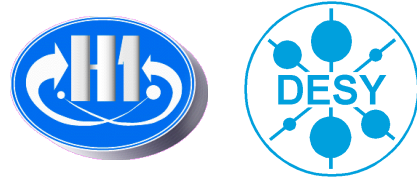


# *H1 recent results and the HERAFitter project*

**Krzysztof Nowak**



**73<sup>rd</sup> PRC meeting**  
**DESY, Hamburg 26<sup>th</sup> April 2012**

# *Talk Outline*

*Organization & Computing*

*Inclusive Measurements*

*Diffraction*

*Hadronic Final States & QCD*

*Heavy Flavour*

*HERAFitter*



# H1 Collaboration Status

H1 Collaboration has well planned future organizational structure

**Future operational model** has been defined  
Priority: preserving high quality of physics output with limited person power

**September 2011:** New model adopted

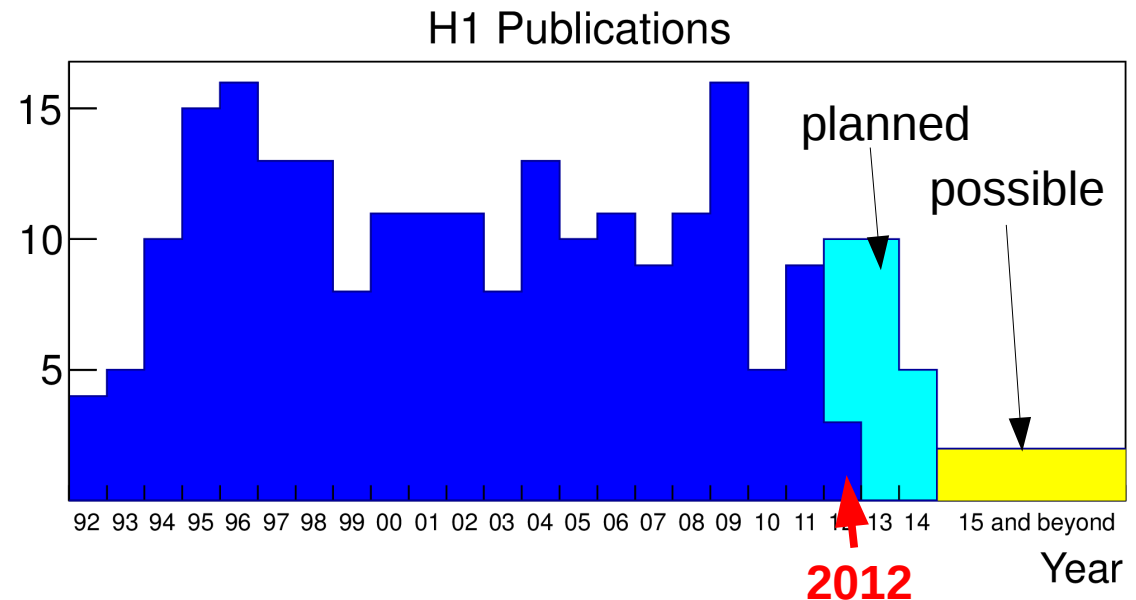
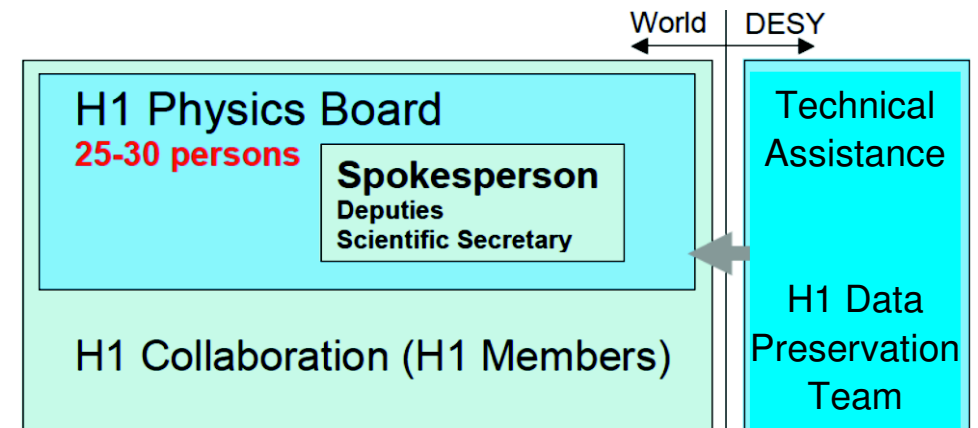
**February 2012:** Physics Board elected

**July 2012:** New model enforced

New spokesperson: **K. Krüger**

Publication plan is efficiently realised

Already 3 publications this year  
~25 ongoing analyses



# *H1 Software and Computing*

## H1 Software Status

Final version of simulation / reconstruction / analysis framework in place

Final polarisation, luminosity measurements fully integrated in H1 software

Coherent HERA I+II ready for data preservation

## H1 Computing Infrastructure

Very efficient MC group, production rate still over 2 billion events per year (see diagram)

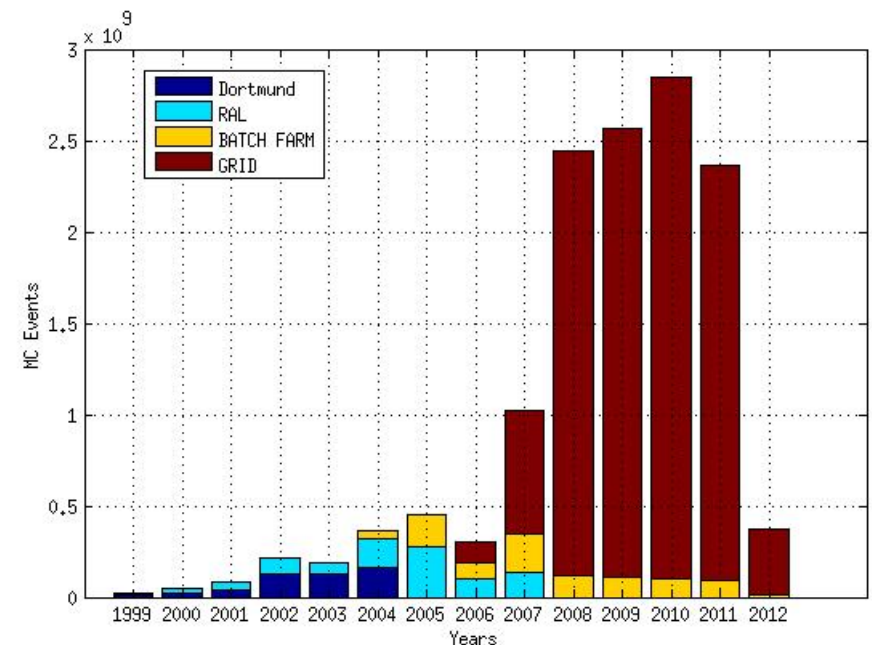
~1000 batch slots, more efficient, faster machines

H1 dCache model recently simplified  
in cooperation with DESY-IT

Modern hardware and up to date SLD5 OS

## H1 Data Preservation Activities

H1 very active,  
more details in Michael Steder's talk



# Recent H1 physics results

## Inclusive Measurements

*DESY-12-062 “A Measurement of the HERA Luminosity using Elastic QED Compton Events”*  
*H1prelim-12-142 “Measurement of  $F_2^{\gamma Z}$  at high  $Q^2$  at HERA”*

Paper

## Diffraction

*DESY-12-041 “Inclusive Measurement of Diffractive Deep -Inelastic Scattering at HERA”*

Paper

## Hadronic Final States & QCD

*H1prelim-12-031 “Normalised Multi-Jet Cross Sections using Regularized Unfolding and Extraction of  $\alpha_s(M_Z)$  in DIS at HERA”*

## Heavy Flavour

*DESY-11-248 “Measurement of Inclusive and Dijet  $D^*$  Meson Cross Sections in Photoproduction at HERA”*  
*DESY-12-059 “Measurement of Beauty and Charm Photoproduction using Semimuonic Decays in Dijet Events at HERA”*

Paper

Paper

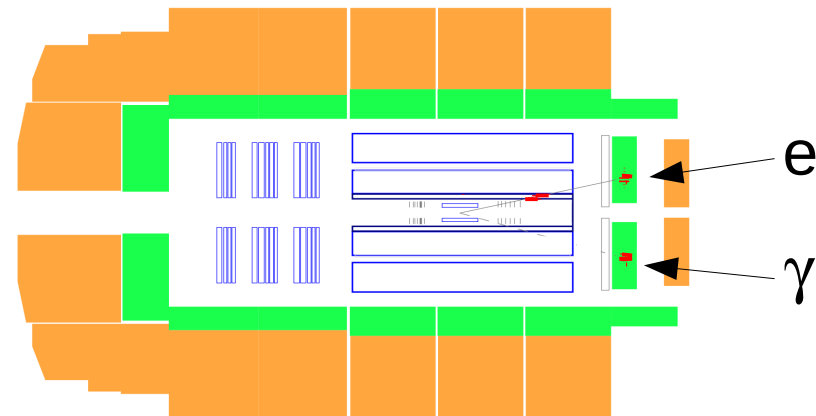
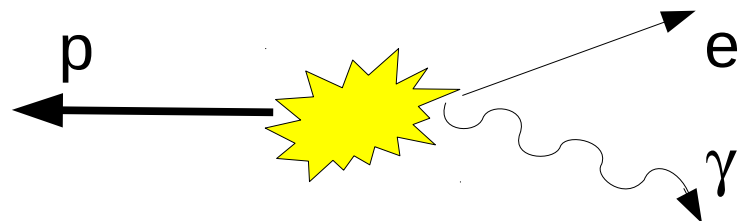
Since last PRC meeting:

- 4 new publications
- 2 new preliminary results

# *Final luminosity for HERA II* (DESY-12-062)

New approach to measure luminosity:

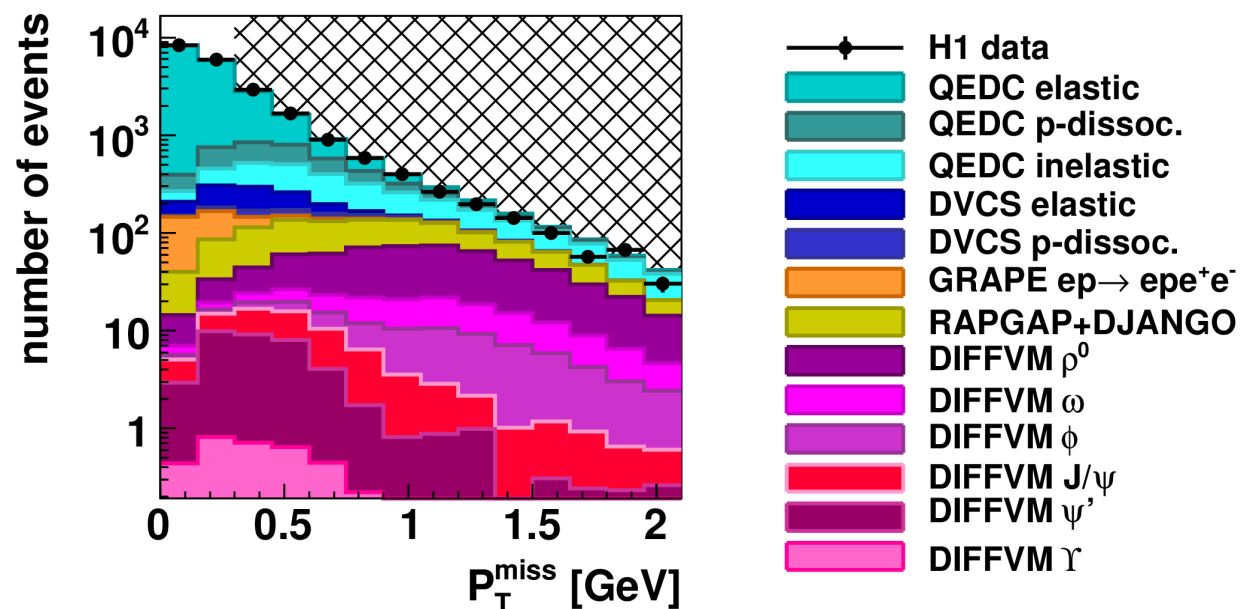
**QED Compton** scattering:



- e and  $\gamma$  with a sizable transverse momenta
- use main detector
- independent of the beam optics
- clear signature

**complication:**

- small ( $\sim 50$  pb) cross section
- need to control many different background contributions



# *Final luminosity for HERA II* (DESY-12-062)

Uncertainty contributions to this luminosity measurement:

*For the full HERA II data sample:*

$$\int \mathcal{L}(t) dt = 350.5 \text{ pb}^{-1} \pm 2.3 \%$$

Experimental uncertainties	1.4%
Background uncertainties	1.2%
QEDC theory uncertainties	1.1%
Statistical uncertainty	0.8%
Total uncertainty	2.3%

Improved precision compared to previously used 3.4% for HERA II data

Luminosity measured with final precision, will be propagated to all HERA II analyses

# First measurement of $F_2^{\gamma Z}$

(H1prelim-12-142)

Final luminosity and polarisation value is used in a new inclusive DIS measurement

$$\frac{\sigma^+(P_L) - \sigma^+(P_R)}{P_L - P_R} = \frac{\kappa Q^2}{Q^2 + M_Z^2} \left[ \mp a_e F_2^{\gamma Z} + \frac{Y_-}{Y_+} v_e x F_3^{\gamma Z} - \frac{Y_-}{Y_+} \frac{\kappa Q^2}{Q^2 + M_Z^2} (v_e^2 + a_e^2) x F_3^Z \right]$$

$\gamma Z$  exchange interference  
contribution to  $F_2$

To directly extract  $F_2^{\gamma Z}$  we need:

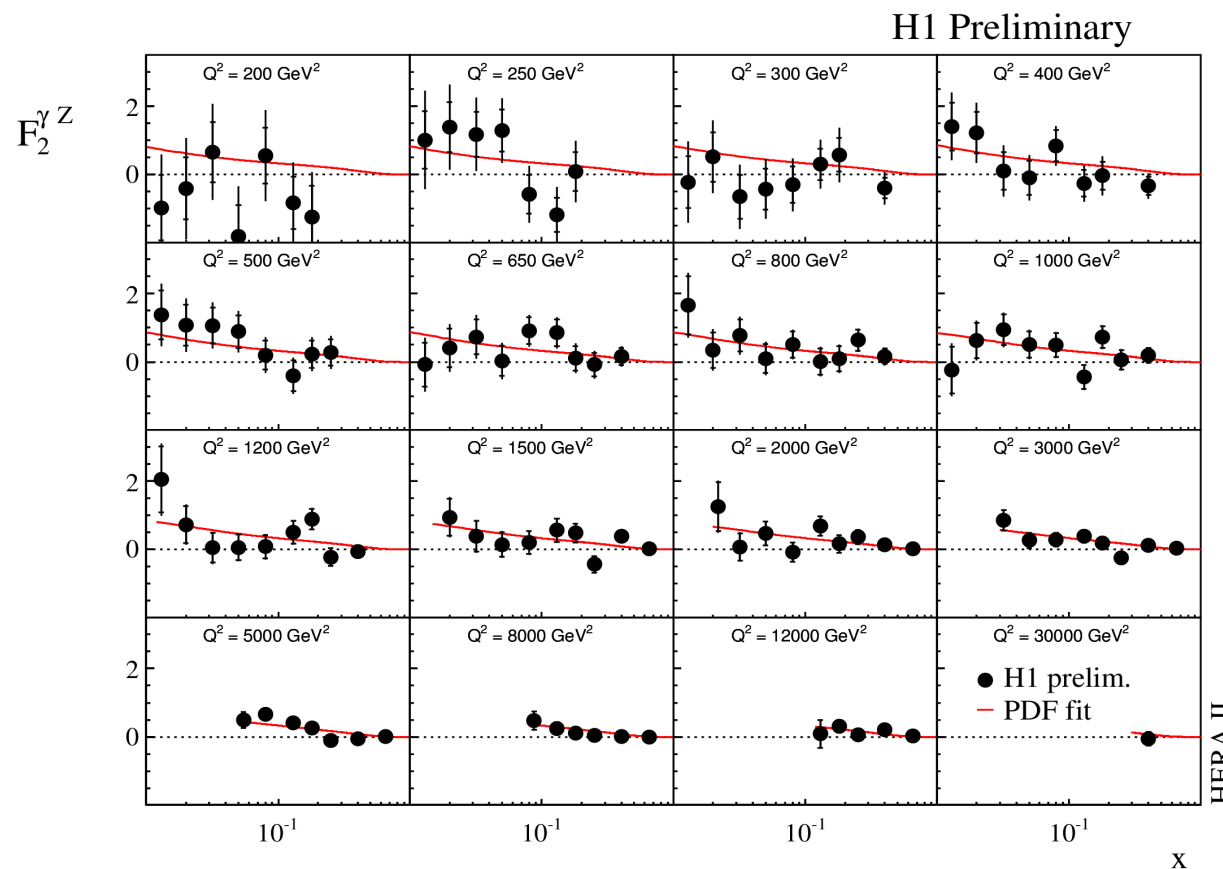
$e^+(\text{PL})$

$e^-(\text{PL})$

$e^+(\text{PR})$

$e^-(\text{PR})$

First extraction of  $F_2^{\gamma Z}$





# First measurement of $F_2^{\gamma Z}$

(H1prelim-12-142)

Final luminosity and polarisation value is used in a new inclusive DIS measurement

$$\frac{\sigma^{\pm}(P_L) - \sigma^{\pm}(P_R)}{P_L - P_R} = \frac{\kappa Q^2}{Q^2 + M_Z^2} \left[ \mp a_e F_2^{\gamma Z} + \frac{Y_-}{Y_+} v_e x F_3^{\gamma Z} - \frac{Y_-}{Y_+} \frac{\kappa Q^2}{Q^2 + M_Z^2} (v_e^2 + a_e^2) x F_3^Z \right]$$

