Recent results from H1

Daniel Traynor, QMUL, 17/05/05

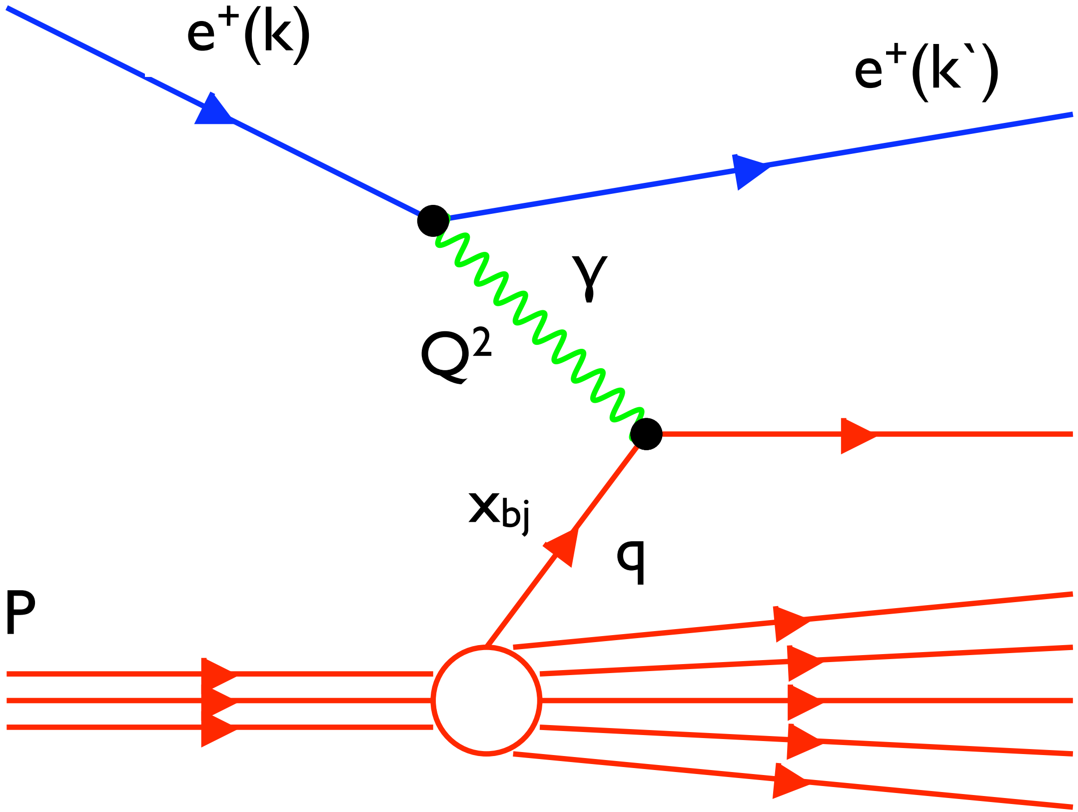
contents

- Basic HERA Physics
- HERAII upgrade
- Jet Physics
- Pentaquarks

Basic HERA Physics


electrons
Protons
W
27.6 GeV
920GeV
PETRA
ZEUS

Kinematics



Four-momentum transfer squared

$Q^2 = -q^2 = (k-k`)^2$

Bjorken x (x_{bj})

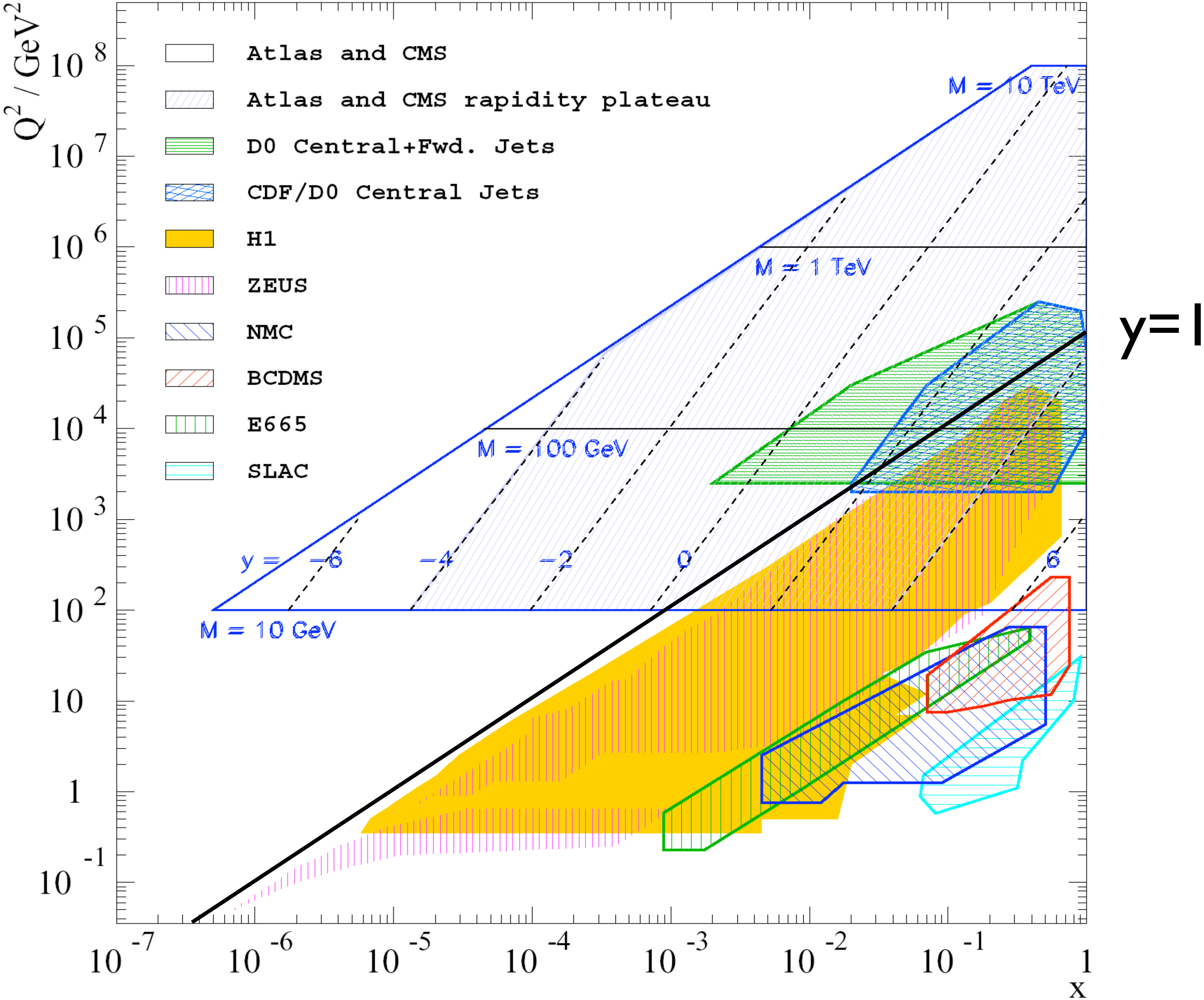
$x = Q^2 / 2p.q$

Inelasticity y

$y = p.q / p.k`$

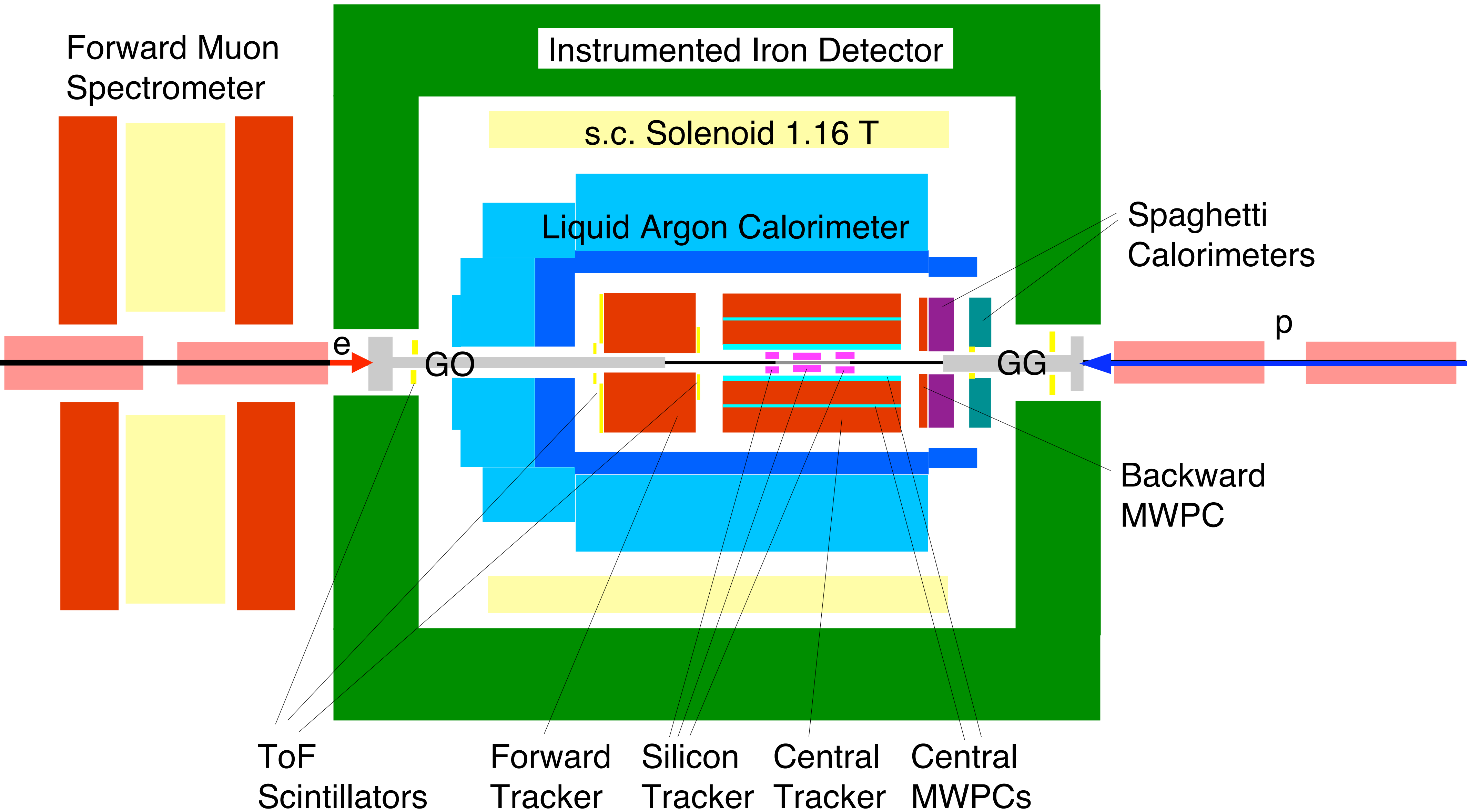
$s = Q^2 / xy = 318$ GeV

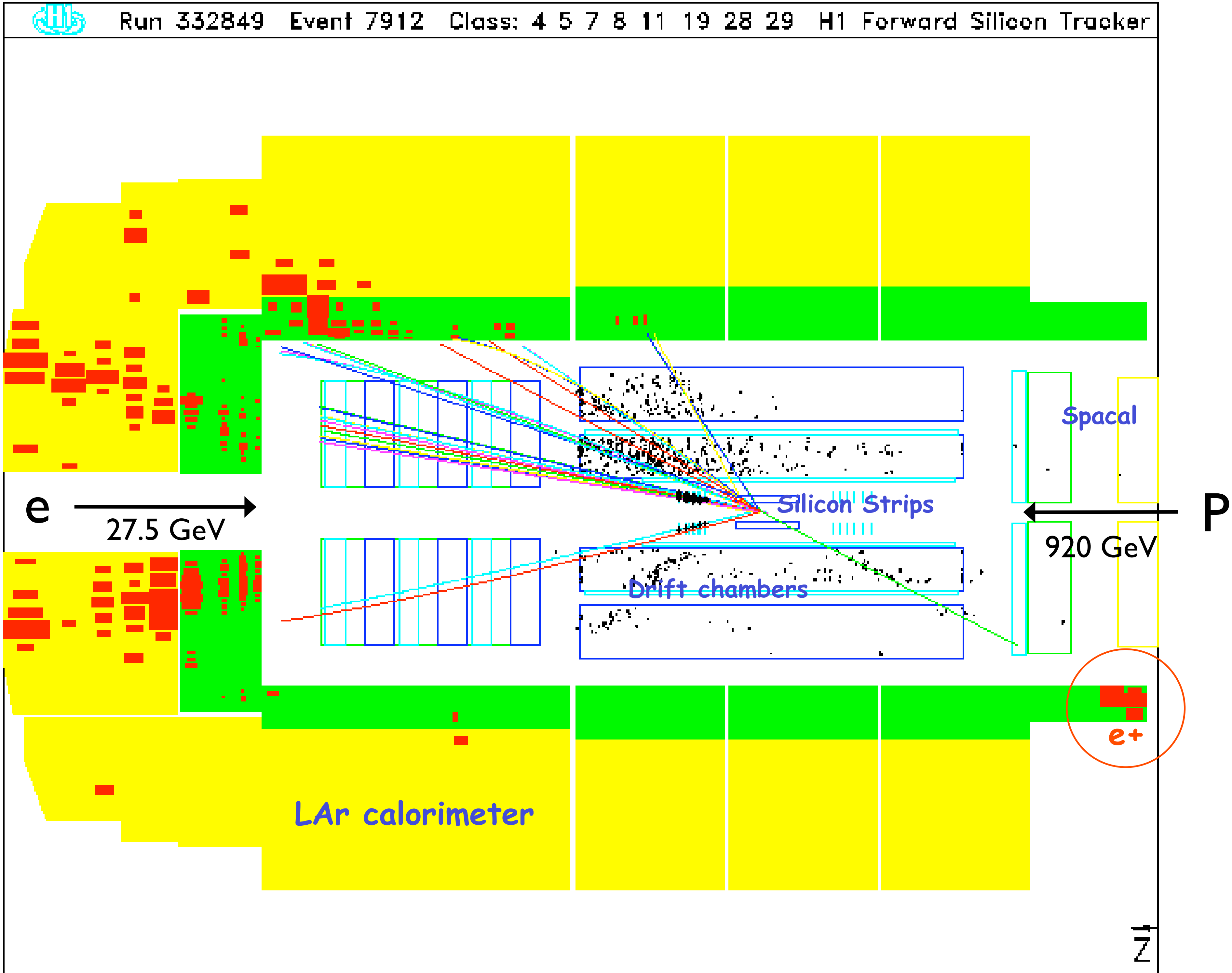
Kinematics overstrained
calculable from electron or proton side



$2 < Q^2 < 30{,}000$ $x_{bj} > 10^{-5}$

How was the acclerator upgrade done

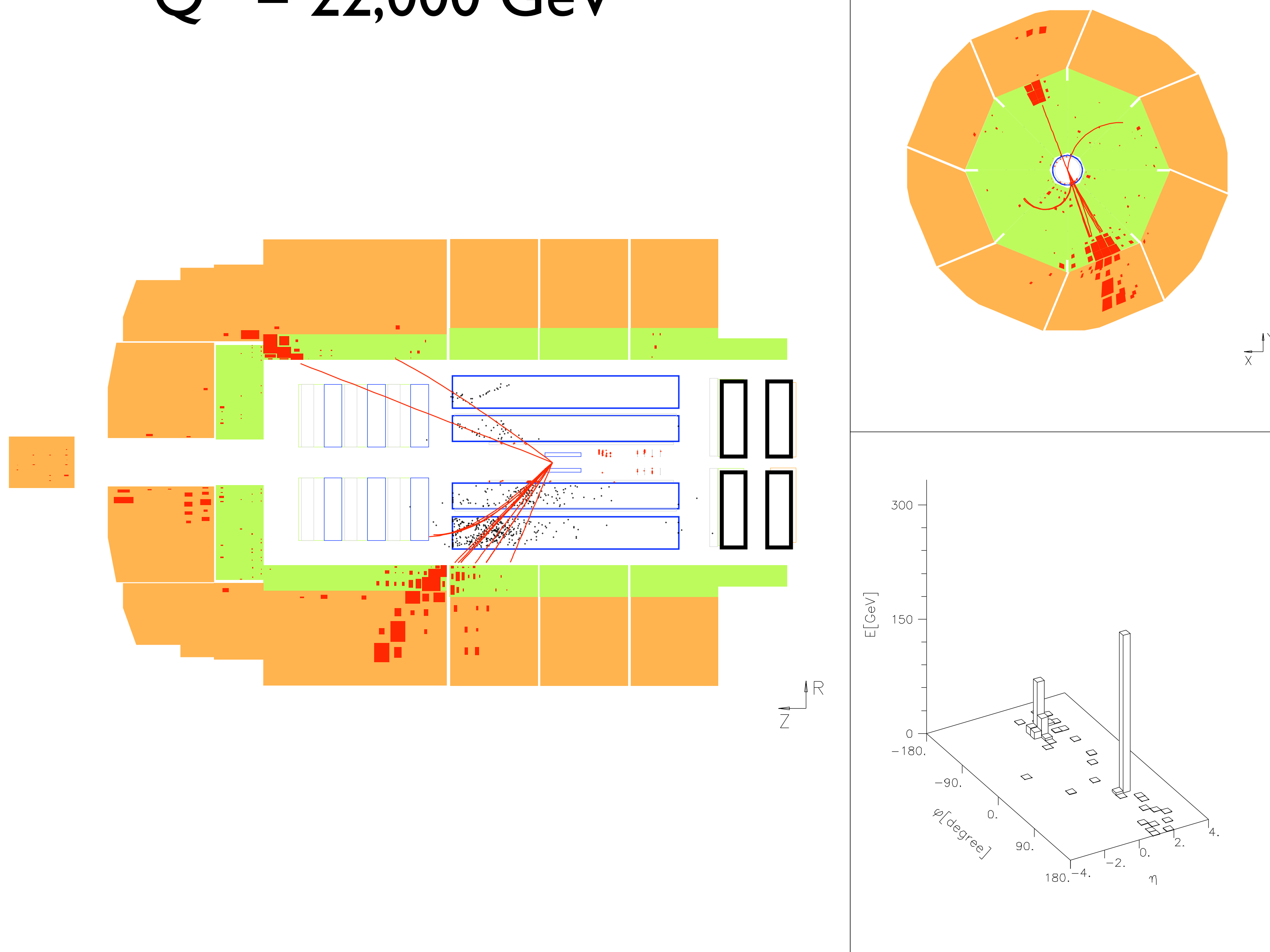




Run 332849 Event 7912 Class: 4 5 7 8 11 19 28 29 H1 Forward Silicon Tracker
e
27.5 GeV
P
920 GeV
Spacal
Silicon Strips
Drift chambers
e+
LAr calorimeter
Z

