LPCC Forward Physics Working Group

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Institute of Physics, Academy of Sciences, Prague

EDS, Saariselka, September 10th, 2013

Mission of the group

- Forward Physics Working Group part of LPCC (LHC Physics Center at CERN)
- Emerged from discussion at Workshop on diffraction and forward physics (CERN, February 2013), initiated by M. Mangano

- Concern:
  - Forward physics, diffraction, exclusive events ... are not the priority for big experiments
  - Complicated to get new detector approved within experiments
  - Difficulties to get enough running time at special LHC beam conditions

- Realized that:
  - Coordinated effort of the forward physics community of all LHC experiments is required in order to continue & expand forward physics program at the LHC

Objectives of subgroups

- Produce CERN Yellow Report
  - "... includes the proceedings of schools and of workshops having a large impact on the future of CERN, the series also includes reports on detectors and technical papers from individual CERN divisions, again the criteria being that the audience should be large and the duration of interest long."

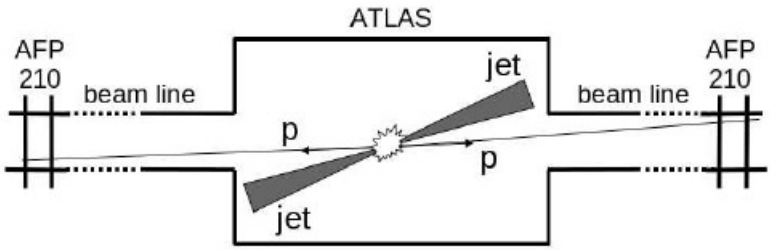
- Demonstrate the physics interest of forward physics, summarize the current results
- Define common strategy for running conditions optimal for forward physics (low-luminosity, special optics)
  - Increase chances that such runs will be delivered
- Provide clearer picture of limitations & overlaps of different experiments
  - Acceptance & resolution, new detector proposals
- Engage theorists to help to bring ideas of new forward physics studies at the LHC

Physics interest

- Modeling of hadron-hadron, p-ion, ion-ion (?) interactions
  - Development of models merging soft and hard production
  - Survival probability factor
  - Multi-parton interactions
  - Measurements with gaps or proton tags
  - Low-x dynamics, saturation
- Diffractive measurements
  - Soft & hard diffraction, structure of pomeron
- Exclusive processes
  - vector meson production, photon-photon interactions, anomalous couplings, exclusive due to gluon-gluon
- Cosmic ray physics
  - LHC measurement can improve modeling of primary and secondary interactions in cosmic ray showers → more precise conclusions on CR shower composition

Detectors

- Forward proton tagging detectors
  - ALFA, TOTEM, AFP, PPS
  - Dominating the discussion at the moment
  - Position and time measurement



Talks by Kenneth Oesterberg, Tom Sykora on Wednesday on TOTEM and AFP plans

- ZDC & LHCf
  - Neutron and photon physics
- Forward Shower Counters upgrade in CMS
- Upgrade plans of High Rapidity Shower Counters for LHCb (Hershel) and ALICE

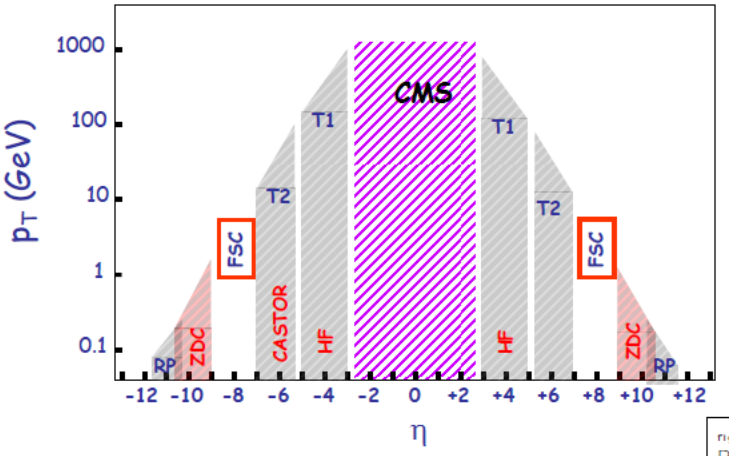


figure adapted from Risto Orava (Diffraction 2006)

- And other forward detectors already well part of ATLAS/CMS/TOTEM (FCAL, HF, CASTOR, T1/T2, MBTS, ...)

Organization

- Conveners: Nicolo Cartiglia (CMS), Christophe Royon (ATLAS)

- Subgroups – each has 2 theorists and one representative from each experiment (ALICE/ATLAS/CMS/LHCb/TOTEM; LHCf also participates)

  - Low-luminosity group (~1pb^{-1}, μ < 1), Lucian Harland Lang and Tim Martin
  - Medium luminosity group (10 – 100pb^{-1}, μ~1), Jochen Bartels and Paula Collins
  - High luminosity group (>10fb^{-1}), Jonathan Hollar and Antoni Szczurek
  - Experimental techniques group Joachim Baechler, Michael Rijssenbecek

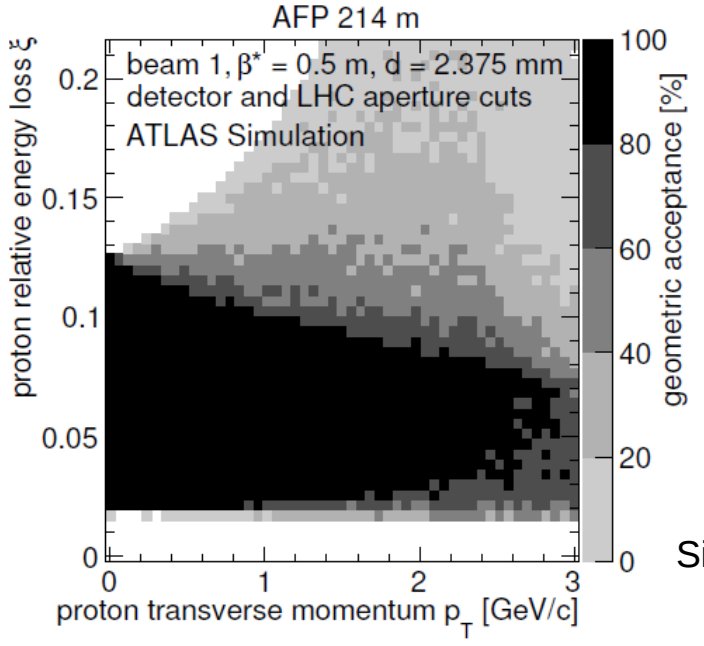
- Members of the steering committee and all the conveners in the backup

- Meetings:
  - 2 day meetings organized every 3-6 weeks at CERN, longer meetings outside CERN
  - 3 held since April

