# Exclusive Elastic and Proton Dissociative $J/\psi$ Photoproduction at low $W_{\gamma p}$

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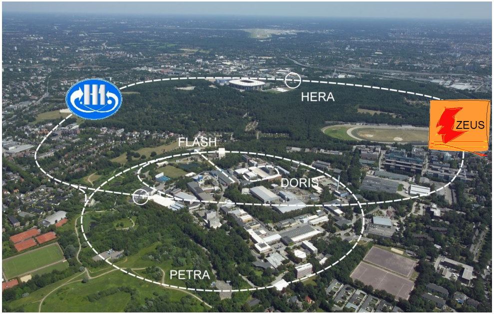
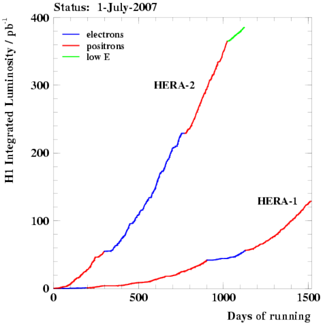
# Introduction

# HERA and H1 at DESY in Hamburg




## HERA

- Electron/positron ($E_e = 27.5\,\mathrm{GeV}$) proton collider.
- Integrated Luminosity $\sim 0.5\,\mathrm{fb}^{-1}$ (1992-2007)

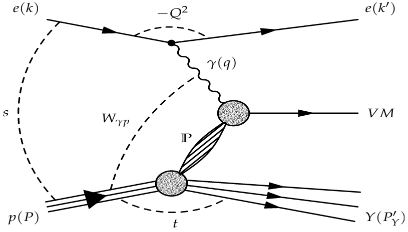



## Energy regions (used in this analysis)

- High energy region: $E_p = 920\,\mathrm{GeV}$, $\sqrt{s} = 318\,\mathrm{GeV}$
- Low energy region: $E_p = 460\,\mathrm{GeV}$, $\sqrt{s} = 225\,\mathrm{GeV}$

# Kinematic Variables

Diffractive vector meson production in $ep$ – scattering




| | Definition |
|---|---|
| centre of mass (cms) energy | $s \equiv (k + P)^2$ |
| photon virtuality | $Q^2 \equiv -q^2 = -(k - k')^2$ |
| squared momentum transfer at proton vertex | $t \equiv (P - \sum_X P'_X)^2$ |
| cms energy in photon proton rest frame | $W^2_{\gamma p} \equiv (P + q)^2 \simeq ys - Q^2$ |

$y$: inelasticity

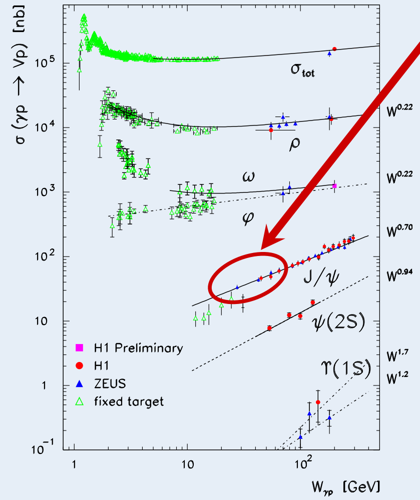
- Photoproduction: Small $Q^2$ region, where the photon becomes almost real.
  In this measurement $Q^2 < 2.5\,\mathrm{GeV}^2$, i.e. no scattered electron is detected
- Deep inelastic scattering (DIS): $Q^2 > 2.5\,\mathrm{GeV}^2$

**Def: Elastic / Proton dissociation**

- Elastic: The proton stays intact after the interaction.
- Proton dissociation: The proton does not stay intact after the interaction.

