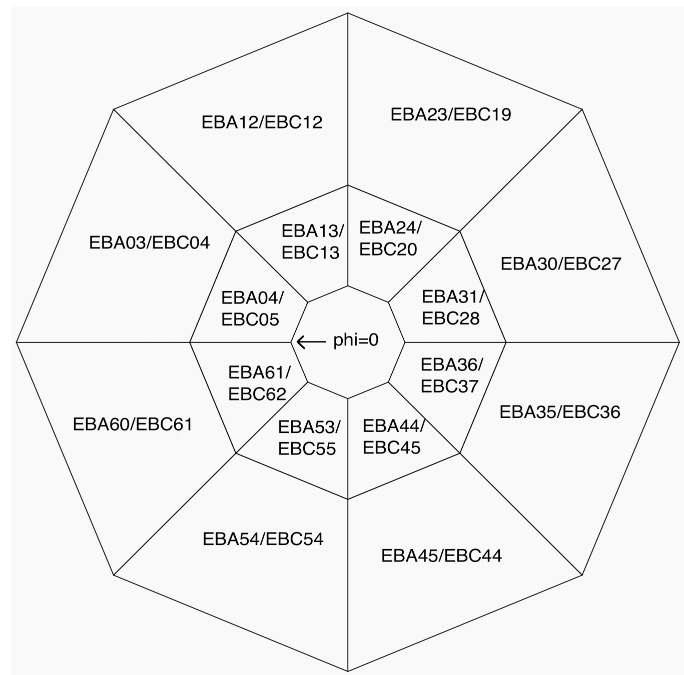
ATLAS Gap Trigger Strategy

Standard jet thresholds too highly prescaled for CEP studies.

Jet Trigger	Prescale (L1)	Rate (Hz)
J10	42000	3.9
J18	6000	1.02
J35	500	1.37
J42	100	3.73

Short term option:
Use Minimum Bias Trigger Scintillators (MBTS), covering a rapidity between 2 and 4 to define a lack of activity in the forward region.

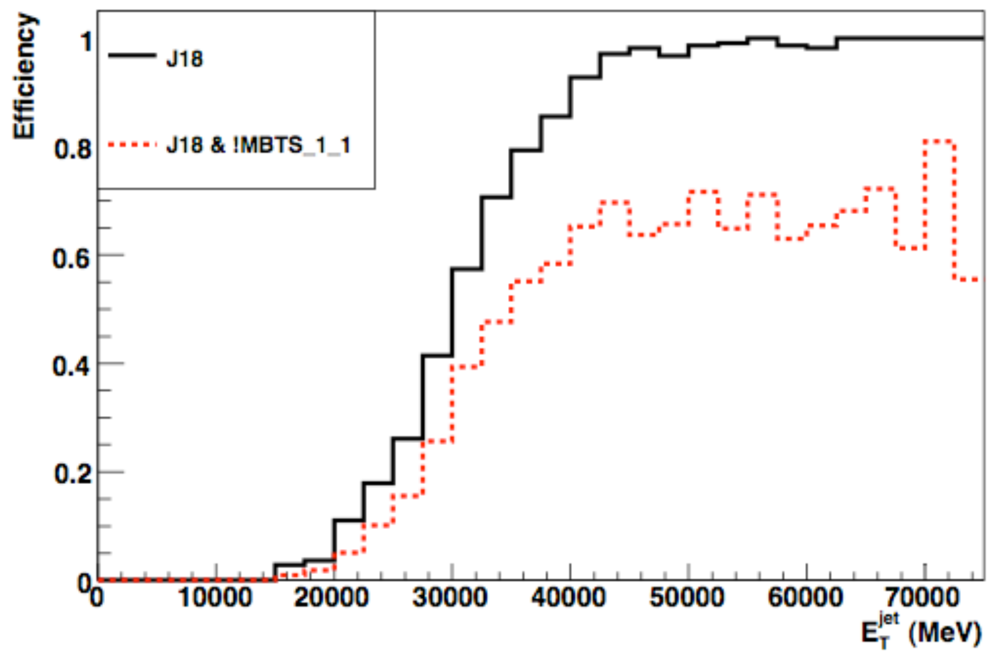
Long term goal:
Use MBTS, BCM, LUCID and ZDC to define a variety of gap definitions.



Possible gap triggers in 10TeV run:

- Require one jet passing J18 (J10 probably too noisy, J35 too high) + veto on MBTS_1_1
  (veto of hits on both sides means no hits on one side or no hits on either side)
- Investigating other MBTS terms such as inner ring veto on one side + outer ring coincidence on other
- Space points at L2 could be used to suppress L1Calo noise