Run 224588 Event 9004 Class: 26 Date 19/10/1998

$$Q^2 = 22{,}000\ \mathrm{GeV}^2$$



HERA2 Upgrade

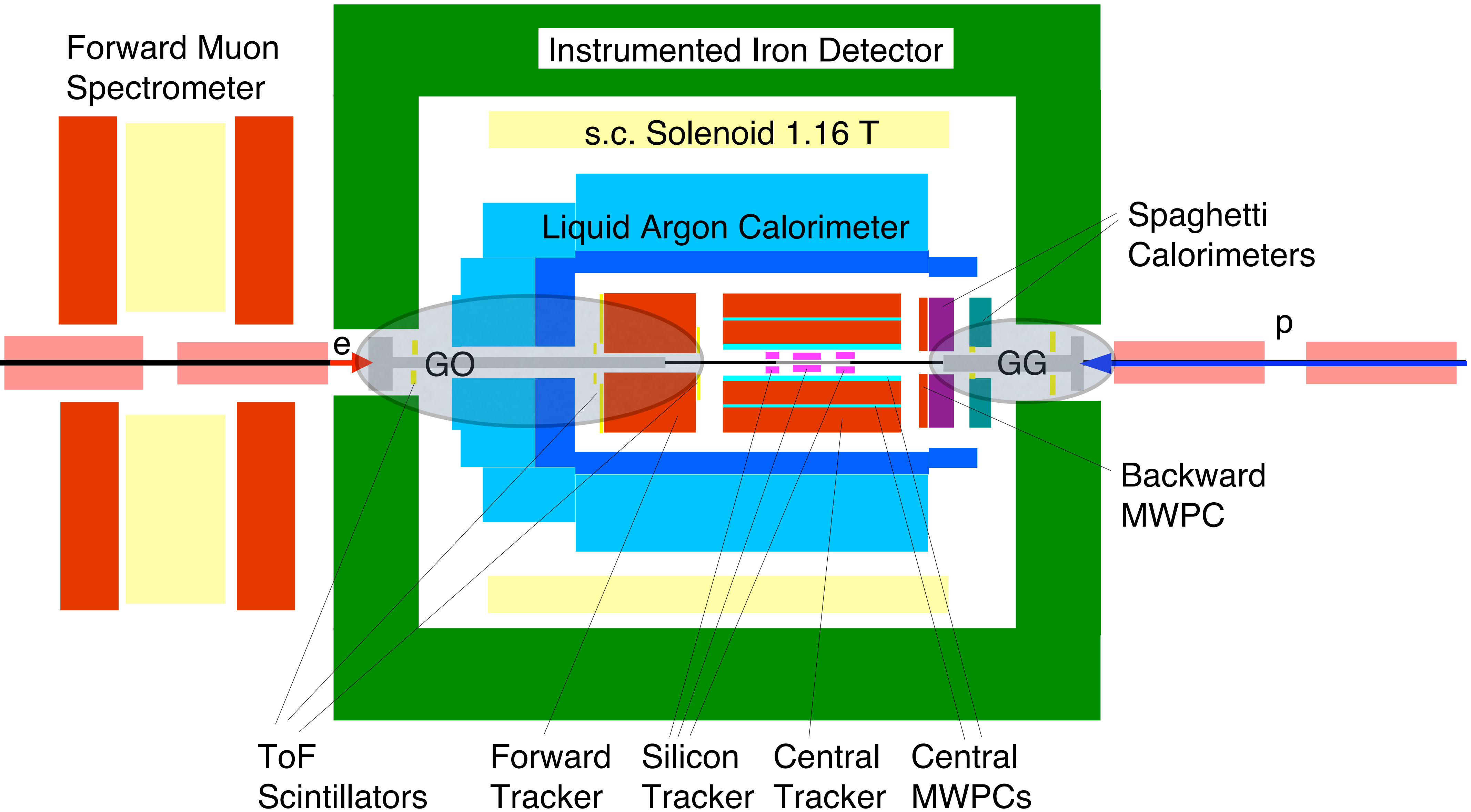
HERA 1 provided 120 pb-1 of mostly e+ data

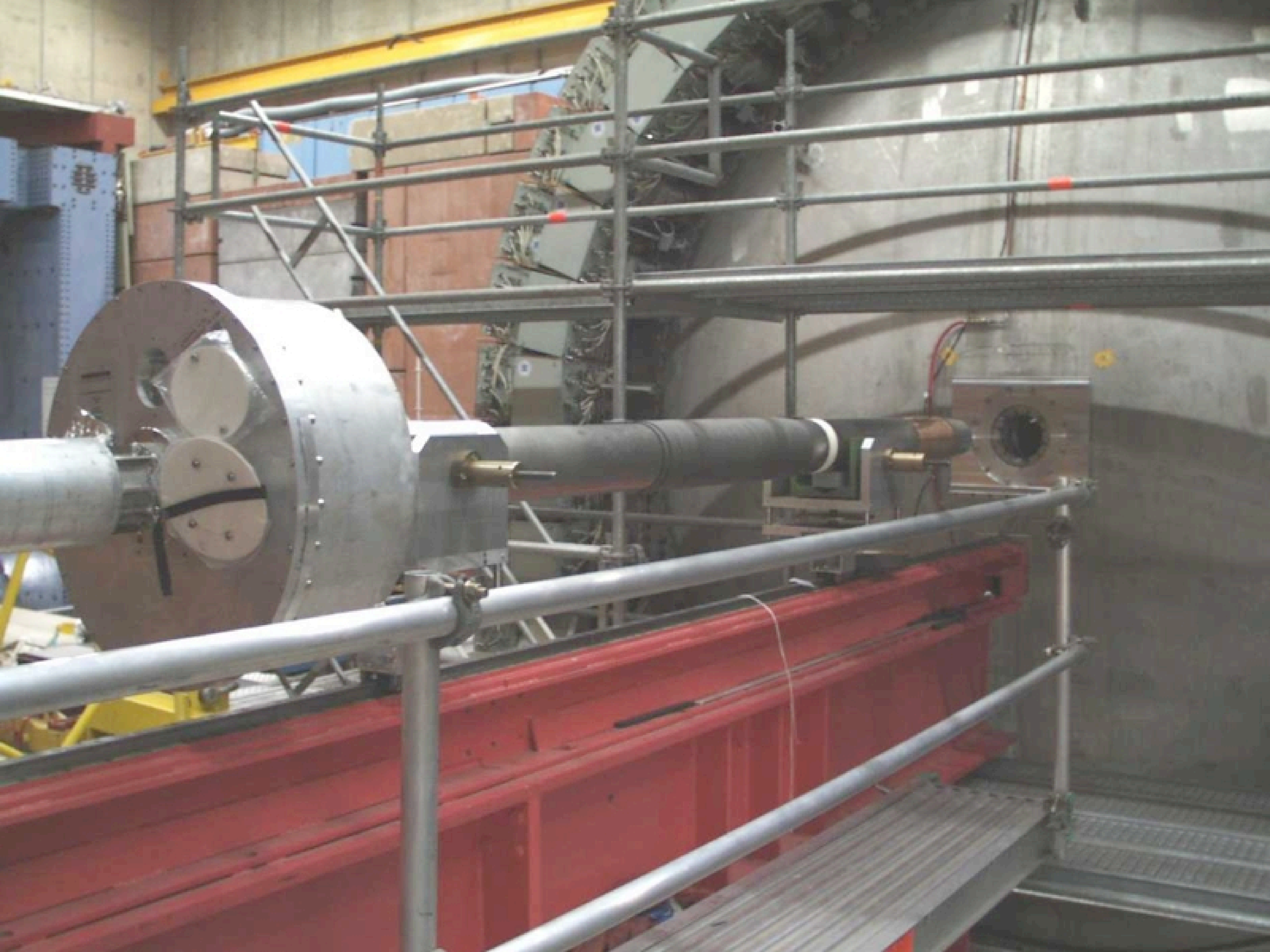
HERA 2 upgrade to provide 1fb^{-1} of data with polarised electrons and positrons.

Use beam focusing magnets to increase peak luminosity x5

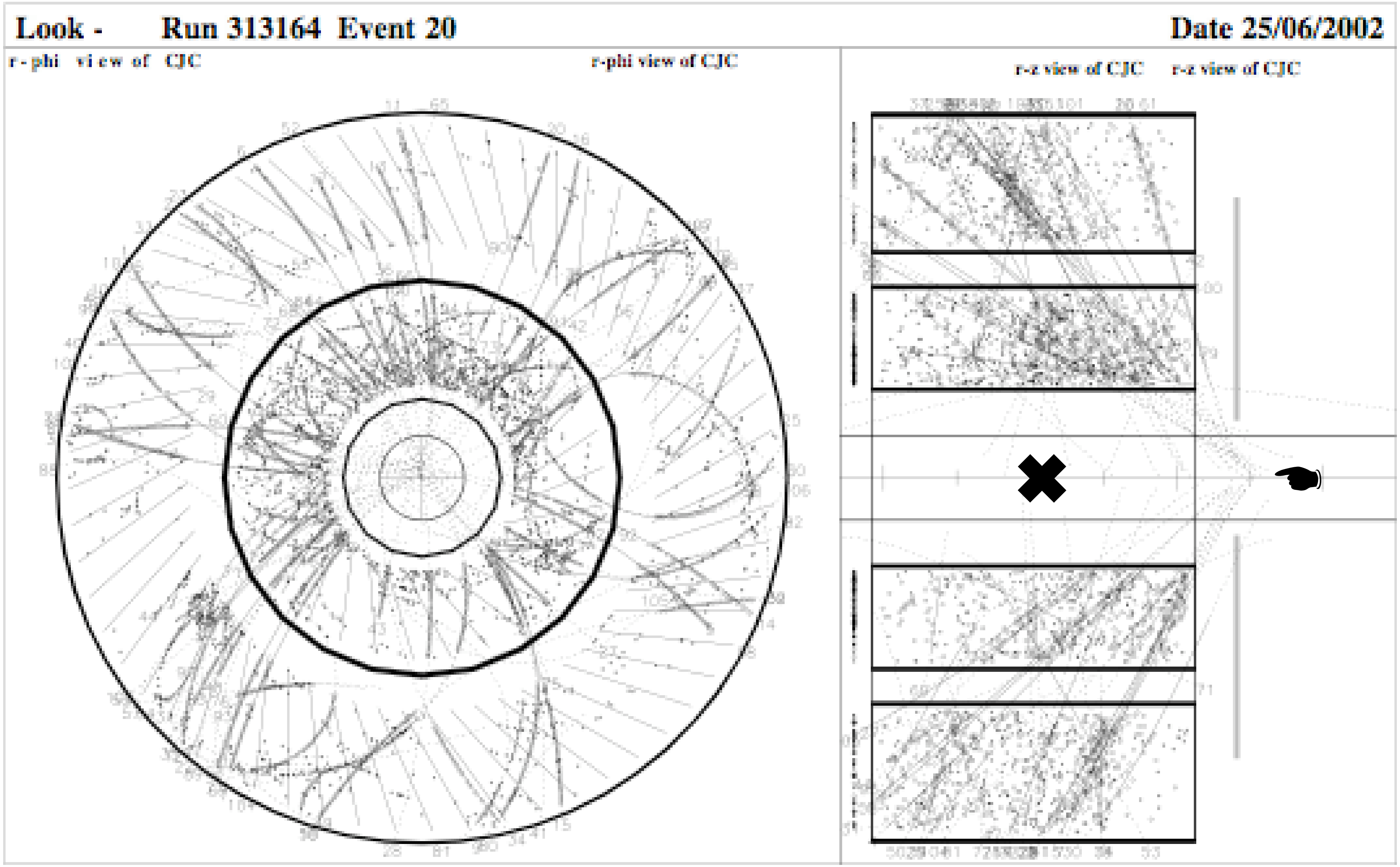
Also upgrade detectors for improved physics potential