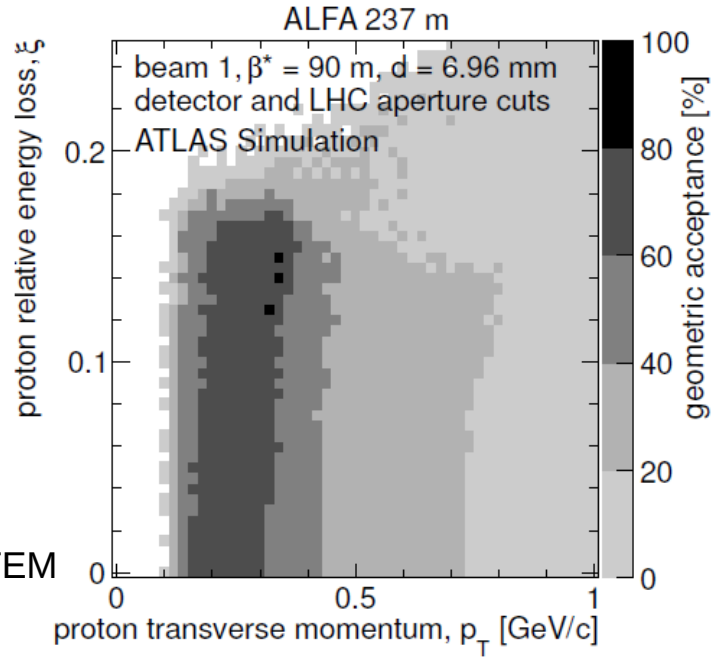
Low-mu group

- Special runs – low luminosity + nominal & special optics (< 1pb^{-1} - 10pb^{-1})
  - Rate of pile-up negligible – simplify analyses
- High β* optics – mostly with vertical detectors
  - TOTEM preferred starting point for diffractive analyses, same for ALFA
  - Large acceptance in ξ for |t| >~ 0.01, resolution poor < 10^{-3}-10^{-2}
  - Tagging & rapidity gaps
- Low β* optics – mostly with vertical detectors
  - High mass diffraction, exclusive production, 0.01 < ξ < 0.15 - interest of AFP & TOTEM

β*=0.5 m – horizontal detectors



β*=90 m vertical detectors



Similar picture for TOTEM

Oldrich Kepka

PRAGUE FZÚ

Modeling of diffractive final states

- Millions of single and double tagged events
- Low β* optics allows to access small ξ → studies with and without gap can constrain rate of proton dissociation

- Study soft diffraction in detail – from low to high masses
  - Test triple pomeron vertex model

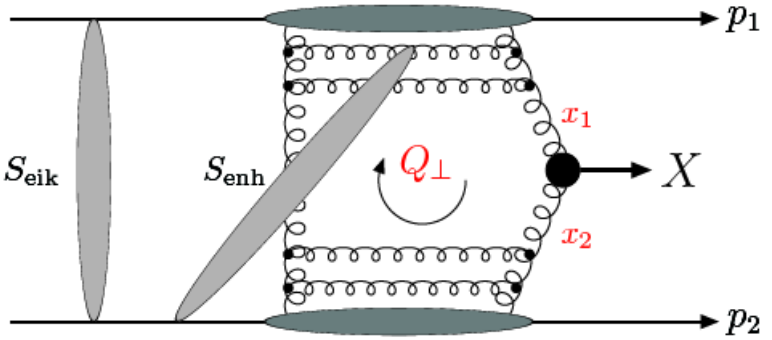
Peter Skands

- Multi-parton interactions in diffraction
  - In Pythia: once Pomeron emitted, collision modeled as Pomeron-proton interaction with standard MPI mechanism to produce – is this universal picture correct?
  - Underlying event type measurements in diffraction

- Are fragmentation functions the same in diffractive processes non-diffractive events?
  - Could we constrain multiplicity distributions and momentum spectra, identified-particle ratios (eg K/π, K*/K, p/π,Λ/p) directly in diffractive processes (as function of M)?

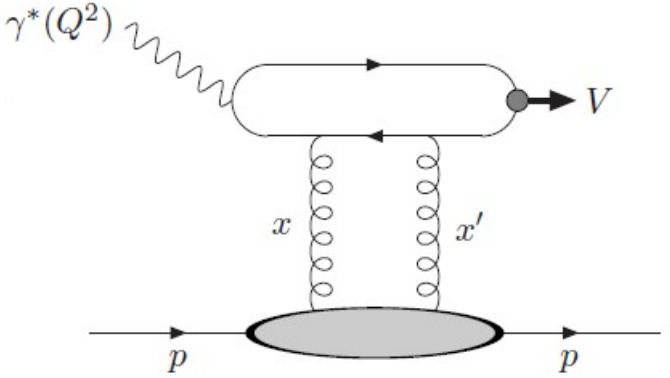
Exclusive low mass processes

Lucian Harland-Lang
Paula Collins



- Exclusive production of mesons – χc, χb, ηc,ηb
  - So far measured by LHCb

- Exclusive photoproduction – Pomeron-photon interaction – C odd states
  - J/ψ, ψ (2S), Υ

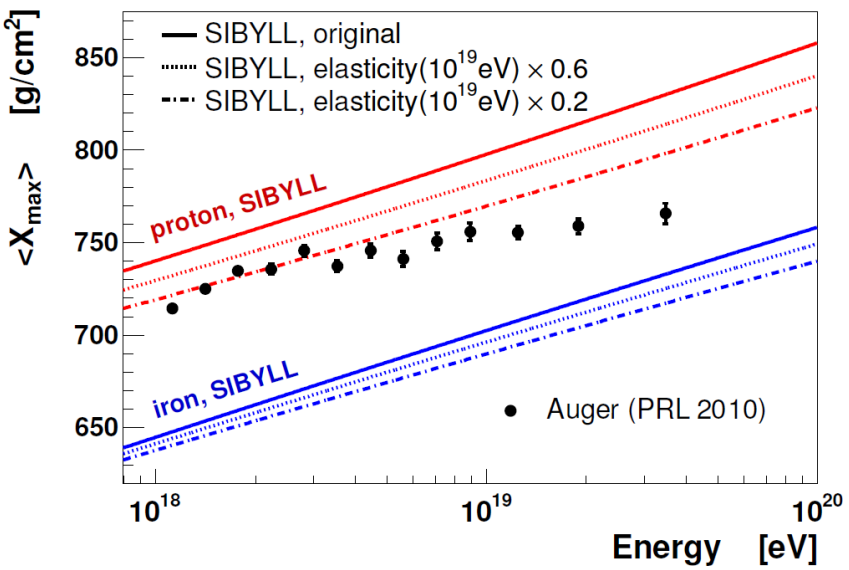


- With / without proton tagging
  - Survival effects, correlations in proton kinematics
  - Dissociation background

