Diffractive Physics:
What answers do we expect from the LHC?

Mario Deile

CERN PH-TOT

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Dominant Event Classes in p-p Collisions

- Non-diffractive inelastic (ND)
- Elastic Scattering
- Single Diffraction
- Double Diffraction
- Double Pomeron Exchange
- Multi Pomeron Exchange

- Processes with large cross-sections!
Signatures of Diffractive Events

- By rapidity gap:

\[ \xi_{i,2} = \frac{\Delta p_i}{p} = \frac{1}{\sqrt{s}} \sum_{i \in X} E_T^{\pm \eta_i} \]

or from rapidity gap:

\[ \xi_{i,2} = e^{-\Delta \eta_{i,2}} \]

→ needs good rapidity coverage

- By leading protons:

needs detectors in beam-pipe insertions far from IP close to the beam (e.g. Roman Pots, moving beam pipes etc.);

Already done at ISR, SppS, HERA, RHIC, Tevatron.

Particularly strong focus on leading proton measurement at LHC.

Roman Pots on both sides of the IPs.
**LHC Experiments: Pseudorapidity Acceptance**

**HF:** calorimeter  
**T1:** CSC tracker

**CASTOR:** calorimeter  
(initially on 1 side of IP5)

**T2:** GEM tracker

**TOTEM Roman Pots:**  
horizontal and vertical with ‘edgeless’ Si detectors

**FP420, IR 3**

0m 6m 14m 16m 140m 147-220m 420m, ~7 km

**ALFA (RP240):**  
vertical Roman Pot with scintillating fibres for absolute lumi. meas.

**LUCID:**  
Cerenkov tubes for relative lumi. calib.

**LHCf:**  
tacker and calo for forward n, π⁰, γ

Mario Deile
No Roman Pots, but Zero Degree Calorimeter for neutral particles.
Identify diffractive events by their rapidity gap and leading neutrals from N* excitations.

See presentation on ALICE diffractive physics programme by R. Schicker.
Total p-p Cross-Section

COMPETE: $\sigma_{\text{tot}} = 111.5 \pm 1.2^{+4.1}_{-2.1} \text{ mb}$

- best fit with stat. error band incl. both TEVATRON points
- total error band of best fit
- total error band from all models considered

Typical range of model predictions: 90 – 130 mb.

Aim of TOTEM / ATLAS at the LHC:
$\sim 1 – 2 \%$ accuracy

Disagreement E811–CDF: 2.6 $\sigma$

“radius increases”
Total Cross-Section and Elastic Scattering at low $|t|$}

### Optical Theorem

\[ \sigma_{tot} = \frac{4\pi}{s} \Im \{ T_{\text{elastic,nuclear}}(t = 0) \} \]

\[
\frac{\mathrm{d}\sigma}{\mathrm{d}t} = \frac{4\pi\alpha^2 (\hbar c)^2 G_4^2(t)}{|t|^2} + \frac{\alpha (\rho - \alpha\phi) \sigma_{tot} G_2^2(t)}{|t|} e^{-\beta|t|} + \frac{\sigma_{tot}^2 (1 + \rho^2)}{16\pi (\hbar c)^2} e^{-\beta|t|}
\]

- $\alpha$ = fine structure constant
- $\phi$ = relative Coulomb-nuclear phase
- $G(t)$ = nucleon el.-mag. form factor = $(1 + |t| / 0.71)^{-2}$
- $\rho$ = Re / Im $T_{\text{elastic,nuclear}}(t = 0)$
Total Cross-Section and Elastic Scattering at low $|t|$

Optical Theorem: \[
\sigma_{\text{tot}} = \frac{4\pi}{s} \Im\left( T_{\text{elastic, nuclear}}(t = 0) \right)
\]

\[
d\sigma dt = \frac{4\pi\alpha^2 (\hbar c)^2 G^4(t)}{|t|^2} + \frac{\alpha(\rho - \alpha\phi)\sigma_{\text{tot}} G^2(t) e^{-B|t|/2}}{|t|}
\]

\[
\frac{\sigma_{\text{tot}}^2}{16\pi (\hbar c)^2} (1 + \rho^2) e^{-B|t|}
\]