Gap Trigger Expectations: Signal Efficiency



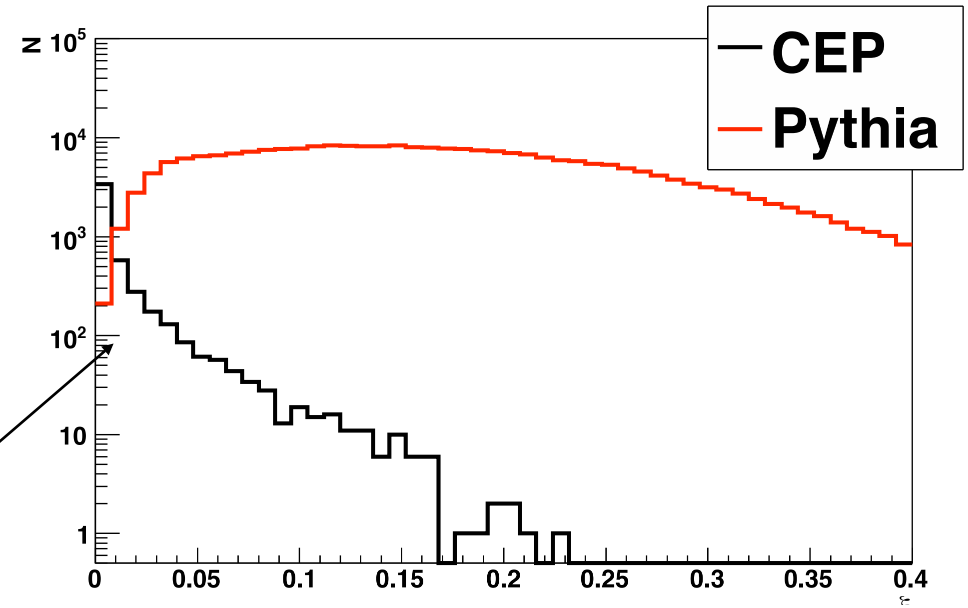
MBTS veto added

- Gap trigger is ~65% for EXHUME CED signal sample (p_T>35 GeV)
  - Hadron Level expect nearly 90% efficient
  - Losses probably due to secondary particles produced via particle interactions with detector

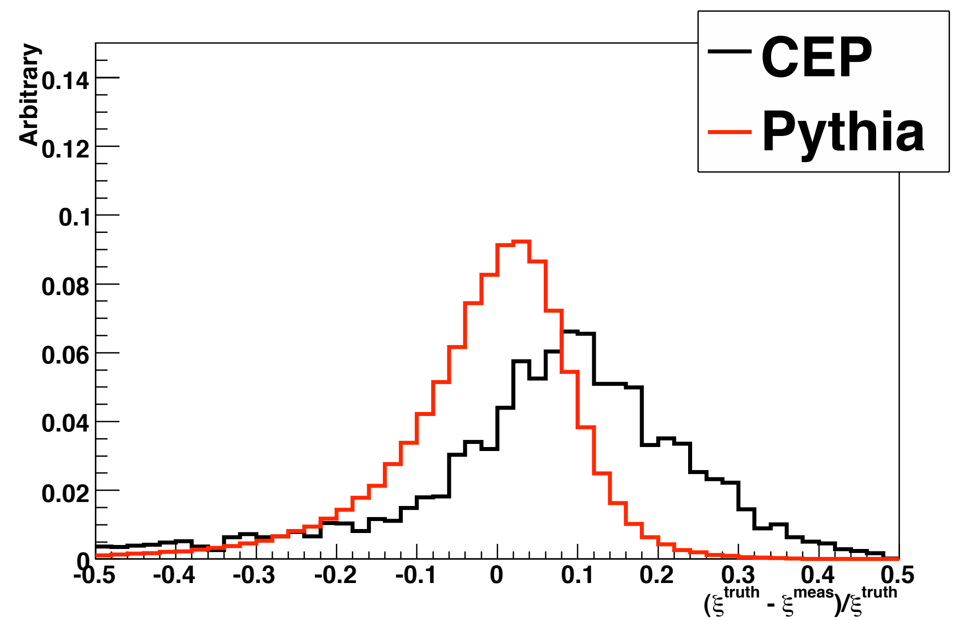
So, we can trigger on these events already tomorrow.
But what about measuring the mass?

Diffractive Observables: ξ

- Usually specify diffractive processes by the fractional momentum loss of proton during interaction, ξ.
- Diffraction and CEP have ξ<<0.1



- If no proton detector ξ can be estimated from calorimeter energy, with 10% precision (not sufficient for Higgs)
- However, the steeply falling distribution introduces a ~5% shift, not seen in the flatter QCD distribution.



For precision measurements we need a dedicated detector!

