Chapter IV: Hard Diffraction

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Forward Physics Working Group

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Overview

- **Almost final version** (>20 pages)
- Topics:
  - Single diffractive jet production (ATLAS AFP/ALFA)
  - Single diffractive W, Z production (CMS-TOTEM and ATLAS AFP/ALFA)
  - Single diffractive J/psi production (CMS-TOTEM)
  - Double Pomeron exchange jet production (ATLAS AFP/ALFA)
  - Double Pomeron exchange photon+jet production (ATLAS AFP/ALFA)
  - Double Pomeron exchange jet-gap-jet production (ATLAS AFP/ALFA)
  - Single diffractive Drell-Yan production (theory)
  - Theory contributions by Roman Pasechnik et al. and Samuel Wallon et al.

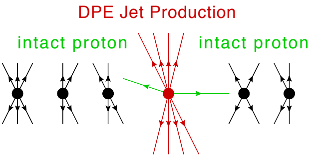
- **Different running conditions investigated**
- **Physics and beam background treatment addressed**
- **Monte Carlo studies performed for 13/14 TeV in all cases**

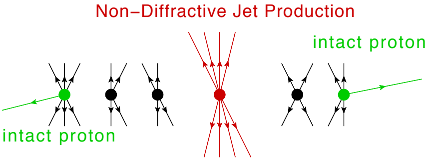
General issues in results on extrapolated yields at $\sqrt{s} = 13/14\,TeV$

Background

Non-diffractive backgrounds will largely be suppressed by proton tagging,
but
- **soft pileup** goes forward
- **beam halo** background also fakes proton signal

Example: non-diffractive event overlaid with minimum-bias protons





CMS-TOTEM background suppression

Background rejection procedure developed on CMS-TOTEM 2012 data at $\sqrt{s}$= 8 TeV, $\beta * = 90m$.

- data driven approach
- based on the correlations between the central system and the forward protons

Proton longitudinal momentum loss, ξ

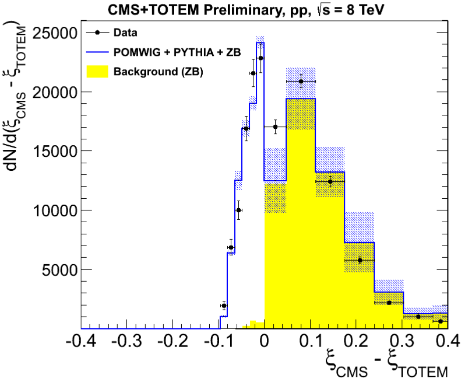
- Measured by TOTEM Roman Pots
- Reconstructed in CMS from PF objects: $\xi = \frac{\Sigma(E^i \pm p_z^i)}{\sqrt{s}}$

$\Rightarrow$ For energy/momentum conservation: $\xi_{CMS} - \xi_{TOTEM} \leq 0$

Proven feasible on 2012 diffractive dijet and J/ψ data (next slide)

Will be applicable to Run II data

Background rejection: SD dijet analysis example



Beam halo and soft PU background estimate:

- MC events (no PU simulation) were associated with randomly taken **data** ZB events (PU included)
- mix passed through selection
  $\rightarrow$ if proton in RP originted from MC $\Rightarrow$ white hist.
  $\rightarrow$ if proton in RP originted from ZB $\Rightarrow$ yellow hist.
- background (ZB) populates region $\xi_{CMS} - \xi_{TOTEM} > 0$

Distribution of the difference between the longitudinal momentum loss of the proton in single diffractive dijet production at LHC, pp→ pjjX, reconstructed with CMS (ξ_{CMS}) and that reconstructed with TOTEM (ξ_{TOTEM}) . The data points (full circles) are compared to a mixture of Monte Carlo (MC) and zero bias (ZB) data events. The MC sample consists of POMWIG events for the single diffractive (SD) signal, scaled down to account for the rapidity gap survival probability, and PYTHIA6 tune Z2* events for the non diffractive (ND) background. Pileup events were not simulated in the MC, but are included in the ZB data. To provide an estimate of the beam halo and soft pileup backgrounds, each MC event was associated to an event taken randomly from the ZB sample. The mixture MC+ZB was passed through the selection procedure. An event with the proton measured in TOTEM roman pots contributed to the white histogram if it originated from the MC sample, or to the yellow histogram if it originated from the ZB sample. The requirement ξ_{CMS}-ξ_{TOTEM} < 0 selects the signal events and rejects the kinematically forbidden region populated by the background events. The remaining contamination of background was estimated to be ~ 4%. The shaded band represents the statistical uncertainty of the MC+ZB sample, which reflects the size of the ZB sample.