# Motivation for this Analysis

## Summary of diff. CS for elastic vector mesons in photoproduction




## Goals

1. Measure in low $W_{\gamma p}$ region.
2. Measure elastic and proton dissociative cross section.

## Remark

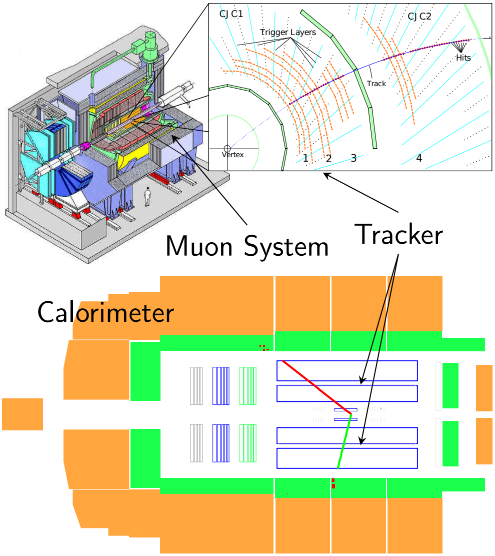
Goal 1 can be achieved because $W_{\gamma p} \propto \sqrt{E_p}$

# Analysis Details

# Decay Channel and Trigger

For low $W_{\gamma p}$ region previous the channel $J/\psi \to \mu\mu$ was used because of $\mu$ trigger.

**But in this analysis we use $J/\psi \to ee$.**




### Fast Track Trigger (FTT)

In the H1 upgrade for HERA II also the trigger system was improved and the Fast Track Trigger was added.

$\Downarrow$

Triggering on particles purely based on track information with good online selection.

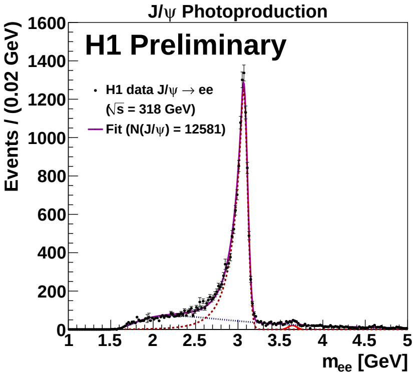
# Kinematic Selection

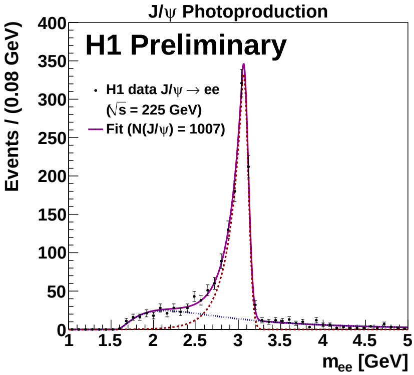
## High Energy Period ($\sqrt{s} = 318\,\mathrm{GeV}$)

- $\mathcal{L} = 112\,\mathrm{pb}^{-1}$
- $Q^2 \leq 2.5\,\mathrm{GeV}^2$
- $|t| \leq 6\,\mathrm{GeV}^2$
- $40 \leq W_{\gamma p}\,[\mathrm{GeV}] \leq 110$

## Low Energy Period ($\sqrt{s} = 225\,\mathrm{GeV}$)

- $\mathcal{L} = 11\,\mathrm{pb}^{-1}$
- $Q^2 \leq 2.5\,\mathrm{GeV}^2$
- $|t| \leq 3.5\,\mathrm{GeV}^2$
- $20 \leq W_{\gamma p}\,[\mathrm{GeV}] \leq 80$

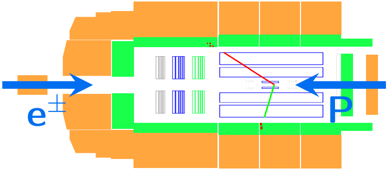


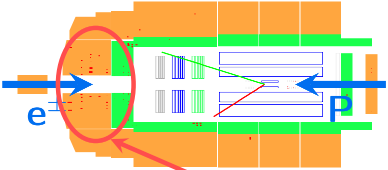



# Elastic and Proton Dissociative Events

**Goal 2: Measure Elastic AND Proton Dissociative Cross Sections**

After selecting $J/\psi$ candidates the data sample still contains elastic AND proton dissociative events!




**Elastic**

Proton stays intact and disappears in the beam pipe.

**Proton Dissociative**

Proton stays not intact and might generate some activity in the forward direction.

# Tagged event

## Problem

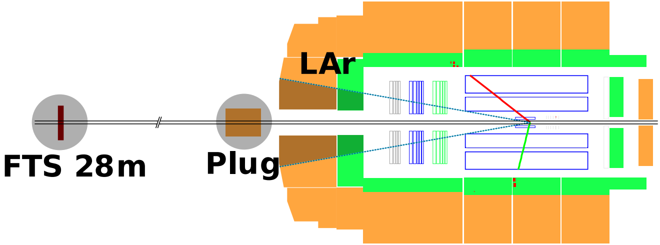
A proton dissociative event might produce a too weak signal in the detector either because the particles are too soft or they disappear in the beam pipe. On the other side an elastic event might produce a signal just because of noise.