Photon induced interactions

X. Rouby

Photon physics

LHC /CMS

Fwd p detection

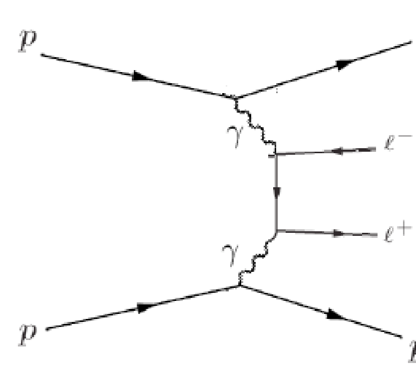
Excl. dileptons

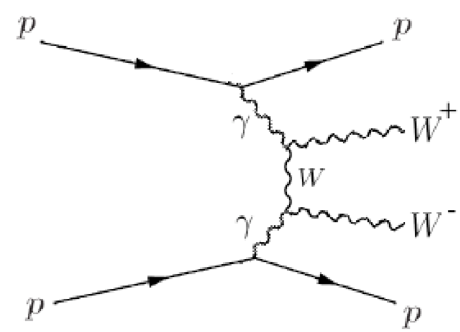
Upsilon

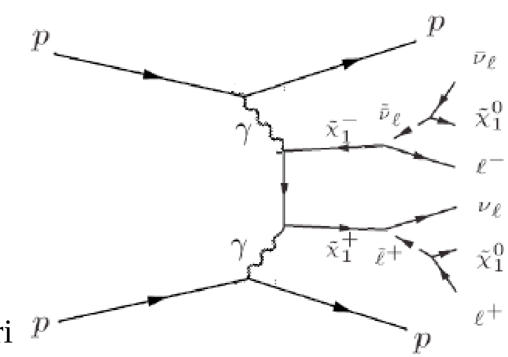
γ γ collision at the LHC (14 TeV)

Cross sections for pp ⟶ ppX

Process	σ_{prod} (fb)		
$\gamma\gamma \to \mu^+\mu^-$	74.7	$\times 10^3$	$p_T > 2.5$ GeV
$\gamma\gamma \to e^+e^-$	10.4	$\times 10^3$	$p_T > 5.5$ GeV
$\gamma\gamma \to W^+W^-$	108.5		-
$\gamma\gamma \to f^+f^-$	4.064		$m_f = 100$ GeV
$\gamma\gamma \to \tilde{f}^+\tilde{f}^-$	0.680		$m_{\tilde{f}} = 100$ GeV
$\gamma\gamma \to H \to b\bar{b}$	0.154		$m_H = 120$ GeV
$\gamma\gamma \to m\bar{m}$	~ 5	$\times 10^3$	$m_m = 1000$ GeV







- Exclusive dileptons: large σ
- γγ W W coupling accessible
- SUSY, ...

Tagging necessary to reject the large pp backgrounds

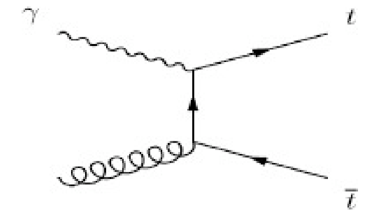
Photon induced interactions

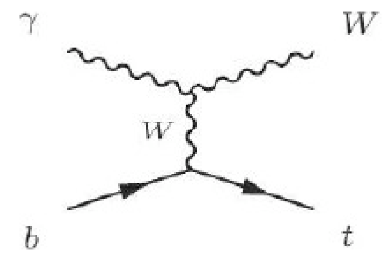
X. Rouby

γ p collision at the LHC (14 TeV)

Cross sections for pp ⟶ pX

Process	σ_{prod} (fb)	
$\gamma q \rightarrow WHq'$	23.0	$m_H = 115$ GeV
$\gamma q \rightarrow WHq'$	17.5	$m_H = 170$ GeV
$\gamma q/g \rightarrow WX$	> 90	-
$\gamma g \rightarrow t\bar{t}$	1.54	-
$\gamma q \rightarrow Wt$	1.01	-
$\gamma q \rightarrow t$	$(368\ k^2_{tu\gamma} + 122\ k^2_{tc\gamma}) \times 10^3$	-

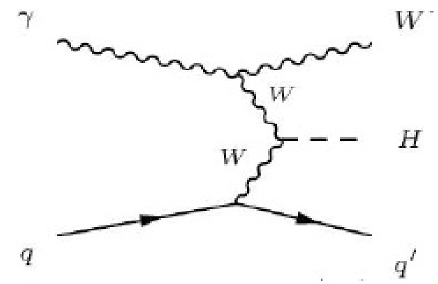




- Higher luminosities than γγ
- Large variety of processes
- Significant cross-sections up to 2 TeV
- Alternative way to pp