ATLAS background suppression

- Soft pileup background can be largely suppressed placing single vertex requirement
- However, suppression is not 100% efficient:
  - finite resolution of the central trackers — merging of nearby vertices
  - too few tracks originating from the soft pile-up vertex

In the ATLAS feasibility studies presented in this Chapter:

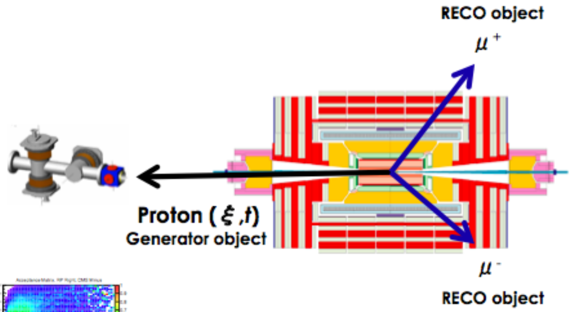
- 4 charged particles required in ATLAS tracker
- vertices merged when distance below 1.5 mm

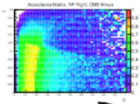
Table 2: Overview of the running scenarios assumed. The ranges of the average number of inelastic pileup interactions and the delivered luminosity are shown in the two right-most columns. The precise values depend on the number of protons in a bunch (N), the number of bunches (k), and the emittance ϵ_N.

β^* [m]	crossing angle [μrad]	ϵ_N [μm rad]	N [10^{11}]	k [bunches]	μ	Luminosity [pb^{-1}/24h]
90	0	2	[0.5 - 1.5]	156	[0.06 - 0.5]	[0.1 - 1]
90	100	2	[0.5 - 1.5]	1000	[0.06 - 0.5]	[0.8 - 7]

- Low luminosity-low pileup ⇒ **potential of physics measurements at the beginning of Run II**
- Two weeks of common running would mean
  - 10 pb^{-1} with a large number of bunches and crossing angle and μ of about 0.1
  - 10 pb^{-1} with few bunches, no crossing angle and μ of about 0.5
  - 100 pb^{-1} with a large number of bunches, crossing angle and μ of about 0.5
- CMS and TOTEM are used jointly. Event yields derived from visible cross section: $\sigma_{visible} = \sigma_{MC} \cdot \frac{N_{sel}}{N_{tot}}$
- **Not meant as full feasibility studies** (physics and beam backgrounds, trigger selection and systematic uncertainties not covered in full detail)
- **Trained on 2012 data**

CMS-TOTEM studies





Which acceptance for event based on the proton (ξ,t)?

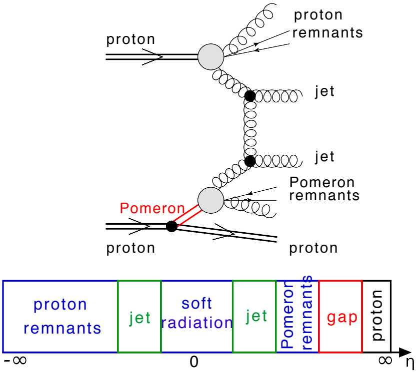
- proton taggers not simulated
- acceptance matrix used instead

ATLAS studies

- Feasibility studies for ALFA and AFP detectors
- Considered optics configurations: $\beta^* = 0.55$ or $90m$
- FPTrack used for the proton transport
- Protons required to be within detector acceptance for a given distance

