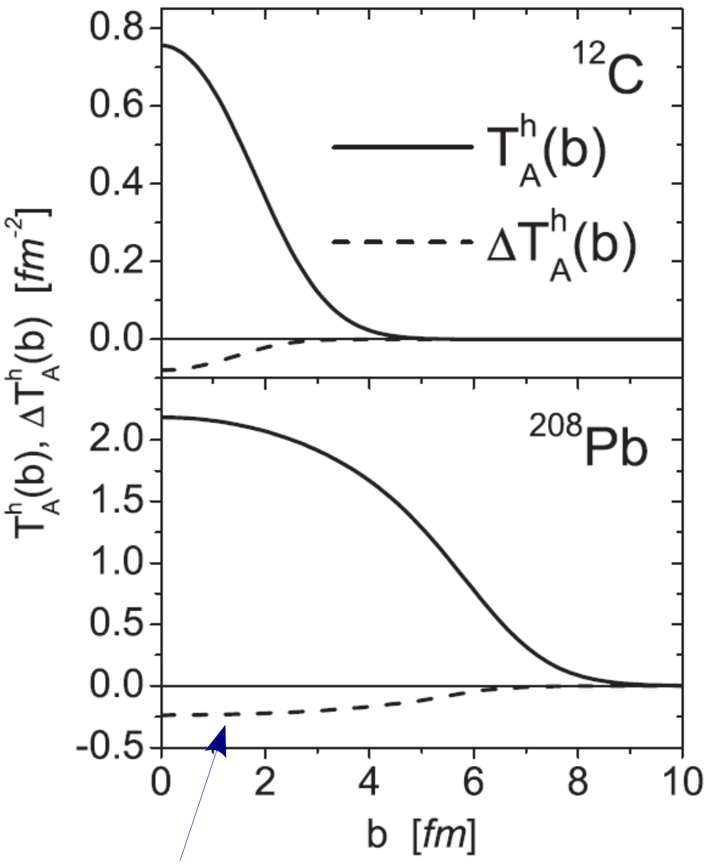
Karlsruhe Institute of Technology

Proton-Lead Hadronic Inelastic Cross Section at 5.02 TeV

Colin Baus on behalf of the CMS collaboration

Glauber Model



SRC correction

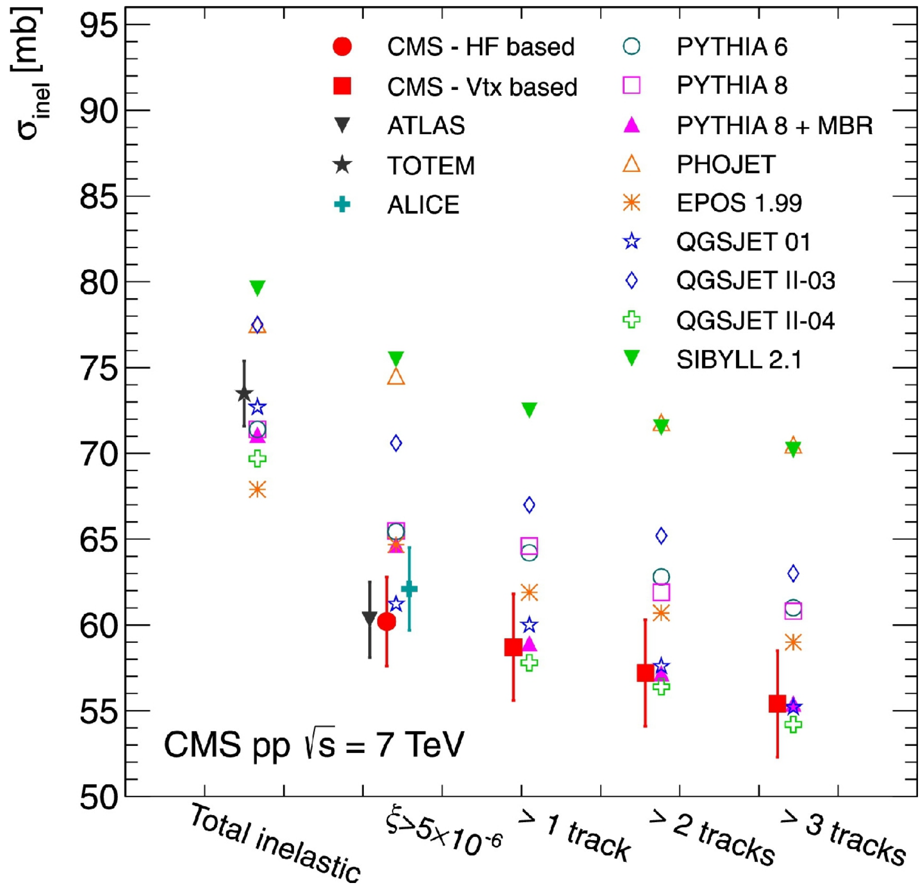
Phys. Rev. C 81, 025204

- Calculation of observables N_{coll} and cross sections for p-A/A-A collisions

$$\sigma_{\mathrm{inel}}^{\mathrm{A+B}} = \int_0^\infty 2\pi b db \left\{ 1 - \left[1 - \hat{T}_{AB}(b)\, \sigma_{\mathrm{inel}}^{\mathrm{NN}} \right]^{AB} \right\}$$