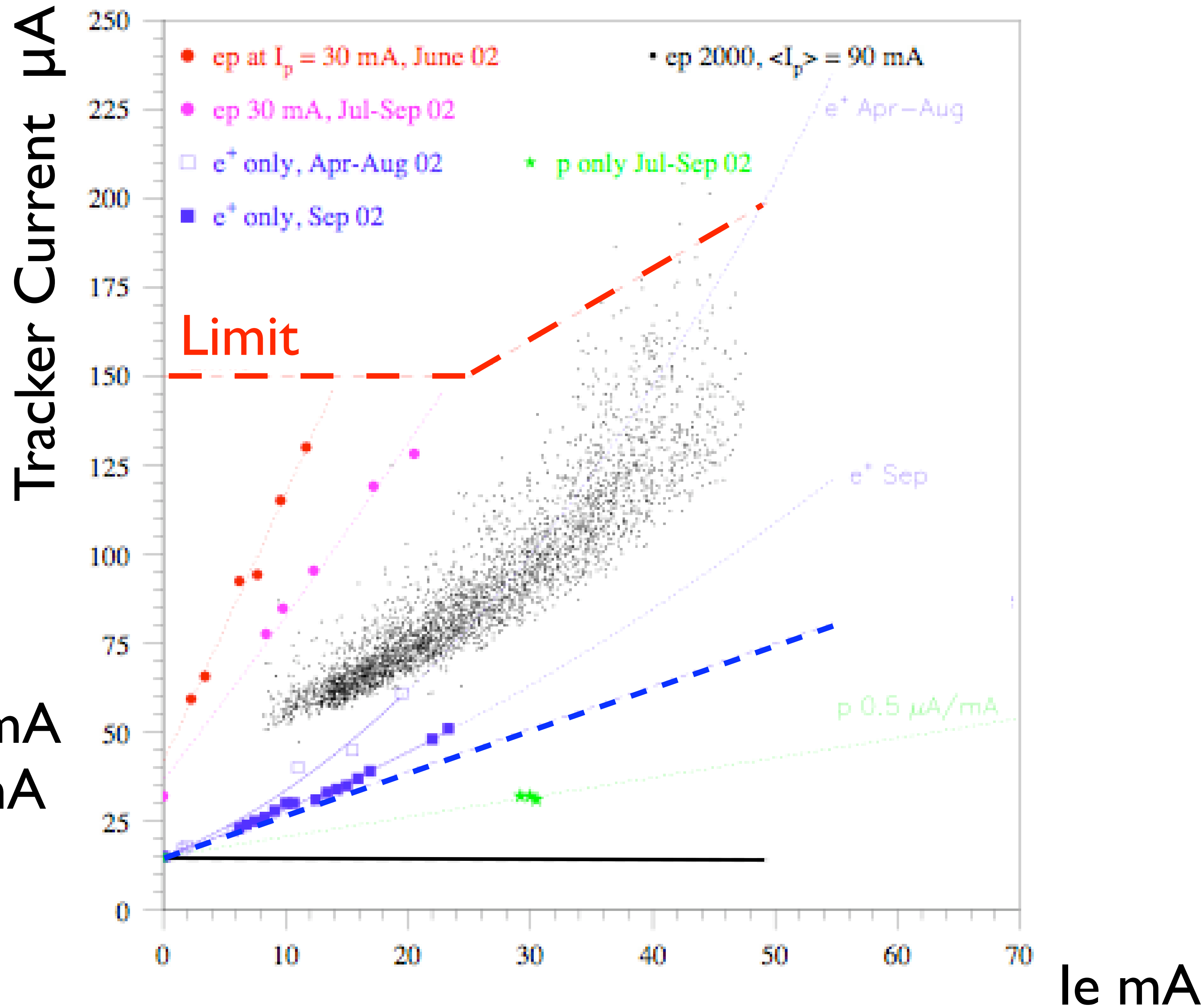
How was the acclerator upgrade done





Very high Backgrounds seen in 2002 start up



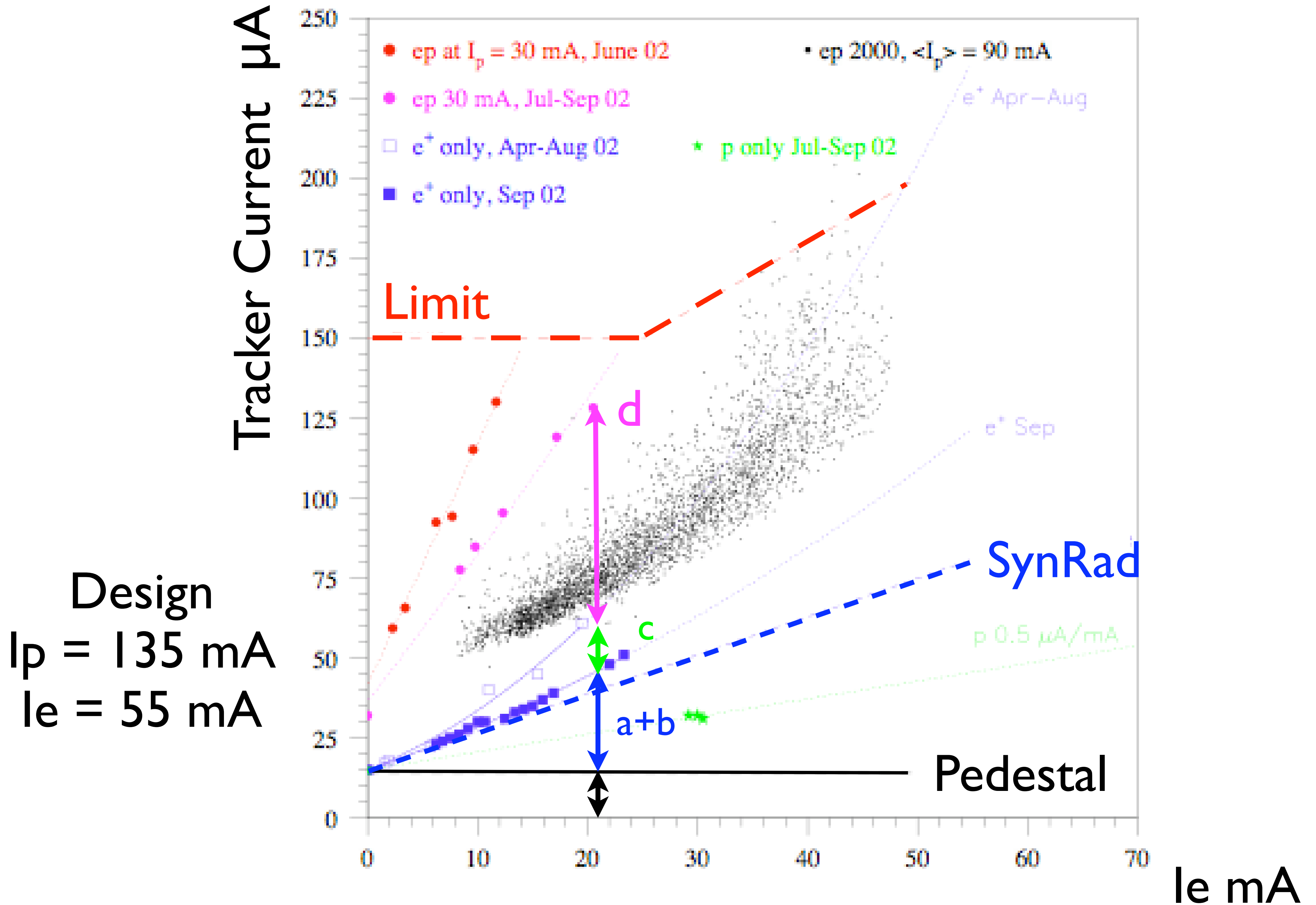


Design
Ip = 135 mA
Ie = 55 mA

How background problems were understood

$$I_{cjc} = I_0 + aI_e + bI_e^2 + cI_p + dI_eI_p$$

- I_0: pedestal
- aI_e: synchrotron radiation
- bI_e^2: positron beam gas interactions
- cI_p: proton beam gas interactions
- dI_eI_p: positron induced proton beam gas interactions



Tracker Current μA
ep at I_p = 30 mA, June 02
ep 30 mA, Jul-Sep 02
e^+ only, Apr-Aug 02
e^+ only, Sep 02
ep 2000, $<I_p>$ = 90 mA
p only Jul-Sep 02
e^+ Apr–Aug
e^+ Sep
p 0.5 μA/mA
Limit
d
c
a+b
SynRad
Pedestal
Design
Ip = 135 mA
Ie = 55 mA
Ie mA

How background problems were solved

$$I_{cjc} = I_0 + aI_e + bI_e^2 + cI_p + dI_eI_p$$

pedestal

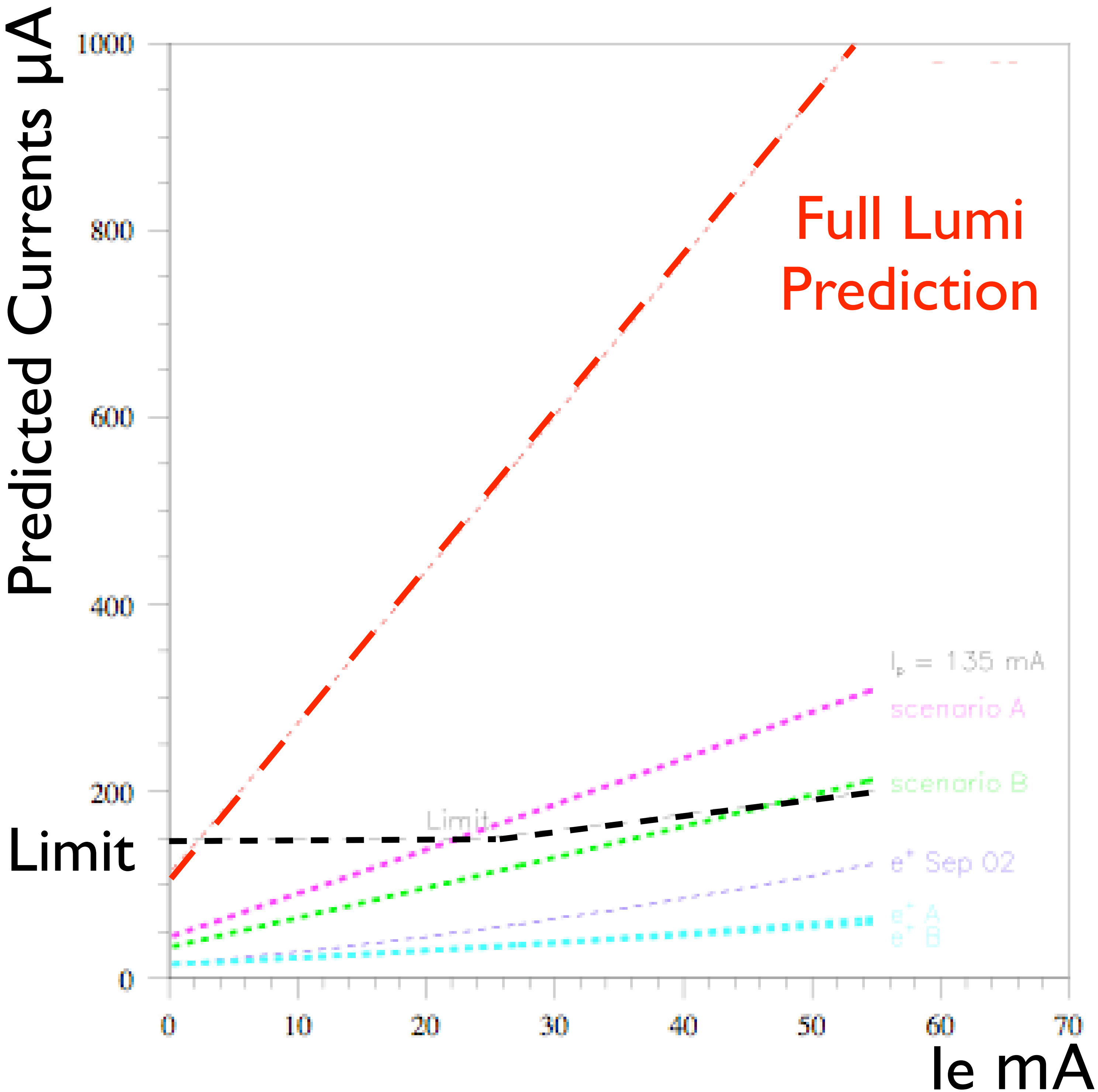
synchrotron radiation

positron beam gas interactions

proton beam gas interactions

positron induced proton beam gas interactions

70% of Background


Predicted Currents µA
Full Lumi
Prediction
Limit
Limit
Ie mA
I_p = 135 mA
scenorio A
scenorio B
e^+ Sep 02
e^+ A
e^+ B
0
200
400
600
800
1000
0
10
20
30
40
50
60
70

Very high Backgrounds seen in 2002

central tracker has current limit of 150micro A

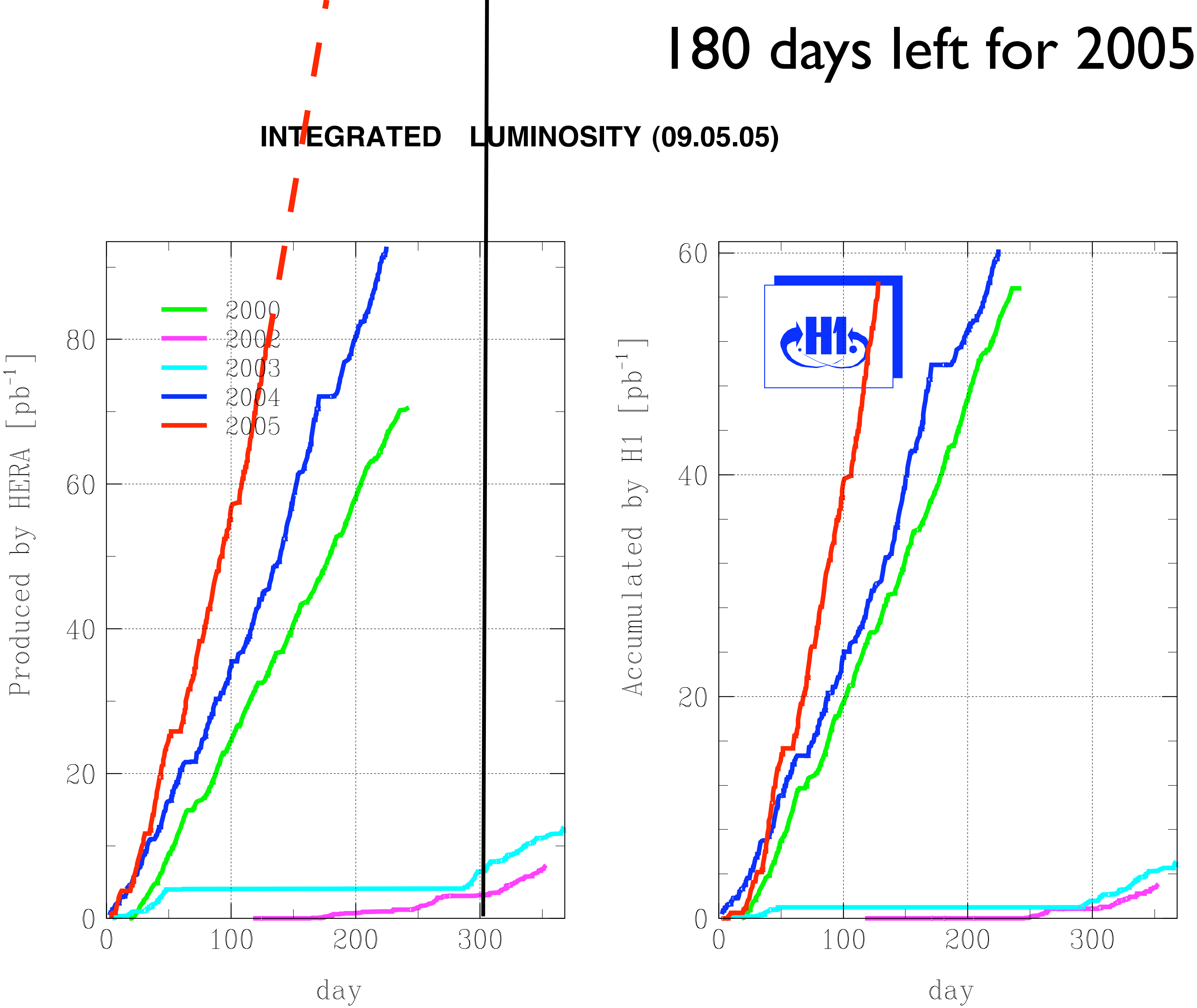
At full luminosity operation we would have had 1 mA

Major study by H1, ZEUS and HERA

Plan of action:
new Collimators
redesign of old collimators
lead shielding
new pumps
bake out with luminosity