Monte Carlo based feasibility studies at $\sqrt{s} = 13/14\,TeV$

Single diffractive jet production



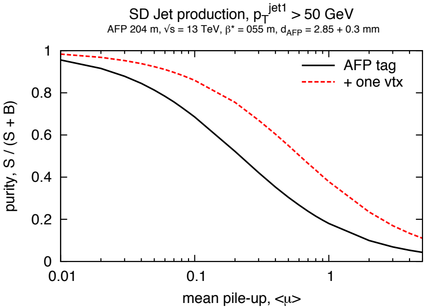
Motivation:

- Gap survival probability
- Pomeron structure
- Correlation between gap size and ξ of the scattered proton

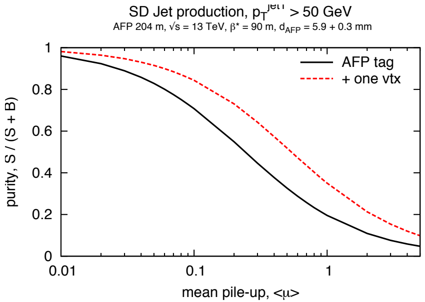
Feasibility studies:
•AFP and ALFA with β^*= 0.55 m and 90 m

Monte Carlo sample:
FPMC (signal) + PYTHIA 8 (non-diff) + PYTHIA8 tune MBR (pileup)

PURITY@$\beta^* = 0.55$m

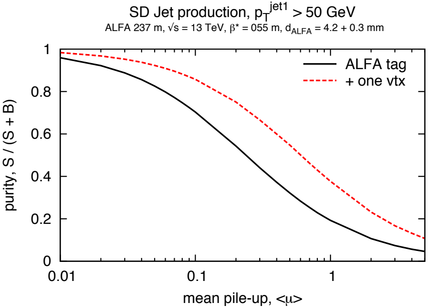


PURITY@$\beta^* = 90$m

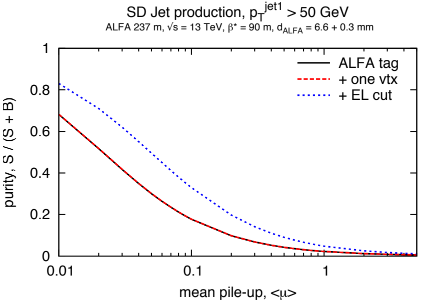


- Purity greater than 50% for $\mu \approx 0.5$
- Purity grows above 80% for $\mu < 0.1$
- No significant dependence on p_T^{JET1} cut

PURITY@$\beta^* = 0.55$m

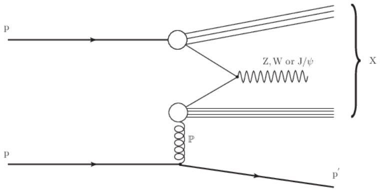


PURITY@$\beta^* = 90$m



- @$\beta^* = 0.55$: conclusions similar to AFP
- @$\beta^* = 90$: dramatic difference.
  $\rightarrow$Purity above 50% only for $\mu < 0.02$

Single diffractive W/Z production



Motivation:

- Gap survival probability
- Probe of the quark content of the diffractive exchange

Feasibility studies:

- **CMS-TOTEM with $\beta^* = 90$ m**
- **ATLAS AFP and ALFA with $\beta^*= 0.55$ m and 90 m**

CMS PAS FSQ-14-001

TOTEM-NOTE-2014-002

Monte Carlo sample:
POMWIG (signal) + PYTHIA8 tune A2 (pileup)

Table 2: Overview of the visible cross-section values obtained in the SD $Z \to e^+e^-$, $Z \to \mu^+\mu^-$, $W \to e\nu_e$, $W \to \mu\nu_\mu$ and $J/\psi \to \mu^+\mu^-$ production channels, shown for events with a proton detected in the CMS z-negative or z-positive directions. The uncertainties shown are statistical.