- Two (theoretically calculable!) effects important
  - **SRC (short range correlations)**
    Nuclear thickness function decreases small b
    → increases cross section
  - **IS (inelastic screening)**
    Shadowing because of exited state
    → decreases cross section
- ≈10% effects with different sign
- Experimentally not explored at high energies

pp Inelastic Cross Section with CMS

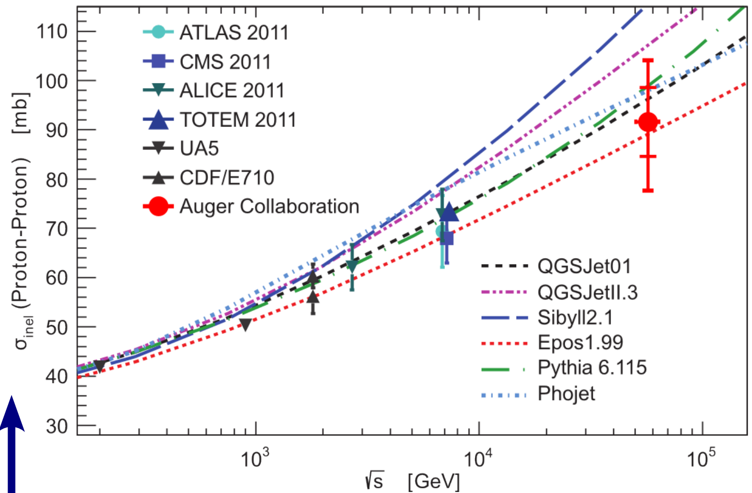


- Inelastic cross section @7TeV measured by many experiments at LHC
- CMS used two methods
  - Pileup distribution: primary vertex counting
  - Event counting: forward calorimeter as trigger for inelastic events

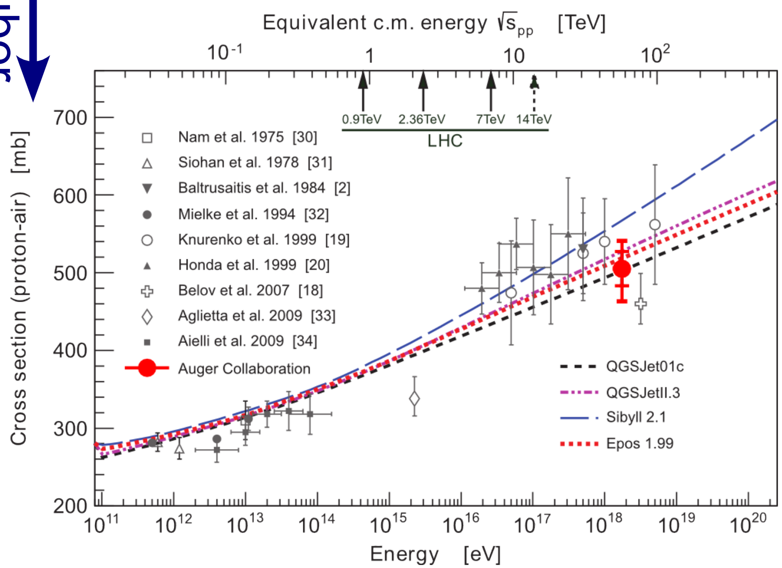
$$\sigma_{inel}(\xi>5\times10^{-6}) = \mathbf{60.2} \pm 0.2(\text{stat.}) \pm 1.1(\text{syst.}) \pm 2.4(\text{lum.})\ \text{mb}$$

Phys. Lett. B, 722 (2013)

p-Air Inelastic Cross Section with Pierre Auger Observatory



Glauber



- pp cross section @57 TeV derived from air shower data
- Measuring p-Air cross section by studying X_{max} distribution

- Glauber model extended by inelastic screening to calculate pp inelastic cross section
- Large uncertainties introduced by model assumptions and by the Glauber calculation

$$\sigma_{pp}^{\rm inel} = [92 \pm 7({\rm stat})^{+9}_{-11}({\rm syst}) \pm 7({\rm Glauber})]\ {\rm mb}$$

Phys. Rev. Lett. 109, 062002

pPb Cross Section Analysis

- We measure the hadronic inelastic cross section by an event counting method

$$\sigma_{\text{inel}} = \frac{N_{\text{inel}}}{\mathcal{L}}$$

- In the acceptance of our detector we extract the visible cross section and correct for
  - Detector noise,
  - Pileup contribution,

$$\sigma_{\text{vis}} = \frac{1}{\mathcal{L}} \frac{N_{\text{cut}} - N_{\text{noise}}}{1/f_{\text{PU}} - f_{\text{noise}}}$$