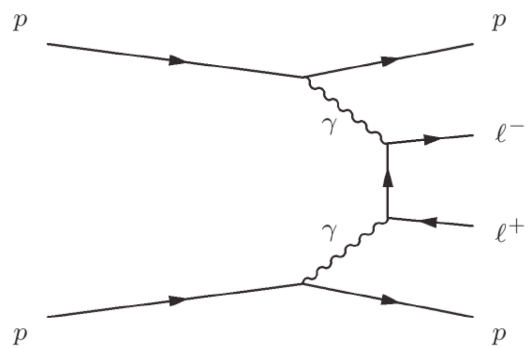
  interactions to study

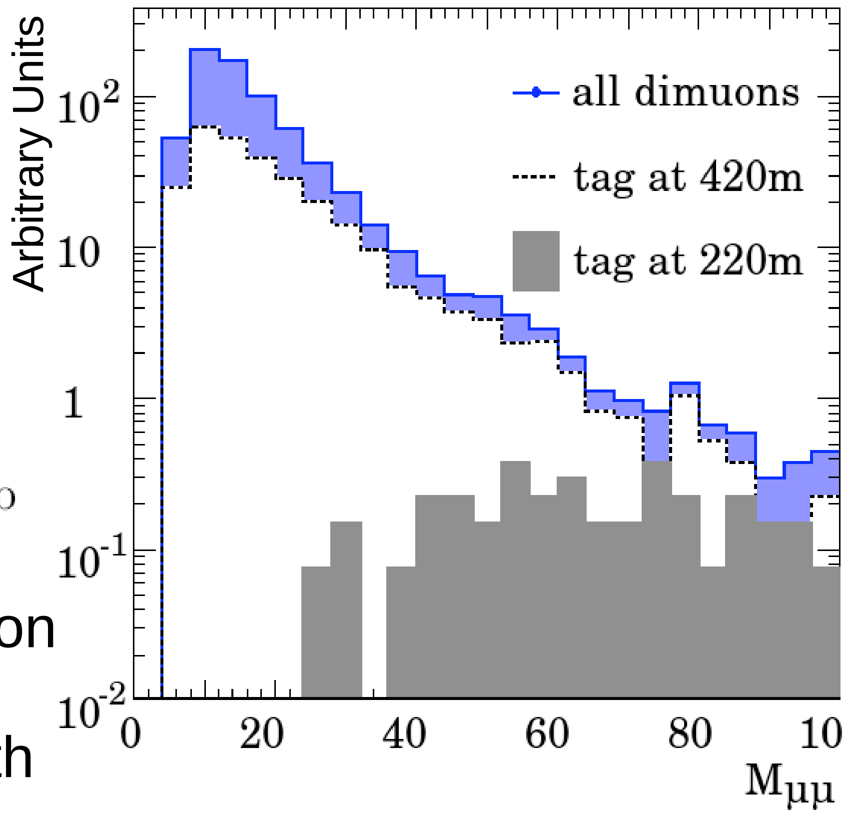
  Higgs, top physics, new physics
- Large survival probability factor



Exclusive dimuons

X. Rouby





1) Measuring both muons in central detector $\sigma_{vis} \approx 7$ pb

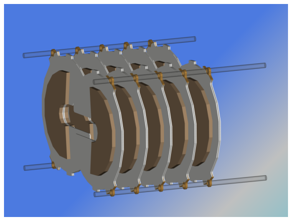
2) Tagging at least one proton

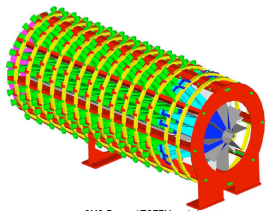
3) Energy reconstruction with very good resolution

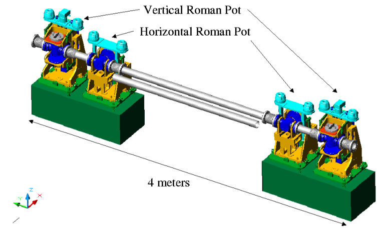
Most of the selected exclusive muon pairs have a proton within forward detector acceptance !