Working with a simple cut therefore is not an option.

## Solution

If an event has enough activity in forward direction, it is labeled as "tagged event".

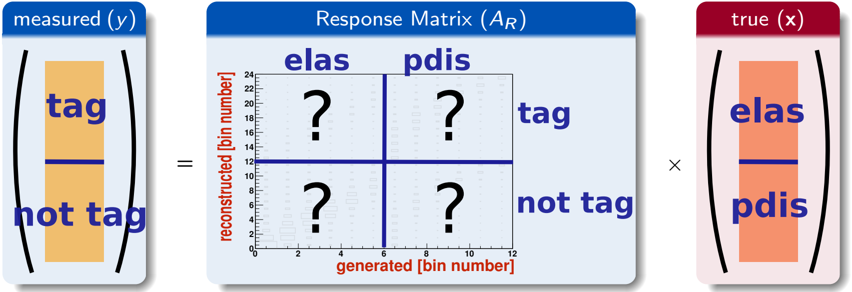
This enriches the tagged event sample with proton dissociative events and the not tagged with elastic events.



# Unfolding the Cross Sections

- Use regularised unfolding for disentangling of elastic and proton dissociative process and for taking correctly into account the migrations.
- Unfolding is done to true variables.

$A_R$ Response matrix
**x** true number of events
$y$ reconstructed number of events
$L$ regularisation matrix




Vector filled with number of signal events from mass distribution fits.

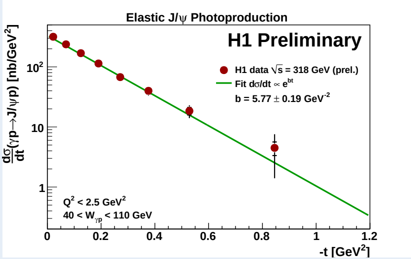
Matrix filled with MC.

**Output of unfolding**

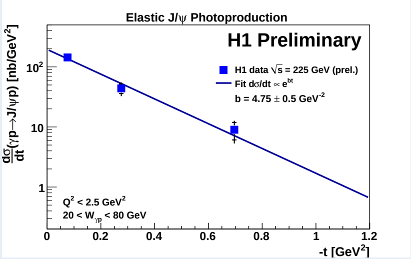
# Results

# Differential Elastic Cross Section as Function of $t$

## High Energy Period




## Low Energy Period

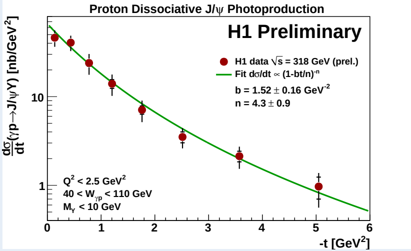



- Differential elastic cross section fitted with an exponential.
  *b*-slope for (error includes statistical and systematic uncertainty)
  high energy period $(5.77 \pm 0.19)\,\mathrm{GeV}^{-2}$
  low energy period $(4.75 \pm 0.5)\,\mathrm{GeV}^{-2}$
- Shallower *b*-slope for low energy period expected because of lower $W_{\gamma p}$ region and positive shrinkage of pomeron trajectory.

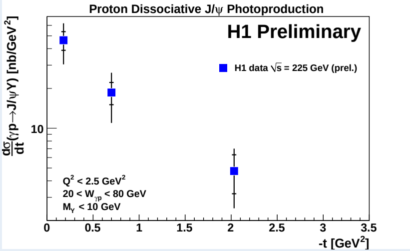
Remark: The normalisation uncertainty of 9 % is not included in the error bars of the data points, but was taken into account for the fit. (This is the same for all cross sections.)