http://www-h1.desy.de/publications/H1_sci_results.shtml

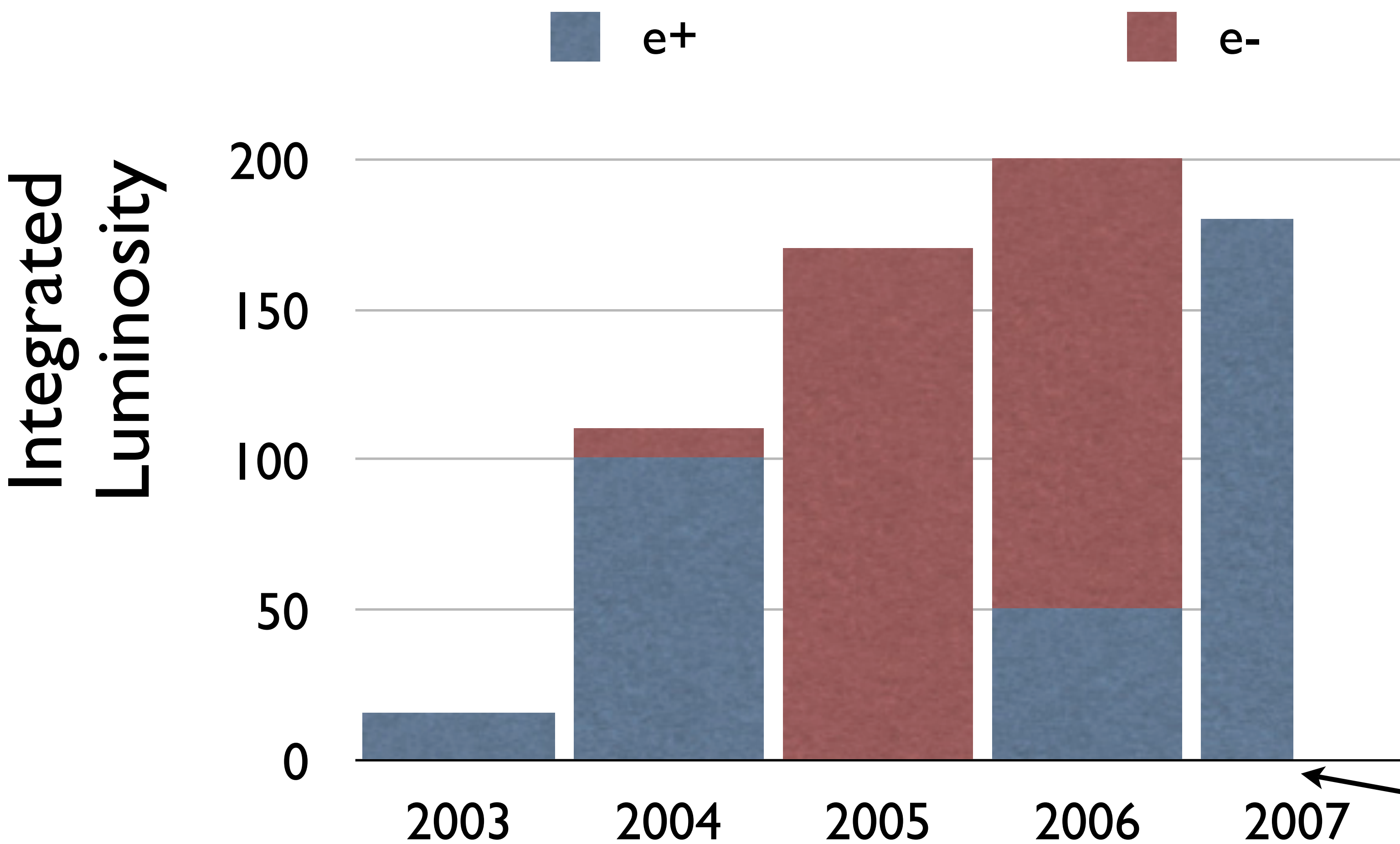
180 days left for 2005 running



Produced by HERA

H1 HV on

Future Plans for HERA 2



By mid 2007

$750\ pb^{-1}$

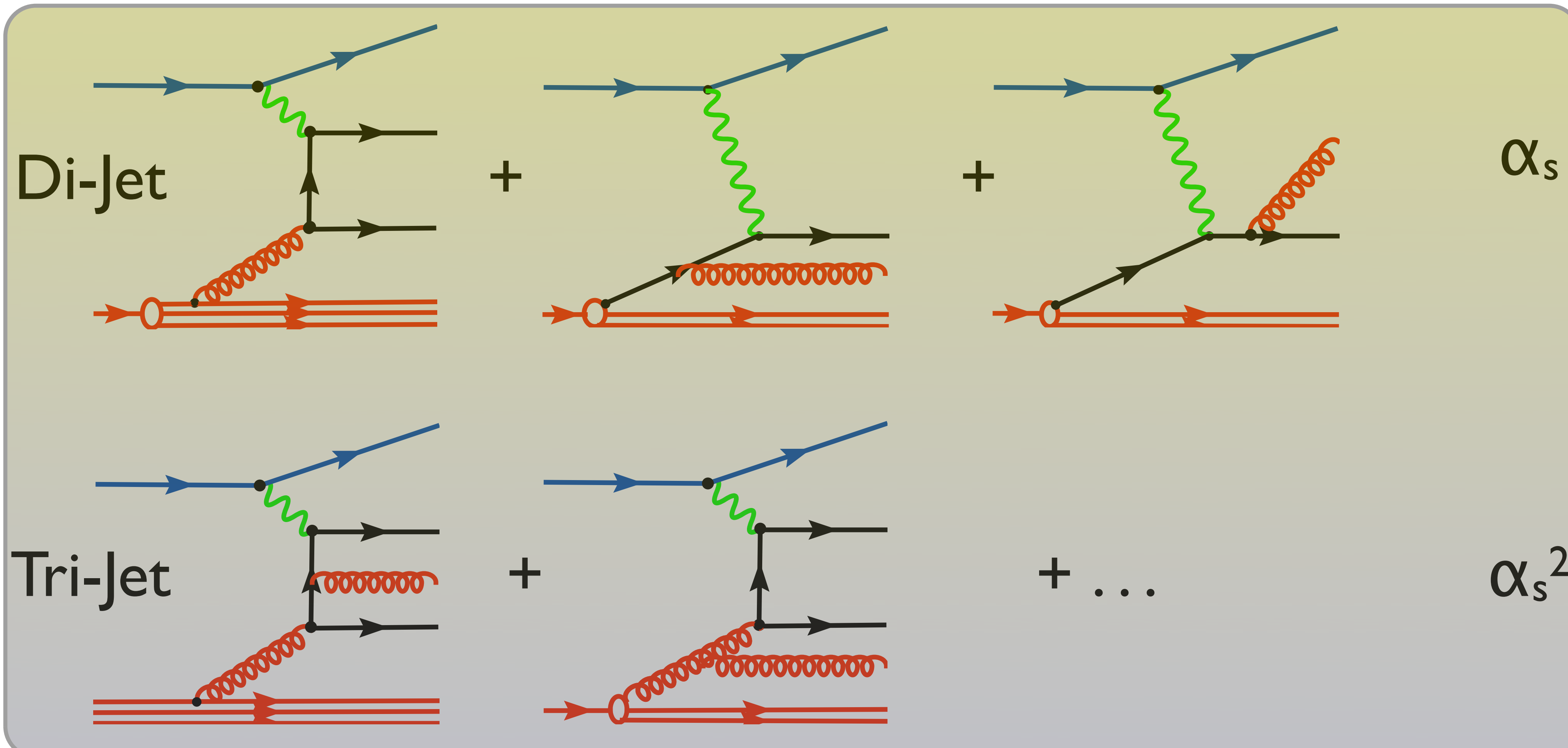
$50\%\ e^{+}$

$50\%\ e^{-}$

We are here

Jet production

Directly sensitive to
QCD radiation, α_s, and
gluon density in proton

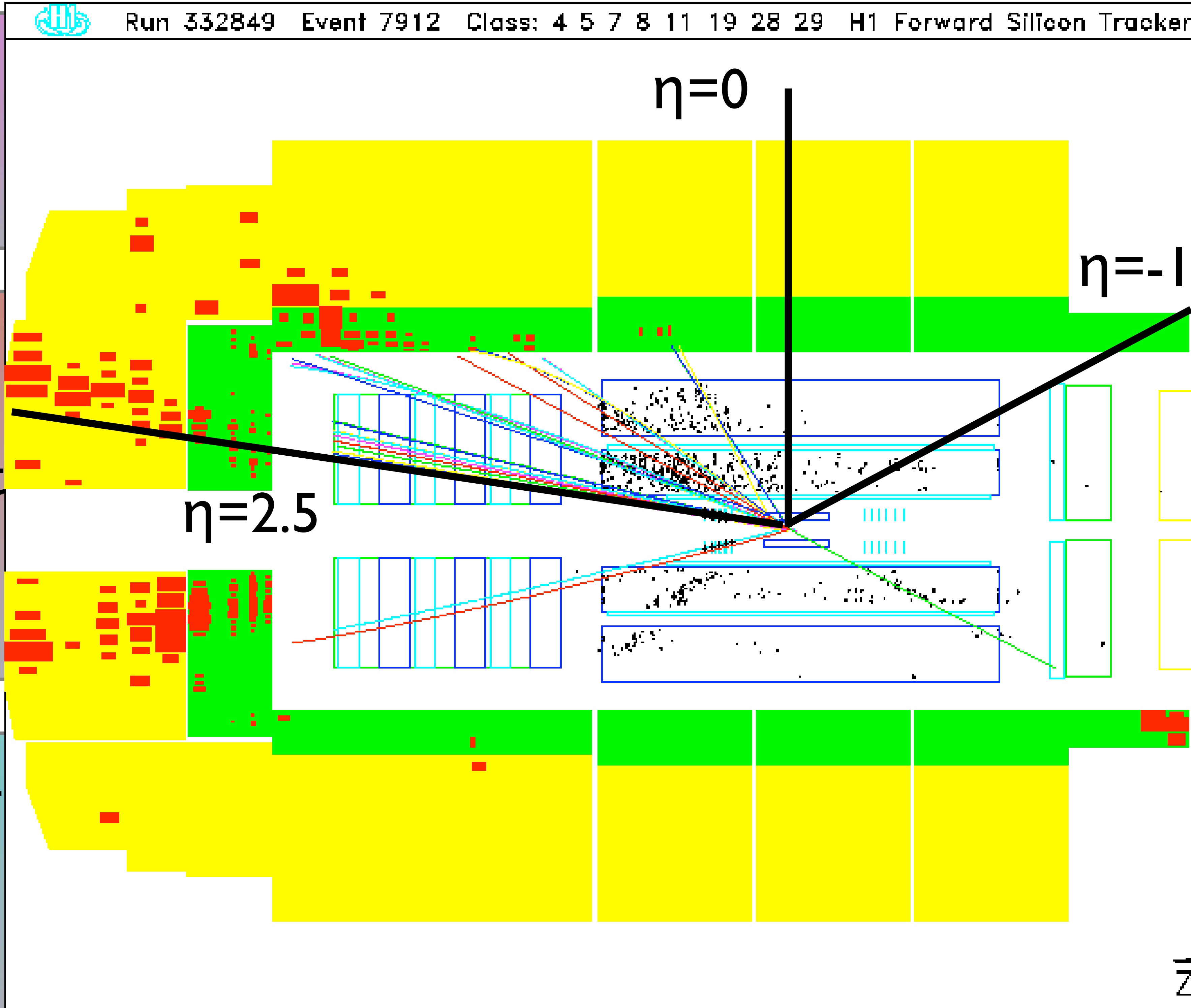


Jet

2.5

T

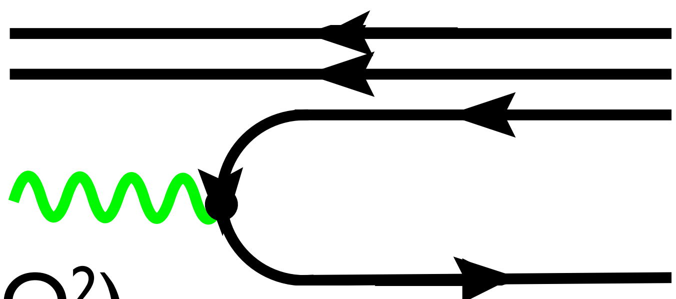
Q^2



Run 332849 Event 7912 Class: 4 5 7 8 11 19 28 29 H1 Forward Silicon Tracker
η=0
η=-1
η=2.5
Z

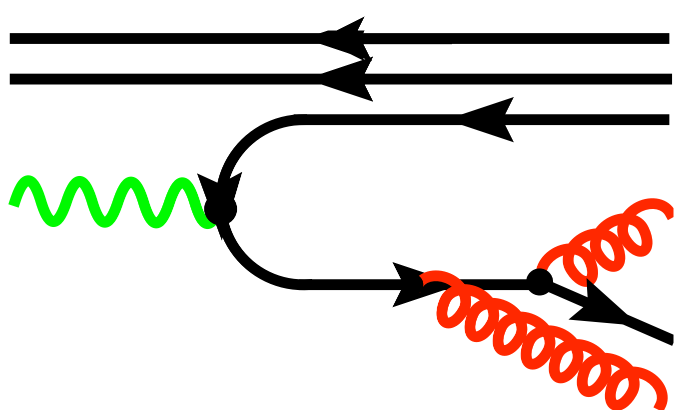
Jets are found in the Breit Frame

Boost to frame where exchange boson is entirely space like → Hard Scale Q^2



$\gamma(0,0,0,-Q^2)$

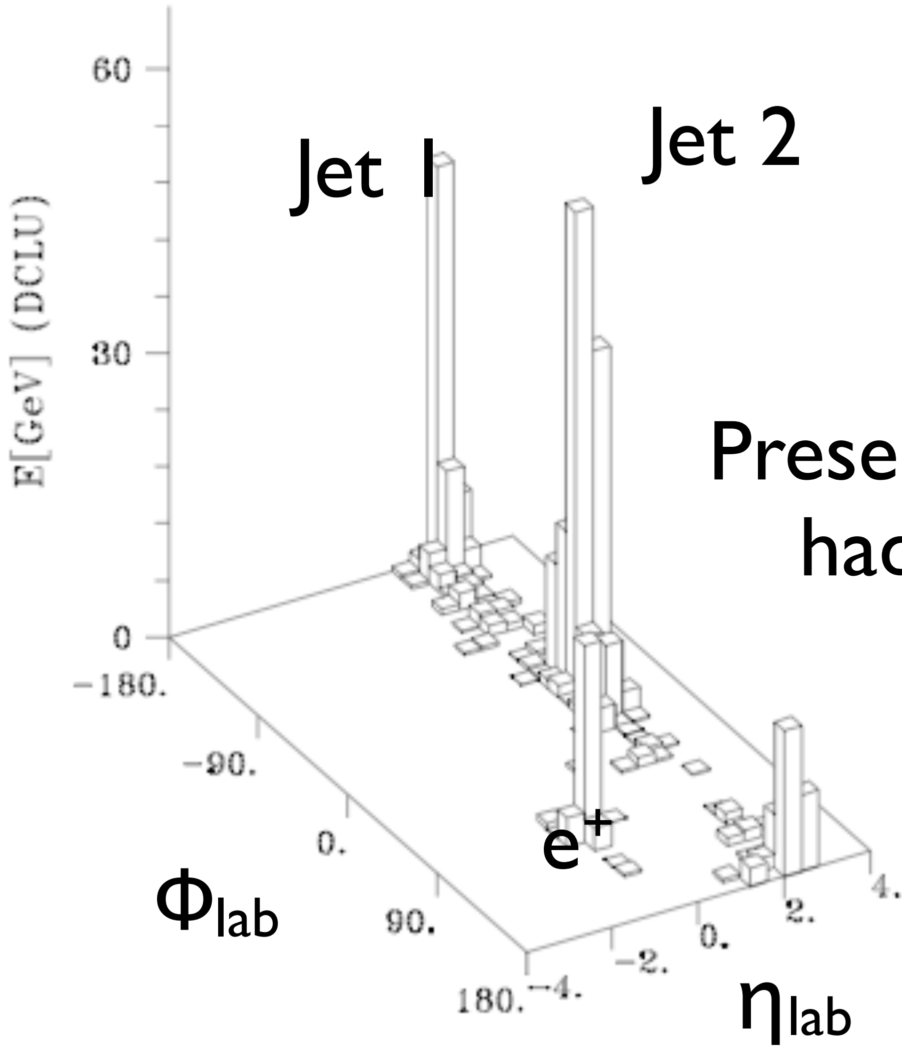
Born level has no E_t in Breit frame!