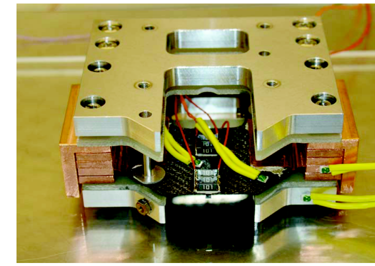
Forward detectors at LHC

TOTEM -T2　CASTOR　ZDC/FwdCal　TOTEM-RP　FP420





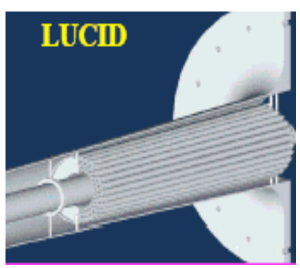


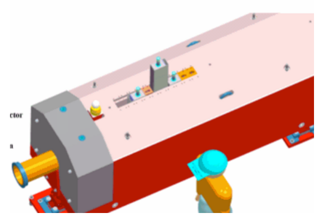


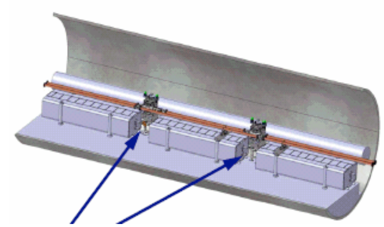
IP5

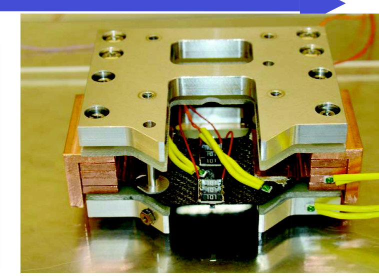
14 m　16 m　140 m　147m - 220 m　420 m

IP1





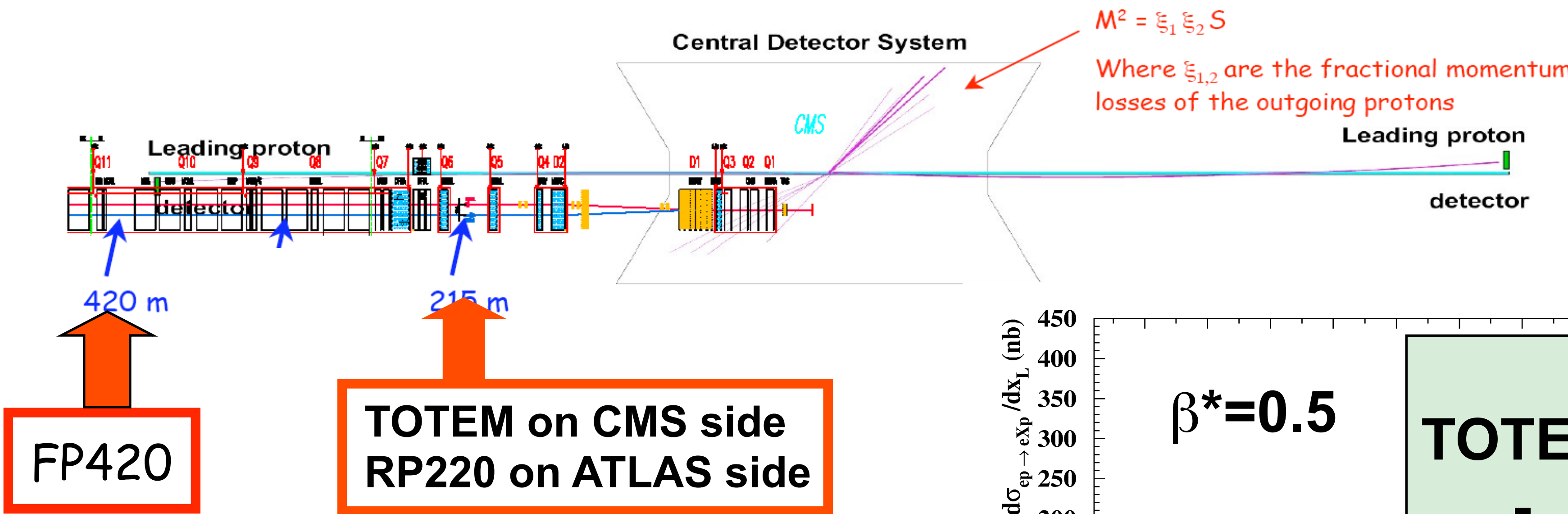


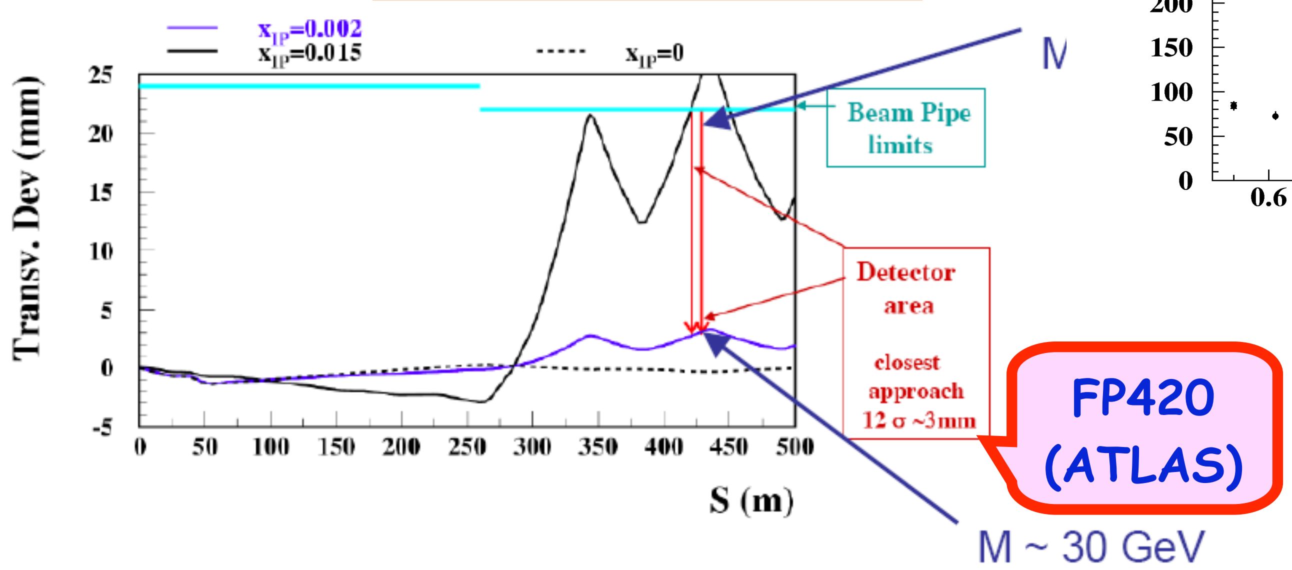


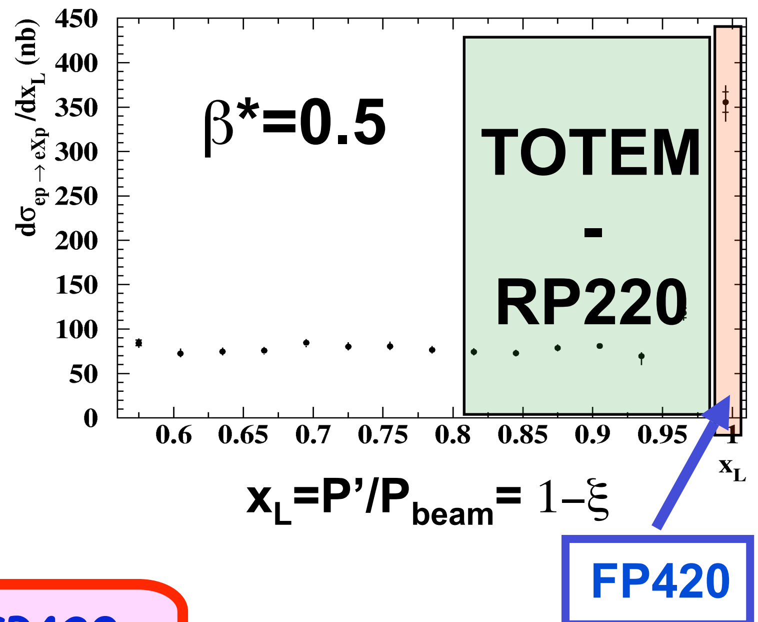
ATLAS

LUCID　ZDC　ALFA/RP220　FP420

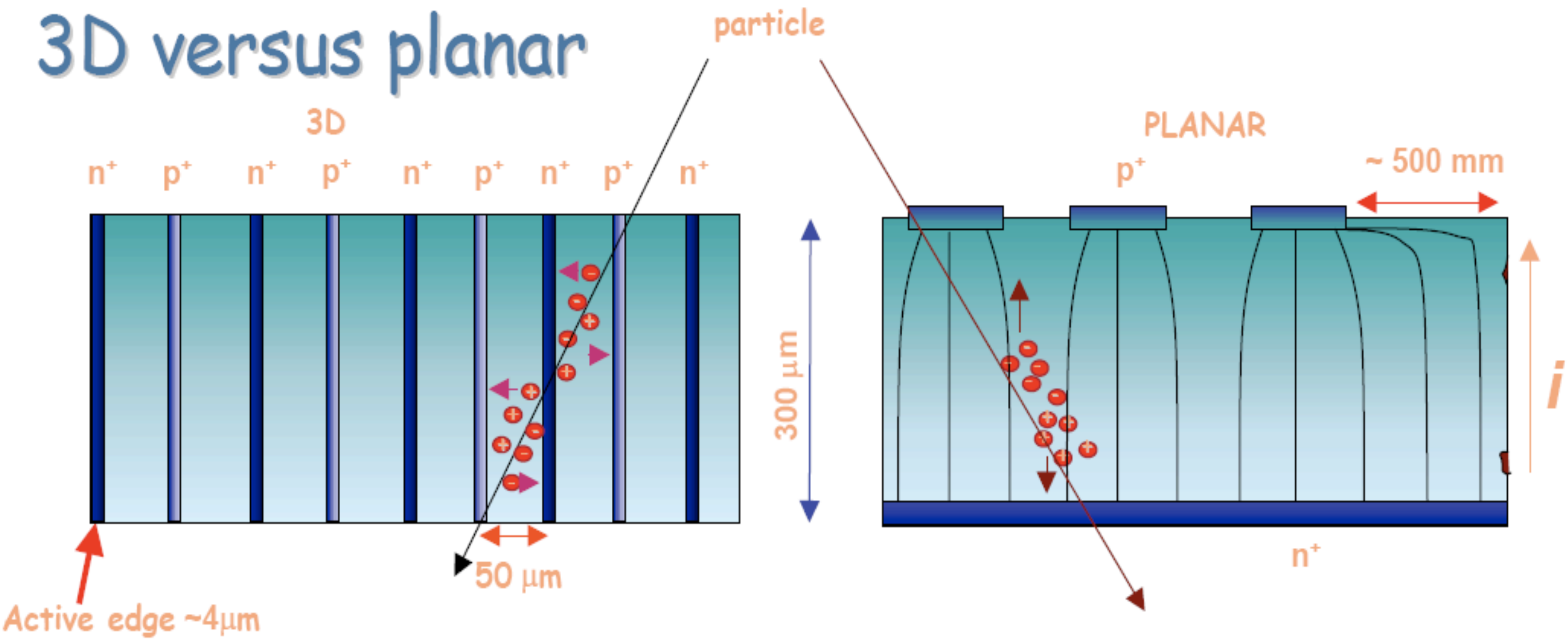
How to measure the protons







