# H1 analysis and the EIC


**24th International Workshop on Deep-Inelastic Scattering and Related Subjects**

**11-15 April 2016, DESY, Hamburg**

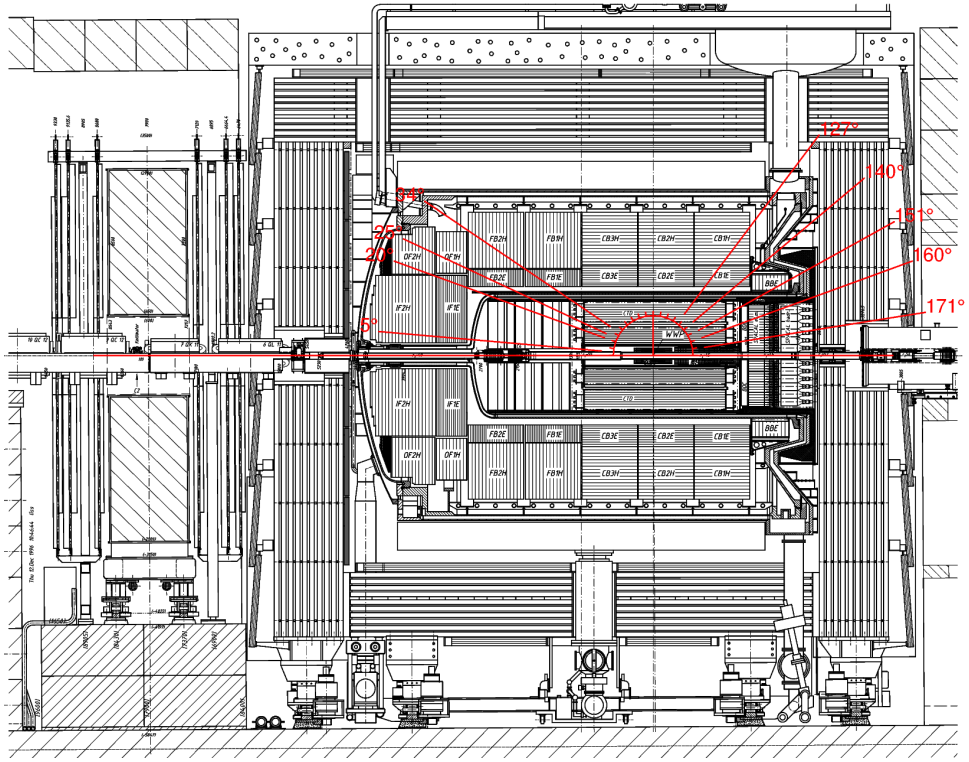

Stefan Schmitt, DESY

10.April 2016

DIS2016 satellite meeting

# The H1 experiment at HERA

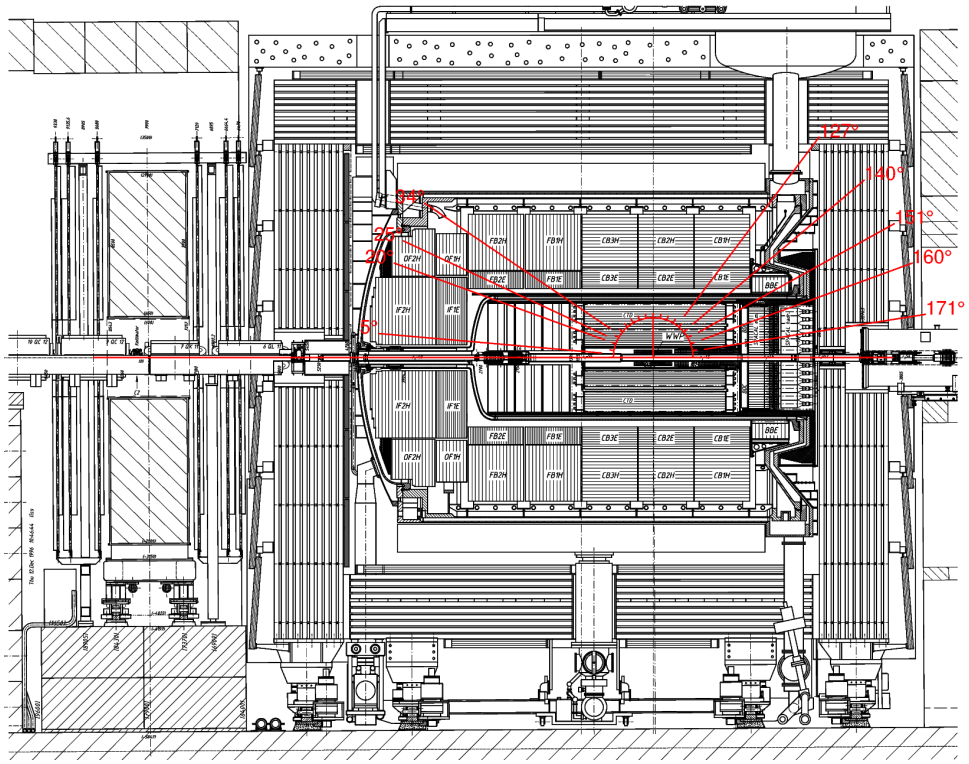
- 1994-2000: HERA-I
  ~100 pb-1
- 2000-2002: upgrade
- 2003-2007: HERA-II
  ~350 pb-1, $e^+p$ $e^-p$
  lepton beam polarisation