QCD produces E_t in Breit frame

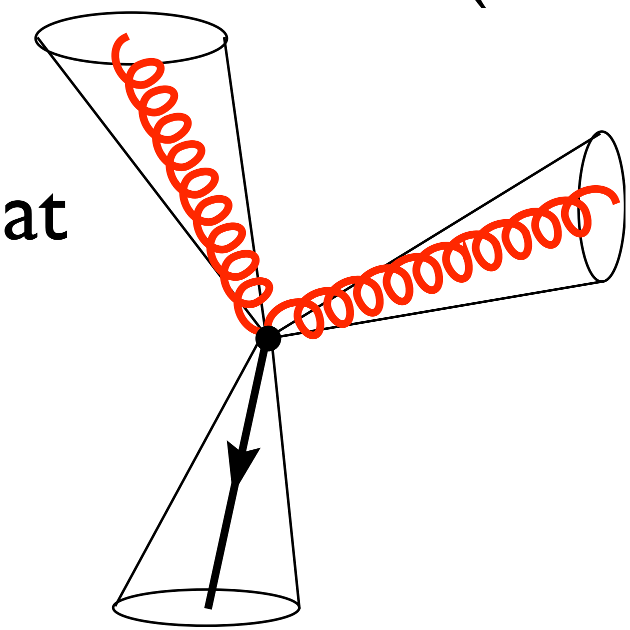
Measure Jets in Data at Detector level

QCD theory (NLO) provides jets at parton level



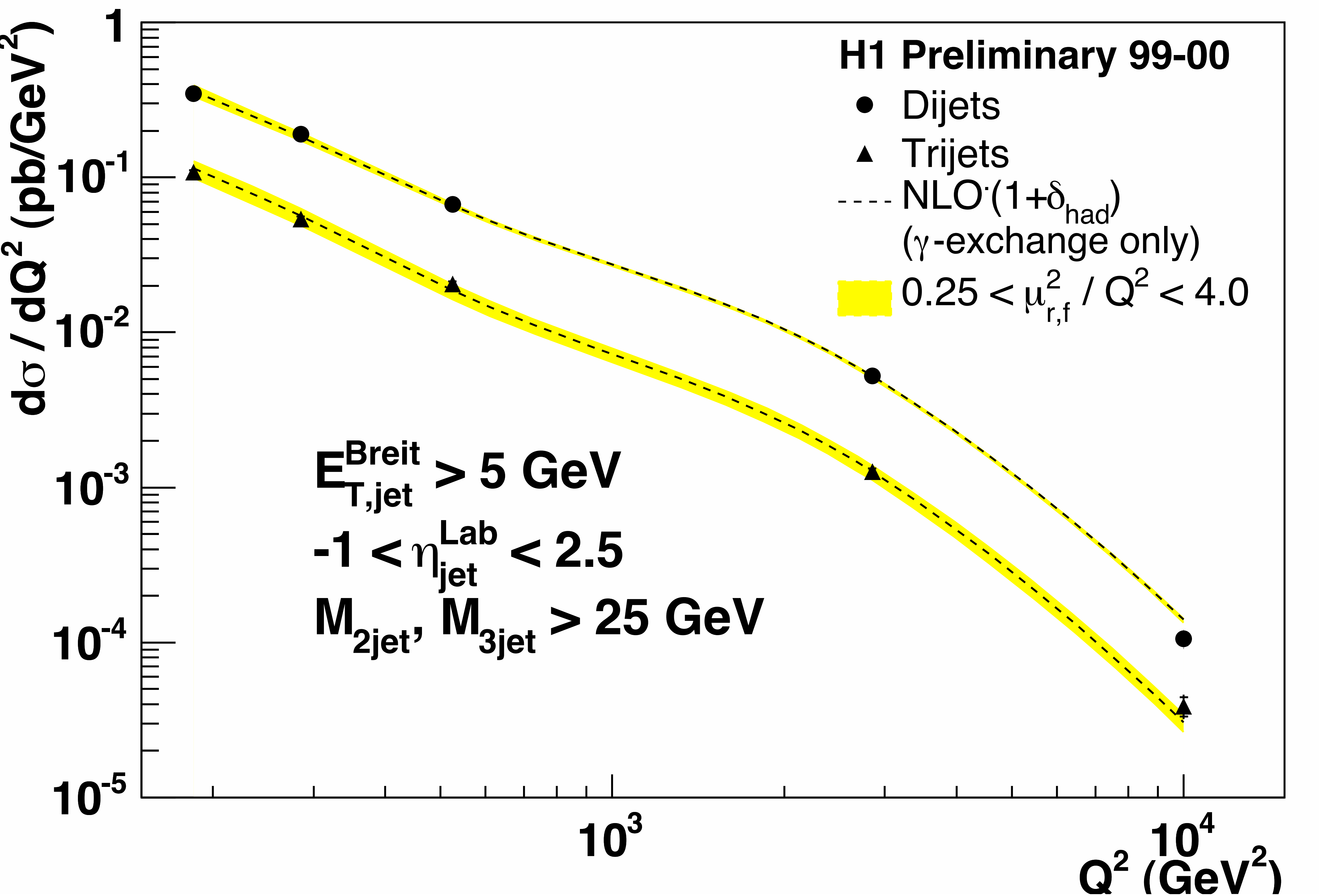
$NLO(1+\delta_{had})$

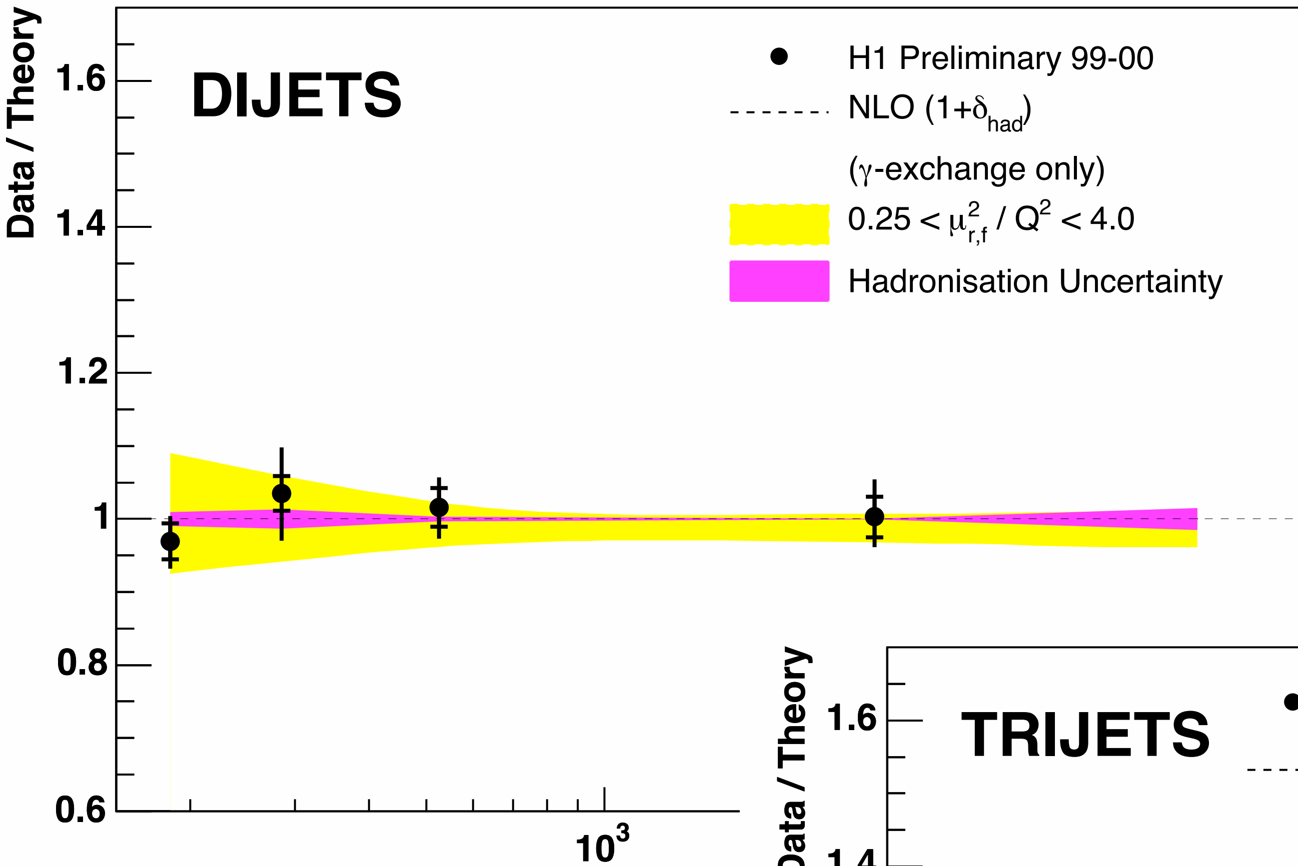
Present results at hadron level



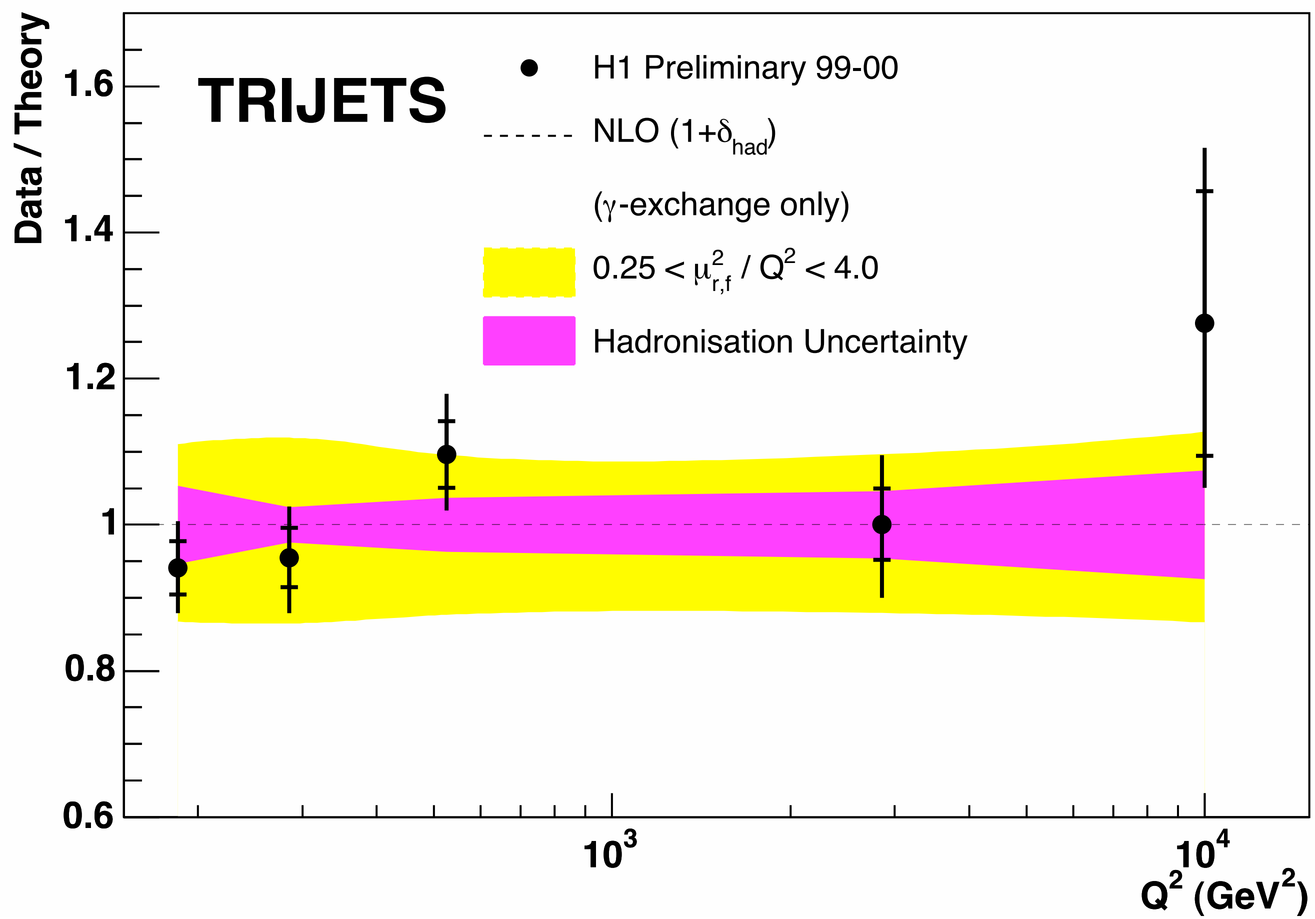
Correct data for Detector effects

Correct to hadron level using LO+PS Monte-Carlo


H1 Preliminary 99-00
Dijets
Trijets
NLO·(1+δ_had)
(γ-exchange only)
0.25 < μ²_r,f / Q² < 4.0
E_T,jet^Breit > 5 GeV
-1 < η_jet^Lab < 2.5
M_2jet, M_3jet > 25 GeV
dσ / dQ² (pb/GeV²)
Q² (GeV²)
1
10⁻¹
10⁻²
10⁻³
10⁻⁴
10⁻⁵
10³
10⁴



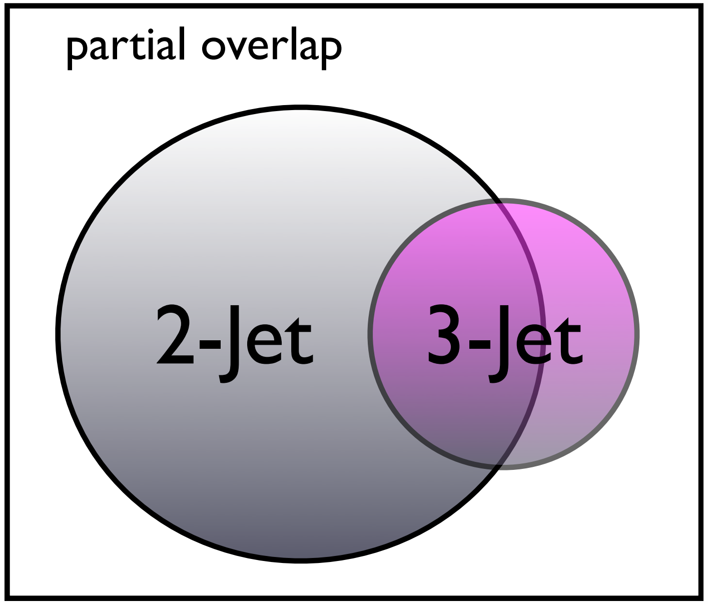
Hadronisation Uncertainty difference from CDM / PS

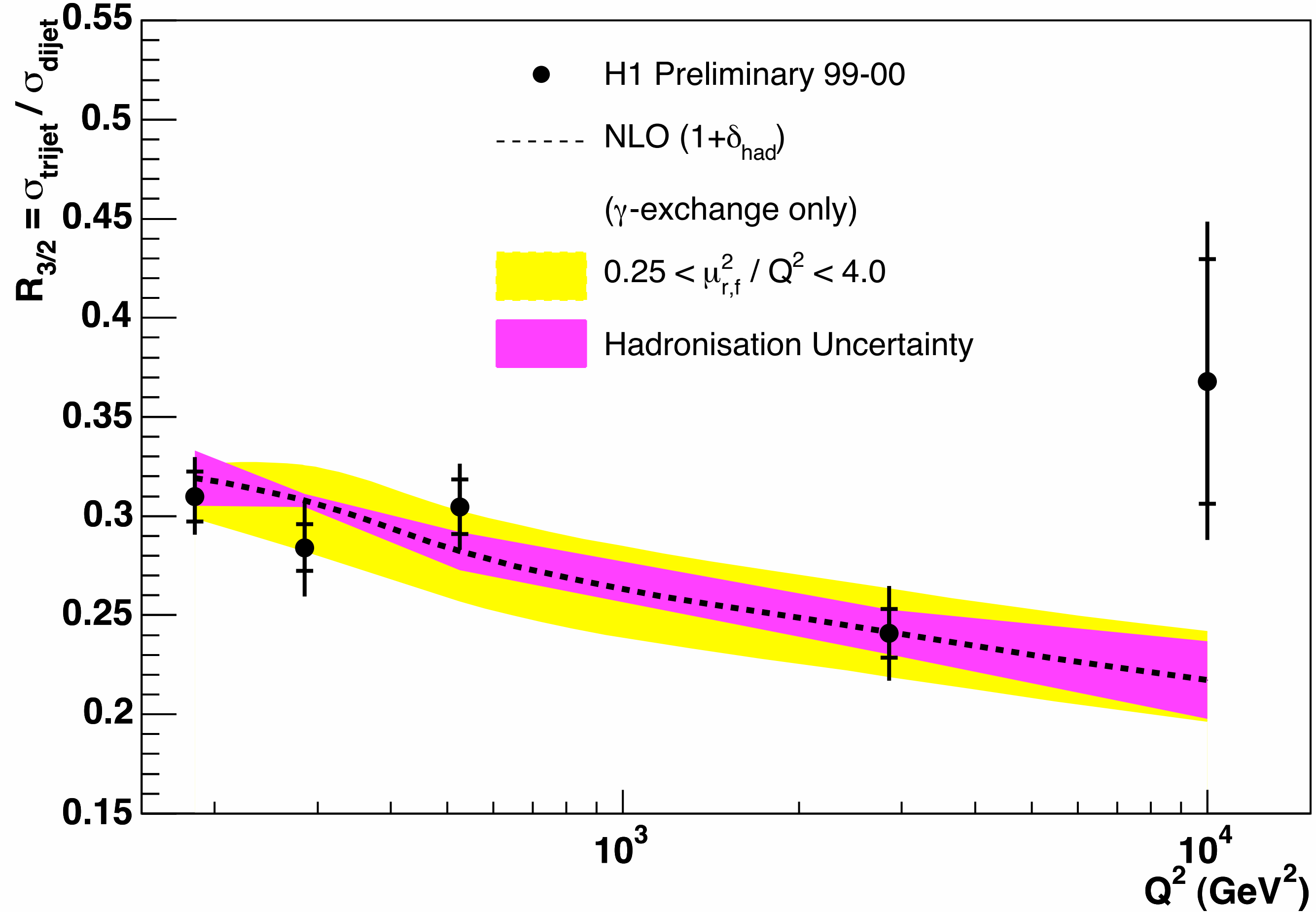


Statistical error for 3-Jets events is large need HERAII

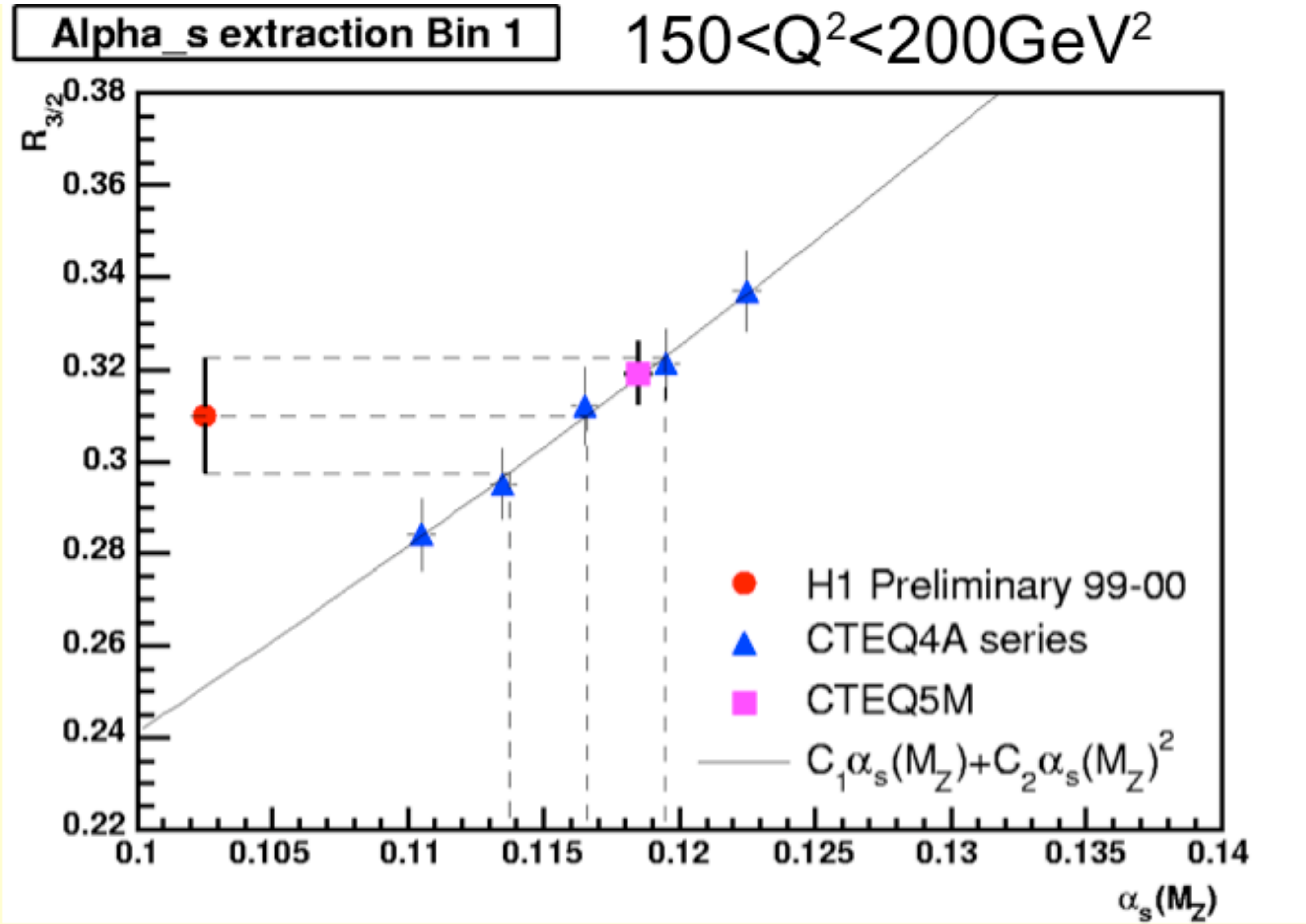
$$R_{3/2} := \sigma_{3jet} / \sigma_{2jet} \sim c_1\alpha_s + c_2\alpha_s^2$$

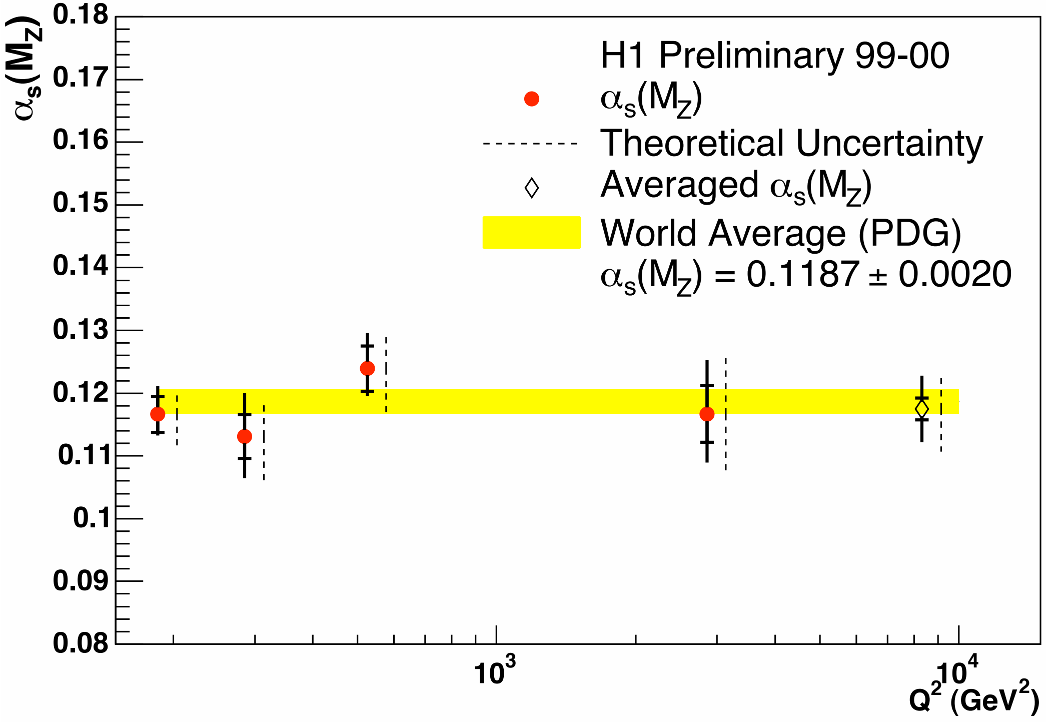
M_{jj} >25 GeV
M_{jjj} >25 GeV

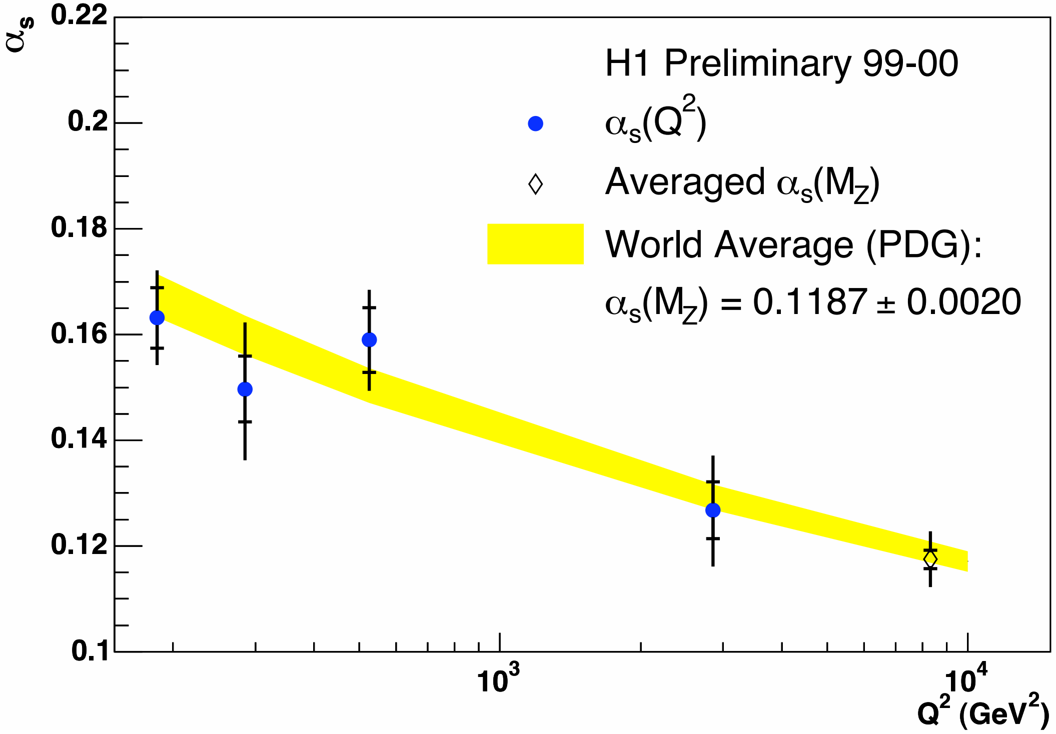




Partial cancellations of uncertainties by taking ratio


Alpha_s extraction Bin 1
150<Q²<200GeV²
R_3/2
0.38
0.36
0.34
0.32
0.3
0.28
0.26
0.24
0.22
0.1
0.105
0.11
0.115
0.12
0.125
0.13
0.135
0.14
α_s(M_Z)
H1 Preliminary 99-00
CTEQ4A series
CTEQ5M
C_1α_s(M_Z)+C_2α_s(M_Z)²