3D Silicon Detector Development



Manchester/Stanford/MBC

3DC Collaboration

Transfer to Industry in progress – SINTEF

Also support from Bonn/LBL/Prague

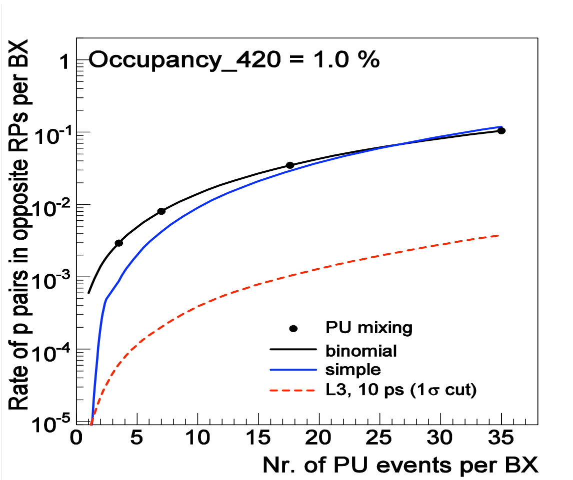
Note: 3D ATLAS R&D Collaboration forming

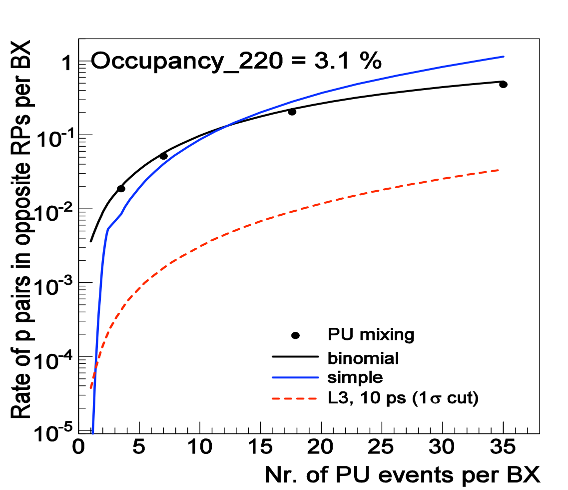
	3D	planar
V_{dep}	< 5-10 V	50-70 V
Q_{1mip}	24000e$^-$	24000e$^-$
C	40-80fF	50-200fF

Fast timing detectors

Diffraction makes up 20-30% of σ_{TOT}: diffractive p's from pile-up fake signal diffr. p's