# Differential Proton Dissociative Cross Section as Function of $t$

## High Energy Period



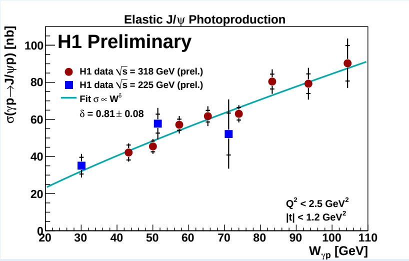

## Low Energy Period



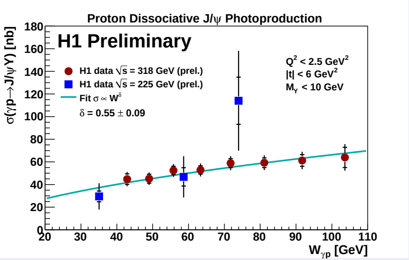

- Fit for low energy period is not performed because of too less data points for same fitting function as used for the high energy period.
- Differential proton dissociative cross section fitted with function behaving as an exponential at low $|t|$ and and follows a power law at larger $|t|$.

# Cross Section as function of $W_{\gamma p}$

## Elastic

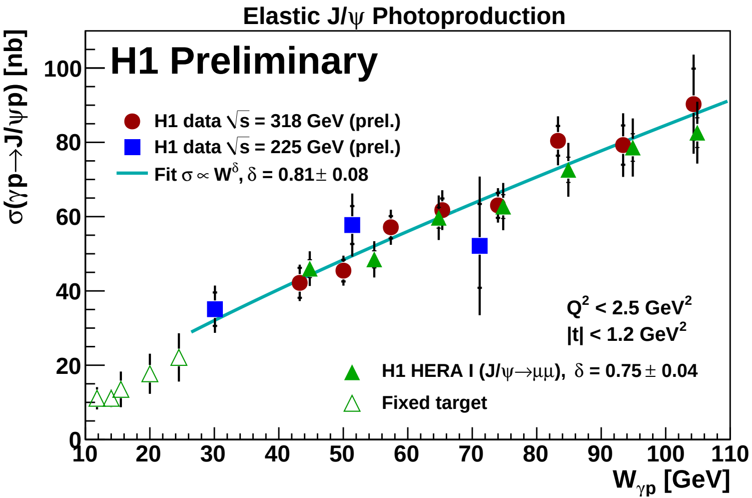



## Proton Dissociative




- Measured values for the elastic slope of $\delta = 0.81 \pm 0.8$ is in agreement with previous H1 measurement (DESY-05-161) $0.75 \pm 0.03 \pm 0.03$.
- Comparing the slope of proton dissociative $\delta$ is not possible since no data are available in the same phase space.

# Elastic Cross Section as function of $W_{\gamma p}$



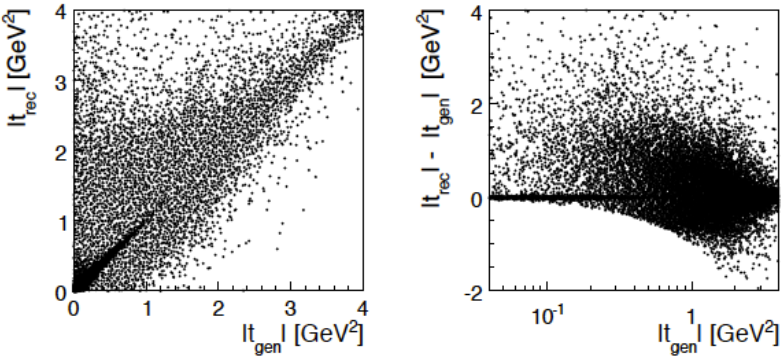
# Summary

## Summary

- Simultaneous measurement of elastic and proton dissociation $J/\psi$ cross sections as function of $t$ and $W_{\gamma p}$.
- Agreement with previous measurements in overlap region.
- Data from low energy run allow extension to lower $W_{\gamma p}$ region.

# Backup

# Difference of using $t_{gen} = -p^2_{t,\psi}$ or true $t_{gen}$




(Plots taken from Ronald Weber's PhD thesis. MC is from $\rho$ production, however the principle is the same.)

Calculating $t$ dependance shows

$$t \simeq -(p_{\vec{t},\psi} + p_{\vec{t},e}^{\prime})^2$$

with $p_{\vec{t},e}^{\prime}$ the momentum of the scattered electron. There is a $Q^2$ dependance missing in case where $t_{gen} = p^2_{t,\psi}$ is choosen.