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$e^+(PL)$

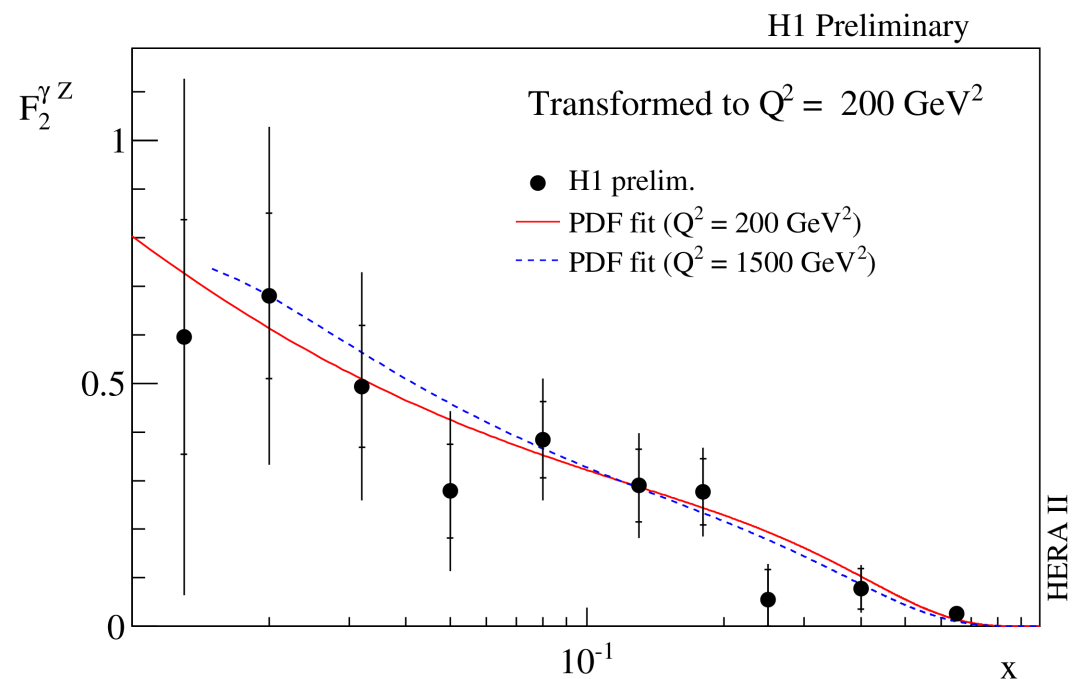
$e^-(PL)$

$e^+(PR)$

$e^-(PR)$

**First extraction of  $F_2^{\gamma Z}$**

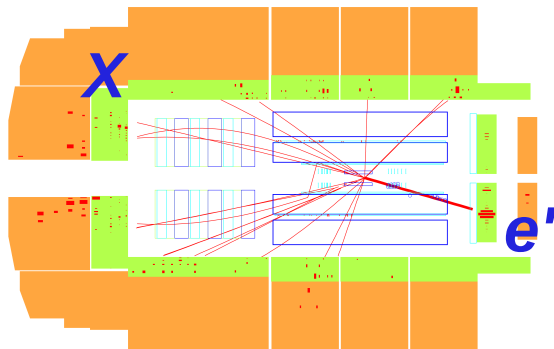
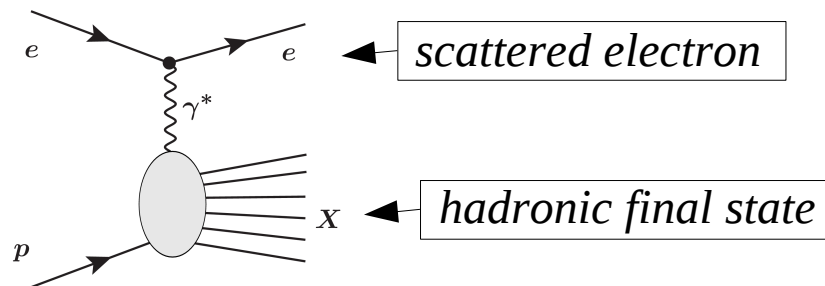
All measurements can be transferred  
to a common  $Q^2$  value



Paper in the publication procedure

# Inclusive diffraction in DIS (DESY-12-041)

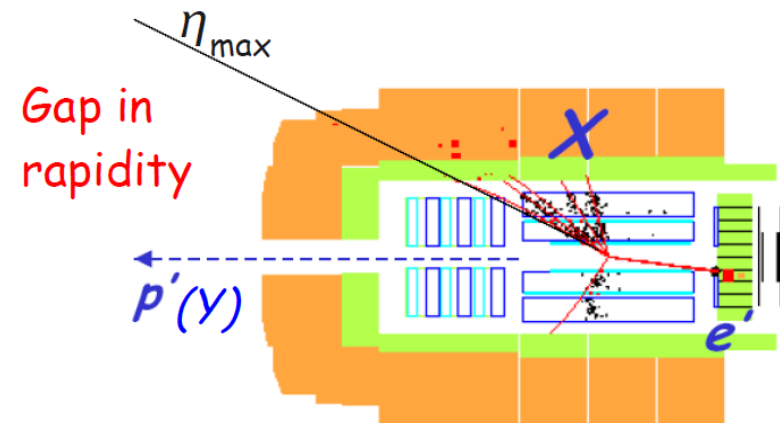
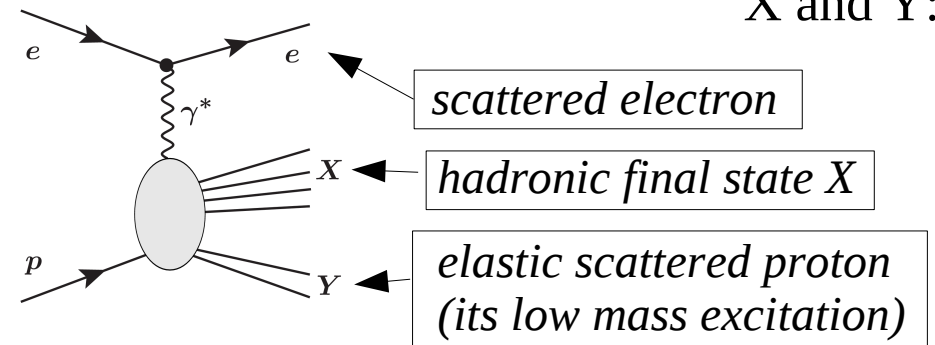
Inclusive DIS:



Typical DIS event

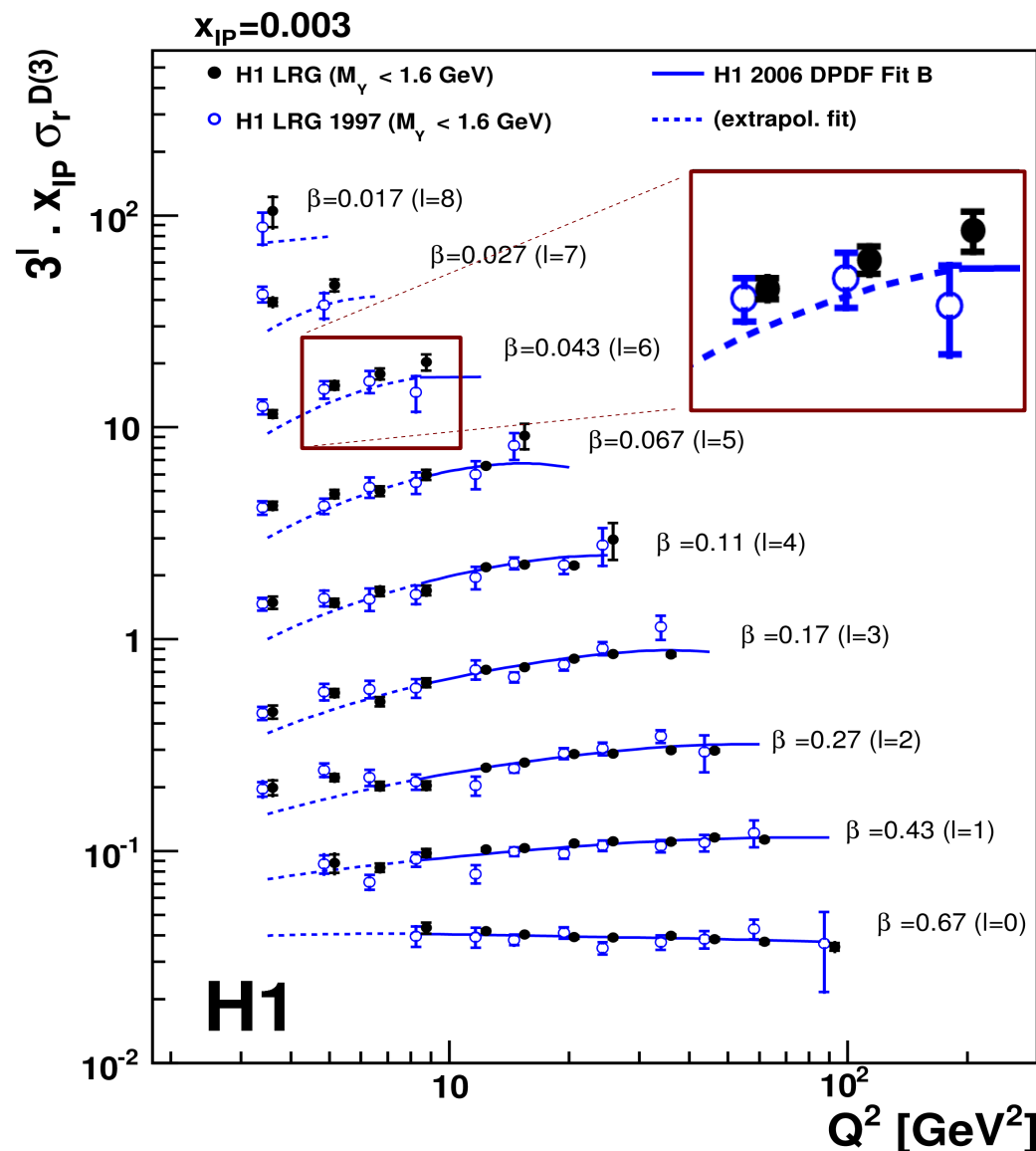
10% of all low- $x$  events are diffractive:

two distinct final states  
X and Y:



Large Rapidity Gap (LRG) selection

# Inclusive diffraction in DIS (DESY-12-041)



Recent H1 results:

- HERA II analysis
- combined with HERA I measurement

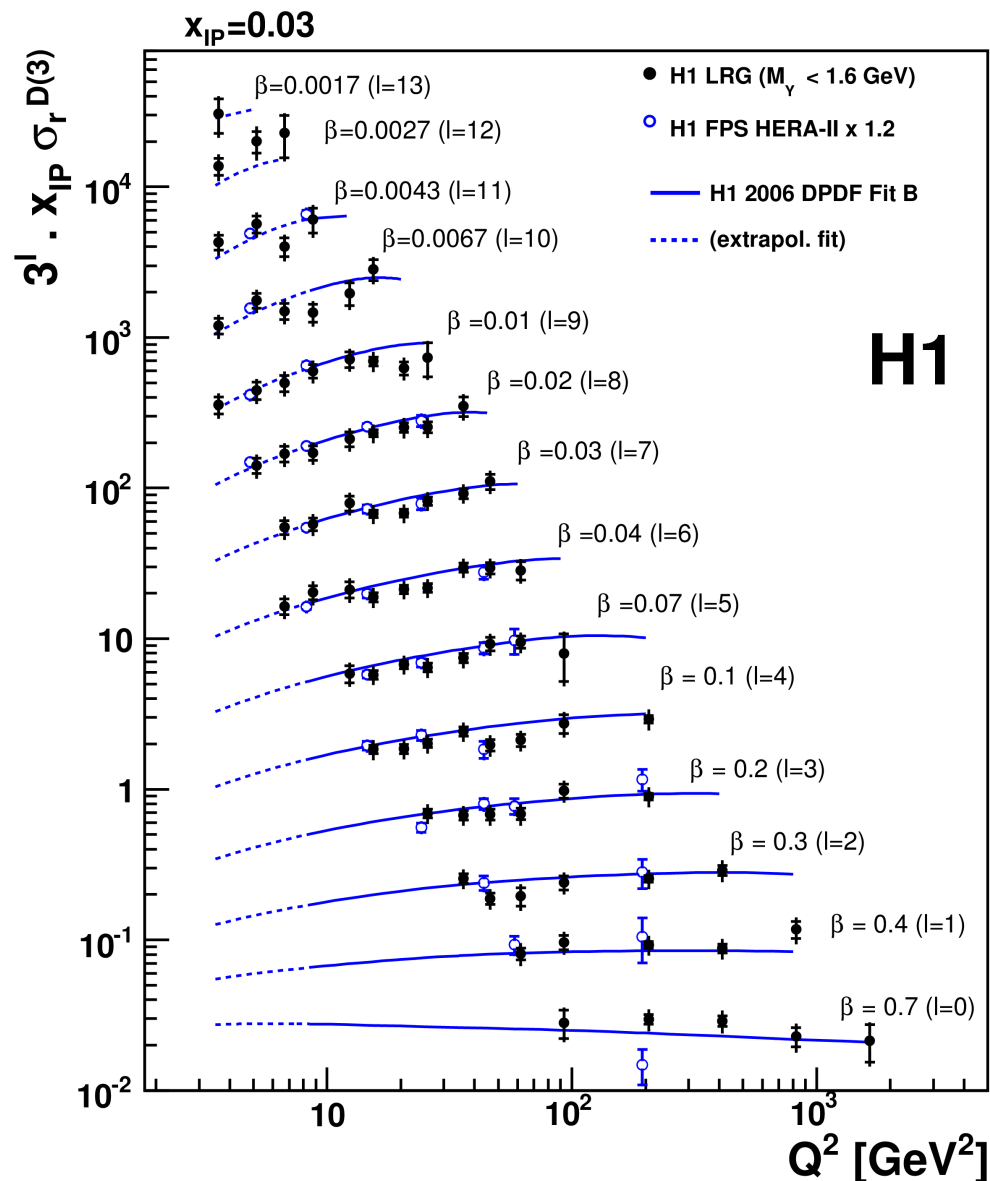
Results consistent with the previous H1 LRG results

Uncertainty significantly reduced

Final word from H1 on diffraction using LRG

Measurement can be used in determination of diffractive PDFs

# Inclusive diffraction in DIS (DESY-12-041)



New LRG results compared to a measurement using Forward Proton Spectrometer (FPS)

Data statistically independent

Dominant sources of systematics are different

**Results fully consistent**

# Normalised multi-jet cross sections

(H1prelim-12-031)

Multi-jet cross section directly sensitive to the strong coupling constant  $\alpha_s$

New measurement profits from an improved HFS calibration with uncertainty of 1%

Unfolding method employed to extract multi-jet cross sections in order to reduce model uncertainty

Simultaneous extraction of:

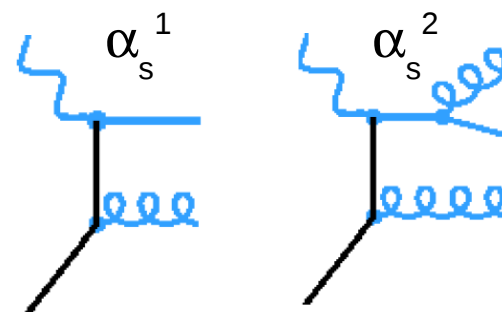
**Trijet** cross sections

**Dijet** cross sections

**Inclusive jet** cross sections

**Inclusive DIS** cross sections

Full correlation matrix calculated (important for fits)



Migration Matrix

			<b>1</b> Trijet $Q^2, \langle p_T \rangle_3, y,$ Trijet-cuts
Particle level		<b>2</b> Dijet $Q^2, \langle p_T \rangle_2, y,$ Dijet-cuts	
	<b>3</b> Incl. Jet $p_T, Q^2, y, (\eta)$		
	<b>4</b> DIS-Events $(Q^2, y)$	<b>5</b> Reconstructed jets without match to generator level	<b>6</b> Reconstructed Dijet events which are not generated as Dijet event
	Detector level		