$\alpha$ = fine structure constant  
$\phi$ = relative Coulomb-nuclear phase  
$G(t)$ = nucleon el.-mag. form factor = $(1 + |t| / 0.71)^2$  
$\rho$ = Re / Im $T_{\text{elastic, nuclear}}(t = 0)$

TOTEM Approach: 
Measure the exponential slope $B$ in the $t$-range $0.002 - 0.2 \text{ GeV}^2$, extrapolate $d\sigma/dt$ to $t=0$, measure total inelastic and elastic rates (all TOTEM detectors provide L1 triggers):

\[
L\sigma_{\text{tot}}^2 = \frac{16\pi}{1 + \rho^2} \times \frac{dN_{\text{elastic, nuclear}}}{dt} |_{t=0}
\]

\[
L\sigma_{\text{tot}} = N_{\text{elastic, nuclear}} + N_{\text{inelastic}}
\]

\[
\sigma_{\text{tot}} = \frac{16\pi}{1 + \rho^2} \times \frac{(dN_{\text{elastic, nuclear}} / dt)|_{t=0}}{N_{\text{elastic, nuclear}} + N_{\text{inelastic}}}
\]
Total Cross-Section and Elastic Scattering at low $|t|$}

**Optical Theorem:**

$$\sigma_{tot} = \frac{4\pi}{s} \mathcal{S}(T_{elastic,nuclear}(t = 0))$$

**ATLAS Approach:**

Measure $d\sigma/dt$ down into Coulomb region and use el.-mag. cross-section for normalisation.

$$\frac{d\sigma}{dt} = \frac{4\pi\alpha^2 (\hbar c)^2 G^4(t)}{|t|^2} + \frac{\alpha(\rho - \alpha\phi)\sigma_{tot} G^2(t)}{|t|} e^{-B|t|/2} + \frac{\sigma_{tot}^2 (1 + \rho^2)}{16\pi(\hbar c)^2} e^{-B|t|}$$

**TOTEM Approach:**

Measure the exponential slope $B$ in the $t$-range 0.002 - 0.2 GeV$^2$, extrapolate $d\sigma/dt$ to $t=0$, measure total inelastic and elastic rates (all TOTEM detectors provide L1 triggers):

$$L\sigma^2_{tot} = \left. \frac{16\pi}{1 + \rho^2} \times \frac{dN_{elastic,nuclear}}{dt} \right|_{t=0}$$

$$L\sigma_{tot} = N_{elastic,nuclear} + N_{inelastic}$$

$$\sigma_{tot} = \left. \frac{16\pi}{1 + \rho^2} \times \frac{(dN_{elastic,nuclear} / dt)}{N_{elastic,nuclear} + N_{inelastic}} \right|_{t=0}$$
Elastic pp Scattering at 14 TeV: Model Predictions

Islam Model:

- $\beta^* = 2625 \text{ m}$ (ATLAS)
- $\beta^* = 1540 \text{ m}$
- $\beta^* = 90 \text{ m}$
- $\beta^* = 2 \text{ m}$

3-gluon exchange at large $|t|$: $\frac{d\sigma}{dt} \sim t^{-8}$

Big uncertainties at large $|t|$: Models differ by $\sim 3$ orders of magnitude!