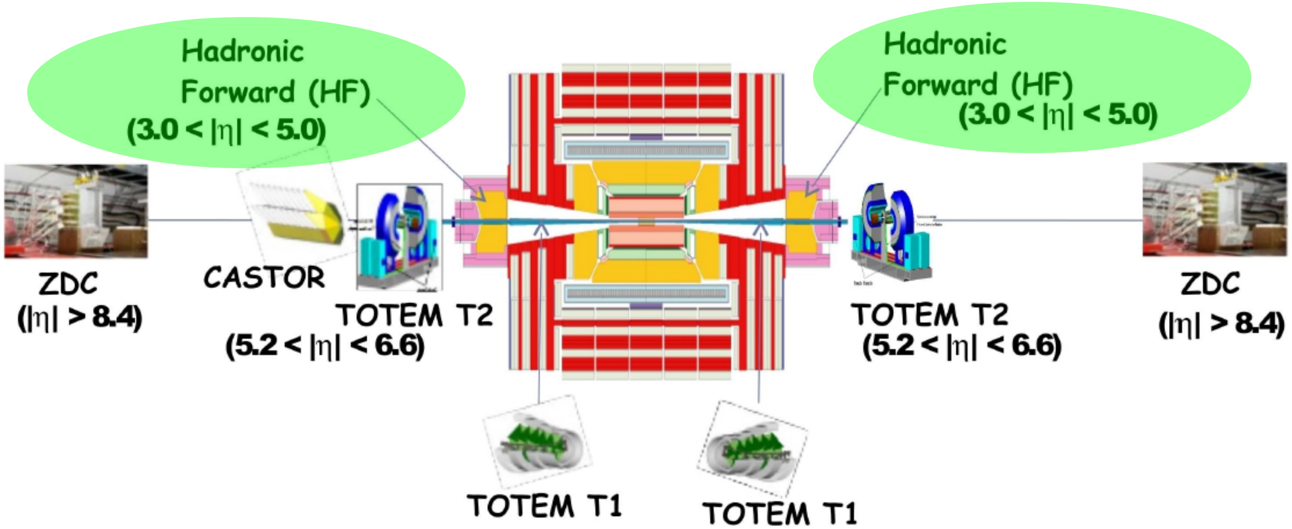
  - and electromagnetic events

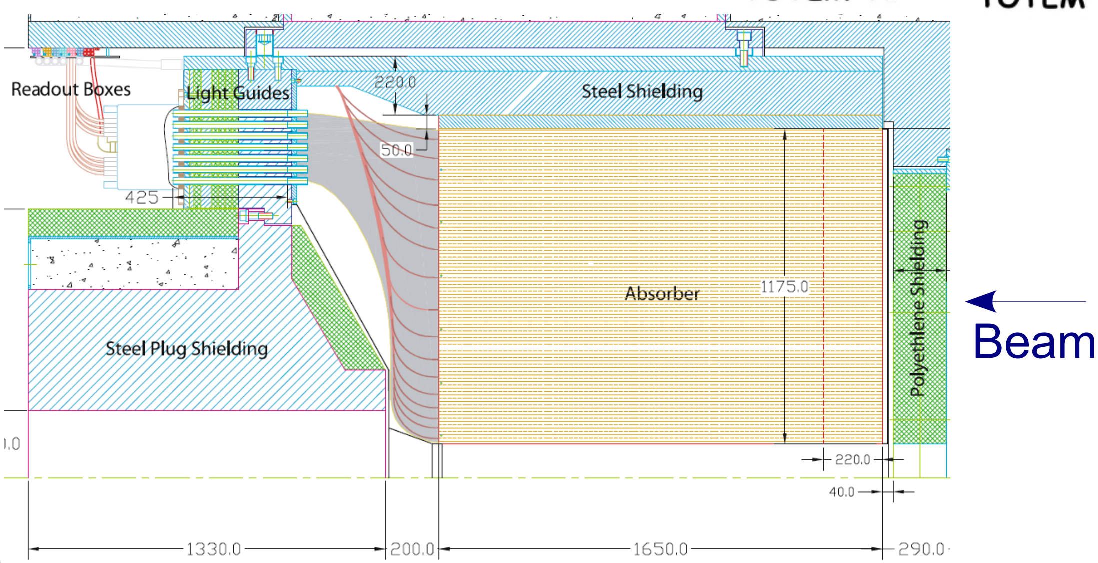
$$\sigma_{\text{vis,had}} = \frac{1}{\mathcal{L}} \frac{N_{\text{cut}} - N_{\text{noise}} - N_{\text{em}}}{1/f_{\text{PU}} - f_{\text{noise}}}$$

- Extrapolate to full phase-space

CMS-FSQ-13-006

Detectors at CMS Interaction Point





Hadronic Forward (HF)

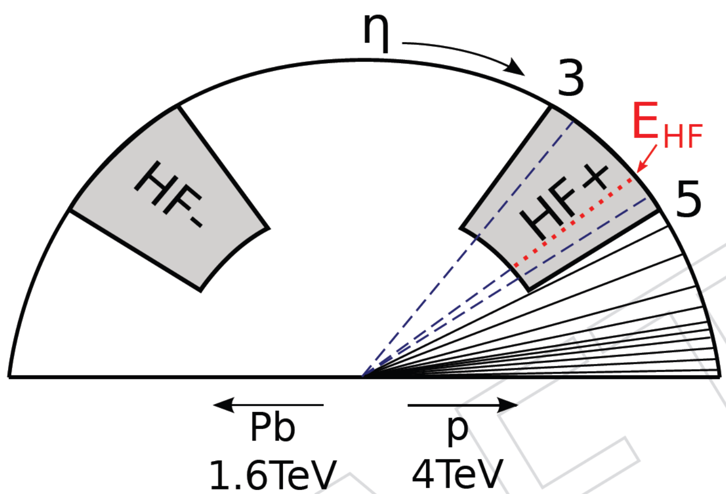
$3<|\eta|<5$, $\sigma_E \approx 20\text{-}40\%$

Steel absorber and quartz fibres:
- Long fibres (EM+HAD)
- short fibres (HAD)

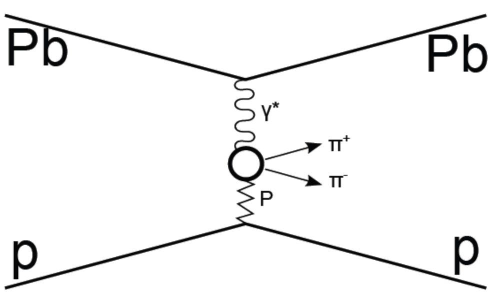
High granularity (432 towers)

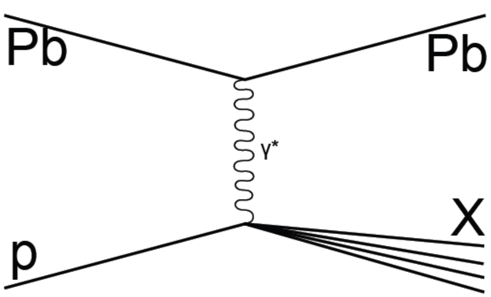
Event Topology

- Non-diffractive events can be selected with high efficiency (≈98%)
- Diffractive and especially single-diffractive events difficult to select