- E(e)=27.5 GeV
- E(p)=920 GeV [was 820 GeV before 1998]
- 2007: low-energy runs: E(p)=460 and 575 GeV

# The H1 experiment

- Detector highlights
  - LAr calorimeter, fine segmentation
  - SpaCal rear calorimeter: high precision for electrons (position and energy)
  - Central tracker $20<\theta<160$

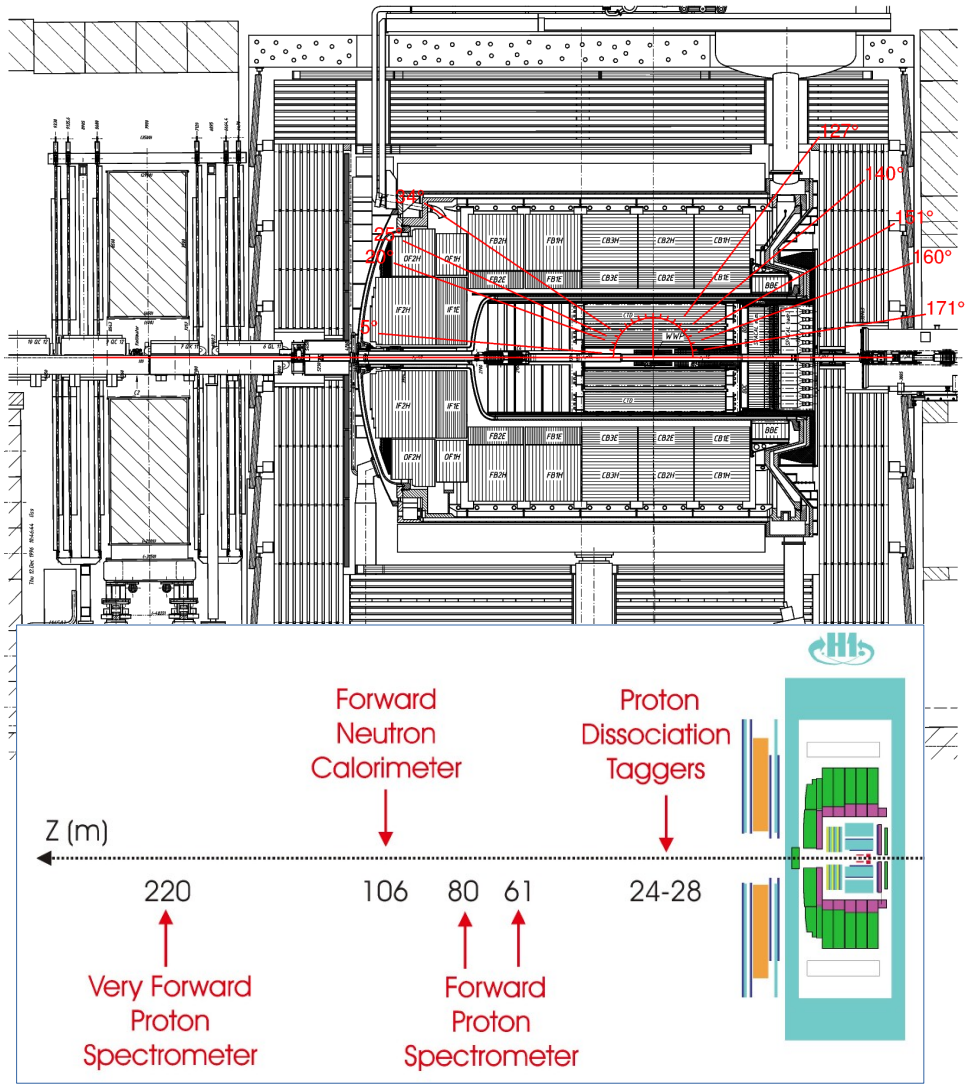



Some highlights of the HERA-II detector:

- Backward silicon tracker (low mom. Electrons)
- Fast track trigger (exclusive final states)
- Forward instrumentation (diffraction, exclusive final states)
- Forward proton and forward neutron/photon detectors
- EM energy scale 0.5%, hadronic energy scale 1%

# Forward instrumentation

- Forward instrumentation (HERA-II configuration)
  - FTS (veto counter) ~30m
  - FPS (proton) ~70m
  - VFPS (proton) ~220m
  - FNC (neutron) ~100m
- Tagged proton for $x_{IP}$<0.025 (FPS/VFPS)
- Statistical separation of elastic and proton dissociative contributions



# The H1 collaboration

- Two spokespersons
  - Stefan Schmitt, Sergey Levonian
- Physics board
  - ~30 H1 members
- Active H1 members
  - ~140 people, on authorlist

- H1 membership rules
  - Be a physicist
  - Contribute to H1

Master students contributing a study become authors of the relevant paper(s)

PhD students or seniors join the collaboration and become members for all papers (+one year after leaving H1)

# H1 Papers

- H1 paper procedure:
  - Presentations in H1 meetings
  - Analyzers, “referees” and H1 management agree analysis is ready
  - Circulate paper draft, “T0 report”
  - Collect H1 comments
  - Answer file, “referee's report”
  - Updated draft [~6 weeks after T0]
  - Final reading [~1 week after 2nd draft]
  - Submit to journal [~1 week]

Editorial board

*Generated from INSPIRE on* ***04/04/2016***

| Citation rank | | H1 |
|---|---|---|
| Total number of citable papers | | 228 |
| Total number of citations | | 19,078 |
| Average citations per paper | | 83.7 |
| h-index | | 74 |
| Renowned papers | (500+ cites) | 3 |
| Famous papers | (250-499 cites) | 12 |
| Very well-known papers | (100-249) | 40 |
| Well-known papers | (50-99) | 60 |
| Known papers | (10-49) | 101 |
| Less known papers | (1-9) | 11 |
| Unknown papers | (0) | 1 |
| Top cited paper: | Σ citations = | 719 |
| 2-nd top cited paper: | Σ citations = | 641 |
| 3-rd top cited paper: | Σ citations = | 522 |

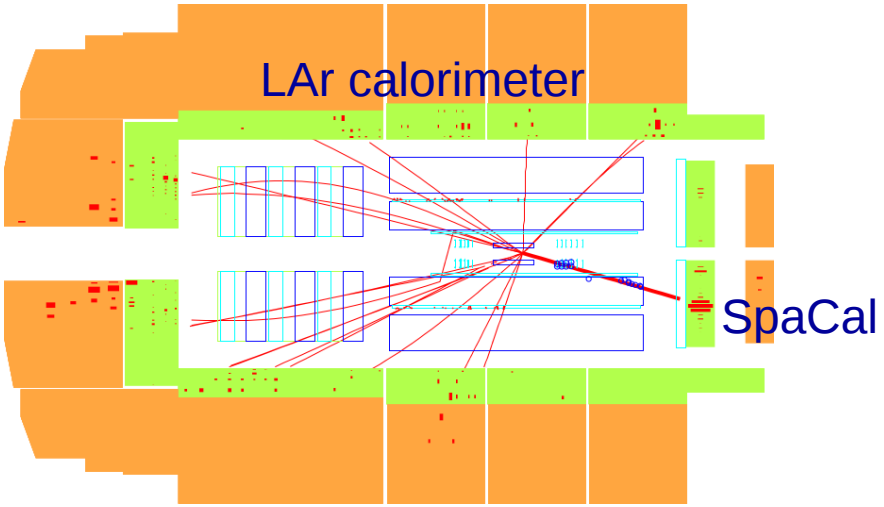
# H1 data

- H1 data and Monte Carlo simulation are stored at DESY
- Accessible by two servers and by batch jobs
- Analysis software: Object oriented, based on root classes (Root → H1OO)
- Reconstruction software: FORTAN based
- MC generators: mostly FORTRAN