TOTEM will measure the complete range with good statistics
Detection of Diffractively Scattered Protons

Transport equations:

\[
\begin{align*}
    y_{\text{det}} &= L_y \theta_y^* + v_y y^* \\
    x_{\text{det}} &= L_x \theta_x^* + v_x x^* + D \xi
\end{align*}
\]

\( (x^*, y^*) \): vertex position
\( (\theta_x^*, \theta_y^*) \): emission angle
\( \xi = \Delta p/p \)

Example: Hit distribution @ TOTEM RP220 with \( \beta^* = 90 \text{ m} \)

Optics properties at RP220:

\[
\begin{align*}
    \beta^* = 1540 \text{ m} & \quad L = 10^{28} - 2 \times 10^{29} \quad 95\% \text{ of all } p \text{ seen; all } \xi \\
    \beta^* = 90 \text{ m} & \quad L = 10^{29} - 3 \times 10^{30} \quad 65\% \text{ of all } p \text{ seen; all } \xi \\
    \beta^* = 0.5 - 2 \text{ m} & \quad L = 10^{30} - 10^{34} \quad p \text{ with } \xi > 0.02 \text{ seen; all } t
\end{align*}
\]
Diffraction at $\beta^* = 0.5 - 2 \text{ m with high Luminosity}$

FP420 Project (IP1 and IP5)

Alternative idea: put detectors in momentum cleaning region IR3 (→ talk by K. Eggert)
Measurement of Diffractive Cross-Sections

Aim: measurement of all kinematic variables and their correlations.

**Single Diffraction:**
(Regge theory)

\[
\frac{d^2 \sigma_{\text{SD}}}{dt \, d\xi} = f_{\text{IP}}(t, \xi) \cdot \sigma_{\text{IP-p}} (s \xi) \sim \frac{1}{\xi^{b+\varepsilon}} e^{-bt} \\
\]

Pomeron flux in proton \( \sim e^{b \, t} / \xi^{1+2\varepsilon} \)

Pomeron-proton cross-section \( \sim (s \xi)^{\varepsilon} \)

Slope parameter at LHC: \( b \sim 5 \text{ – 7 GeV}^{-2} \) \( \Leftrightarrow \) distance of diffractive interaction \( R \sim 0.5 \text{ fm} \)

\( \xi \) and \( t \) dependence experimentally confirmed up to Tevatron, but total SD cross-section lower.

**Difficulty in Single Diffraction:**

Mass from proton measurement:

\[
M = \sqrt{\xi s} \\
\sigma(\xi) \sim 2 \times 10^{-3} \\
\]

(principally limited to \( 10^{-4} \) by beam energy spread!)

\( \rightarrow \) Mass resolved for \( M > 450 \text{ GeV} \)

\( \rightarrow \) need to calculate \( M \) directly from diffractive system

**Rapidity Gap vs. Proton Momentum**

**Example: Single Diffraction** measured with $\beta^* = 90$ m (protons with all $\xi$ detected).

Proton momentum resolution: $\beta^* = 90$ m: $\sigma_p(\xi) = 1.6 \times 10^{-3}$

Rapidity gap measurement resolution: $\sigma(\Delta \eta) = 0.8 - 1$

Compare the proton momentum loss $\xi$ with the rapidity gap $\Delta \eta$: verify $\Delta \eta = -\ln \xi$

<table>
<thead>
<tr>
<th>$\xi$–range</th>
<th>M (SD) [GeV]</th>
</tr>
</thead>
<tbody>
<tr>
<td>$&lt; 1 \times 10^{-7}$</td>
<td>$&lt; 5$</td>
</tr>
<tr>
<td>$1 \times 10^{-7} - 1.6 \times 10^{-3}$</td>
<td>$5 - 450$</td>
</tr>
<tr>
<td>$1.6 \times 10^{-3} - 0.045$</td>
<td>$450 - 3000$</td>
</tr>
<tr>
<td>$&gt; 0.045$</td>
<td>$&gt; 3000$</td>
</tr>
</tbody>
</table>
Rapidity Gap Survival in Hard Diffraction