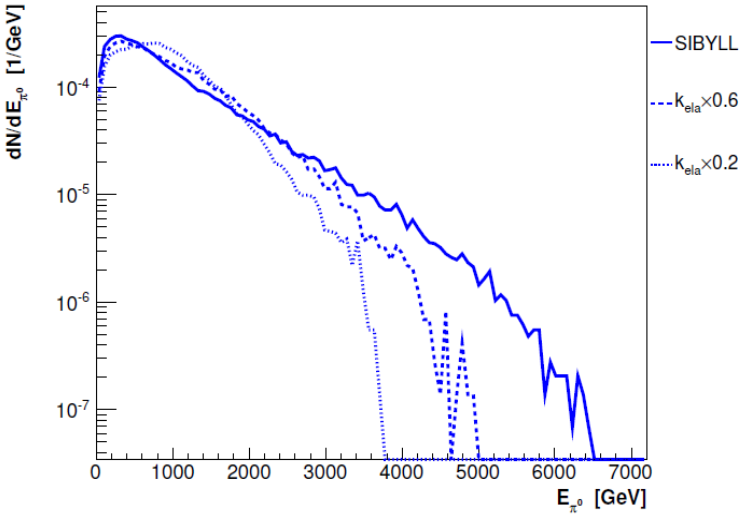
- Acceptances & resolutions discussed and (to be) summarized and provided to theorists to allow calculations for realistic experimental scenarios

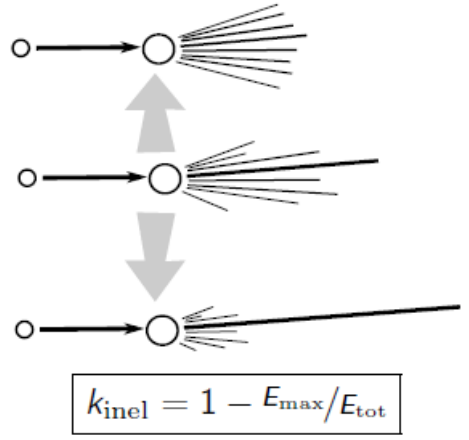
Cosmic Ray Showers

R. Urlich

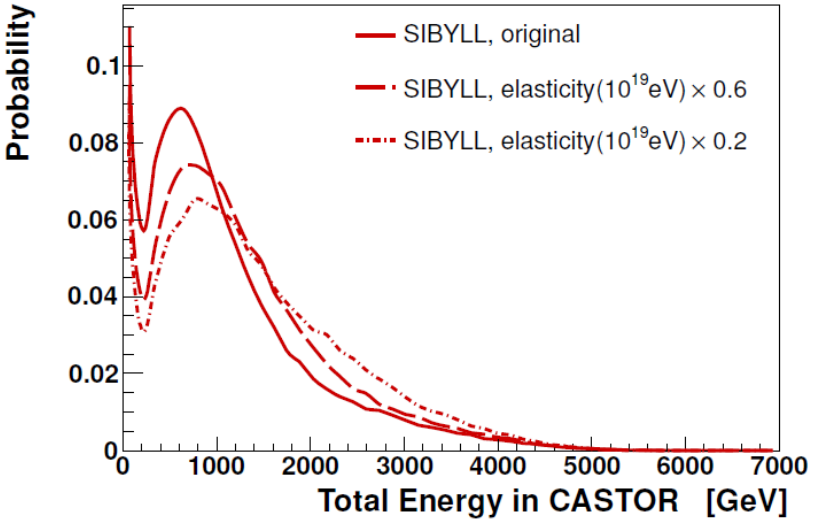


- Cosmic ray interactions occur at much higher energies than LHC can test
- However, subsequent interactions occur at lower energies
- Example: elasticity – redistribution of energy between the leading particle and the secondary particle can be constrained at LHC





$$k_{\mathrm{inel}} = 1 - E_{\mathrm{max}}/E_{\mathrm{tot}}$$

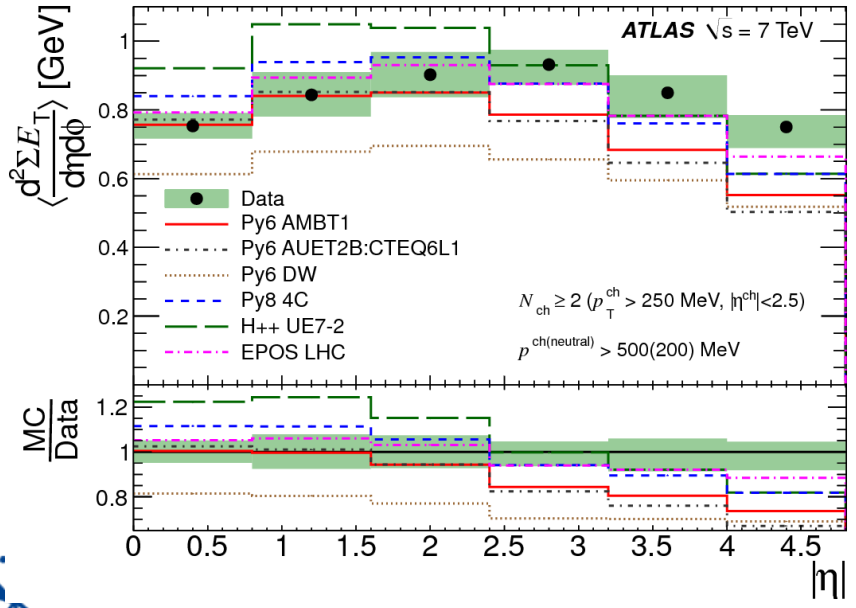


See talk by Petr Travnicek on Friday

Common definition of observables

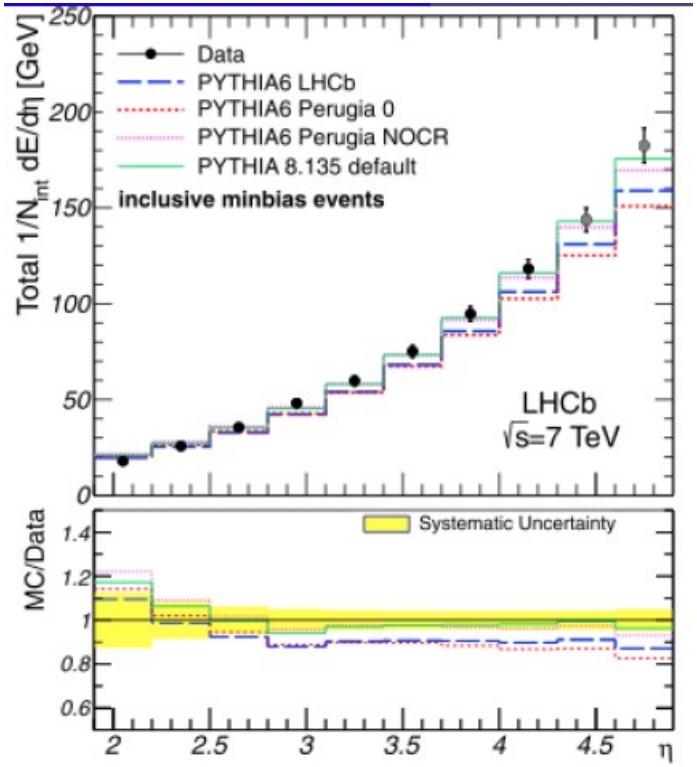
- Agreed to have same hadron definition between different measurement
  - Easier comparison between the measurements, consistent set of measurements
- Difficult to agree on a common phase-space once the analysis is finished
- Example of the analysis which a common definition was accepted
  - Fwd energy flow measurement in ATLAS, CMS, LHCb, (ALICE?)
  - At least 1 charged particle with pT > 200 MeV in 1.9 < η < 2.4