	$Z \to e^+e^-$	$Z \to \mu^+\mu^-$	$W^+ \to e^+\nu_e$ $W^- \to e^-\bar{\nu}_e$	$W^+ \to \mu^+\nu_\mu$ $W^- \to \mu^-\bar{\nu}_\mu$	$J/\psi(\mu^+\mu^-)$
σ_{vis} [pb]	1.34 ± 0.02	2.04 ± 0.02	16.37 ± 0.21	20.30 ± 0.23	332.5 ± 2.9

Table 3: Overview of the expected event yields with the statistical uncertainty, for an integrated luminosity of 10 pb^{-1} in the SD Z or W and J/ψ production channels.

LHC Scenario	SD Boson Z	SD Boson W	SD J/ψ
10 pb^{-1}	30 ± 1	340 ± 10	3080 ± 90

AFP, both optics,
ALFA with $\beta^* = 0.55$ m:

- purity greater than 50% for $\mu \approx 0.2$
- purity above 80% for $\mu < 0.06$

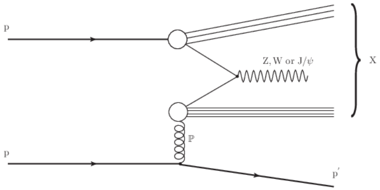
ALFA with $\beta^* = 90$ m:

- purity above 50% only for $\mu < 0.02$

process	purity	L_1 sig.	L_1 N_{ev}	L_2 sig.	L_2 N_{ev}	L_3 sig.	L_3 N_{ev}	rate [Hz]
AFP 204 m, $\beta^* = 0.55$ m, $\mu = 0.1$								
SD $W \to l\nu$	0.7	0	0.3	1	3	4	30	0.001
SD $Z \to ll$	0.7	0	0.2	1	2	3	20	0.001
AFP 204 m, $\beta^* = 90$ m, $\mu = 0.1$								
SD $W \to l\nu$	0.6	0	0.2	1	2	3	20	0.001
SD $Z \to ll$	0.6	0	0.1	1	1	2	10	0.0005
ALFA 237 m, $\beta^* = 0.55$ m, $\mu = 0.1$								
SD $W \to l\nu$	0.7	0	0.1	1	1	2	10	0.0005
SD $Z \to ll$	0.6	0	0.08	1	0.8	2	8	0.0005
ALFA 237 m, $\beta^* = 90$ m, $\mu = 0.01$								
SD $W \to l\nu$	0.7	0	0.03	0	0.3	1	3	0.002
SD $Z \to ll$	0.7	0	0.02	0	0.2	1	2	0.001

Monte Carlo sample used:
FPMC (SD and DPE events) + PYTHIA8 (non-diff)

Single diffractive J/ψ production



Motivation:

- Gap survival probability
- Probe of the quark content of the diffractive exchange

Feasibility studies:

- **CMS-TOTEM with $\beta^* = 90$ m**

CMS PAS FSQ-14-001

TOTEM-NOTE-2014-002

Monte Carlo sample:
POMPYT v2.6 (signal) + PYTHIA8 tune A2 (pileup)

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	$Z \to e^+e^-$	$Z \to \mu^+\mu^-$	$W^+ \to e^+\nu_e$ $W^- \to e^-\bar{\nu}_e$	$W^+ \to \mu^+\nu_\mu$ $W^- \to \mu^-\bar{\nu}_\mu$	$J/\psi(\mu^+\mu^-)$
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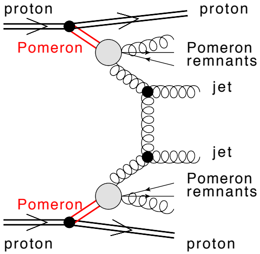
DPE jet production



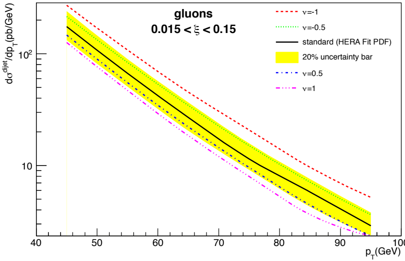
Motivation:

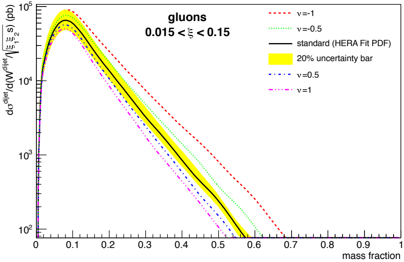
- Gap survival probability
- Pomeron structure
- Correlation between a gap size and ξ of the scattered proton