Diffractive DIS at HERA

\[ \sigma \sim F^D(\beta, Q^2, \xi, t) \otimes \hat{\sigma}_{jj} \otimes |S|^2 \]

diffractive structure function

gap survival probability

hard scattering cross-section

- shape of function \( F^D \) similar
- normalisation different (factor 10)
Rapidity Gap Survival Probability: 2 gaps vs 1 gap

\[ R(SD/ND) \propto F_p^D |S|^2 \]

\[ R(DPE/SD) \propto \frac{F_p^D F_p^S |S|^2}{F_p^D |S|^2} \]

Suppression similar for 2 gaps and 1 gap

\[ |S|^2 \sim \frac{R(SD/ND)}{R(DPE/SD)} \]
Central Diffraction (DPE)

5-dimensional differential cross-section:
\[
\frac{d^5 \sigma}{dt_1 dt_2 d\xi_1 d\xi_2 d\phi} = \frac{1}{\xi_1^{1+\varepsilon}} \frac{1}{\xi_2^{1+\varepsilon}} e^{-b|t_1| - b|t_2|}
\]

Any correlations?

Mass spectrum: change variables \((\xi_1, \xi_2) \rightarrow (M_{PP}, y_{PP})\):

\[
M_{PP}^2 = \xi_1 \xi_2 \text{ s;} \quad y_{PP} = \frac{1}{2} \ln \frac{\xi_1}{\xi_2}
\]

\[
\frac{d^2 \sigma}{dM^2 dy} = \frac{1}{(M^2)^{1+\varepsilon}}
\]

\(\beta^* = 90\text{m}: \sigma(M) = 20 \text{ – 70 GeV}\)

1.4 nb / GeV ⇔ 50 events / (h • 10GeV) @ 10^{30} cm^{-2} s^{-1}

→ sufficient statistics to measure the inclusive mass spectrum

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Central Production

High gluon fraction in Pomeron (measured by HERA, Tevatron)
⇒ Use the LHC as a gluon-gluon collider and look for resonances in $d\sigma/dM$

**Special Case: Exclusive production**

- clean signature and redundancy: measure both protons and central system
- exchange of colour singlets with vacuum quantum numbers
  ⇒ Selection rules for system $X$: $J^{PC} = 0^{++}, (2^{++}, 4^{++})$

Study the kinematic properties of exclusive production (e.g. $t$-spectrum and $p_T$ distrib. of $X$), compare with inclusive production ($M = X + ?$)

seen at the Tevatron
### Exclusive Production: Examples

**Predictions for the LHC:**

<table>
<thead>
<tr>
<th>System M</th>
<th>$\sigma_{\text{excl}}$</th>
<th>Decay channel</th>
<th>BR</th>
<th>Events at $L_{\text{int}} = 0.3 \text{ pb}^{-1}$</th>
<th>Events at $L_{\text{int}} = 0.3 \text{ fb}^{-1}$</th>
</tr>
</thead>
<tbody>
<tr>
<td>$\chi_{c0}$ (3.4 GeV)</td>
<td>3 $\mu$b [KMRS]</td>
<td>$\gamma J/\psi \rightarrow \gamma \mu^+\mu^-$ $\pi^+\pi^-K^+K^-$</td>
<td>$6 \times 10^{-4}$</td>
<td>140</td>
<td>140000</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>0.018</td>
<td>4500</td>
<td>4.5 x 10$^6$</td>
</tr>
<tr>
<td>$\chi_{b0}$ (9.9 GeV)</td>
<td>4 nb [KMRS]</td>
<td>$\gamma Y \rightarrow \gamma \mu^+\mu^-$</td>
<td>$\leq 1.5\times 10^{-3}$</td>
<td>$\leq 0.5$</td>
<td>$\leq 500$</td>
</tr>
<tr>
<td>jj ($\eta_1 - \eta_2 &gt; 1$, $E &gt; 50$ GeV)</td>
<td>0.2 nb</td>
<td></td>
<td></td>
<td>60</td>
<td>60000</td>
</tr>
<tr>
<td>$\gamma\gamma$ (E &gt; 5 GeV)</td>
<td>600 fb</td>
<td></td>
<td>0.18</td>
<td>180</td>
<td></td>
</tr>
</tbody>
</table>