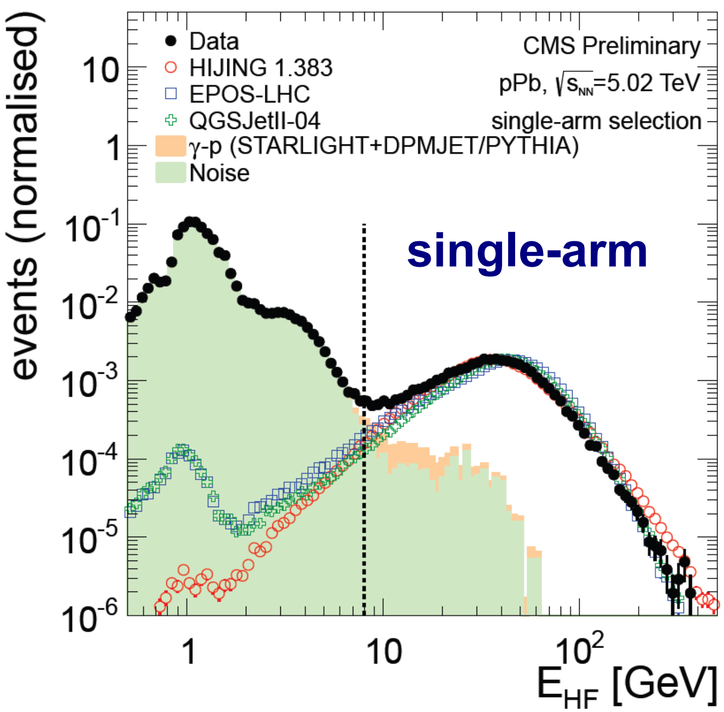
- Photo-nuclear collisions are excluded from measurement
- Equivalent-photon (Weizsäcker-Williams) approximation handled by Starlight generator combined with DPMJET or PYTHIA