Tom Sykora



Marco Meissner

inclusive MB: at least 1 track in 1.9<η<4.9 with p > 2 GeV



Oldrich Kepka

Medium luminosity

- 10-100pb^{-1}
  - 10 pb^{-1}: μ=1 → 1 day, μ=0.1 → 1 – week
  - Horizontal detectors, high mass $0.01 < \xi < 0.15$ production

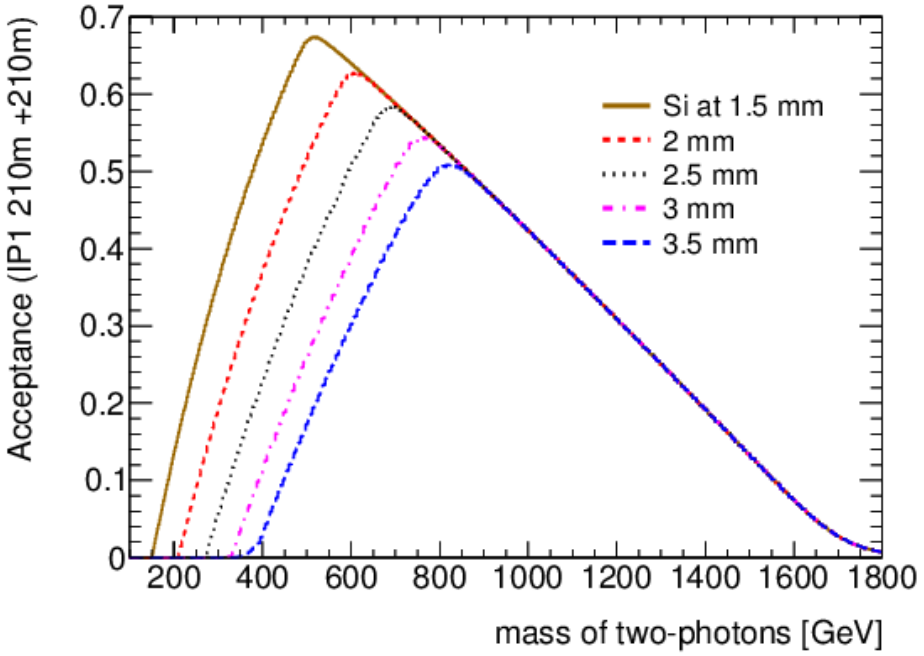
- Measurements probing pomeron structure in events with hard scales
  - Hard single diffraction – W, jetjet
  - Dijets, gamma+jets
  - BFKL (jet-gap-jet = hard color exchange; Mueller-Navelet jets)

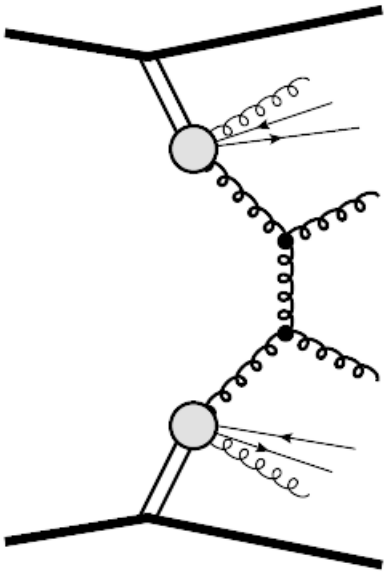
See talk by C. Royon on Tuesday

- Double tagged events – combinatorial pile-up background suppressed by fast timing
  - Matching time-of-flight information with vertex position
  - Timing techniques still in development – assume limited timing resolution of 30 ps
- Which purity is needed for each measurement?
- What is the pile-up condition to make these measurements?

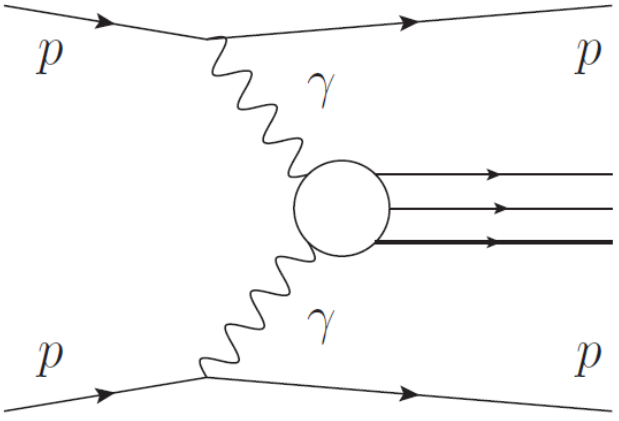
Mass acceptance

- Large acceptance between 400 GeV < Mx < 1.5 TeV



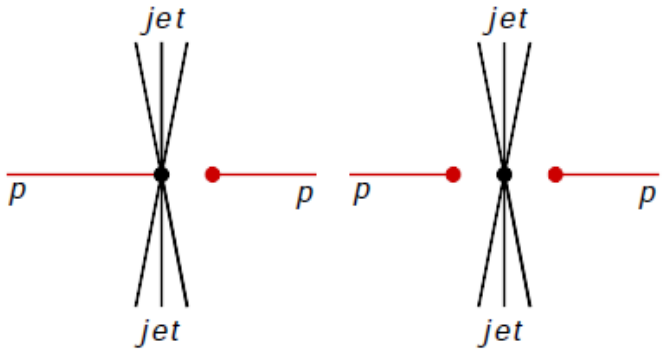


Also Pomeron exchanges, exclusive gluon exchange, Pomeron-photon



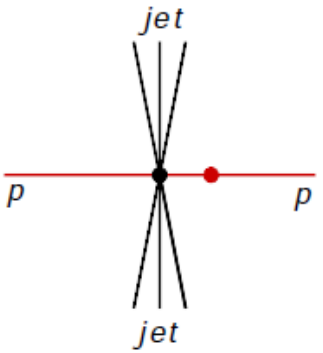
Background due to multiple collision

Single Tagged Soft Interaction(ST)

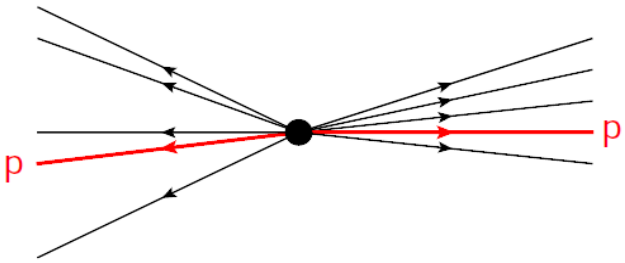


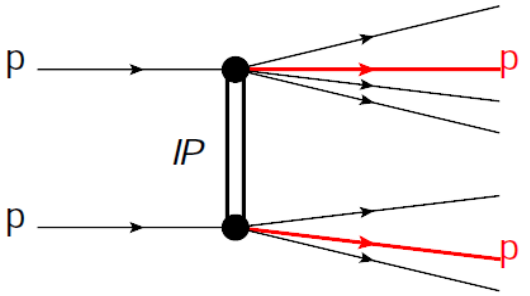
SD JJ + ST ND JJ + ST + ST

Double Tagged Soft Interaction(DT)