$\beta^* = 90$ m  
$L = 10^{29} - 3 \times 10^{30}$

$\beta^* = 0.5 - 2$ m  
$L = 10^{30} - 10^{34}$
Other Central Production Processes

Odderon = hypothetical analogon to Pomeron with $C = -1$
QCD: Pomeron = 2 gluons, Odderon = 3 gluons

Pomeran – Photon fusion

Pomeran – Odderon fusion

systems with $C = P = -1$ : e.g. $J/\Psi$, $Y$

See Photon/Odderon studies by Alice.
Detection of Central Production

Ideal scenario:
reconstruct kinematics from protons AND resonance decay products (→ redundancy!)

But:
Only possible for small production rapidities $y$
i.e. symmetric events $\xi_1 \approx \xi_2$

$$y_{pp} = \frac{1}{2} \ln \frac{\xi_1}{\xi_2}$$

$$\beta^* = 90 \text{ m }$$
only RP220

$$L = \text{ too low for } \chi_b, H$$

$$\chi_b \rightarrow \gamma Y \rightarrow \gamma \mu^+\mu^-$$

$$\chi_c \rightarrow \pi^+\pi^- K^+K^-$$

$$\gamma J/\psi \rightarrow \gamma \mu^+\mu^-$$

$$\xi(p1) > 0.002: \text{ resolved}$$

$$\xi(p2) < 0.002: \text{ detected, unresolved}$$

$$\xi(p1, p2 \text{ resolved})$$

$$M_{pp}^2 = \xi_1 \xi_2 s$$
Detection of Central Production

Ideal scenario:
reconstruct kinematics
from protons AND
resonance decay products
(\(\Rightarrow\) redundancy!)

But:
Only possible for small
production rapidities \(y\)
i.e. symmetric events
\(\xi_1 \approx \xi_2\)

\[
y_{PP} = \frac{1}{2} \ln \frac{\xi_1}{\xi_2}
\]
Various Higgs studies:

- SM with \( m_H = 120 \) GeV:
  \[ \sigma \times \text{BR} (H \rightarrow bb) = 2 \text{ fb} \, , \, \text{S/B} \sim 1 \]

- MSSM \( M_H^{\text{max}} \) scenario
  \( (m_A = 120 \) GeV, \( \tan \beta = 40) \)
  \[ \sigma \times \text{BR} (h \rightarrow bb) = 20 \text{ fb} \]

- NMSSM scenario \( (m_h = 93 \) GeV, \( m_a = 10 \) GeV)
  \[ \sigma \times \text{BR} (h \rightarrow aa \rightarrow 4\tau) = 4.8 \text{ fb} \, \text{but S/B} \geq 10 ! \]

Difficulty of diffraction at high luminosity: Pile-up of several events per bunch crossing;
\( L = 1 \times 10^{34} \): 35 events / bunch crossing

Combinations faking DPE signature:
  e.g. (single diffraction) + (non-diffractive inelastic) + (single diffraction)

\[ \rightarrow \text{Leading protons and central diffractive system have to be matched:} \]
timing measurements in leading proton detectors (10 – 20 ps in FP420) \( \rightarrow z(\text{vertex}) \)
Summary: Questions on diffraction addressed by the LHC

- Total p-p cross-section measurement on the ~1% level
- Differential elastic cross-section measured over 4 orders of magnitude in $t$
  with very different scattering mechanisms
- Event topologies and differential cross-sections of diffractive processes
  (Tools: leading proton detectors, different specially designed beam optics,
  good rapidity coverage)
- Rapidity gap studies based on proton tagging
- Study of central production with search for resonances:
  inclusive vs exclusive processes
CMS+TOTEM Forward Detectors

**T1:** $3.1 < \eta < 4.7$  **CSC trackers**

**T2:** $5.3 < \eta < 6.5$  **GEM trackers**

**Roman Pots:**
- RP147
- RP220

**CASTOR calorimeter**

Symmetric experiment: RPs on both sides! → Unique tool for diffraction
CMS + TOTEM: Acceptance

largest acceptance detector ever built at a hadron collider

90% (65%) of all diffractive protons are detected for $\beta^* = 1540 \pm 90$ m

$\eta = - \ln \tan \theta/2$
Leading proton detection at distances down $10 \sigma_{\text{beam}} + d$

Need “edgeless” detectors (efficient up to physical edge) to minimise width $d$ of dead space.