Example: fragment of the H1OO documentation

| | |
|---|---|
| H1Part | H1 Particle base class |
| H1PartCand | H1 Particle Candidate |
| H1PartCandArrayPtr | data access class for a TClonesArray of H1PartCand |
| H1PartCandIterator | Semi-abstract base class for iterator access to particle candidates |
| H1PartComp | base class for identified particles |
| H1PartConvPhoton | class for Photon->e+ e- |
| H1PartConvPhotonArrayPtr | data access class for a TClonesArray of H1PartConvPhoton |
| H1PartDstar | class for dstar to Kpipi |
| H1PartDstarArrayPtr | data access class for a TClonesArray of H1PartDstar |
| H1PartDstarK03Pi | class for dstar to pi_s K0 pi pi |
| H1PartDstarK03PiArrayPtr | data access class for a TClonesArray of H1PartDstarK03Pi |
| H1PartDstarKPiRhoPi | class for D* -> D0 pi_s -> K pi rho pi_s |
| H1PartDstarKPiRhoPiArrayPtr | data access class for a TClonesArray of H1PartDstarKPiRhoPi |
| H1PartEm | class for identified electrons |
| H1PartEmArrayPtr | data access class for a TClonesArray of H1PartEm |
| H1PartFNC | class for FNC neutrons |
| H1PartFNCArrayPtr | data access class for a TClonesArray of H1PartFNC |
| H1PartFPS | class for FPS protons |
| H1PartFPSArrayPtr | data access class for a TClonesArray of H1PartFPS |
| H1PartGenJetArrayPtr | data access class for a TClonesArray of H1PartJet |
| H1PartID | base class for identified particles |
| H1PartInclJetArrayPtr | data access class for a TClonesArray of H1PartJet (inclusive) |
| H1PartJPsi | class for J/Psi particles (elastic, inelastic production) |
| H1PartJPsiArrayPtr | data access class for a TClonesArray of H1PartJPsi |
| H1PartJet | H1 Jet Candidate |
| H1PartJetArrayPtr | data access class for a TClonesArray of H1PartJet |
| H1PartK0 | class for K0->pi+ pi- |
| H1PartK0ArrayPtr | data access class for a TClonesArray of H1PartK0 |
| H1PartLambda | class for Lambda->p pi- + CC |
| H1PartLambdaArrayPtr | data access class for a TClonesArray of H1PartLambda |
| H1PartLightVMDiff | class for diffractive light vm particles |
| H1PartLightVMDiffArrayPtr | data access class for a TClonesArray of H1PartLightVMDiff |
| H1PartMC | Monte Carlo Particle with information from the PDG |
| H1PartMCArrayPtr | data access class for a TClonesArray of H1PartMC |

# HERA kinematics




DIS event at low $Q^2$: electron in SpaCal
Proton remnant disappears in the forward (proton) direction.
Hadrons in central detector+remnant
→ high W

- Electron outside detector: "photoprod." $Q^2<2$ GeV$^2$
- Electron in SpaCal: "low $Q^2$" $4<Q^2<100$ GeV$^2$
- Electron in LAr: "high $Q^2$" $Q^2>150$ GeV$^2$
- $Q^2=sxy$, $W^2=Q^2(1/x-1)$
- HERA: low-x and high-W

# Ideas for H1 analyses

- Many analysis are open
- Only a few examples are given here
  - Charged current in low-energy runs
  - Diffractive PDF fit
  - Inclusive diffraction with forward proton (VFPS)
  - Vector meson production
  - DVCS
  - K0 and Λ cross sections at low/high $Q^2$
  - Charm and beauty with electrons

# Inclusive charged current

- Total CC cross section in low energy runs

  link to cosmic ray physics, high energetic neutrinos.

  Analysis will be statistically limited but still interesting

| Ep [GeV] | 460 | 575 | 820 | 920 |
|---|---|---|---|---|
| E(ν) [TeV] | 27 | 34 | 48 | 54 |
| | ow-energy run | | HERA-I | HERA-II |
| | | | | |

Table: equivalent neutrino energy for fixed-target interaction

**Proposal by D. Haidt**

...
the short runs at reduced energy may be used to measure the W-propagator
term in the way we did in our first paper on e+p --> nu + anything (DESY 94-12). The corresponding neutrino energies, when interpreting the process in the proton rest frame, are 27, 34 and 54 TeV. The cross section measurements would be unique and very helpful to the neutrino telescope and astrophysics groups. They make extrapolations from 600 GeV to the EeV region !

The analysis will be straightforward and may follow the method in our old paper.