Feasibility studies:

• ATLAS AFP and ALFA with β^*= 0.55 m and 90 m

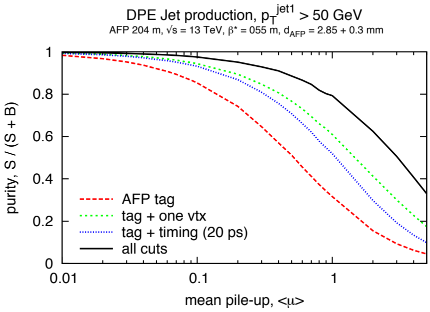
(Rapidity gap survival probability set to 3%)



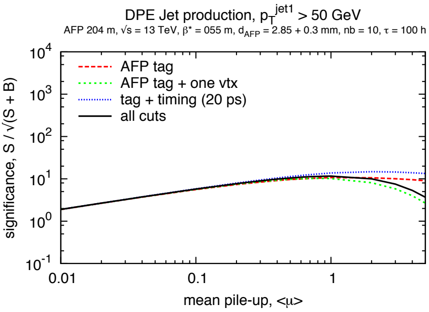


DPE jet production

PURITY@$\beta^* = 0.55$m

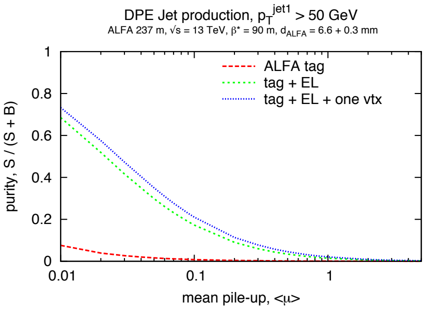


SIGNIFICANCE@$\beta^* = 0.55$m

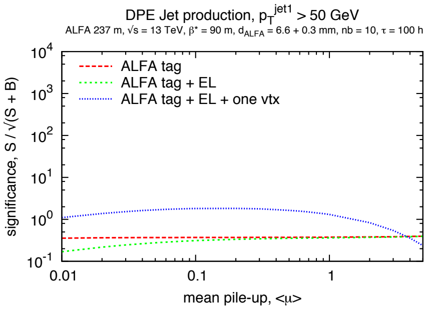


- High purity for low low μ but small significance
- Significance maximized for $\mu \approx 1$
- Similar results for 90m optics

PURITY@$\beta^* = 0.55$m

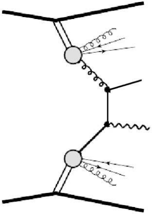


SIGNIFICANCE@$\beta^* = 0.55$m



- Purity $> 60\%$ only for $\mu < 0.02$
- High acceptance for soft central exclusive processes (background)
- Significant measurement only possible with long runs O(100h)

DPE γ+jet production



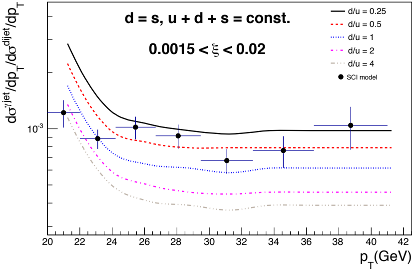
[arXiv:1306.4901]

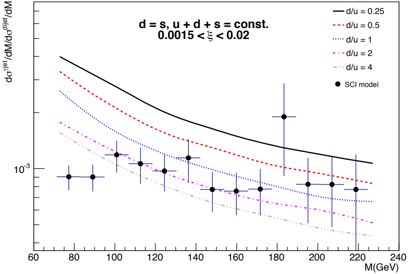
Motivation:

- Test Pomeron universality
- Probe Pomeron quark content
- Disentangle models (SCI and resolved Pomeron)