Example of H->bb:overlay of 3 events (2 SD + non-diffr. dijets) fakes signal perfectly and with prob. 10^{10} x higher than signal. Can be reduced by fast timing det.



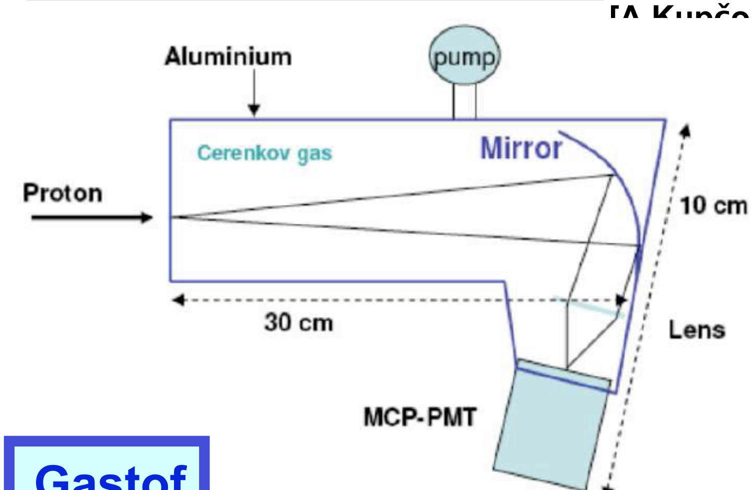


[A Kupčo and M.T]

10ps (2-3mm) resol. may separate different vertices

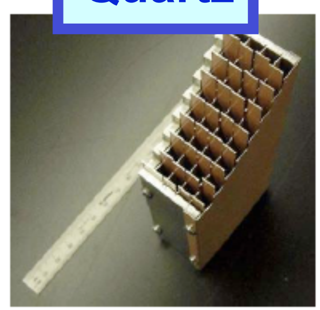
BG Rejection up to

UTA, Louvain, Fermilab, Saclay, Stony Brook, Chicago, Alberta, Argonne



Gastof

Quartz



Test beams indicate:
10-20 ps by Gastof
20-30 ps by Quartz

Disadvantage of Gastof: no space resol

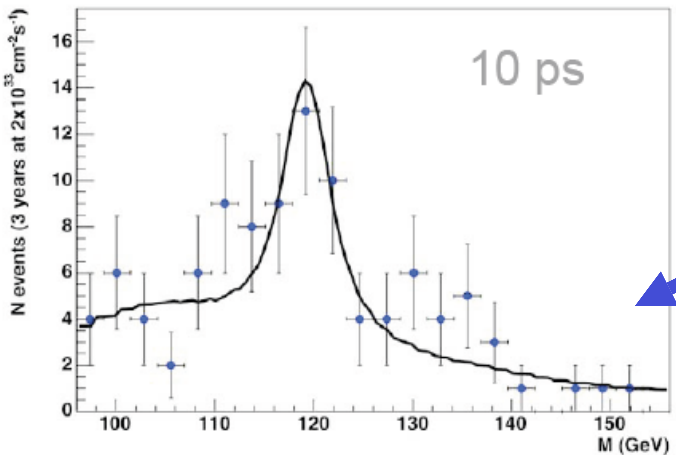
Future: 1-2 ps? Space resolution?
Combination of Gas and Quartz