ND JJ + DT





Single Tag (ST) Interactions					
probability					
default	0.18	0.045	–	0.0055	0.038
MBR	0.12	0.040	0.42	0.0054	0.030
cross section [mb]					
default	2.3	0.40	–	0.32	3.0
MBR	1.3	0.38	0.34	0.30	2.3
	SD	DD	CD	ND	MB

Double Tag (DT) Interactions					
probability [10^{-3}]					
default	0.47	0.37	–	0.014	0.13
MBR	0.31	0.36	26.0	0.012	0.37
cross section [μb]					
default	6.1	3.3	–	0.81	10
MBR	3.5	3.4	21	0.67	28
	SD	DD	CD	ND	MB

default – Schuler and Sjöstrand (PomFlux = 1)

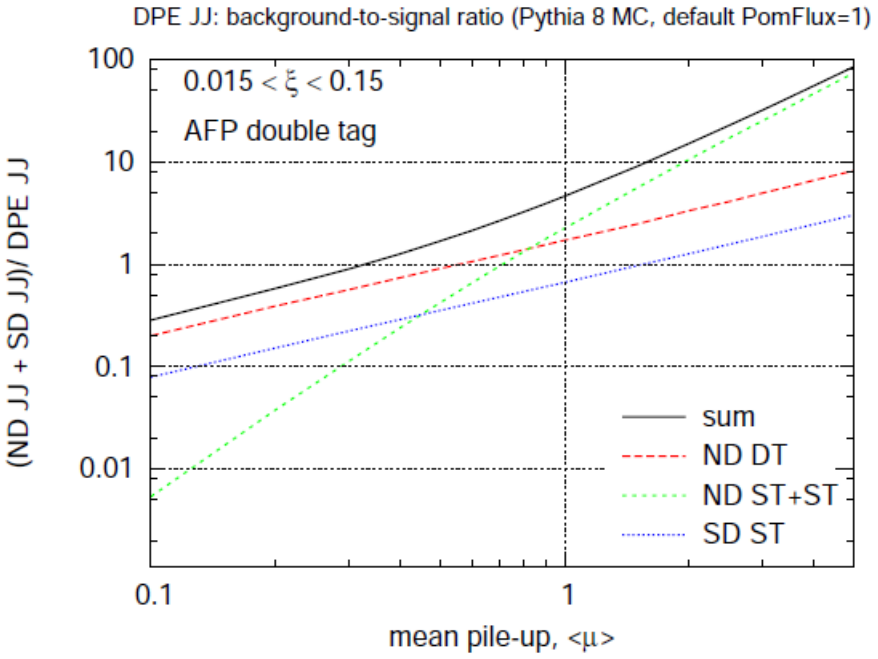
MBR (PomFlux = 5)

- DT: e.g. double diffractive dissociation with leading protons created during hadronization propagating to the forward direction
  - Large differences between generators → can TOTEM gives constraints?

Double pomeron exchange

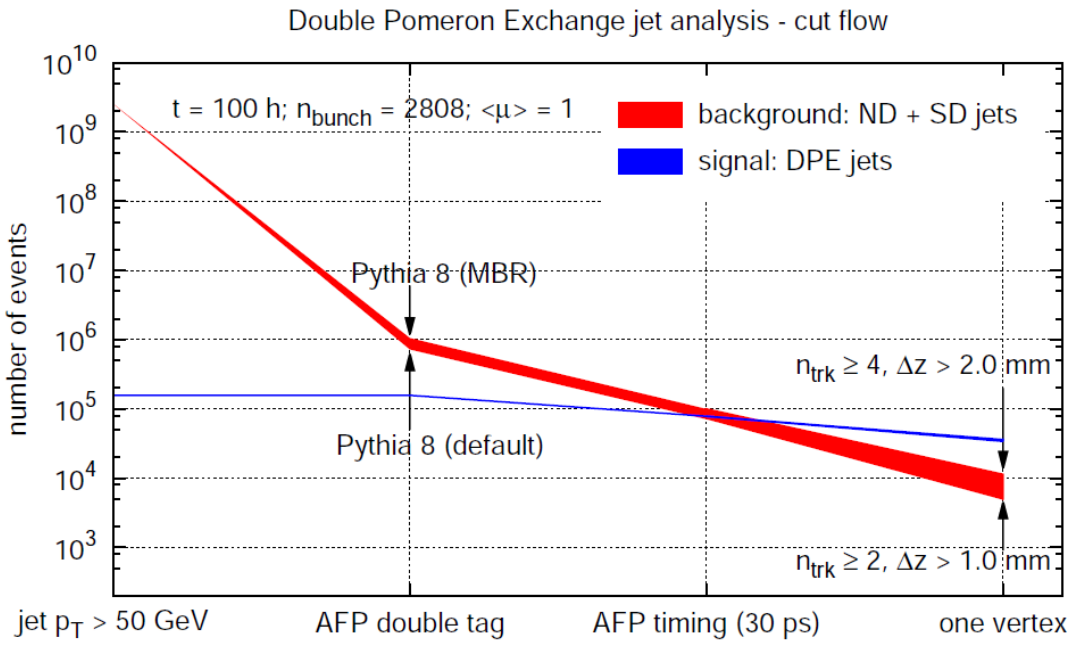
M. Trzebinsky & R. Staszewski

- Example process to study the effect of pile-up
- For low μ, protons from hadronization dominate
- For low μ=1 both combinatorial background and protons from hadronization



- Timing & single vertex events
  - Signal with high high purity (90%)

- Input from current TOTEM measurements can significantly improve predictions of the intime pile-up
- Instrumental bcg. also discussed



High luminosity group

- 10 fb^{-1} – ~100 fb^{-1}, nominal running condition (β^*=0.5m and high pile-up)

- Combinatorial background is an issue
  - As precise timing as possible required ~ <10ps (resolution of 2.1mm on vertex position), in develpoment
- Further suppression of background needed – exclusive events QED/QCD
  - Use correlation between protons and central system kinematics

- Focus on 1-3 measurements that:
  - Are not covered by low-lumi/medium lumi working groups
  - Are experimentally “easy” (=maybe not impossible) with high pileup and forward proton tracking+timing
  - Still have interesting sensitivity in light of current/projected LHC results using central detectors only
  - Can be significantly improved using forward proton information

pp → pWWp

J. Hollar

- Dominated by γγ → WW, sensitive to anomalous quartic (and triple) gauge couplings
  - Current sensitivity with 7 TeV untagged γγ → WW is already beyond CMS 7 TeV
    γ → WWγ