TOTEM: specially designed silicon strip detectors (CTS), efficient within 50 \(\mu\text{m}\) from the edge

“edgeless” Si strip detectors
(10 planes per pot)
Leading Proton Detection: FP420 (IP1 and IP5) and ATLAS RP220

Proton spectrometers proposed: at 220m and ~420 m from IP1 and at ~420m from IP5

Two (or three) stations for each spectrometer

Two pockets for each station: tracking and timing detectors

Mechanical design based on movable “Hamburg Pipe”: 

![Diagram of Leading Proton Detection](image)
New Idea: Proton Measurement in IP3

Detects protons from all interaction points.

Acceptance in Momentum Loss $\xi$
**ALFA (RP240):**
vertical Roman Pot with scintillating fibres for absolute lumi. meas.

**LUCID:**
Cerenkov tubes at $|z| \sim 17 \text{ m} \ (5.4 < |\eta| < 6.1)$ for relative lumi. calib.

**LHCf:**
tracker and calo for forward $n$, $\pi^0$, $\gamma$
The Experiments: ALFA (IP1)

Roman Pot Unit

MAPMTs
FE electronics & shield
PMT baseplate
optical connectors
scintillating fibre
detectors glued on ceramic supports
10 U/V planes
overlap & trigger

Roman Pot

Top view:

Same configuration on the other side of IP1
The Experiments: LHCf (IP1)

Arm 1

140m

Arm 2

scintillating fibers

scintillators

tungsten layers

ATLAS

beam pipe
detector box
TAN area

scintillators

tungsten layers

Silicon layers

INCOMING NEUTRAL PARTICLE BEAM
Characteristics of Diffractive Events

Non-diffractive events:

Exchange of colour:
Initial hadrons acquire colour and break up.
Rapidity gaps filled in hadronisation

→ Exponential suppression of rapidity gaps:

$$P(\Delta \eta) = e^{-\rho \Delta \eta}, \quad \rho = \frac{dn}{d\eta}$$

Diffractive events:

Exchange of colour singlets with vacuum quantum numbers ("Pomerons")

→ rapidity gaps $\Delta \eta$ with $P(\Delta \eta) = \text{const.}$

Many cases: leading proton(s) with momentum loss $\Delta p / p \equiv \xi$
(typically $\xi < 0.1$)
Elastic Scattering - from ISR to Tevatron

- exponential region $ds/dt \sim e^{-B|t|}$

- exponential slope $B$ at low $|t|$ increases: $B \sim R^2$

- ~1.5 GeV$^2$

- ~0.7 GeV$^2$

- ~1.7 GeV$^2$
Elastic Scattering - from ISR to Tevatron

Diffractive minimum: analogous to Fraunhofer diffraction: \(|t| \sim p^2 \theta^2\)

- exponential slope \(B\) at low \(|t|\) increases
Elastic Scattering - from ISR to Tevatron

Diffractive minimum: analogous to Fraunhofer diffraction: \[|t| \sim p^2 \theta^2\]

- exponential slope B at low |t| increases
- minimum moves to lower |t| with increasing s
  \(\rightarrow\) interaction region grows (as also seen from \(\sigma_{\text{tot}}\))
- depth of minimum changes
  \(\rightarrow\) shape of proton profile changes
- depth of minimum differs between pp, p\(^-\)p
  \(\rightarrow\) different mix of processes
Elastic Scattering Acceptance