$$\alpha_s(m_Z) = 0.1175 \pm 0.0017 \pm 0.0050^{+0.0054}_{-0.0068}$$

± statistical ± systematic ± theoretical

How to Improve the Measurement

Increase statistics with HERA II data

Decrease hadronic energy scale uncertainty to 1%

Hadronisation uncertainty use MC@NLO

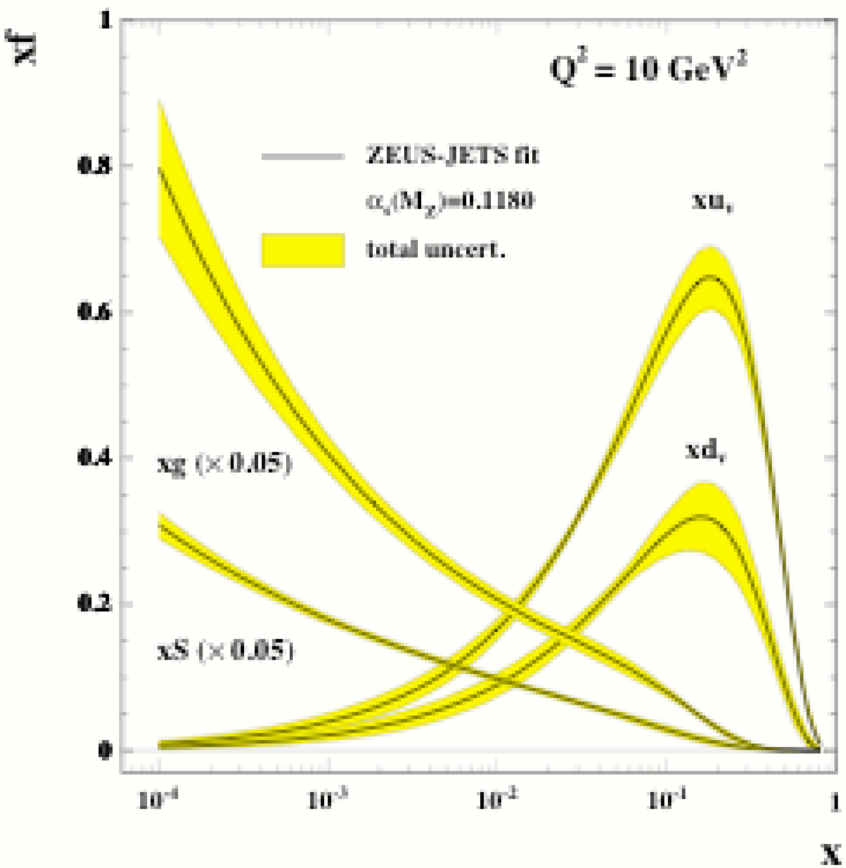
NLO scale uncertainty use NNLO?

Want to do more than just measure α_s!

The ZEUS-JETS QCD fit

- ZEUS-JETS QCD analysis uses the full set of HERA-I inclusive DIS data and two sets of jet data
  - Cuts on inclusive data in fit:
    - $Q^2 \geq 2.5\ GeV^2$, $W^2 > 20\ GeV^2$

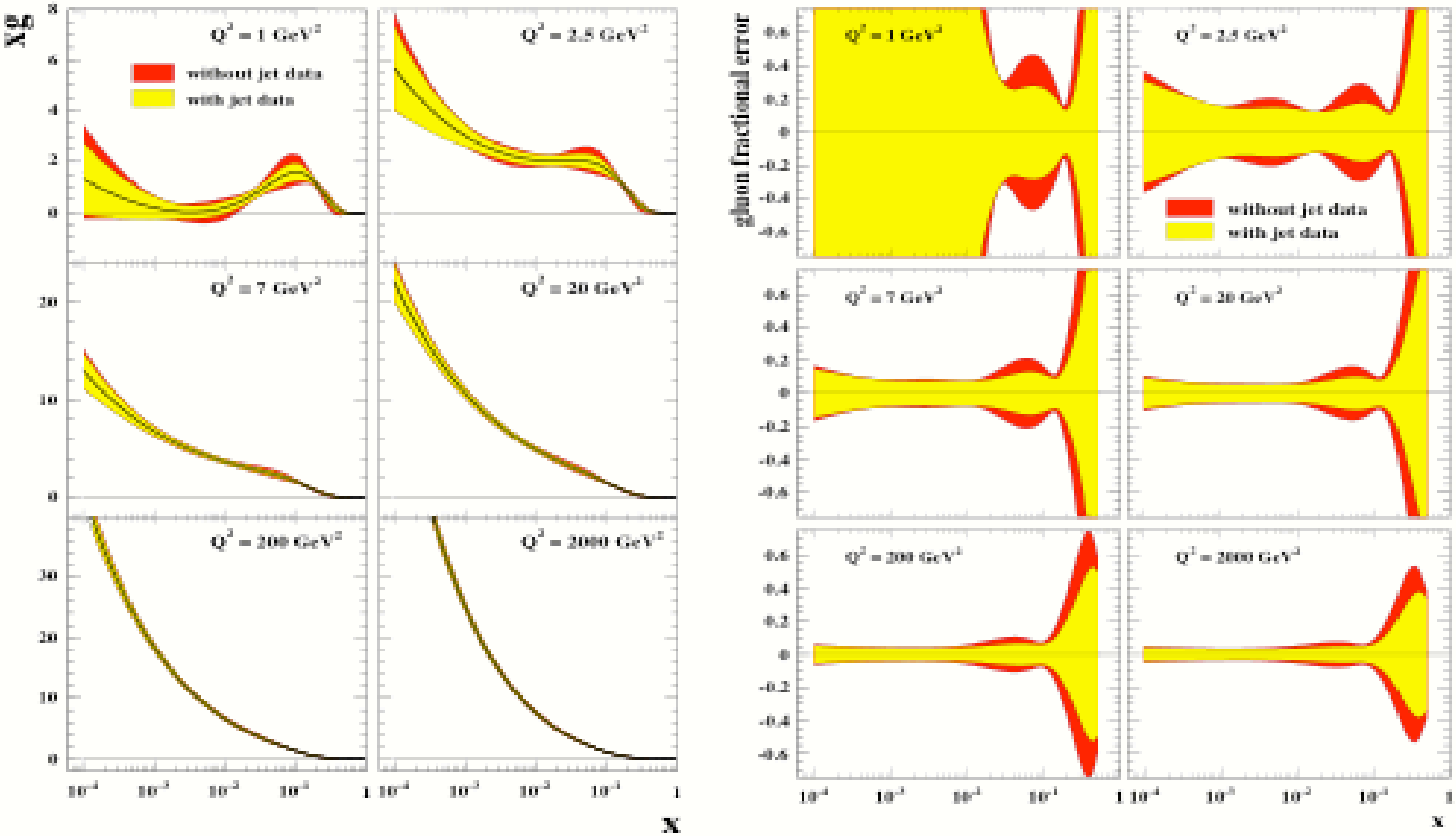
ZEUS Data Set	N_{data}
NC e+p 96-97	242
CC e+p 94-97	29
NC e-p 98-99	92
CC e-p 98-99	26
NC e+p 99-00	90
CC e+p 99-00	30
DIS jets e+p 96-97	30
γp two-jets e+p 96-97	38
χ^2/data-points	470/577



NOTE: Full details of the ZEUS-JETS fit have been presented previously, see HERA-LHC PDF subgroup meeting, "Addition of jet data to the ZEUS QCD Fit", Claire Gwenlan, June 2004. Also see DESY-05-050.

from HERA/LHC workshop

Impact of jet data on the gluon PDF

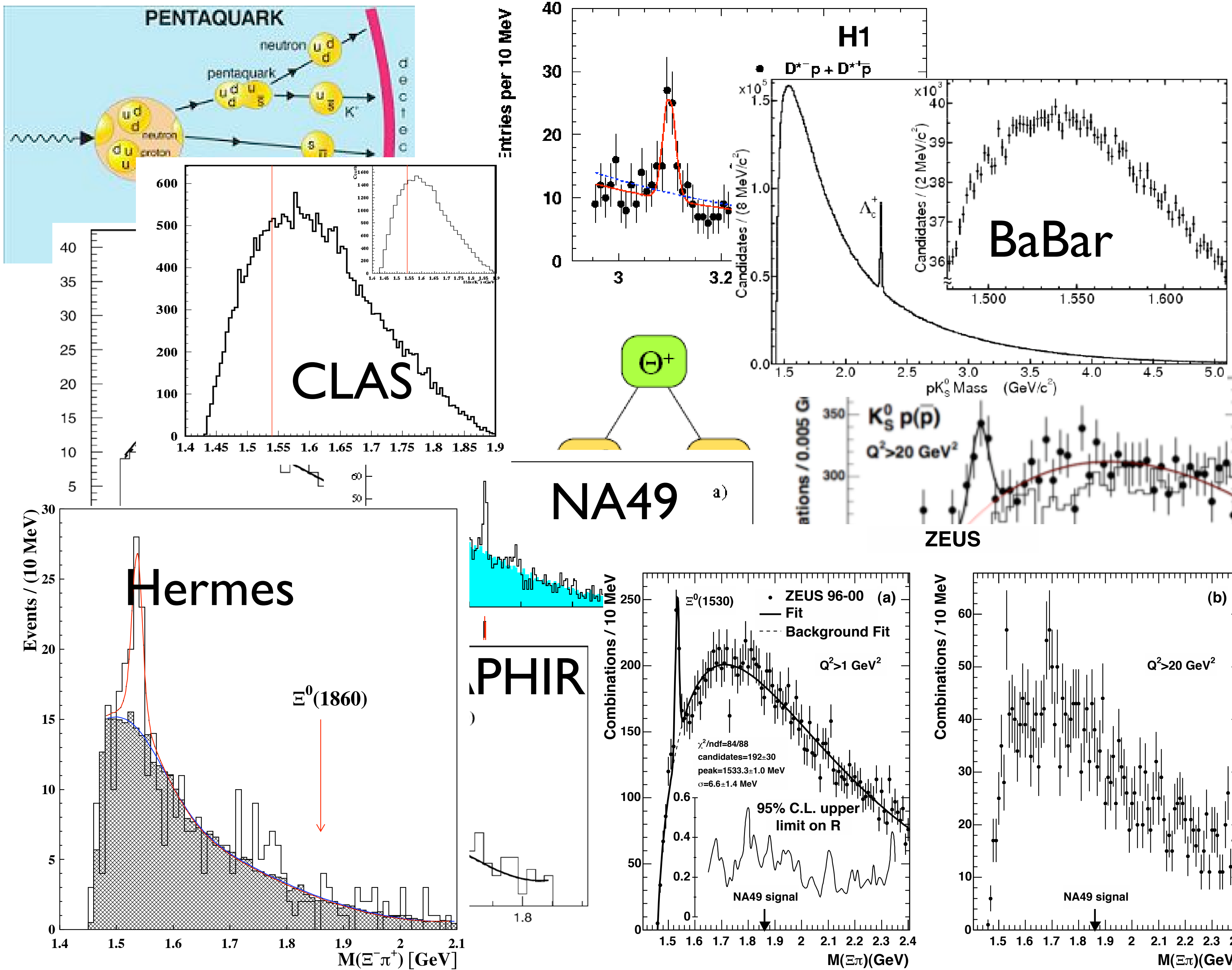


- Inclusion of jet data improves knowledge of gluon at mid-to-high-x
  -> improvement persists up to high scales

5

$\rightarrow$ Improvement of xG at $x \sim 0.01 - 0.1$

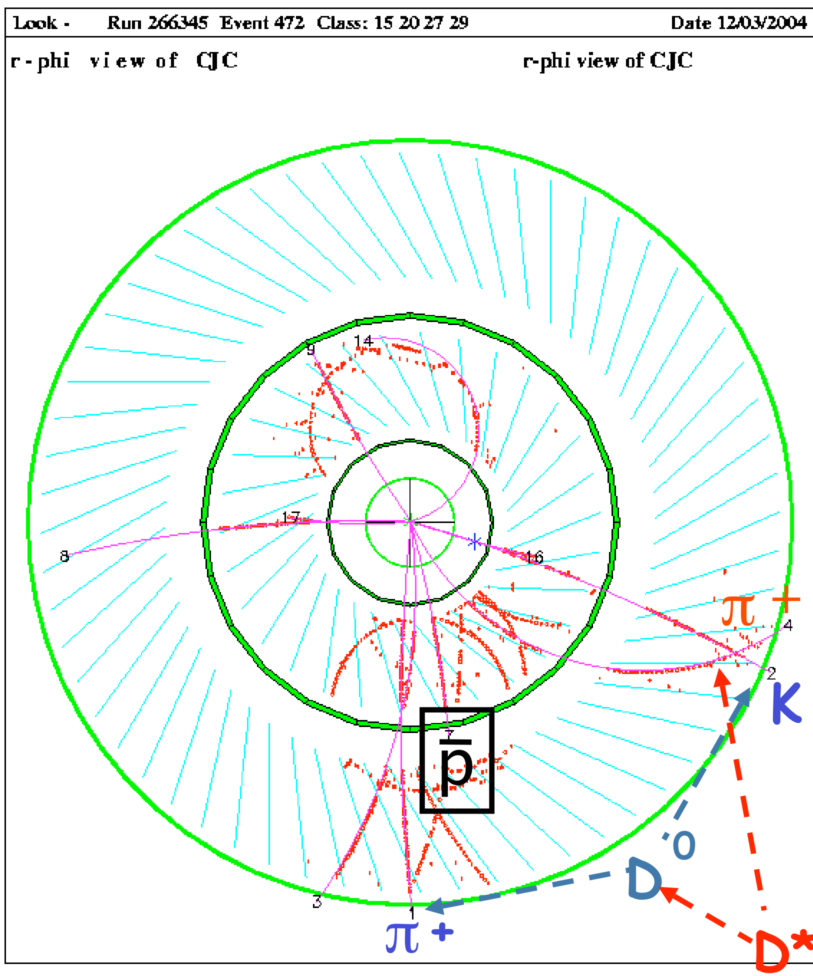
Pentaquarks

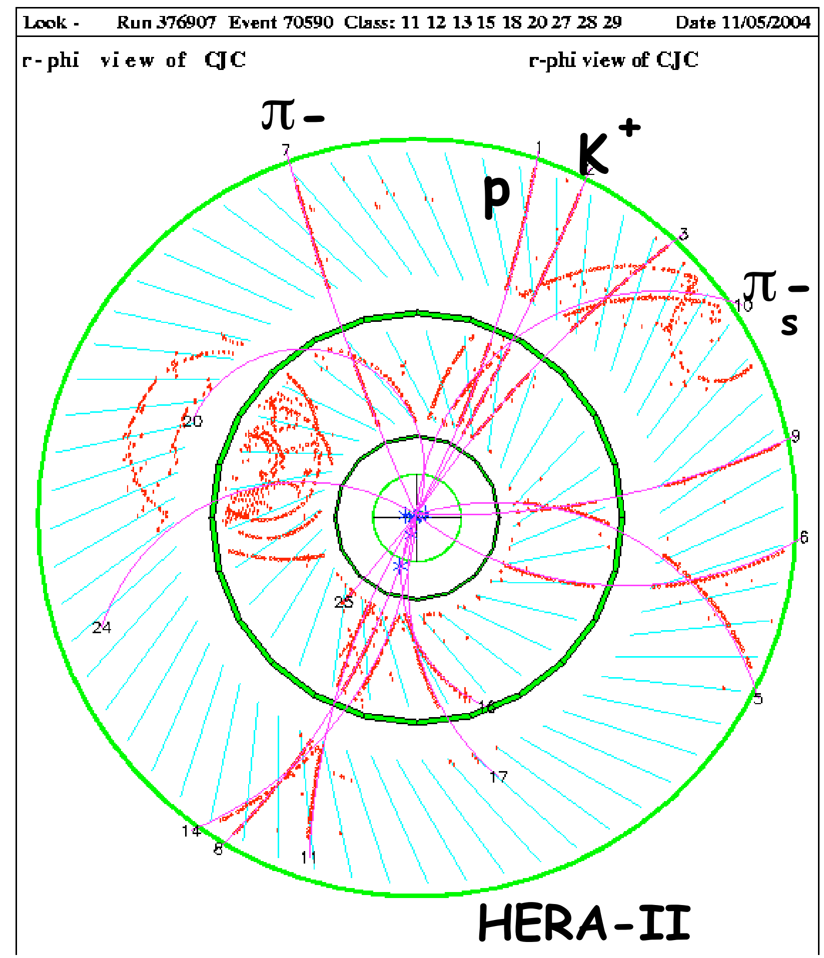

PENTAQUARK
neutron
pentaquark
proton
H1
D*⁻p + D*⁺p̄
Entries per 10 MeV
BaBar
pK^0_S Mass (GeV/c^2)
Λ_c^+
CLAS
Θ^+
NA49
a)
K^0_S p(p̄)
Q^2>20 GeV^2
ZEUS
Hermes
Events / (10 MeV)
Ξ^0(1860)
M($\Xi^-\pi^+$) [GeV]
PHIR
Ξ^0(1530)
ZEUS 96-00
Fit
Background Fit
(a)
Q^2>1 GeV^2
χ^2/ndf=84/88
candidates=192±30
peak=1533.3±1.0 MeV
σ=6.6±1.4 MeV
95% C.L. upper limit on R
NA49 signal
Combinations / 10 MeV
M(Ξπ)(GeV)
(b)
Q^2>20 GeV^2

pentaquark	quark content	seen by	not seen by
$\theta^+ \to pK^0_s$	$uudd\bar{s}$	LEPS, CLAS, ZEUS, HERMES, (13)	H1 ,e+e-, HERA-B, CDF, PHENIX, (17)
$\theta^{++} \to pK^+$	$uuud\bar{s}$	CLAS, STAR	HERMES, BaBar
$\Xi^{--} \to \Xi^- \pi^-$	$\bar{u}ddss$	NA49	HERMES, ZEUS, BaBar, (9)
$\Xi^0 \to \Xi^- \pi^+$	$ud\bar{d}ss$	NA49	HERMES, BaBar
$\theta^0_c \to D^{*-}p$	$uudd\bar{c}$	H1	ZEUS,+