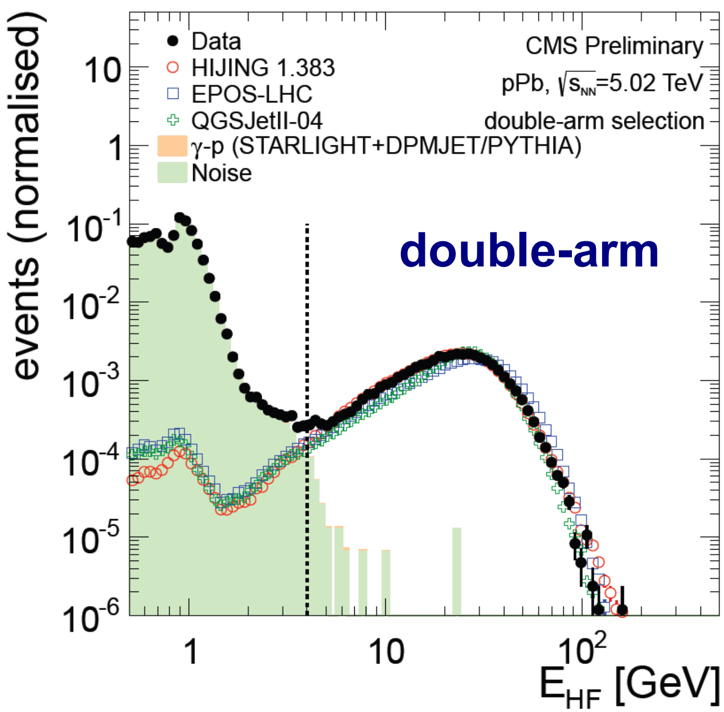




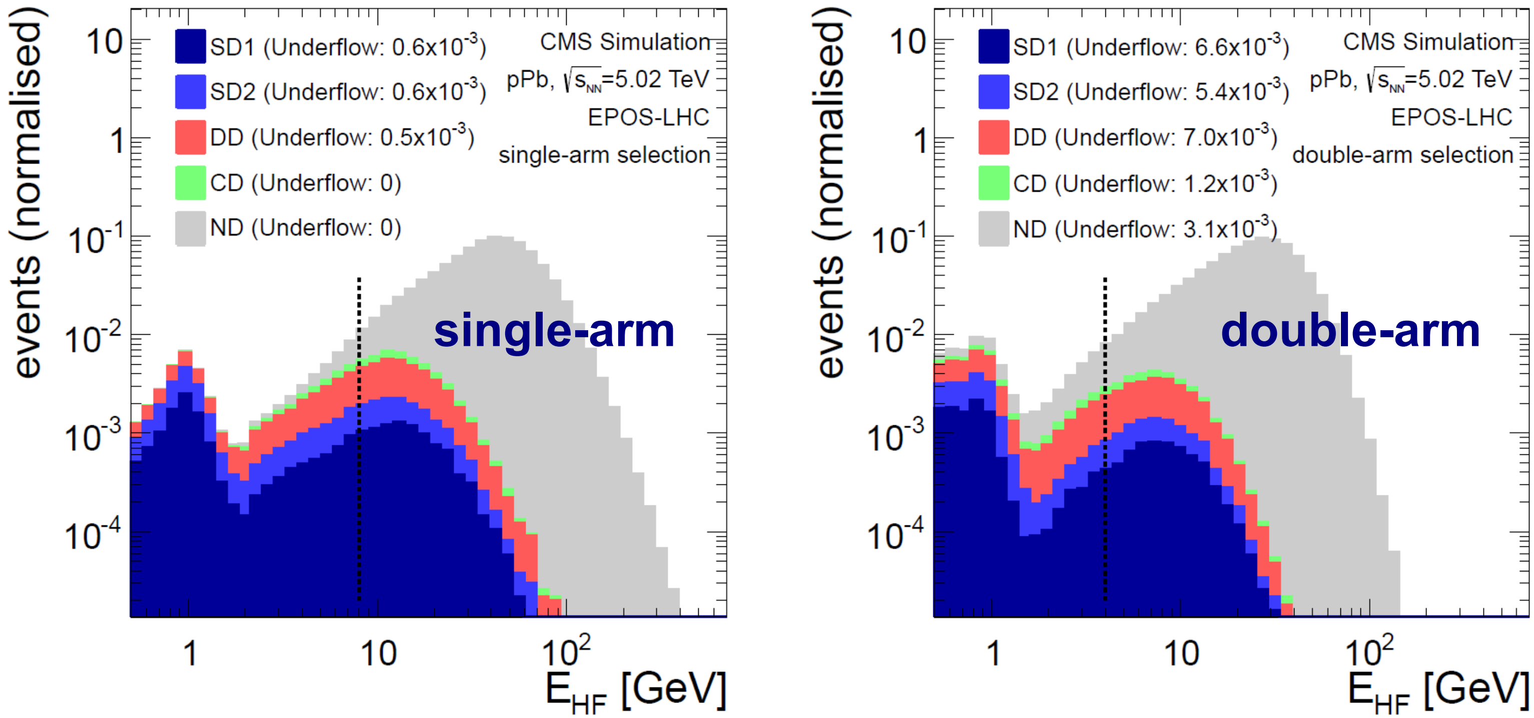
Event selection

- ZeroBias data (trigger on beam presence only)
- Highest signal for a tower in the HF calorimeters E_{HF}
  - single-arm/without coincidence (of η+ and η- side)
  - double-arm/with coincidence





Diffractive Events



Model	Selection	SD [%]	DD [%]	CD [%]	ND [%]	∑ [%]	Ratio (MC)	Ratio (Data)
EPOS-LHC	No selection	4.5	4.5	1.1	90.0	100	-	
	Single-arm	1.7	2.4	0.7	88.9	93.7	0.969	0.966
	Double-arm	1.1	1.8	0.5	87.3	90.8		

visible hadronic (double/single)

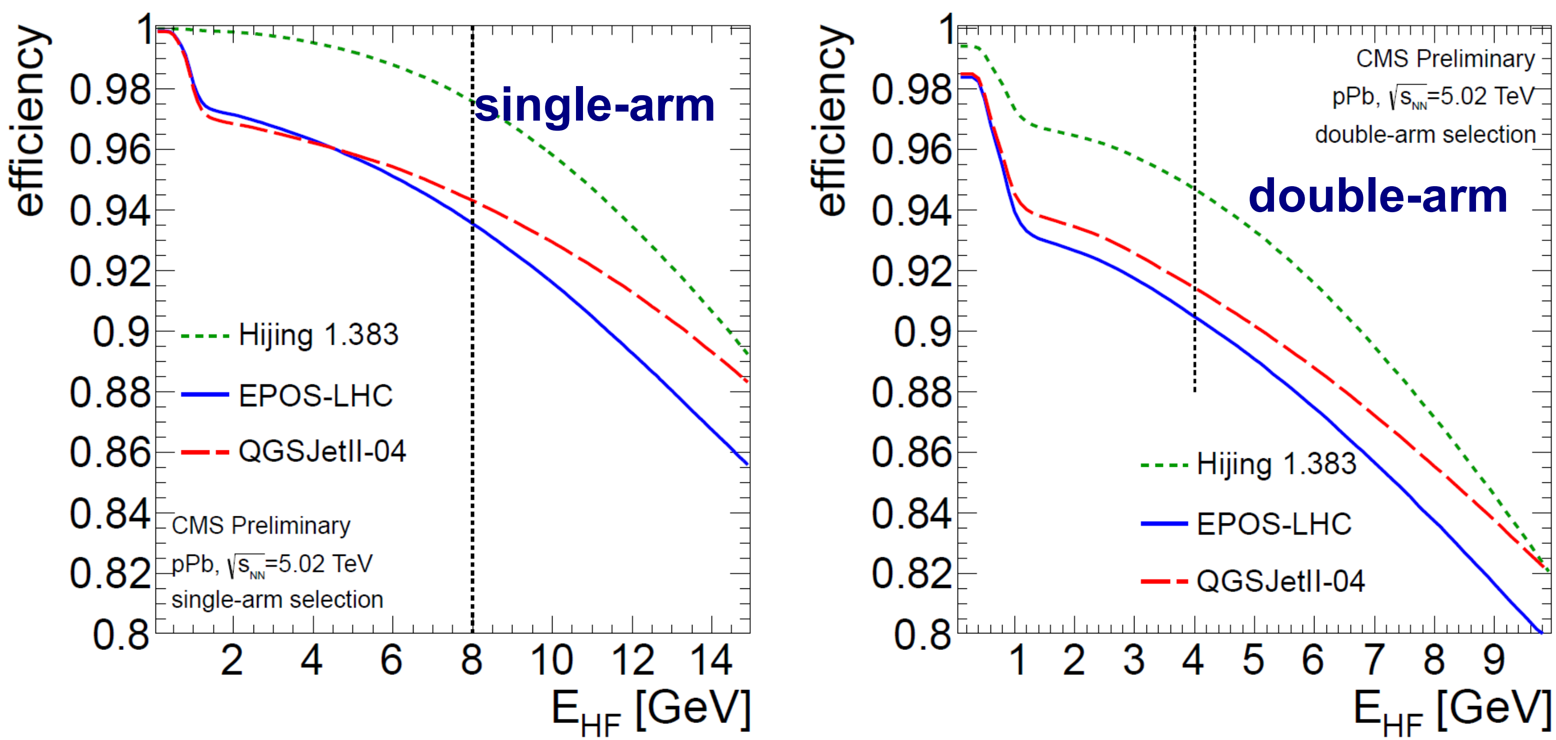
EPOS σ_{diff}~1.12 to match ratio seen in data