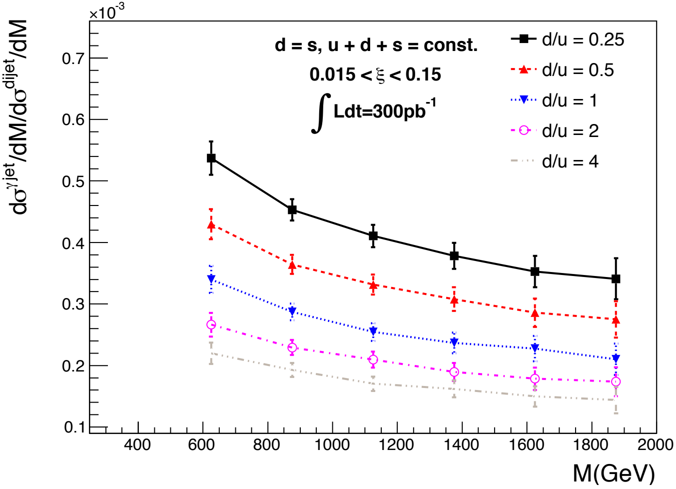
Feasibility studies (14 TeV):

- **ATLAS AFP with $\beta^{*}= 0.55$ m**



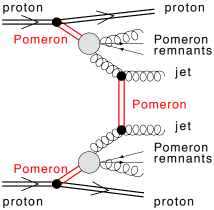


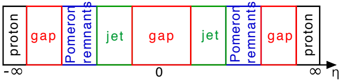
DPE γ+jet production ATLAS AFP



Taking into account the typical mass resolution around 3%, a significant measurement can be achieved with an integrated lumi of 300 pb^{-1}

DPE jet-gap-jet production



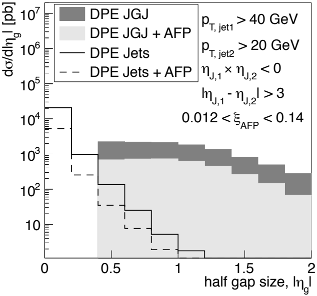


Motivation:

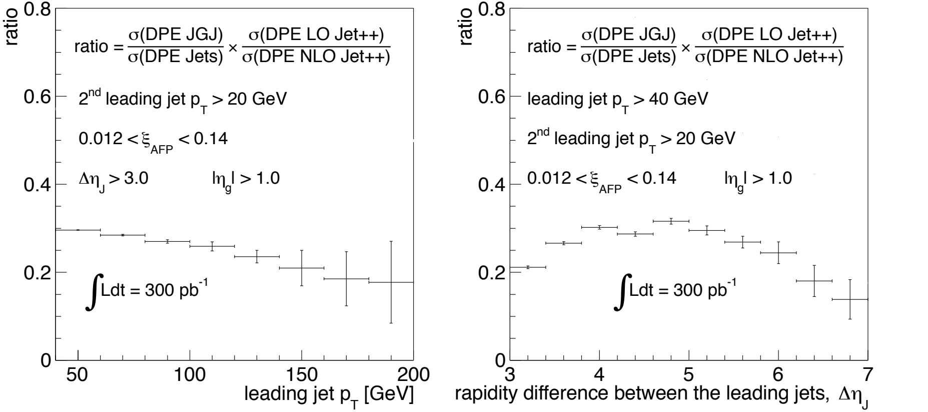
- Process never measured experimentally
- Test BFKL dynamics

Feasibility studies (14 TeV):

- **ATLAS AFP with $\beta^* = 0.55$ m**



Monte Carlo: FPMC (DPE Jets and DPE JGJ)



Integrated luminosity of 300 pb-1 considered

Theory contributions

- **Single diffractive Drell-Yan and vector bosons production at the LHC**
  by Roman Pasechnik, Boris Kopeliovich and Irina Potashnikova
- **Probing hard diffraction at LHC with ultraperipheral scattering**
  by Renaud Boussarie, Andrey Grabovsky, Lech Szymanowski, Samuel Wallon

Will not be included in the chapter as they are, but rather summarised in agreement with the authors

In short

Chapter IV almost finished

- Only two theory contributions missing – in the process of including them
- Final reading by Marta+Maciej to follow

- Release by end of April!

BACKUP