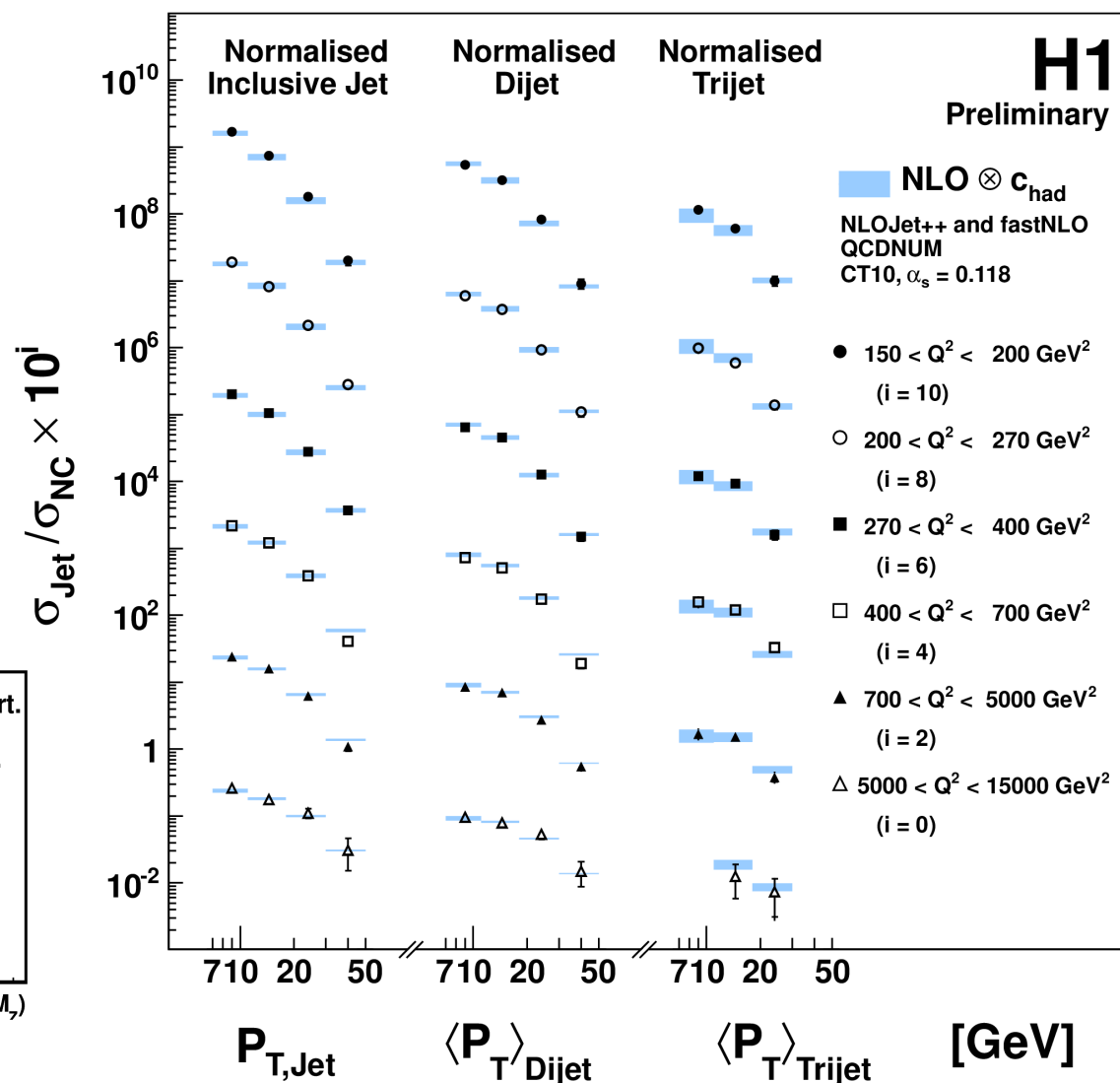
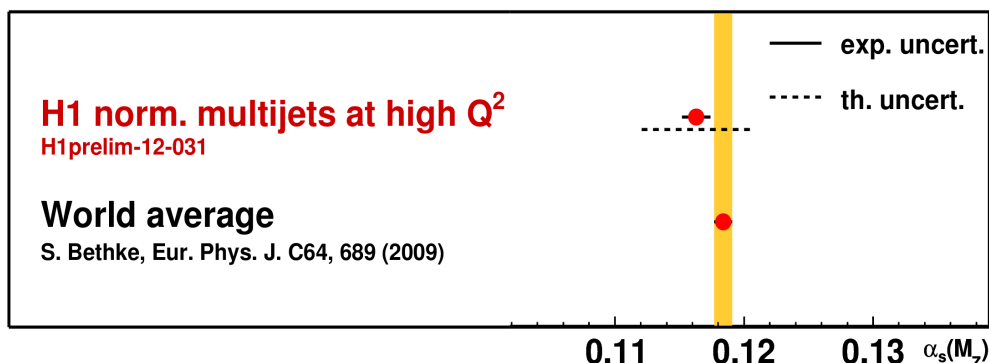
# Normalised multi-jet cross sections

(H1prelim-12-031)

Measured cross sections

- very good statistical precision
- low systematic uncertainty
- in good agreement with a prediction from NLO QCD

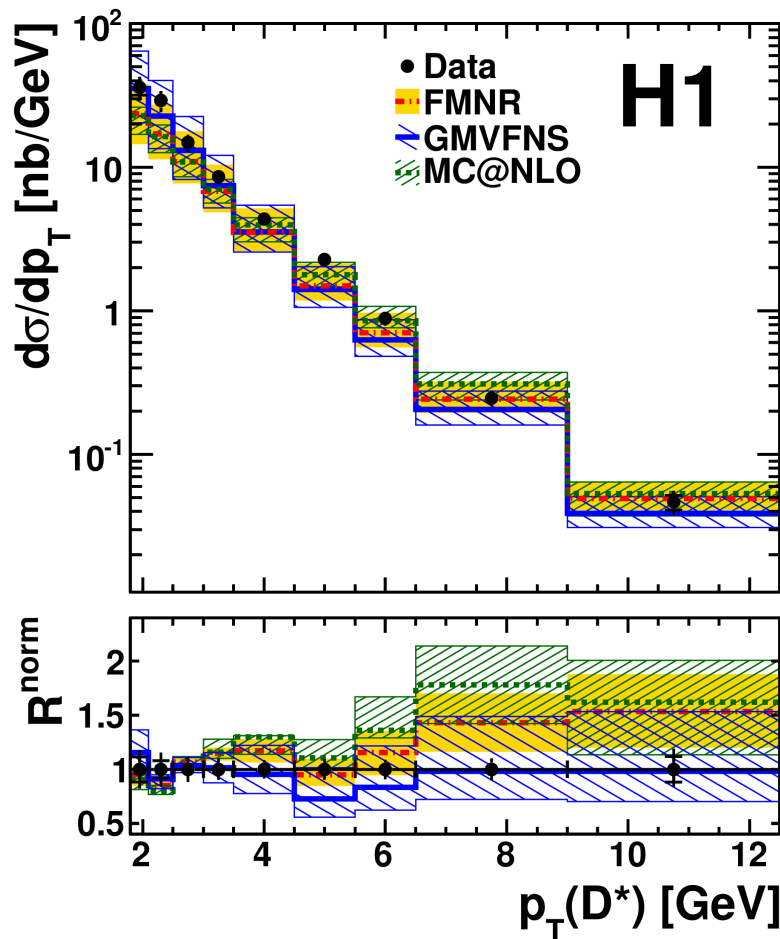
$$\alpha_s(M_Z) = 0.1163 \pm 0.0011 (\text{exp}) \\ \pm 0.0042 (\text{th})$$



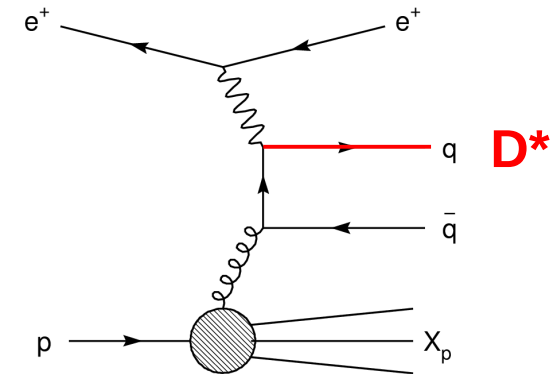
# Open Charm in photoproduction (DESY-11-248)

Heavy flavours dominantly produced in boson-gluon fusion  
 $D^*$  selection via decay channel:

$$D^{*\pm} \rightarrow D^0 \pi^\pm \rightarrow K^\mp \pi^\mp \pi^\pm$$



In photoproduction  $Q^2 \sim 0$ :  
 $m_c$  and  $p_T$  provide scale  
 for pQCD calculation