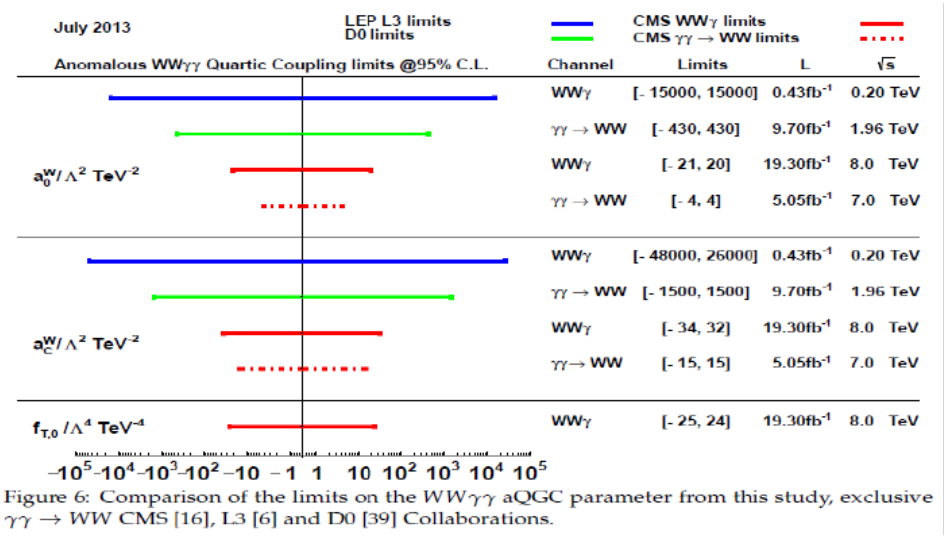
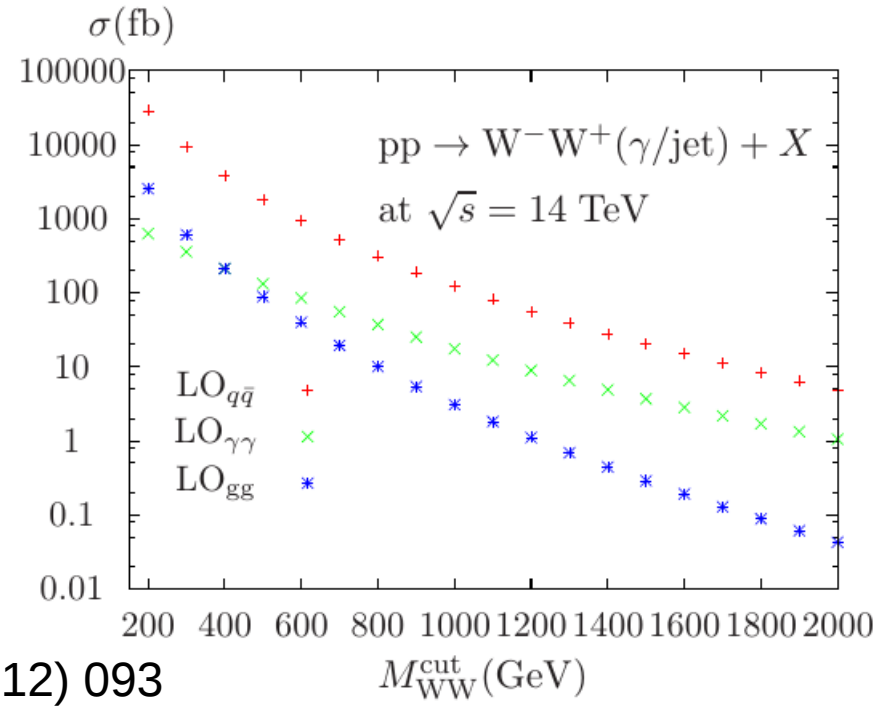
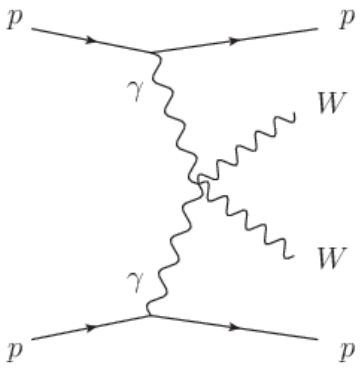


Figure 6: Comparison of the limits on the $WW\gamma\gamma$ aQGC parameter from this study, exclusive $\gamma\gamma \to WW$ CMS [16], L3 [6] and D0 [39] Collaborations.

- γγ → WW including (p-dissociation) is a large fraction of the total WW cross section at high mass
  - Interesting because of the small but persistent access over SM in ATLAS/CMS WW cross section measurements

CMS PAS SMP-13-009





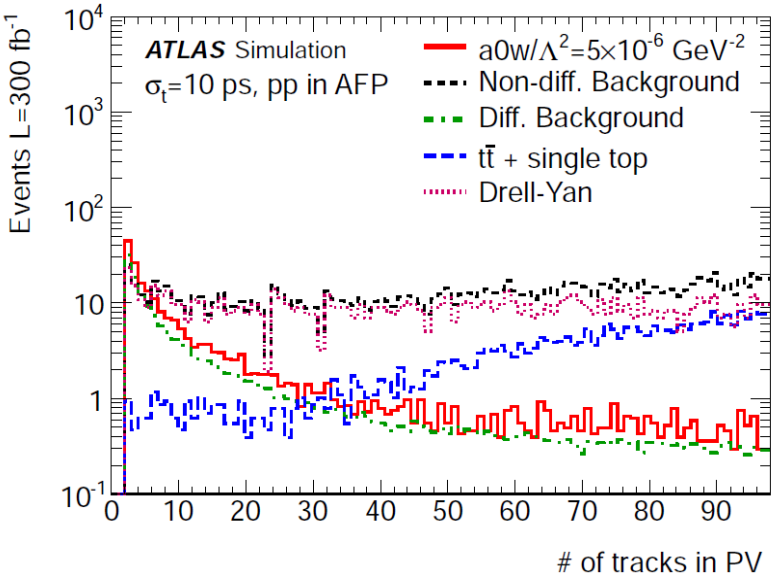
JHEP 1211 (2012) 093

pp → pWWp

- Advantages of proton tagging:
  - Remove proton-dissociation: trade-off of statistics for smaller systematic/theoretical uncertainties
  - Backgrounds: limits current untagged analyses to em final state (CMS) or high-mass tails (D0)
    - Attempt to recover SM-like same-flavor (mm and ee) and semileptonic (lnjj) final states
  - Kinematic constraints: differential measurements vs. Wγγ, etc.