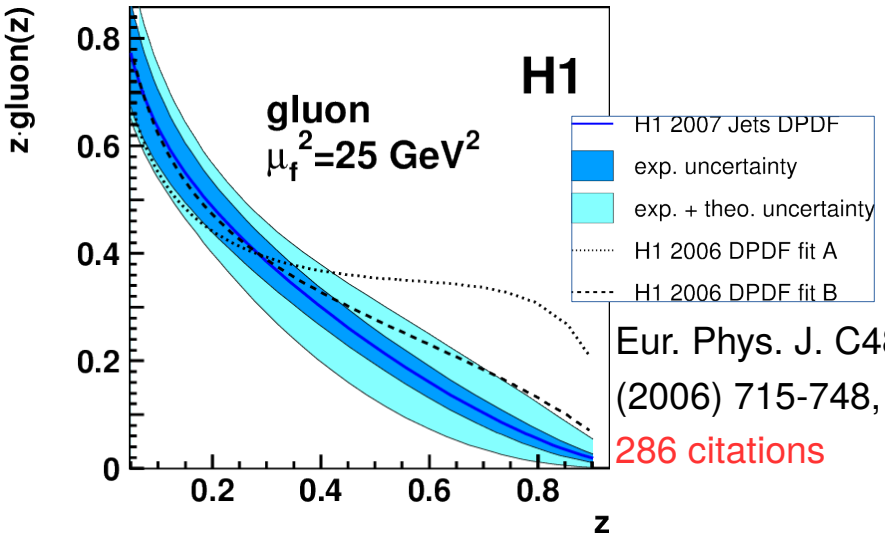
1993 we could make a contribution with 14 events. Among them we had also a radiative event. It may therefore conceivable to select in addition a sample of events e+p --> nu+gamma+anything to obtain a measurement
at an average energy around a few TeV. In that case we would cover the
region where the W-propagator gets important.

# Diffraction

- Diffractive PDF fits

  Last H1 fit is 10 years old

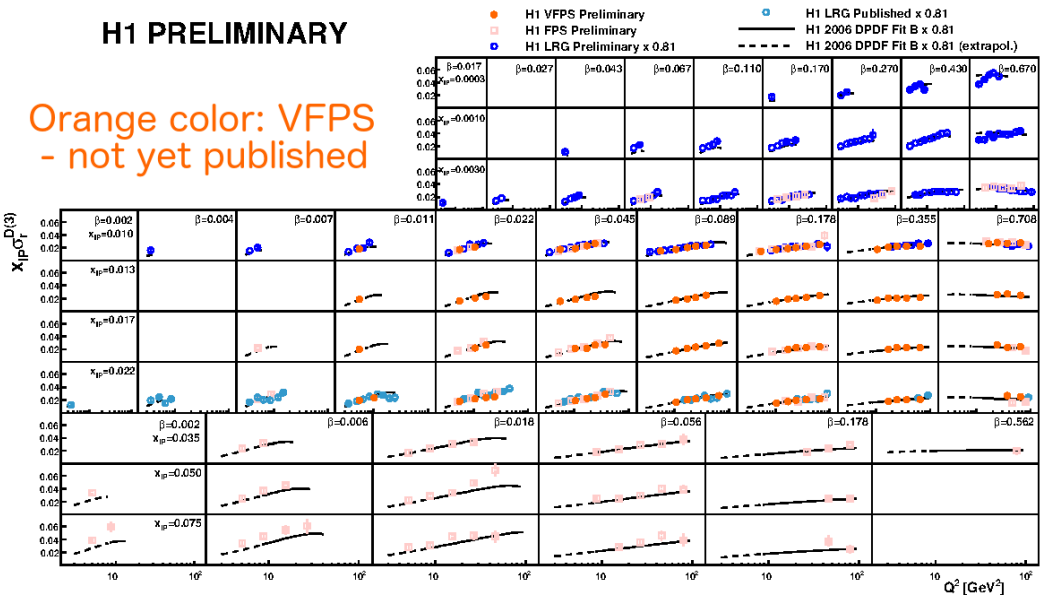
  New high-statistics cross section data from HERA-II available: inclusive, jet production, D* production




Eur. Phys. J. C48 (2006) 715-748, 286 citations

- Inclusive F2D4 measurement using VFPS

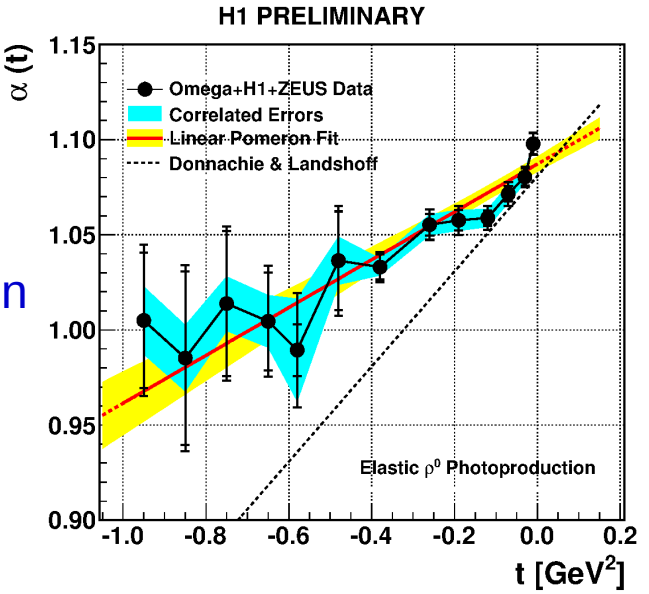
  Not published but people from DESY and Brussels are interested.