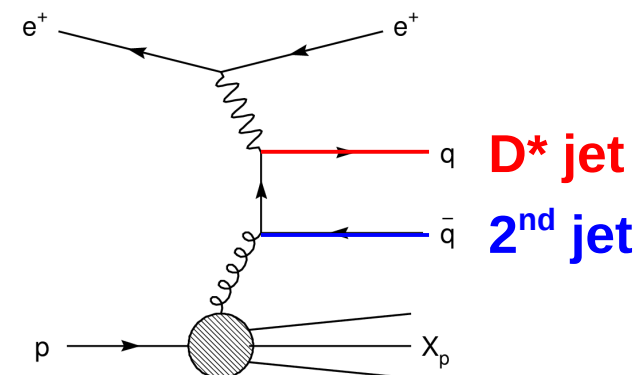
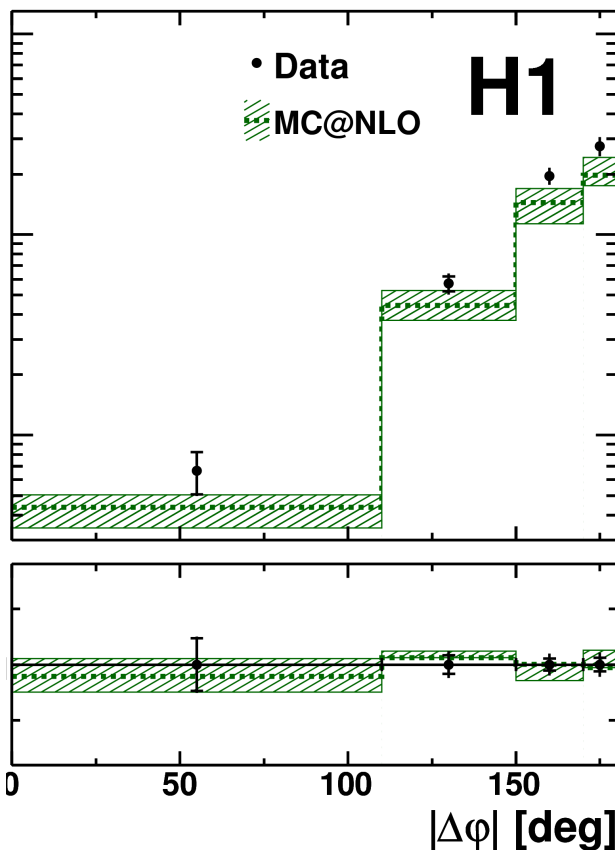
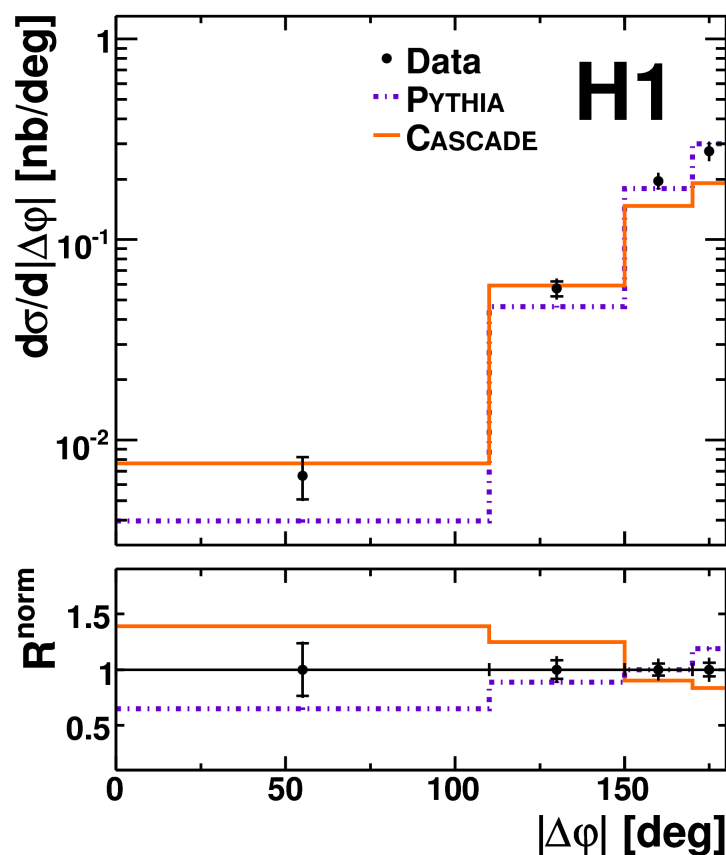
Cross sections well described by NLO calculations

Experimental data much more precise than theory predictions  
 (dominant uncertainty due to scale variations)

# Open Charm in photoproduction (DESY-11-248)

Heavy flavours dominantly produced in boson-gluon fusion

**D\* + jet selection** ( $\Delta\phi$ ) gives sensitivity to parton dynamics  
(intrinsic  $k_T$  of a gluon in a proton: CASCADE)



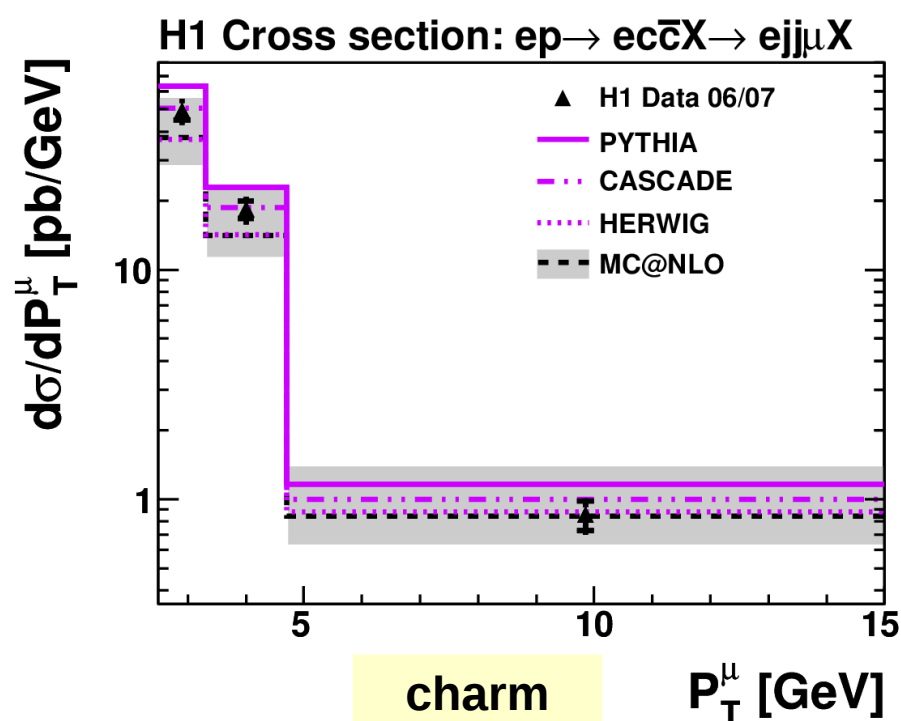
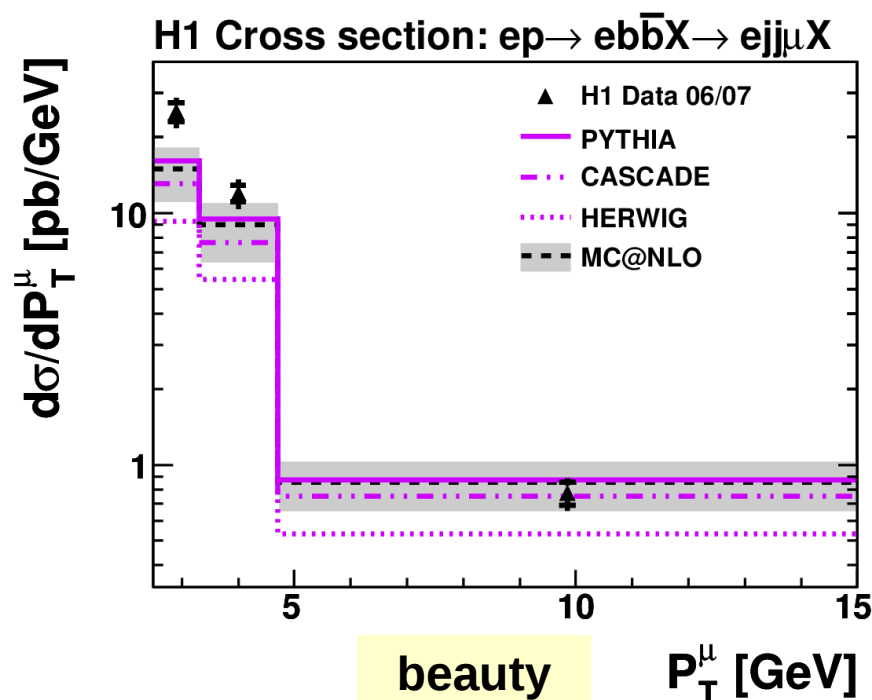
Models fail to describe all the details of charm jet production



# Beauty and Charm photoproduction

(DESY-12-059)

Beauty and charm production measured with two jets and a muon  
 Very precise flavour separation based on multivariate analysis  
 (variables sensitive to lifetime and mass of b-hadrons)



Predictions in a reasonable agreement with measurement  
 Precision of the measurement better than NLO calculation precision