- The feasibility of the measurement was illustrated using full simulation in ATLAS

- Beam induced background to be quantified
  - Existing and future high intensity ALFA/TOTEM runs – analysis ongoing



Other exclusive processes

- pp → pγγp
  - At high mass expected to be dominated by γγ → γγ
  - Small in the SM for pp (arXiv:1305.7142), but shows up as a high-mass excess in a wide variety of exotic BSM scenarios
  - Vertexing – how well the vertex γγ can be known (could be significantly different between ATLAS/CMS) ? Do we see enough cross section for converted photons?
  - Studies needed
- pp → pjjp
  - Important constrain of the higgs production.
  - Very hard to fight combinatorial background for large pileup
  - Shown feasible for 20-50 interaction / bunch crossing
  - Using kinematic correlations between protons and central jet system

Experimental techniques subgroup

- Technical aspects important to be shared between the collaborations
- Roman pots
  - ATLAS switched to well tested RP technology
- Movable beam pipes (needed at 420 m)
- Timing detectors: QUARTIC or similar, Diamonds, Sampic readout
  - L1Trigger, Resolution better then 10ps, efficiency close to 100%, high rate up to 100MHz, Radiation and tolerant
- Backgrounds and pile up at high luminosity runs (discussion and analyses ongoing)
  - 1) IP: single diffractive pile-up events
  - 2) Secondary interactions in upstream beam elements
  - 3) Beam Halo

- See detailed discussion by Tom Sykora and Kenneth Oesterberg on Wednesday For ATLAS and TOTEM upgrade plans

Summary

- LPCC Forward Working group is active now Participation very welcome
- LPCC Page: http://lpcc.web.cern.ch/lpcc/
- Indico Meetings: https://indico.cern.ch/categoryDisplay.py?categId=4870

- October 15, CERN
- November 18-19-20, Cracow
- January 14-15, CERN
- Last week of February – 1 week of March, CERN (to be confirmed)
- April 14-18, Trento

- Milestones:
  - Cracow meeting: define topics required further studies for the CERN Yellow Report
  - Spring 2014: Provide first draft of the report

Backup

Group structure

- Steering committee:

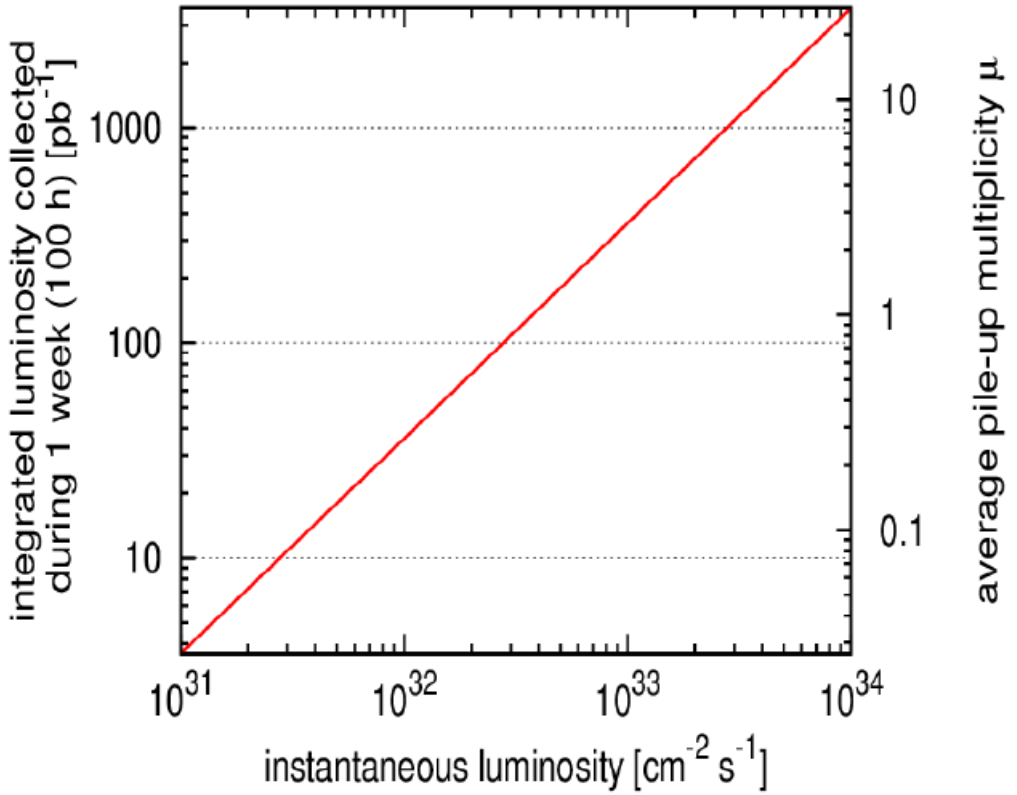
  Martin Poghosyan (Alice), Gerardo Herrera (Alice), O. K. (ATLAS), Michael Albrow (CMS), Michele Arneodo (CMS), Paula Collins (LHCb), Takashi Sako (LHCf), Alessia Tricomi (LHCf), Risto Orava (TOTEM), Joachim Baechler (TOTEM), Kenneth Oesterberg (TOTEM), Michelangelo Mangano (LPCC), David Berge (ATLAS, contact for cosmic rays)

- Low-luminosity group
  - Lucian Harland Lang (theory), Valery Khoze (theory), Martin Poghosyan (Alice), Tim Martin (ATLAS), Antonio Vilela (CMS), Dima Volyanskyy (LHCb), Takashi Sako (LHCf), Alessia Tricomi (LHCf), Valentina Avati (Totem)
- Medium luminosity group
  - Cyrille Marquet (theory), Jochen Bartels (theory), Gerardo Herrera (Alice), Christophe Royon (ATLAS), Nicolo Cartiglia (CMS), Ronan McNulty (LHCb), Paula Collins (LHCb), Ken Osterberg (TOTEM)
- High luminosity group
  - Rikard Enberg (theory), Antoni Szczurek (theory), Jonathan Hollar (CMS), Risto Orava (TOTEM), Rafal Staszewski (ATLAS)
- Experimental techniques group
  - Michael Rijssenbecek (ATLAS), Joachim Baechler (TOTEM)

Luminosity condition

- For fixed bunch structure (25 ns, 2800 bunches) collected luminosity proportional to number of pp interactions (defined in terms of inelastic cross section)