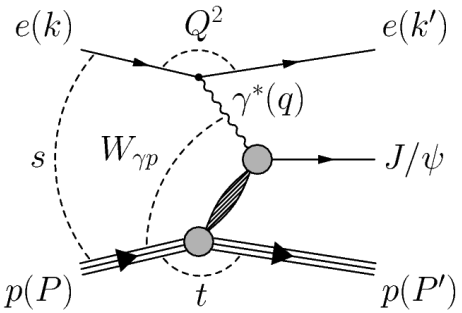
# Vector mesons

- Light (ρ,ϕ) and heavy (J/ψ,ψ',ϒ) vector mesons
  - Only ρ and J/ψ in γp analyzed
  - Todo: measurements in γp and DIS, beam polarisation, spin, etc

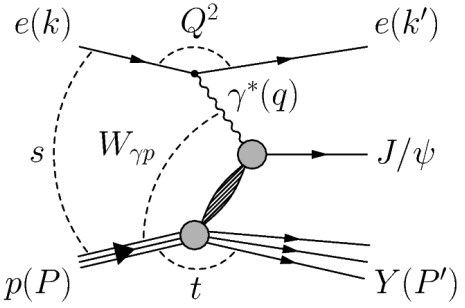
Rho in photo-production ongoing analysis

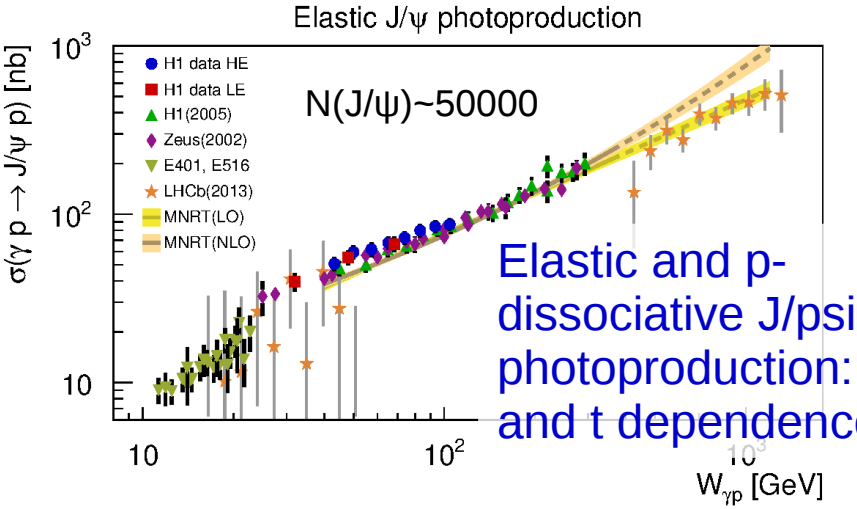



elastic




p-dissociative



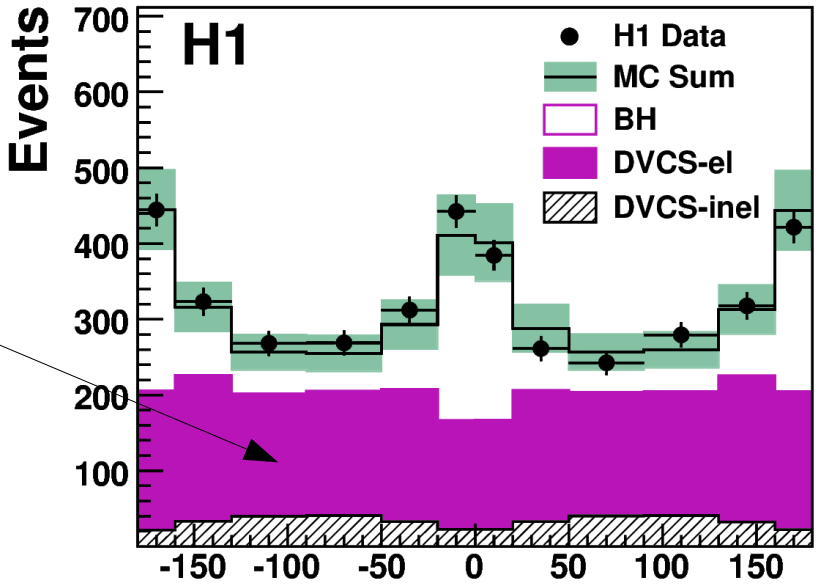




Elastic and p-dissociative J/psi in photoproduction: W and t dependence