QGSJetII-04 similar but less DD (σ_{diff}~1.5 needed to get ratio seen in data)

Hijing has no diffraction for pA included

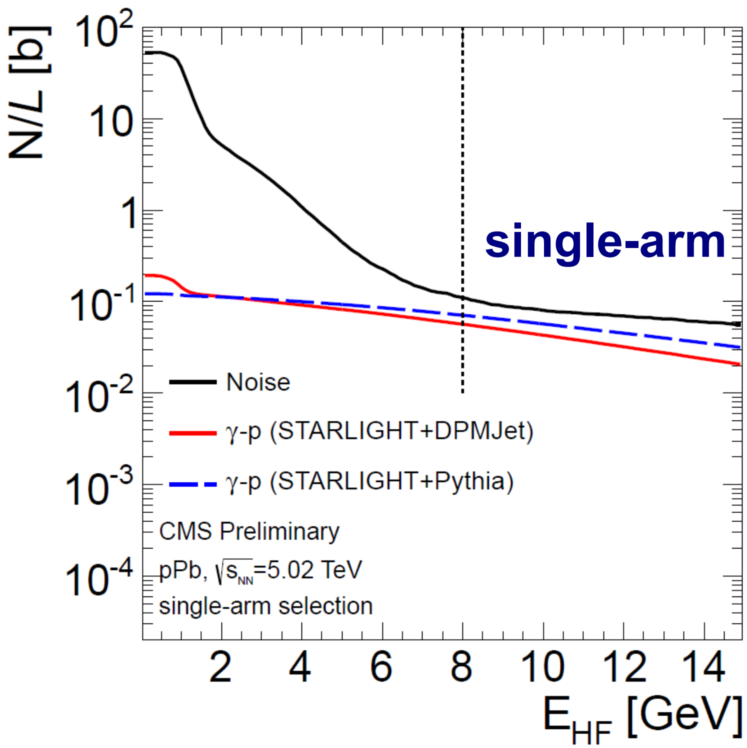
Corrections

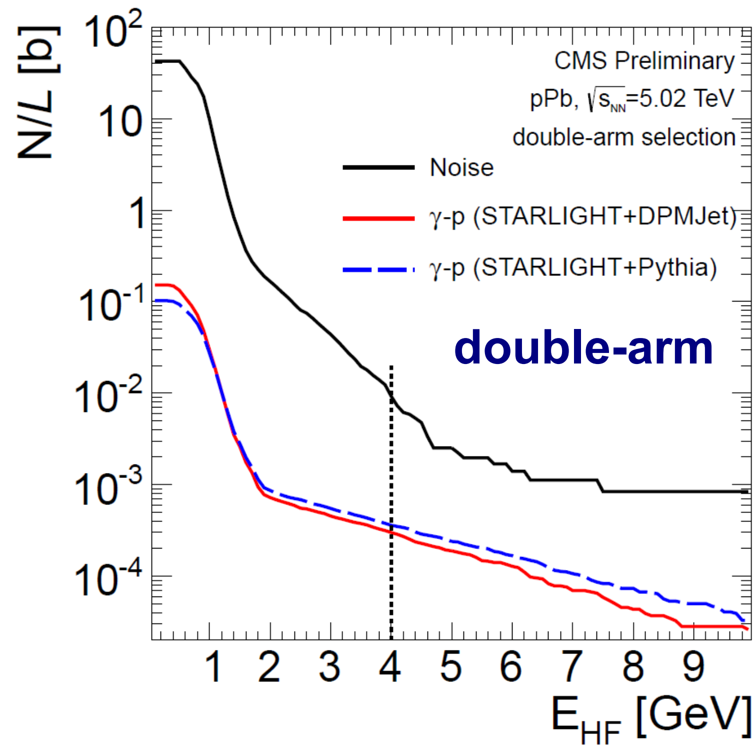
- Selection efficiency for diffractive and non-diffractive events worse for **double-arm** selection