# *HERAFitter Platform*

Legacy of HERA preserved in a long-term project HERAFitter

HERAFitter is a ready QCD platform to analyse new data in context of PDFs

It is now publicly available under GNU General Public License

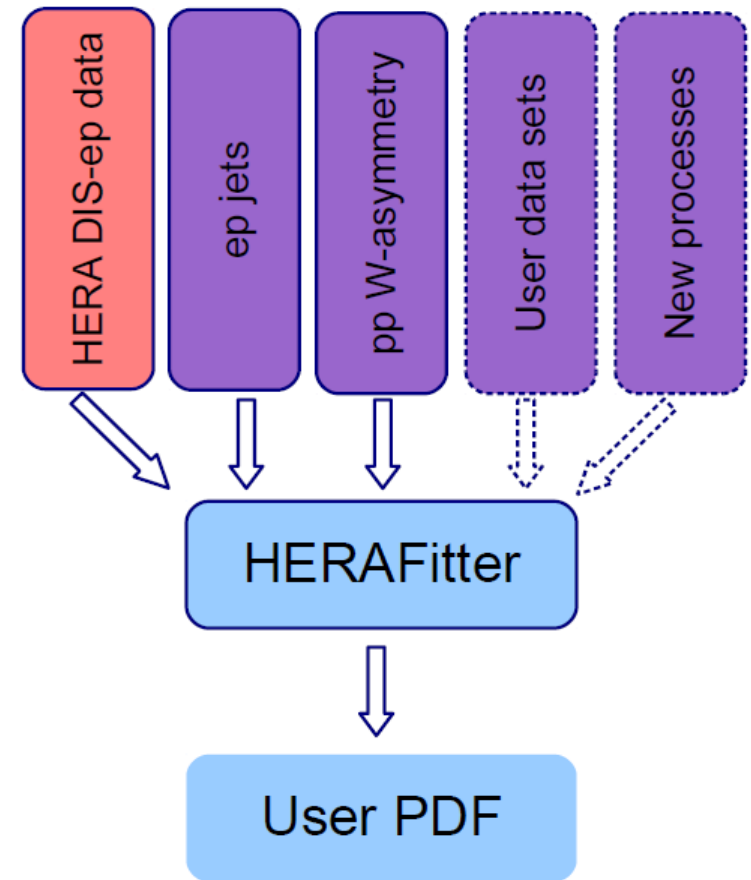
The code was originally used to determine HERAPDF

Package developers:

- H1 and ZEUS members
- LHC experiments
- Theory groups

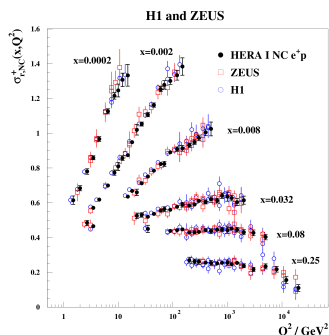
Modular strategy adopted

- independent development of separate modules
- new modules can be added fairly easy



# HERAFitter Platform

## experimental data



**Data:** HERA, Tevatron, LHC,  
fixed target experiments

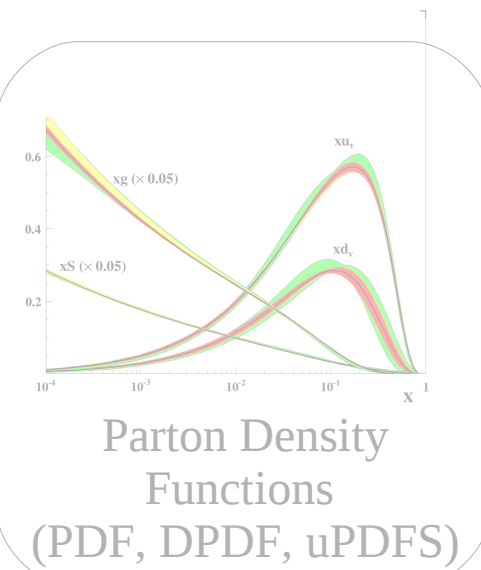
### Processes:

Inclusive DIS, Jets, Diffraction  
Drell-Yan, Top production  
W and Z production

## theory calculations

**Heavy Flavour schemes:** MSTW, CTEQ, ABM  
**Jets, W, Z:** FastNLO, Applgrid  
**Top:** Hathor  
**Evolution:** QCDNUM,  $k_T$  scheme  
**Other:** NNPDF reweighing  
 Dipole model

HERAFitter



$\alpha_s(M_Z)$ ,  $m_c$ ,  $m_b$ ,  $m_t$  ...

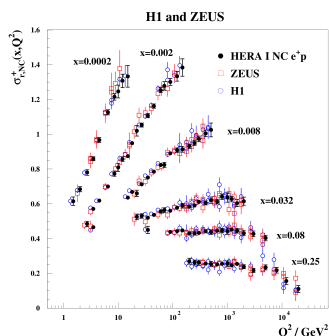
Theoretical cross  
sections

Comparisons to other  
PDFs (lhapdf)

Active and committed contributions from all the involved theory groups,  
regular participation in meetings, etc.

# HERAFitter Platform

## experimental data



**Data:** HERA, Tevatron, LHC, fixed target experiments

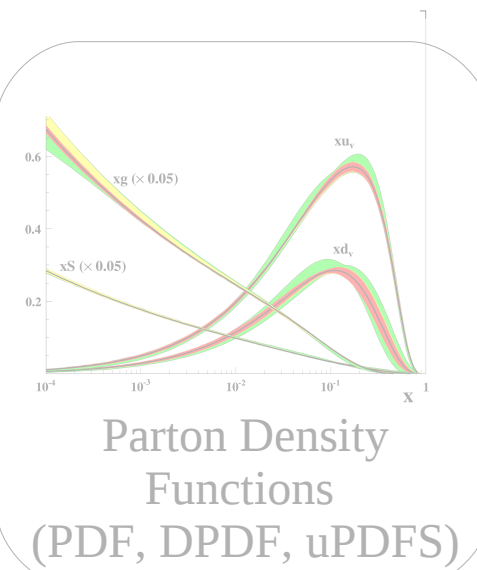
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**Other:** NNPDF reweighting  
Dipole model

HERAFitter



$\alpha_s(M_Z), m_c, m_b, m_t \dots$

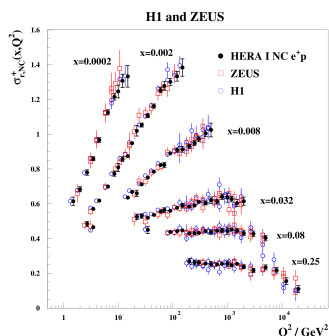
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# HERAFitter Platform

## experimental data



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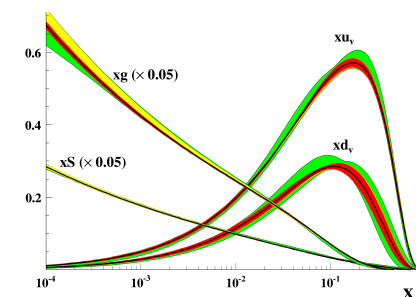
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## theory calculations

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**Evolution:** QCDNUM,  $k_T$  scheme  
**Other:** NNPDF reweighing  
 Dipole model

HERAFitter



Parton Density  
 Functions  
 (PDF, DPDF, uPDFs)

$\alpha_s(M_Z)$ ,  $m_c$ ,  $m_b$ ,  $m_t$  ...

Theoretical cross  
 sections

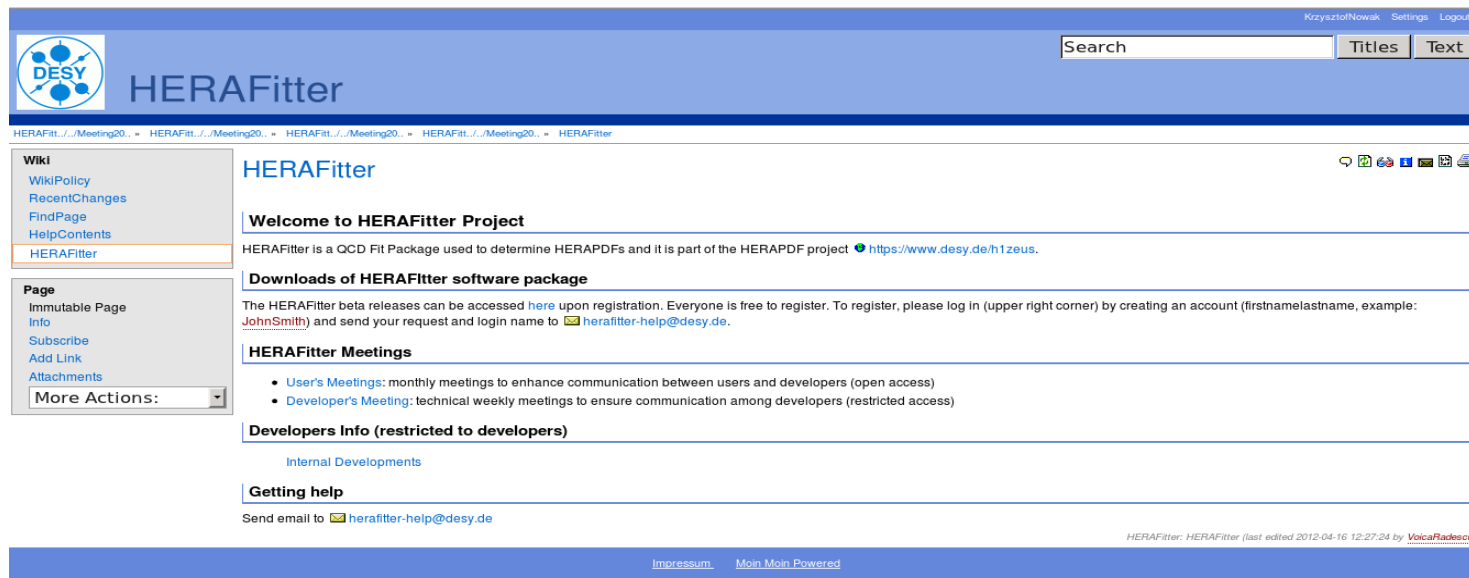
Comparisons to other  
 PDFs (lhapdf)

Active and committed contributions from all the involved theory groups, regular participation in meetings, etc.