Eur.Phys.J.C73 (2013) 2466, 51 citations

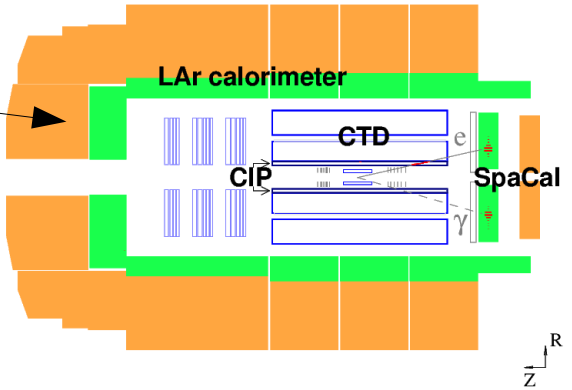
# DVCS

- Published: DVCS cross-section and beam-charge asymmetry measured at low y: background from BH ~40%

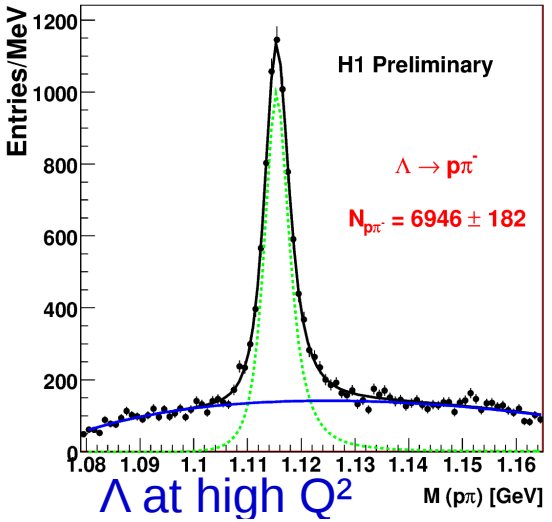



Physics Letters B 681 (2009) 391, 65 citations

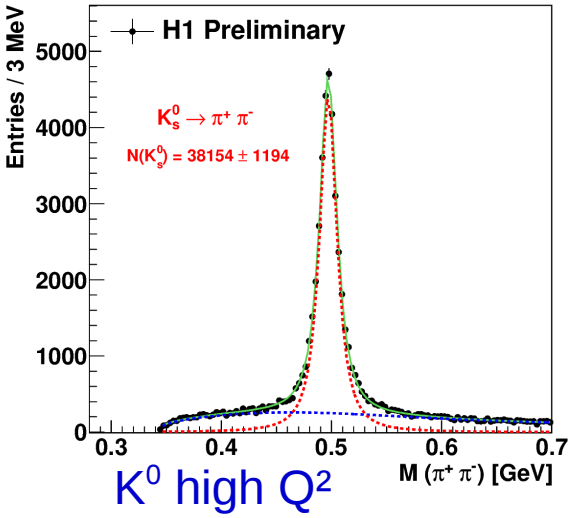
- Deeply-virtual Compton Scattering at high y~0.5: BH ~98%, but beam-charge and beam-spin asymmetries could be measured. Active analysis presently is on hold, analyser is at DESY.