Corrections

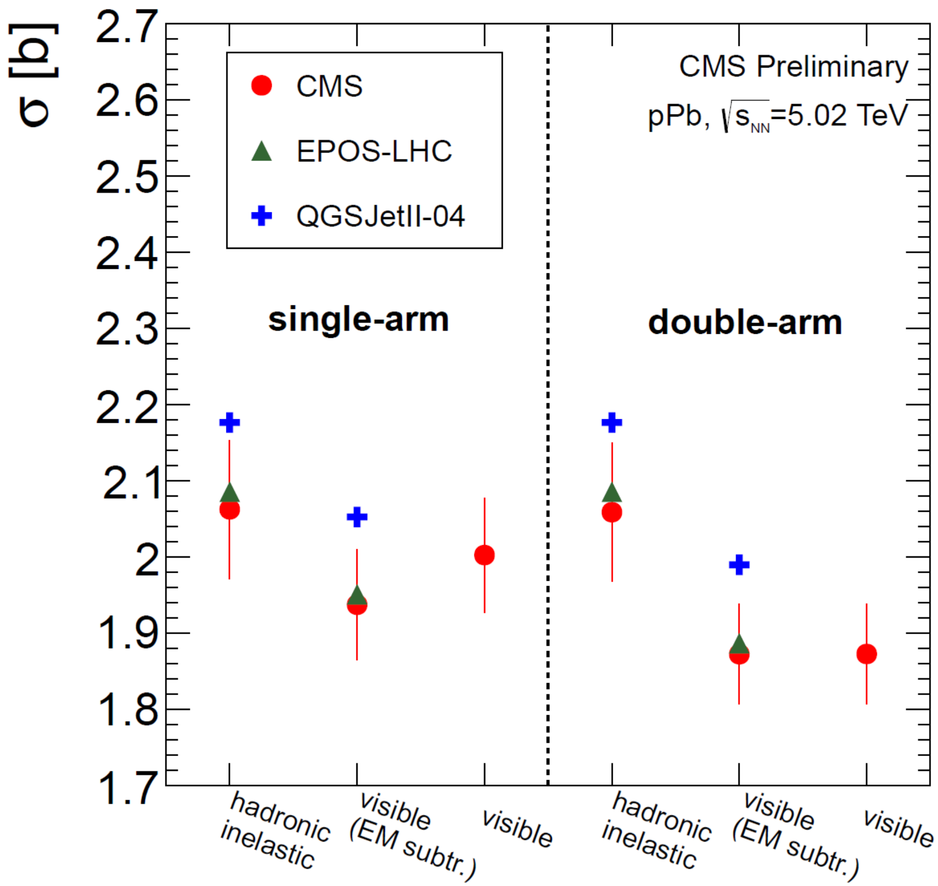
- Different for the two selections:
  - **Single-arm**: 102mb (Noise), 63mb (EM), 1.8% (Pileup)
  - **Double-arm**: 9mb (Noise), 0.3mb (EM), 1.8% (Pileup)





Corrections

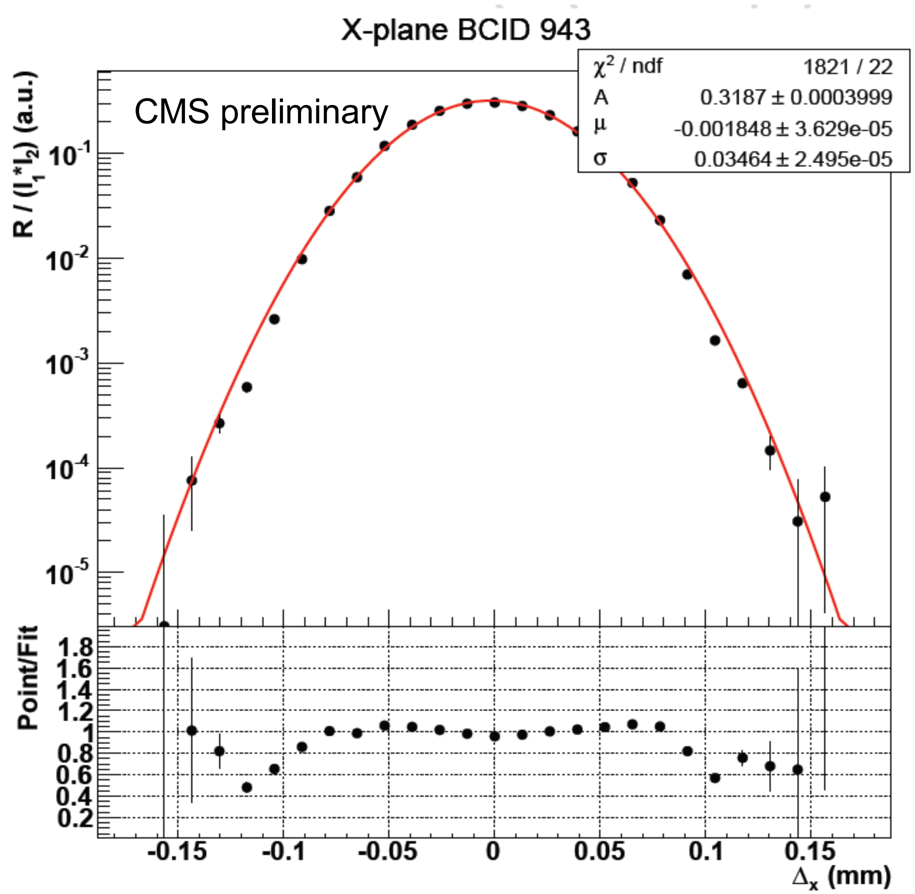
Selection	σ_{vis} (b)	$\sigma_{\text{vis,had}}$ (b)	σ_{inel} (b)
$E_{\text{HF}} > 8$ GeV (single-arm)	2.003	1.938	2.063
$E_{\text{HF}} > 4$ GeV (double-arm)	1.873	1.873	2.059

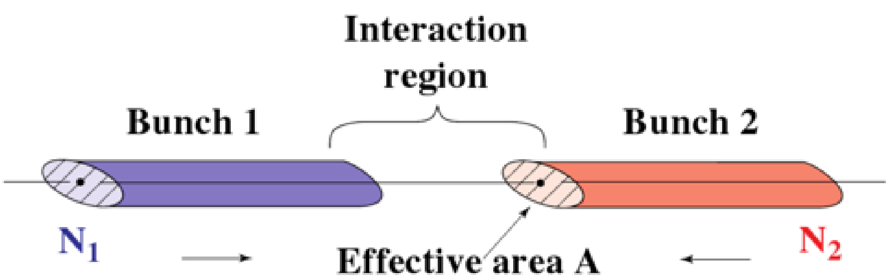


- ***Visible*** cross section and ***visible (EM subtracted)*** cross section different because of acceptance and EM contribution
- Extrapolated **hadronic inelastic** cross section are within 4mb

Luminosity

- Cross section independent method of luminosity calibration
- Beam profile: Rate vs. beam separation fitted for 2013 data
- Van-der-Meer scan analysis based on HF (zero counting) combined with beam currents
- After corrections (beam effects and length scale): **3.5%** uncertainty