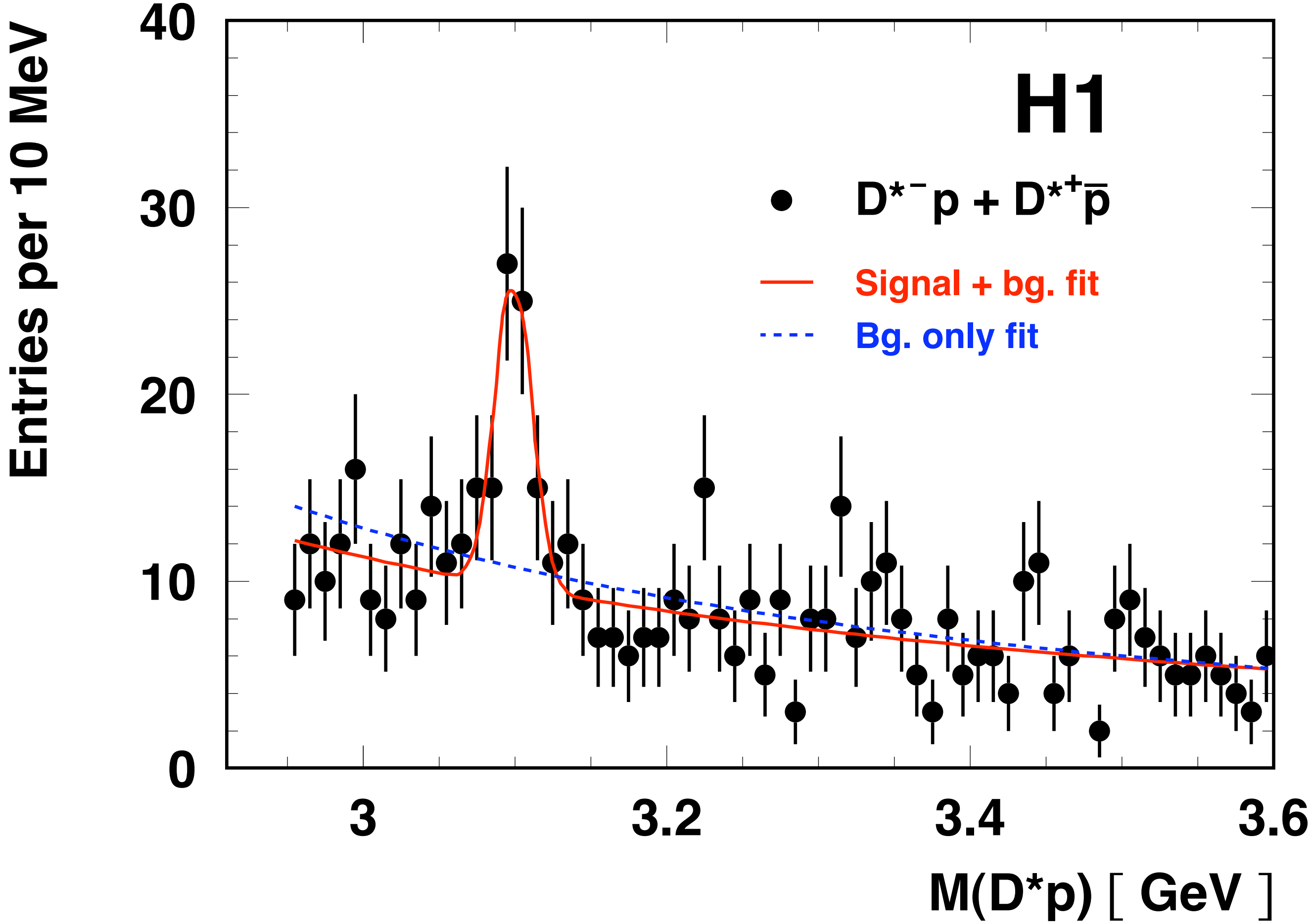
Typical D*p candidates

$\theta_c \rightarrow (D^*\bar{p}) \rightarrow D^0\pi^+_s \rightarrow K^-\pi^+\pi^+$ $\theta_c\ (D^*p) \rightarrow D^0\pi^-_s \rightarrow K^+\pi^-\pi^-$





Observation of D*p(3100) resonance @ H1



D*p(3100) = uuddc

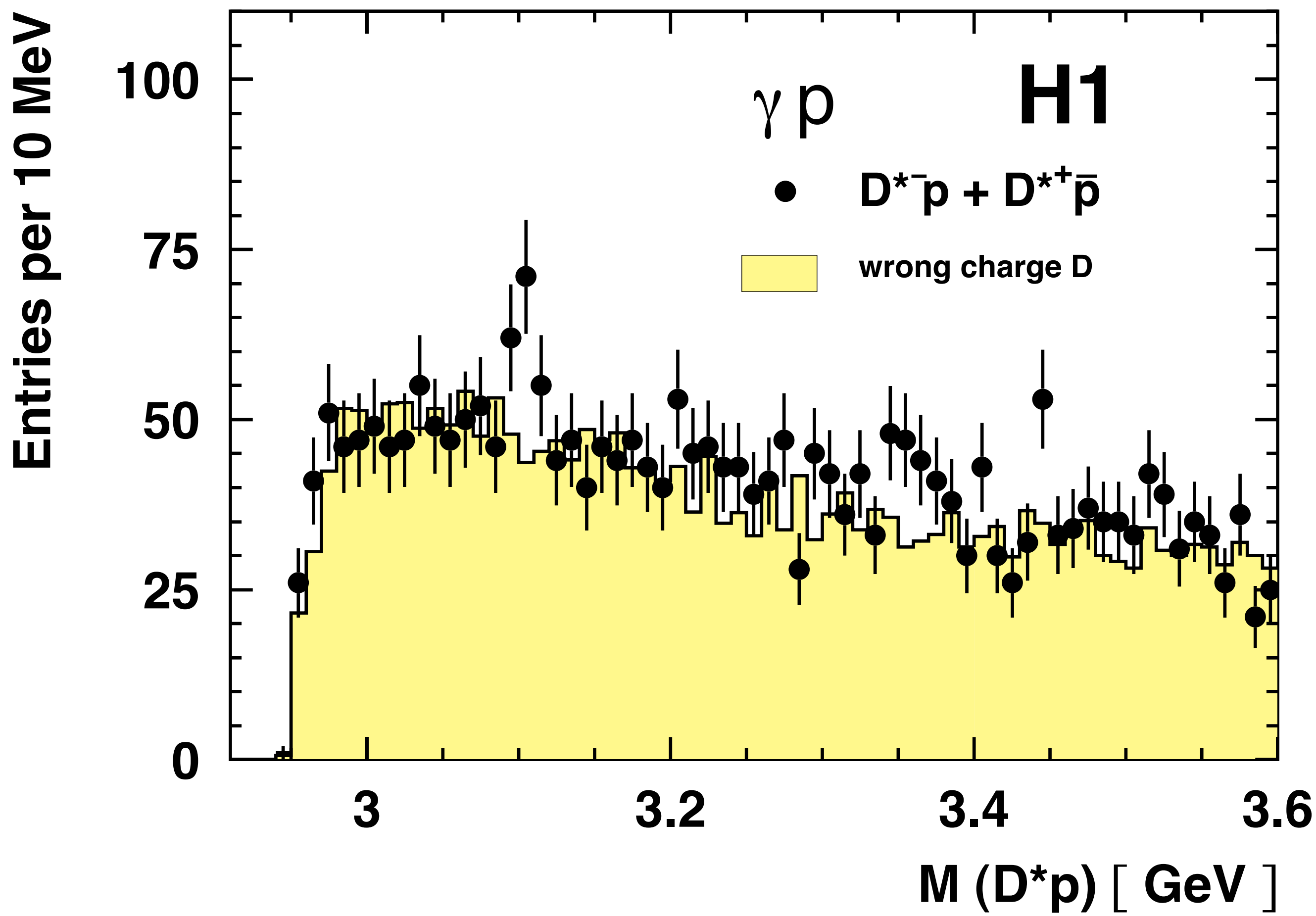
DIS

$1 < Q^2 < 100$ GeV^2

Uncorrected rate R(D*p(3100)/D*)= 1.46 ± 0.32 %

Background fluctuation probability 5.4σ

A.Atkas et al., Phys. Lett. B588(2004)17. HERA-I, 75 pb^{-1}



Also seen in independent photoproduction sample

Results of D*p(3100) Searches

H1 observation in ep → ccX

Negative results from

ALEPH e+e- → Z0 → cc
FOCUS γN → cc X
CDF pp → cc X
BELLE e+e- → ϒ(4s) → B^0B^0
ZEUS ep → cc X

Different physics processes investigated (except ZEUS)
Detailed analysis of D*p(3100) from H1 needed

Acceptance corrected $R_{cor}(D^*p(3100)/D^*)$

Kinematic region: $1 < Q^2 < 100\ GeV^2$ & $0.05 < y < 0.7$

pseudo-rapidity $\eta = -\log(\tan(\Theta/2))$
D*-inelasticity $z = (P \cdot pD^*)/(P \cdot q)$

$$R_{cor}(D^*p(3100)/D^*) = 1.59 \pm 0.33\%^{+0.33}_{-0.45}\%$$

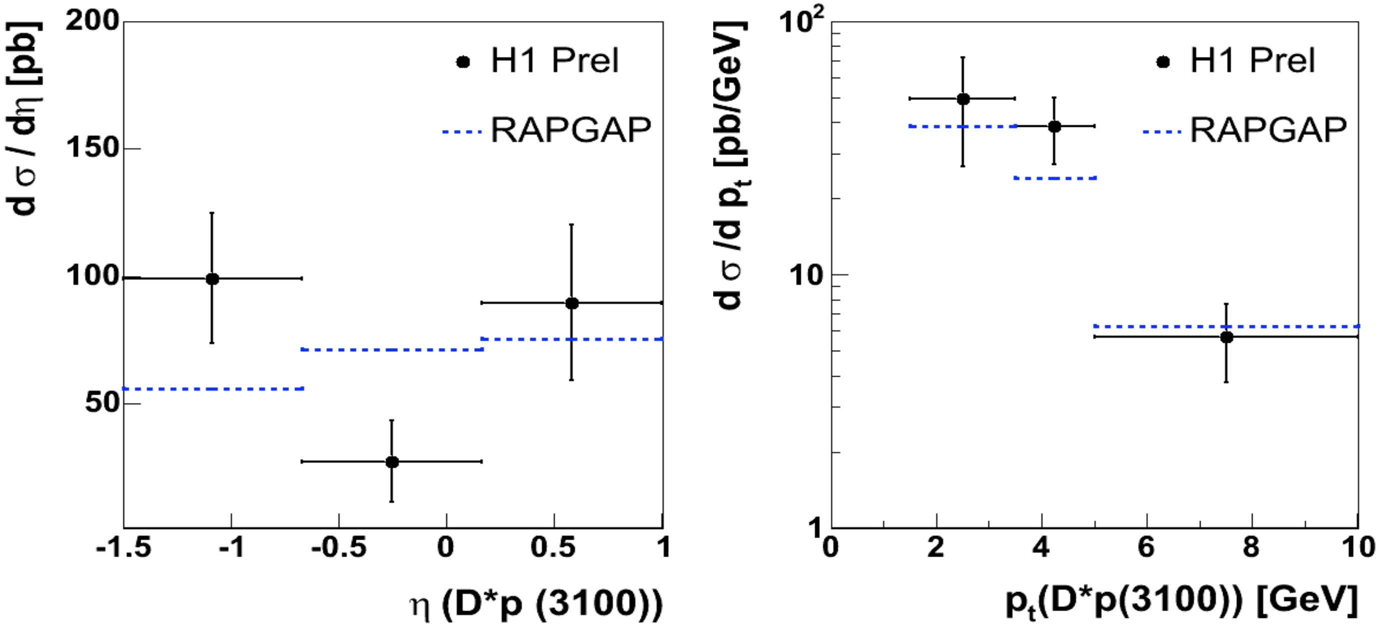
In the visible D* range as given in our publication:
Visible D*p range: Pt(D*p)>1.5 GeV, $-1.5<\eta(D^*p)<1$
Visible D* range: Pt(D*)>1.5 GeV, $-1.5<\eta(D^*)<1$, z(D*)>0.2

$$\sigma(D^*p(3100))/\sigma(D^*) = 2.48 \pm 0.52\%^{+0.85}_{-0.64}\%$$

Extrapolated to the full D* phase space in D*p(3100) decay:
Visible D*p/D* range: Pt>1.5 GeV, $-1.5<\eta<1$

σ(D*p(3100)) for D*p observables

Statistical errors only



D*p(3100) production is:

Suppressed for central η in the lab.

MC approach in reasonable agreement with p_t- and z-distributions of D*p(3100)

pentaquark	quark content	seen by	not seen by
$\theta^+ \rightarrow pK_s^0$	$uudd\bar{s}$	LEPS, CLAS, ZEUS, HERMES, (13)	H1 ,e+e-, HERA-B, CDF, PHENIX, (17)
$\theta^{++} \rightarrow pK^+$	$uuud\bar{s}$	CLAS, STAR	HERMES, BaBar
$\Xi^{--} \rightarrow \Xi^- \pi^-$	$\bar{u}ddss$	NA49	HERMES, ZEUS, BaBar, (9)
$\Xi^0 \rightarrow \Xi^- \pi^+$	$ud\bar{d}ss$	NA49	HERMES, BaBar
$\theta_c^0 \rightarrow D^{*-}p$	$uudd\bar{c}$	H1	ZEUS,+