# Strangeness in DIS




Λ at high $Q^2$

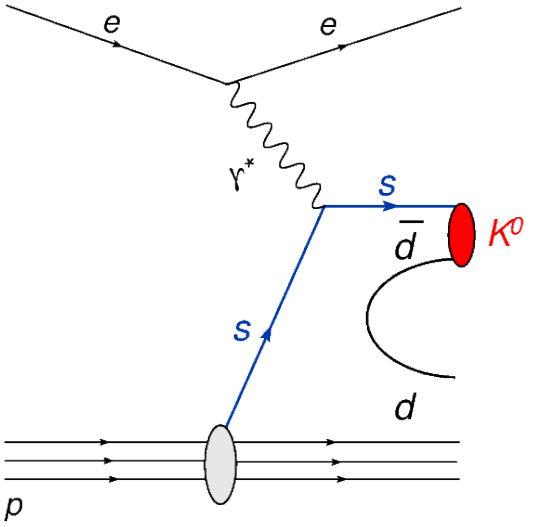


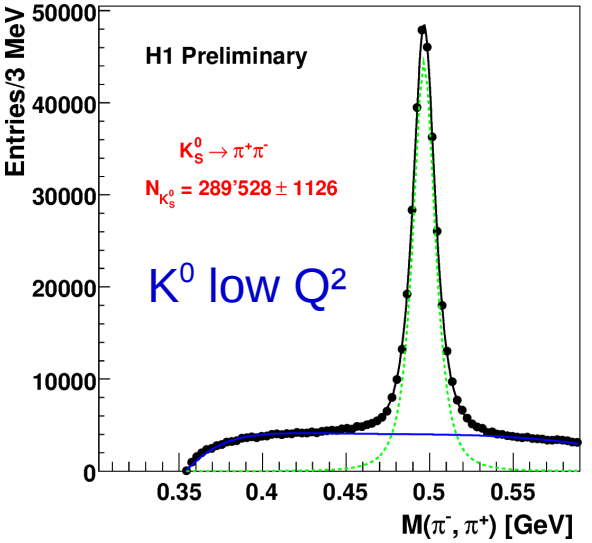

$K^0$ high $Q^2$

$K^0$ and Λ production at low/high $Q^2$ – cross-section measurements

Preliminary analyses of Hera-II data shown at conferences → to be finished

Possible addition (idea by G. Schnell) study helicity transfer from beam to Λ

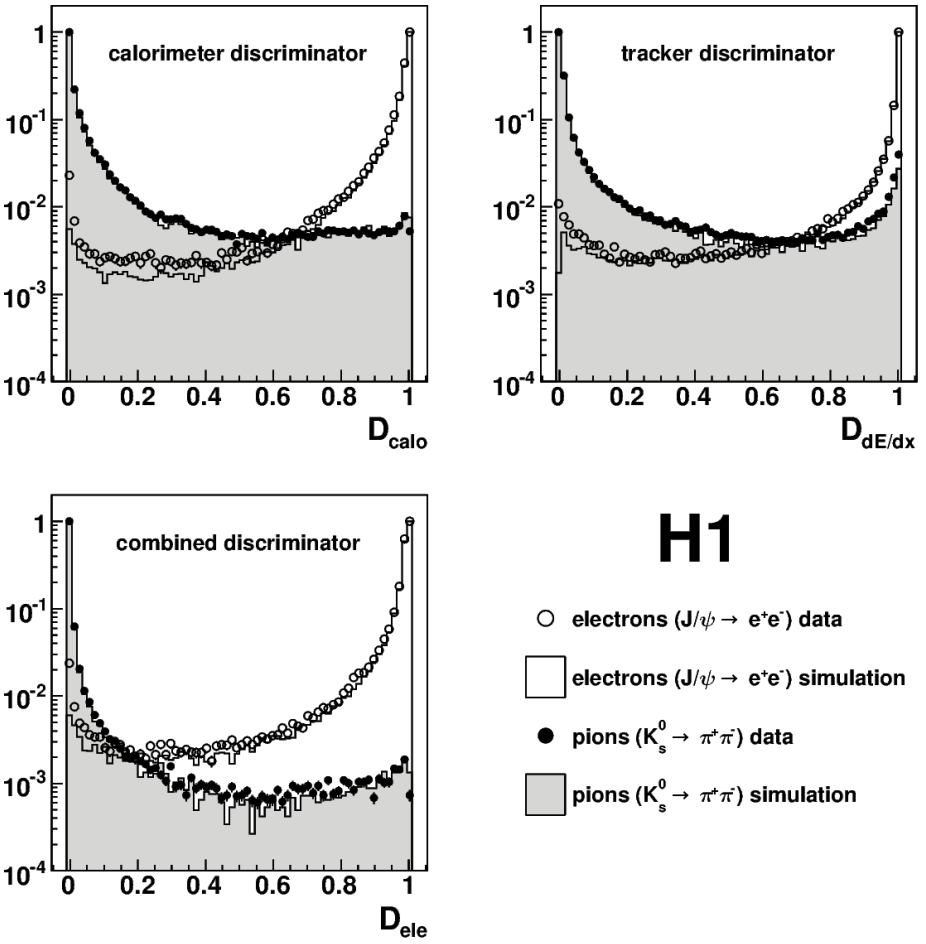



$K^0$ low $Q^2$

# Charm and beauty

- Sophisticated electron discriminator for use with the hadronic final state. So far exploited only by one analysis → huge potential: Br(c→e)~10%
- Examples
  - Precision $F_2(c)$ or $F_2(b)$
  - $F_L(c)$ (low E runs)
  - (maybe) charm in charged current - difficult



# Analysis help at DESY

- Many H1 members are around at DESY and possibly could contribute, e.g. student supervision / analysis help / paper draft
- To give a few names (list is not complete):
  - D.Britzger, K.Daum, D.Krücker, K.Krüger, J.List, J.Olsson, S.Levonian, S.Schmitt
- Contact the spokespersons if interested to join H1

# Summary

- Many interesting H1 analyses are still open, for example
  - Low energy runs
  - Diffraction
  - Exclusive final states, e.g. vector mesons and DVCS
  - Hadronic final state, charm & beauty
- In several cases, analyses exist and simply have to be finished
- A more complete discussion of possible future HERA analyses is available from the workshop held in 2014

  Future Physics with HERA data for Current and Planned Experiments

  https://indico.desy.de/conferenceDisplay.py?confId=10523