Acceptance for elastically scattered protons depends on machine optics ($\beta^*$)

**TOTEM:** $\beta^* = 1540$ m, 90 m, 2 m

**ATLAS:** $\beta^* = 2625$ m

**Expected uncertainty in $\sigma_{\text{tot}}$:**
- TOTEM: $\sim 1\%$
- ATLAS: $\sim 5\%$

**Measurements down to lowest $|t|$ need reduced beam emittance**

and very close detector approach to the beam → difficult
Measurement of $\rho = \Re f(0) / \Im f(0)$

\[
\beta^* = 1540 \text{m}, \quad \epsilon_N = 1 \text{mm rad}
\]

\[
\rho = 0.1361 \pm 0.0015 \pm 0.0058 - 0.0025
\]

COMPETE Prediction for LHC:

\[
\rho \quad \text{(at higher } s) \quad \sim 1 / \ln s \quad \text{for } s \to \infty
\]

\[
\rho \quad \text{is interesting for } \sigma_{\text{tot}}:
\]

\[
\text{prediction of } \sigma_{\text{tot}} \quad \text{via dispersion relation: } \quad \rho(s) = \frac{\pi}{2 \sigma_{\text{tot}}(s)} \frac{d\sigma_{\text{tot}}}{d \ln s}
\]

Try to reach the interference region:

- move the detectors closer to the beam than $10 \sigma + 0.5$ mm
- run at lower energy $\sqrt{s} = 2p < 14$ TeV: $|t|_{\text{min}} = p^2 \theta^2$
Elastic and Diffractive Fractions of $\sigma_{\text{tot}}$

$\sigma_{\text{el}} / \sigma_{\text{tot}} \sim 30\%$ at the LHC?

$\sigma_{\text{el}} / \sigma_{\text{tot}} = 50\%$ : black disk limit

The proton not only grows but becomes blacker. Saturation?

SD / total ratio observed to decrease.

At 14 TeV? Various models:
Interpretation of diffractive PDF’s

proton PDF’s

diffractive PDF’s

diffractive vs proton PDF’s:

- larger gluon content
- harder gluon structure
Measurement of Resonances

Ideal scenario:
reconstruct kinematics
from protons AND
resonance decay products
(\( \rightarrow \) redundancy!)

But:
Only possible for small
production rapidities \( y \)
i.e. symmetric events
\( \xi_1 \approx \xi_2 \)

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\]
Higgs (SM, MSSM)

SM with $m_H = 120$ GeV:

$\sigma \times BR (H \rightarrow bb) = 2 \text{ fb}$
$30 \text{ fb}^{-1}$, $\delta m = 3$ GeV: $S/B = 11/10$

$\sigma \times BR (H \rightarrow WW^*) = 0.4 \text{ fb}$
$30 \text{ fb}^{-1}$: $S/B = 8/3$

MSSM Examples:

$m_A = 130$ GeV

<table>
<thead>
<tr>
<th>$m_A$</th>
<th>$\sigma \times BR (A \rightarrow bb)$</th>
</tr>
</thead>
<tbody>
<tr>
<td>130 GeV</td>
<td>0.07 fb</td>
</tr>
<tr>
<td>130 GeV</td>
<td>0.2 fb</td>
</tr>
</tbody>
</table>

$\tan \beta = 30$

$\tan \beta = 50$

$\delta m = 3$ GeV: $S/B = 11/10$

$m_A = 100$ GeV

<table>
<thead>
<tr>
<th>$m_A$</th>
<th>$\sigma \times BR (A \rightarrow bb)$</th>
</tr>
</thead>
<tbody>
<tr>
<td>100 GeV</td>
<td>0.4 fb</td>
</tr>
<tr>
<td>100 GeV</td>
<td>1.1 fb</td>
</tr>
</tbody>
</table>

$\tan \beta = 30$

$\tan \beta = 50$

$\delta m = 3$ GeV: $S/B = 8/3$