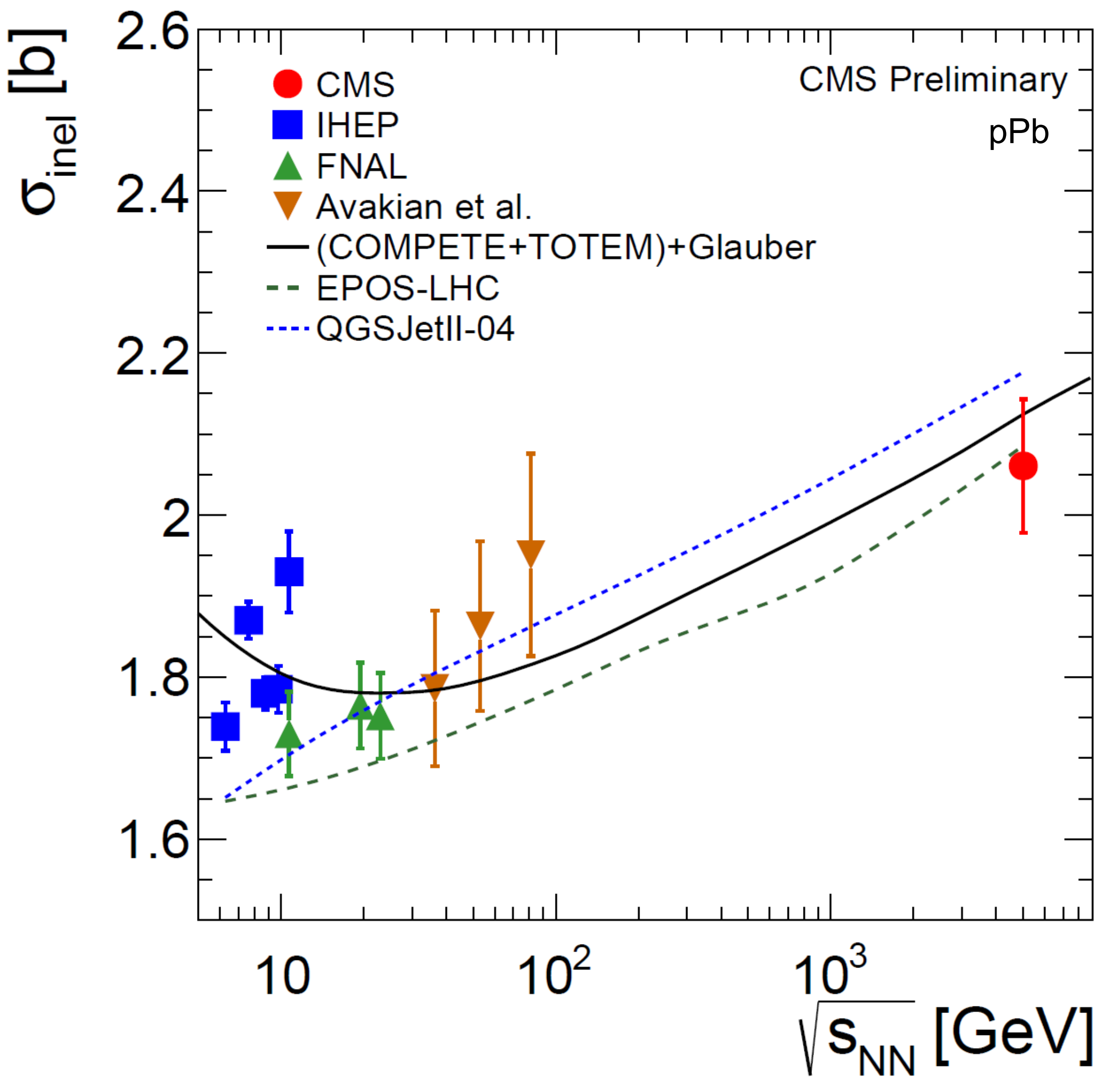


Results

$$\sigma_{\text{inel}} = (2.061 \pm 0.003(\text{stat.}) \pm 0.039(\text{syst.}) \pm 0.072(\text{lumi.}))\ \text{b}$$

Source of uncertainty		Single-arm	Double-arm
Luminosity measurement		3.5%	3.5%
Pileup uncertainty		<0.1%	<0.1%
Extrapolation $\sigma_{\text{vis,had}} \to \sigma_{\text{inel}}$	Model difference	0.5%	1.6%
	optimised σ_{diff}	1.5%	2.0%
Photo-nuclear correction		0.2%	<0.1%
Modelling uncertainty		1.7%	0.8%
Event selection		0.6%	0.2%
Noise subtraction		1.2%	0.2%
Total without $\sigma_{\mathcal{L}}$		2.7%	2.7%
Total with $\sigma_{\mathcal{L}}$		4.4%	4.4%
Both selections combined		4.0%	

Results



CMS Preliminary
pPb
CMS
IHEP
FNAL
Avakian et al.
(COMPETE+TOTEM)+Glauber
EPOS-LHC
QGSJetII-04
σ_{inel} [b]
2.6
2.4
2.2
2
1.8
1.6
10
10^2
10^3
$\sqrt{s_{NN}}$ [GeV]

Summary

- Hadronic inelastic cross section measured with the CMS experiment in pPb collisions at 5.02 TeV

- Standard Glauber model lies within uncertainties
  - SRC and IS seem to cancel out
- QGSJetII-04 (based on Gribov-Glauber approach) slightly above uncertainty of data
- EPOS-LHC (enhanced with energy sharing of nucleons) compatible with data

- QGSJetII-04: larger diffractive cross section would agree better with visible single-arm/double-arm ratio and could reduce cross section