Key point: yield of photoelectrons

CED H→bb using Forward Proton Tagging

h→bb, mhmax scenario, ATLAS L1 triggers, 420m only, 5 mm from beam

Huge Pile-up bg for diffractive processes: overlap of three events (2*SD+non-diffr. Dijets). Reduced by Fast Timing detectors: t-resol. required: 2 ps for high lumi!



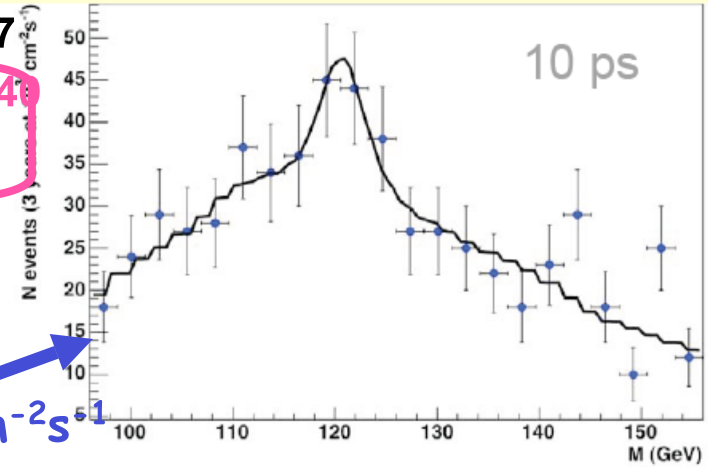
JHEP 0710:090,2007

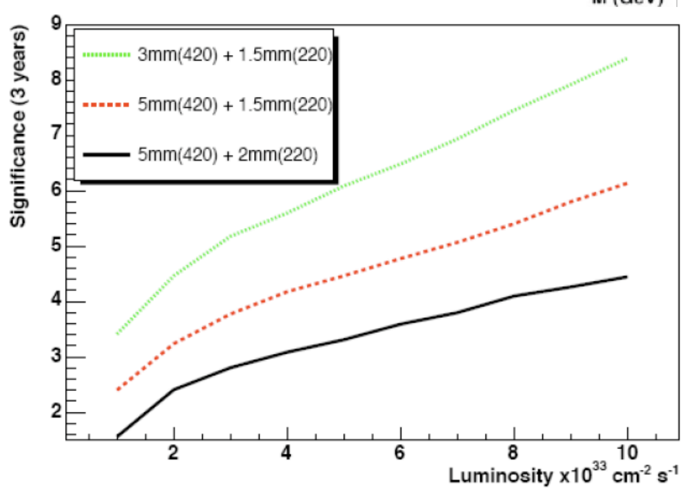
m_A=120 GeV, tanβ=40

$\sigma_{h\to bb}$=17.9 fb

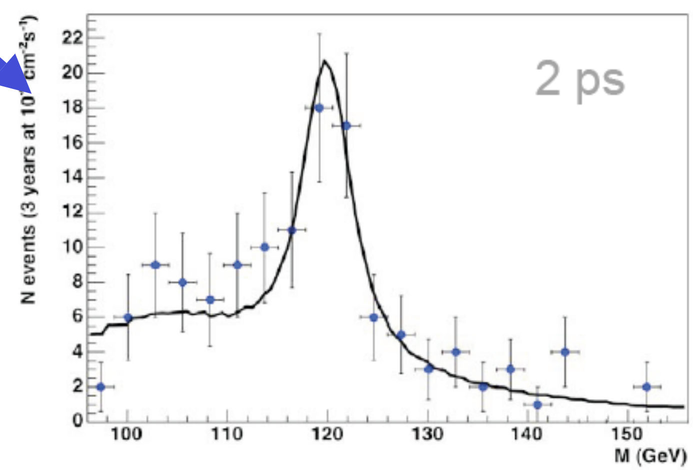
3 years at $2\times10^{33}cm^{-2}s^{-1}$

3 yrs at $10^{34}cm^{-2}s^{-1}$





Assume 220m Pots at L1



Summary

Forward physics will play a large role in the LHC startup studies
Main topics with present detectors:

- Forward jets (BFKL evolution, rapidity gaps).
  - Only needs ~10 pb^{-1} of data.
  - Helps understand forward jets for VBF studies
- Central exclusive production (10-100pb^{-1} of data).
  - Helps to understand underlying event, parton distributions, Sudakov suppression
  - Constrains theoretical models

R&D for forward detectors over, approval process started on both experiments. Install in 2010 shutdown?

- Precision CEP
- photon-photon
- photon-proton