- mu = 0.1 → ~10pb^{-1} in 1 week (100 h)
- mu = 1 → ~100pb^{-1} in 1 week

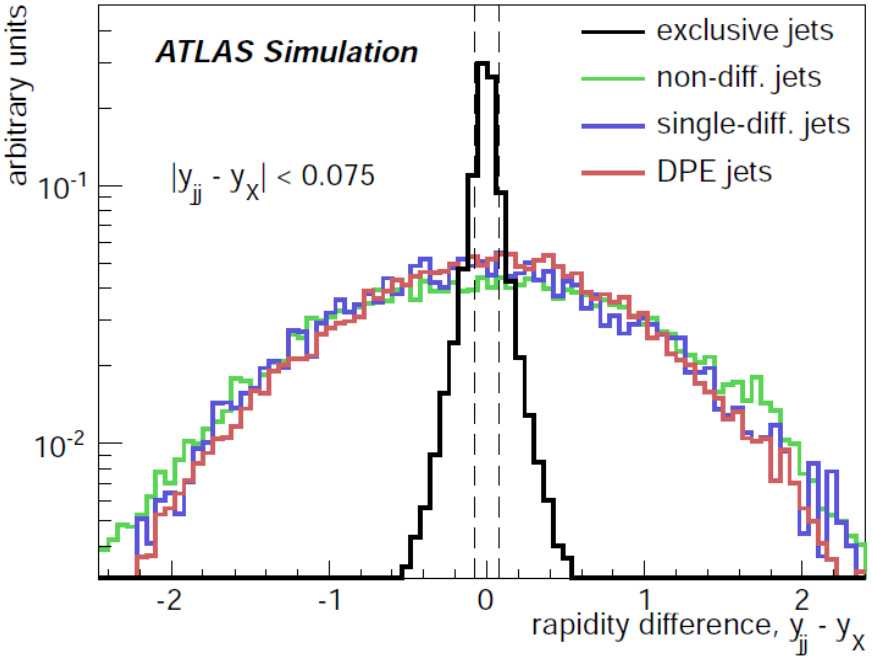


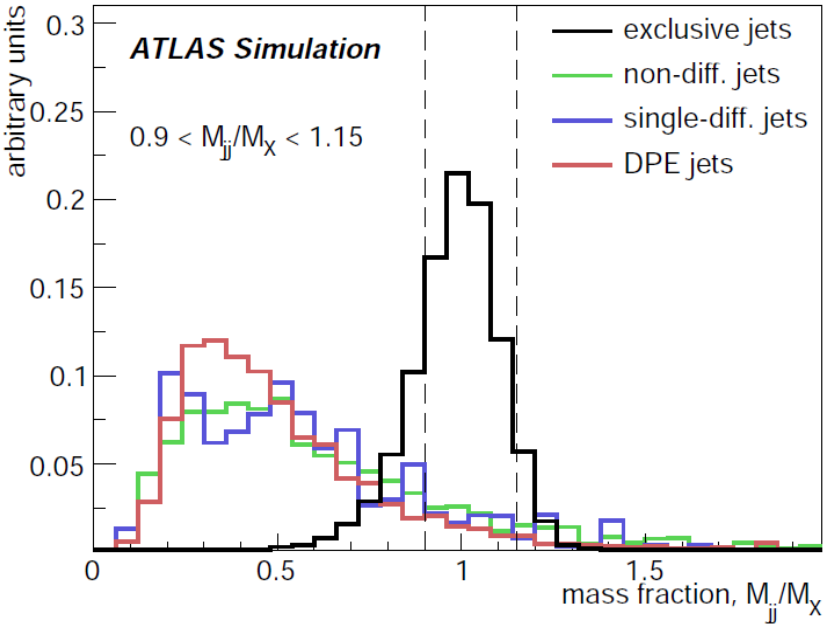
Exclusivity in jets

- Important AFP addition
  - Kinematic correlation between central detector and AFP
- Difference y_{jj}-y_X of rapidity of the jet system and rapidity of proton system $y_X = 0.5 \cdot \ln\left(\frac{\xi_1}{\xi_2}\right)$

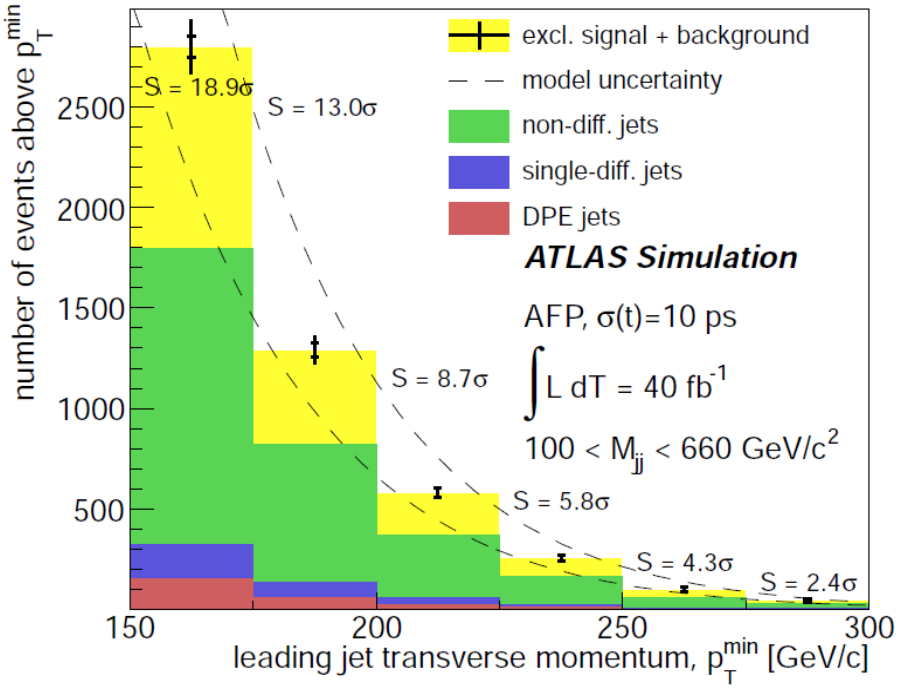
$$M_X = \sqrt{s \cdot \xi_1 \cdot \xi_2}$$

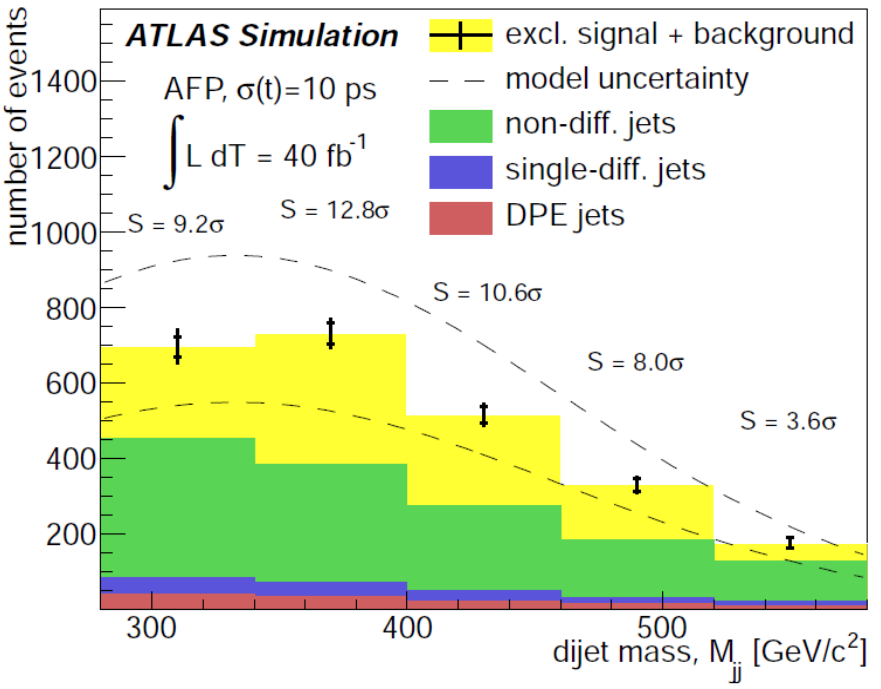
- Ratio of the jet system mass to the missing mass calculated in AFP
- Rejecting also events with tracks outside of jets to improve S/B





Exclusive jets – Results





- Signal and background yields integrated above certain leading jet p_T or invariant mass
- Integrated luminosity L = 40fb^{-1} at pile-up mu = 23
  - Prove of principle also for mu = 46
- Error bars are statistical and systematic uncertainties (2%)
- Dashed line represents theoretical model uncertainty (from Tevatron constrains)