# HERAFitter Platform

It is an open source project with the first beta release accessed through the HEPFORGE site:

<http://projects.hepforge.org/herafitter>



## Method of communication:

Mail-support: [herafitter-help@desy.de](mailto:herafitter-help@desy.de)

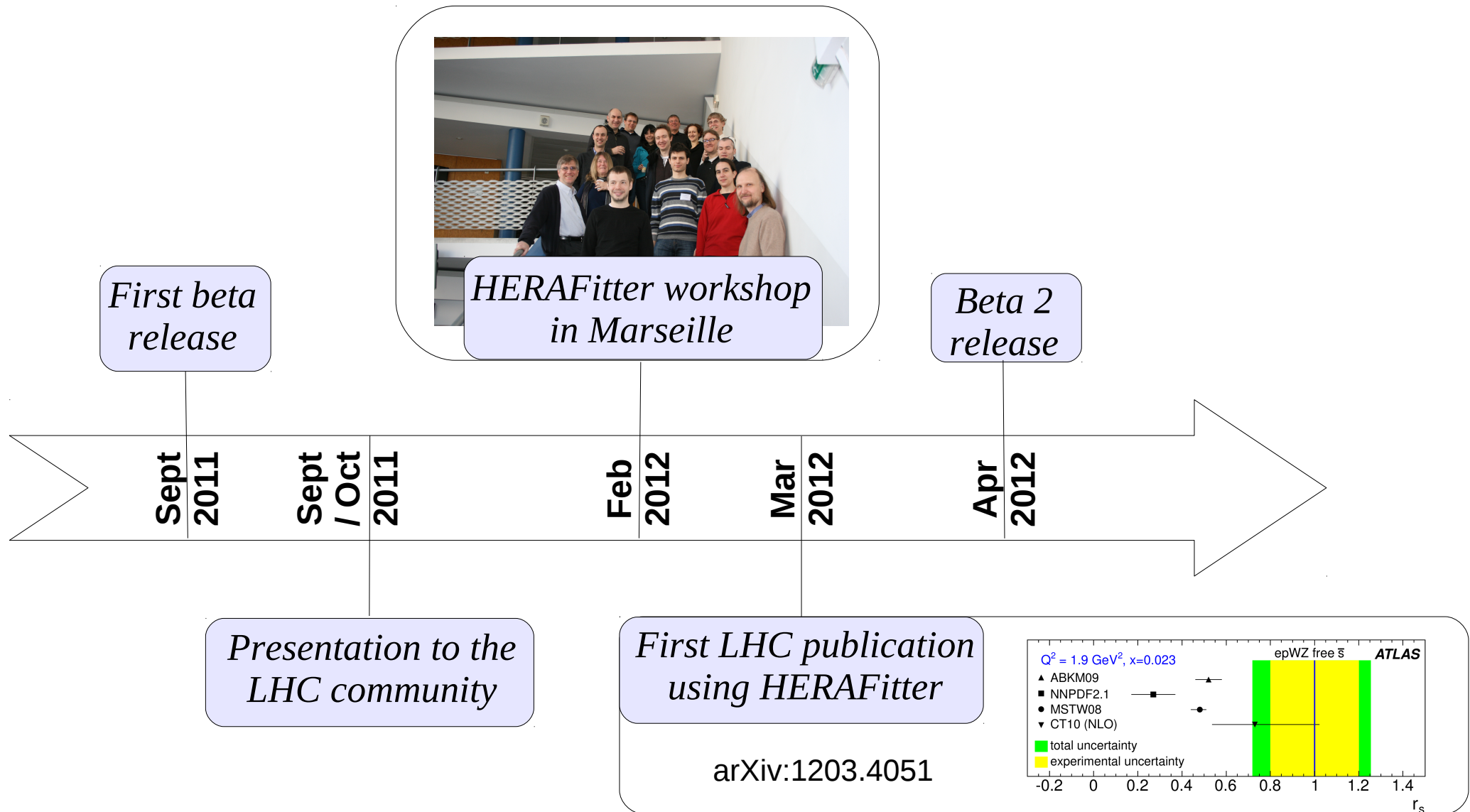
Weekly developers meetings

<https://znwiki3.ifh.de/HERAFitter/HERAFitterInternal/FitForumMeetings>

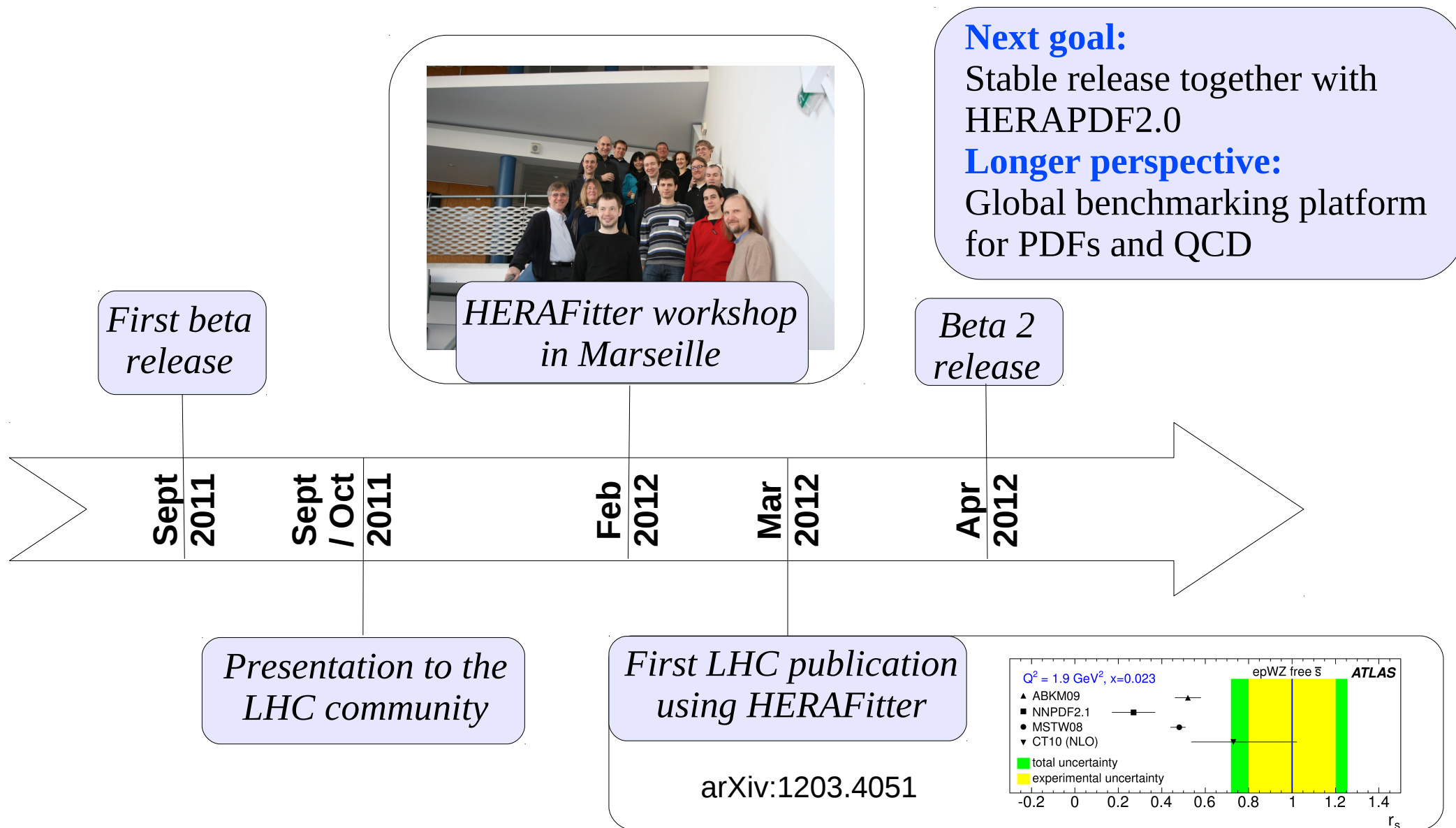
Monthly users' meetings

<https://znwiki3.ifh.de/HERAFitter/HERAFitterMeetings>

# *HERAFitter timeline*



# HERAFitter timeline





# Summary

**H1 Collaboration** well on track, ~25 ongoing analyses, several new results presented

- Final luminosity analysis for HERA II
- First ever measurement of  $F_2^{\gamma Z}$
- Final inclusive diffraction in DIS
- Very active Heavy Flavour and QCD groups

**HERAFitter** team very active

- Recognition in the PDF community
- Rapidly grown to be a global initiative
- Active participation of many theory groups
- Used as PDF fitting tool in both ATLAS and CMS