K0 Reconstruction

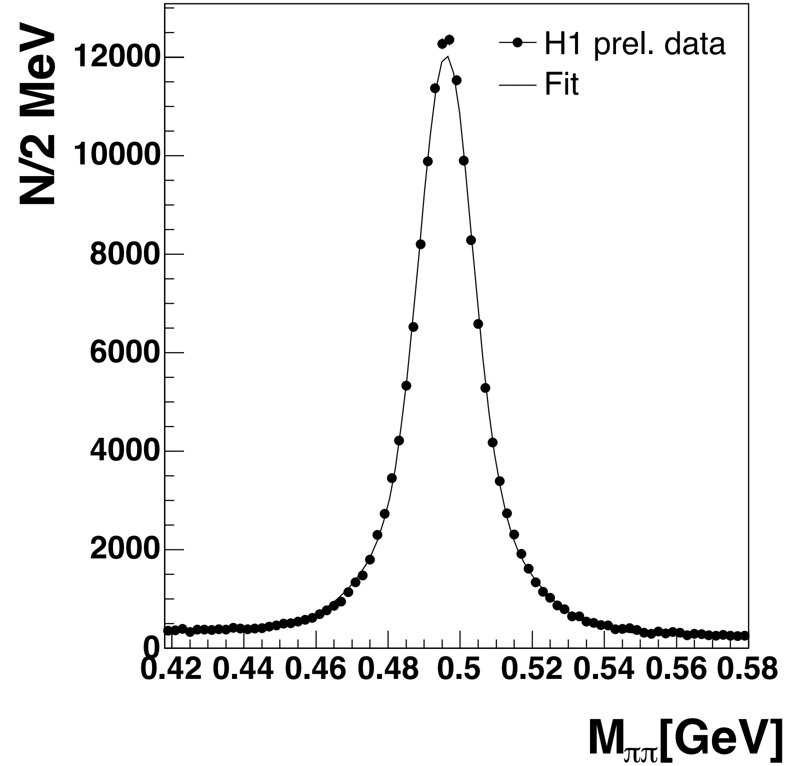
$K^0_s \to \pi^+\pi^-$

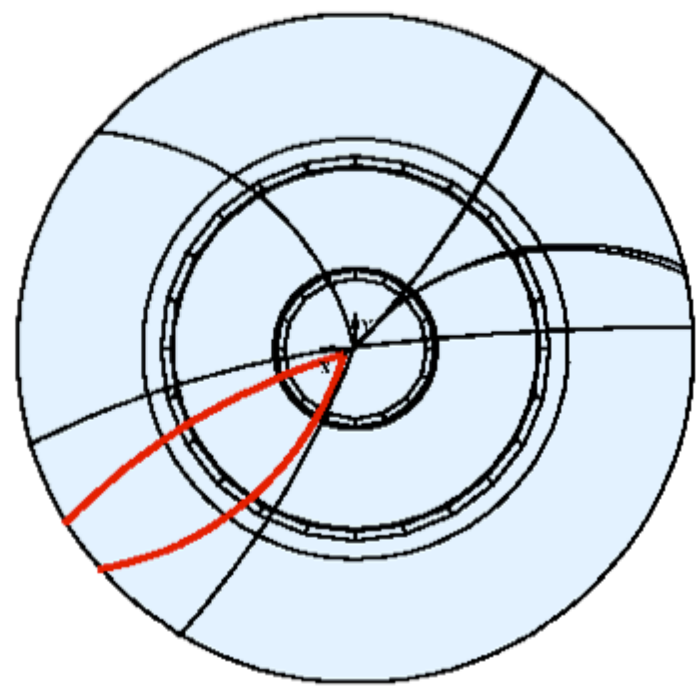
K0s selection

secondary vertices : combinations of oppositely charged tracks

pt>0.3 GeV, |η|<1.5

$K^0_s \approx 140,000$



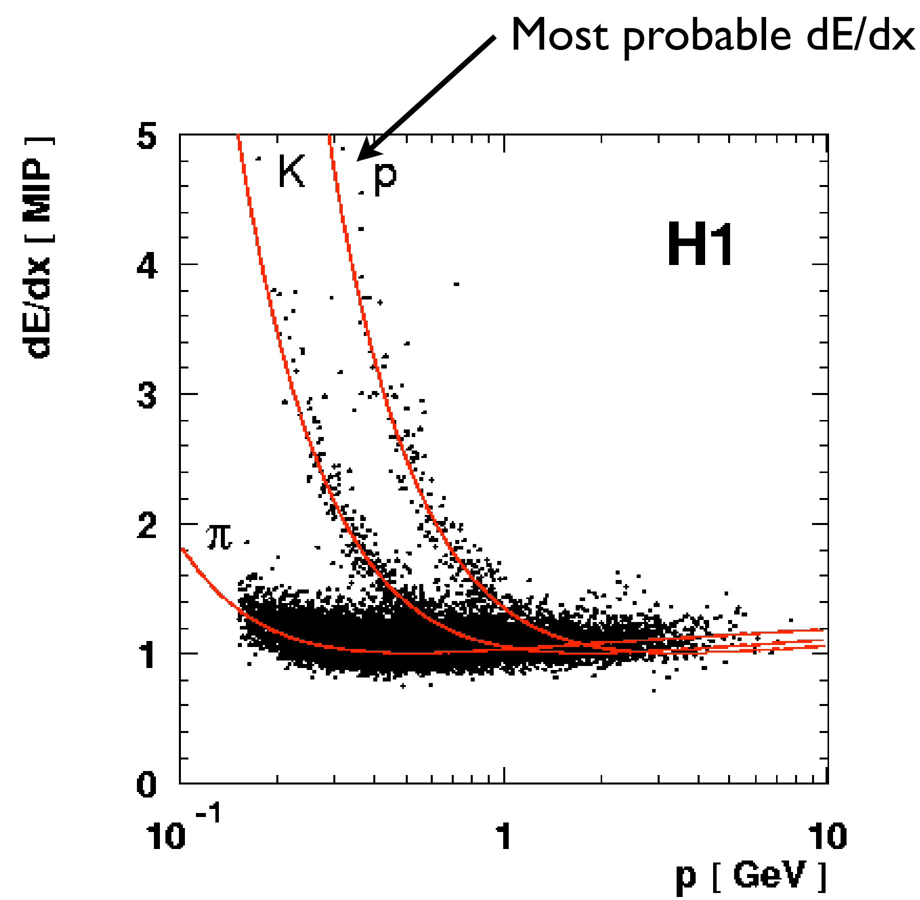


Proton selection via dE/dx

Most likely dE/dx from Bethe Bloch parameterisation

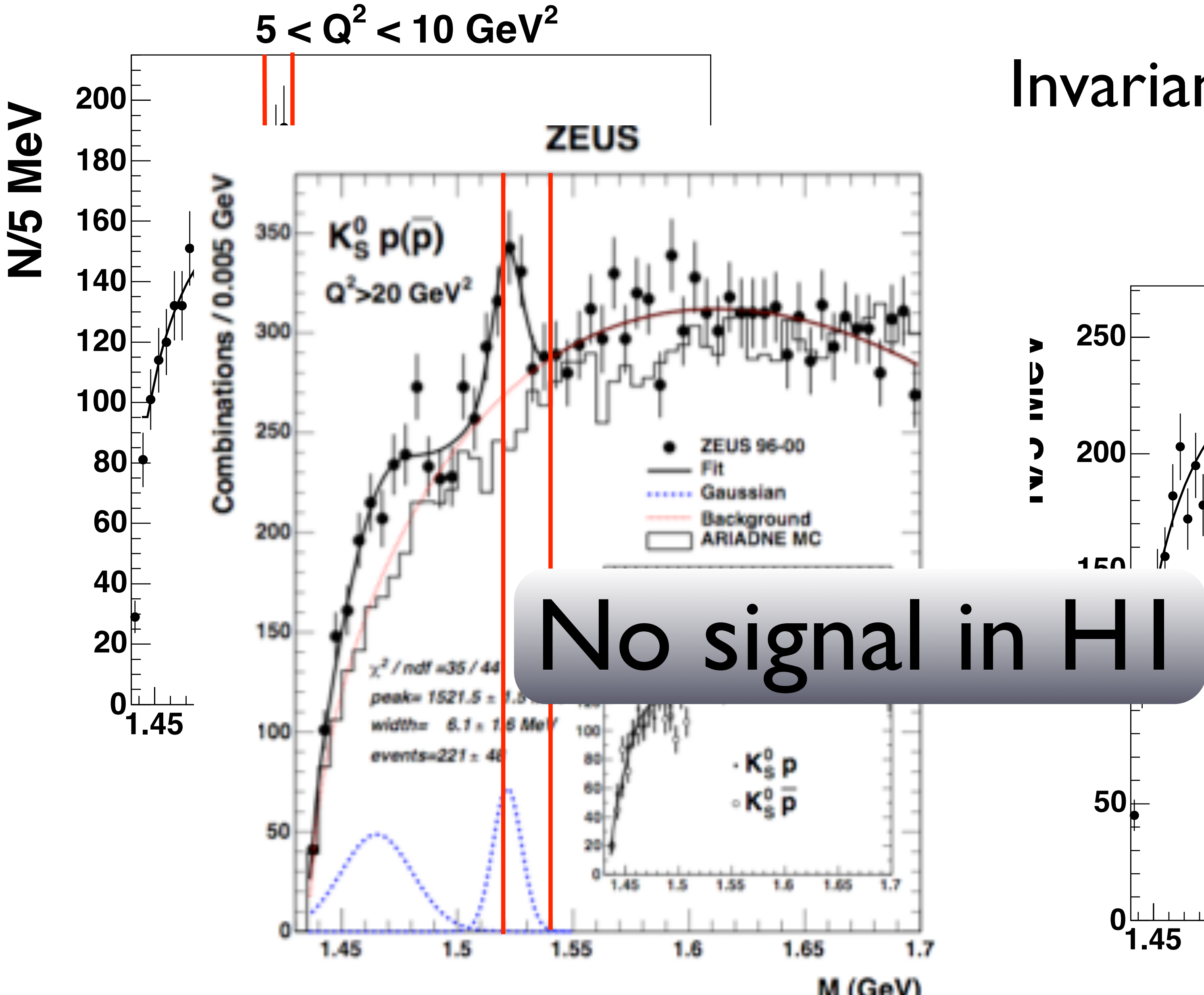
Use likelihoods for separation of protons

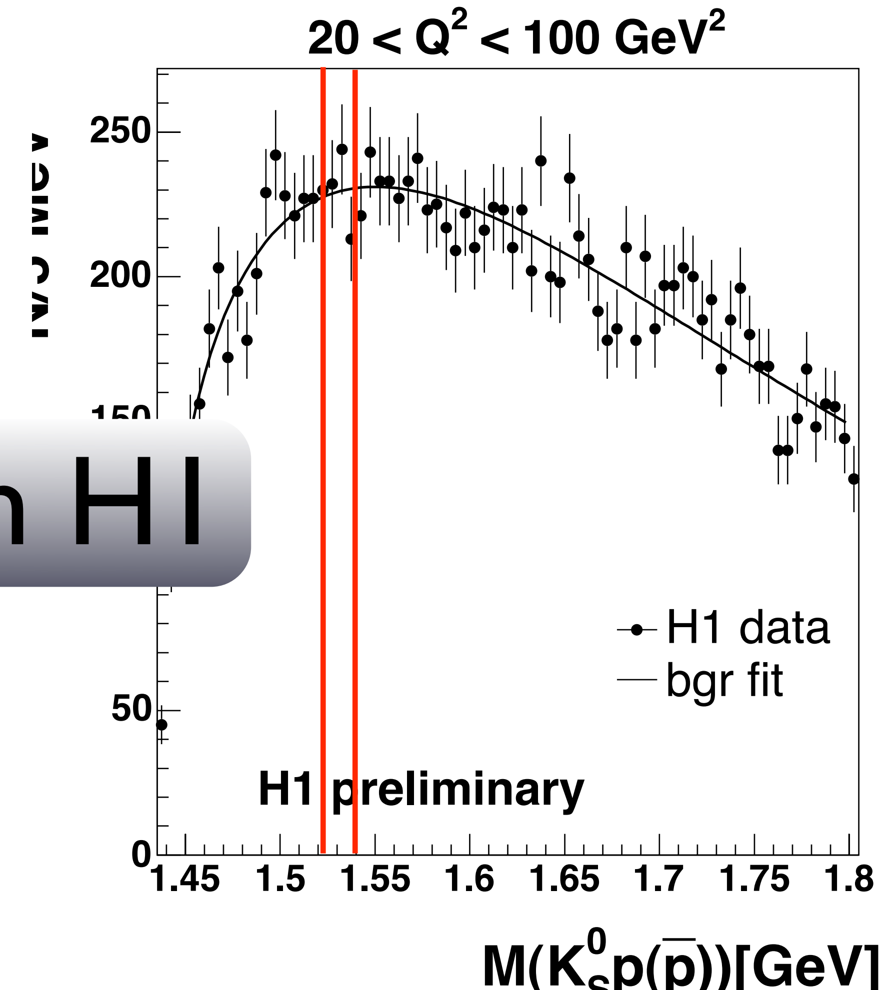
Average proton selection efficiency ~90%



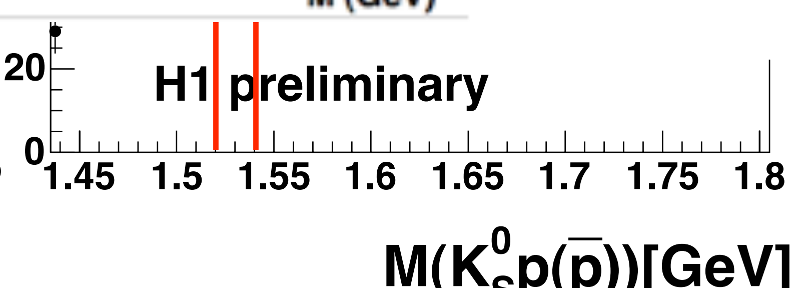
π-suppression probability 86%, 96% at low momenta (p<1.5 GeV)

Invariant $K^0_s\, p(\bar{p})$ mass





No signal in H1

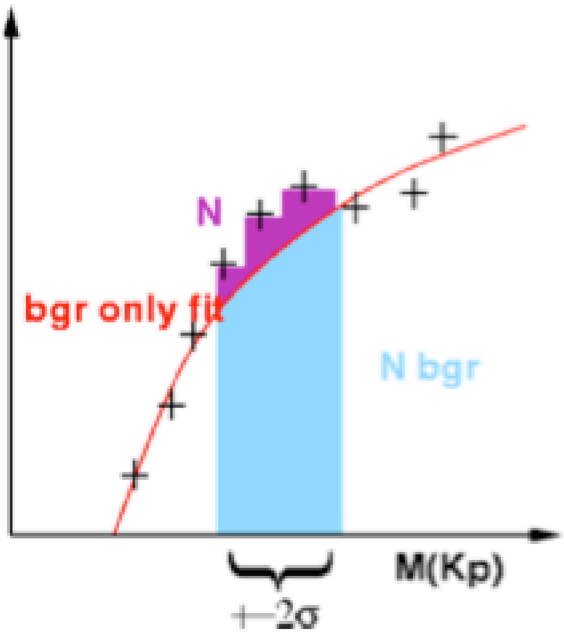


Visible range:

$p_t(K^0_s p) > 0.5$ GeV,

$|\eta(K^0_s p)| < 1.5$

Extracting Upper Limits on θ+ production



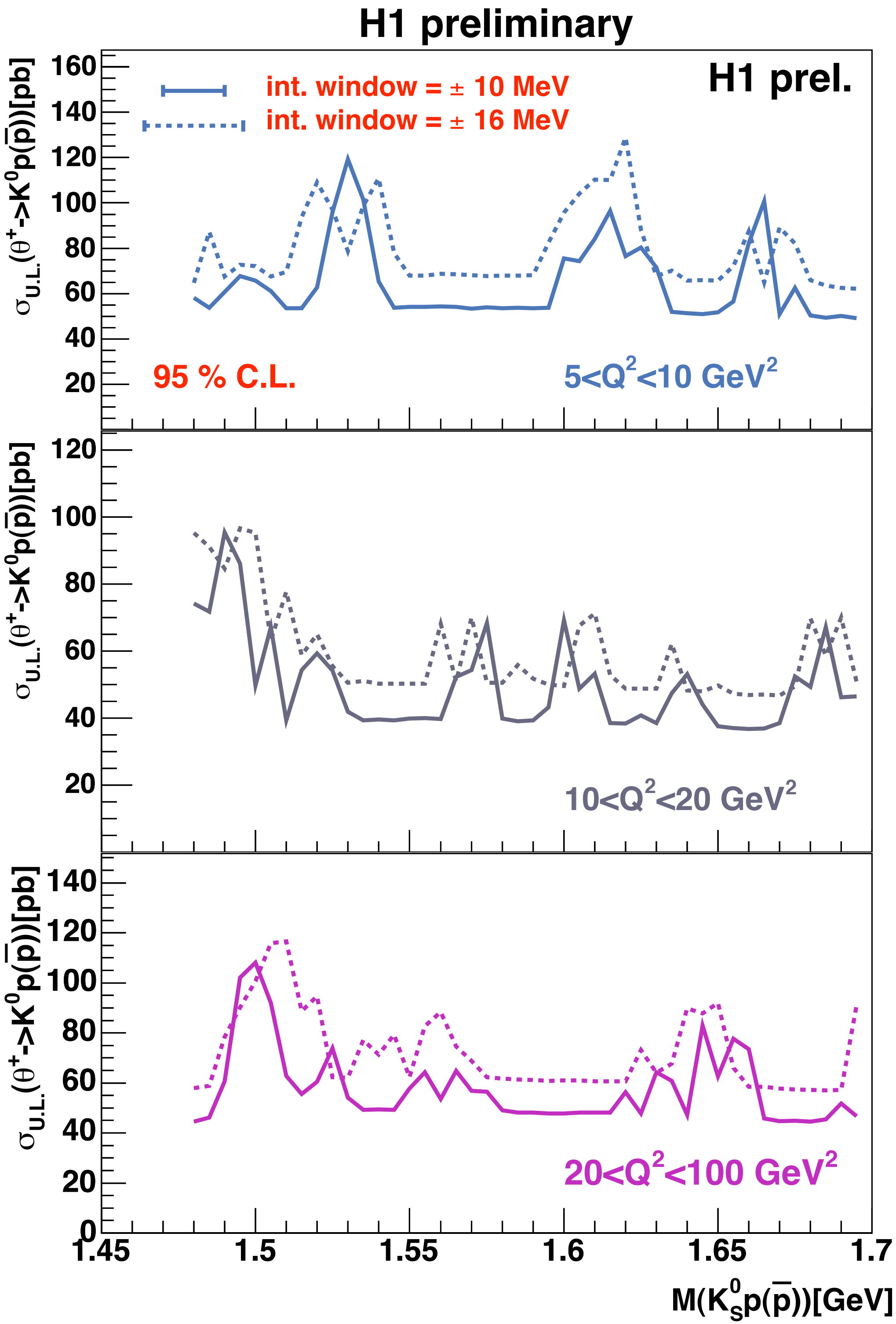
- fit background
- background subtraction in integration window
  M ± 10 MeV, ±16 MeV
  corr. to 2σ assuming a resolution of 5(8) MeV
- scan M in the range 1.48 to 1.7 GeV
- upper limit on N(θ+) (95% C.L.)

$$\sigma_{U.L.}(\theta+ \to K^0\ p) = \frac{N_{u.l.}(\theta+ \to K^0_s\ p)}{BR * \varepsilon * L}$$

- $BR(K^0_s \to \pi^+ \pi^-) * BR(K^0 \to K^0_s) = 0.343$
- $L = 75\ pb^{-1}$

Signal Monte Carlo

- RAPGAP 3.1
  change decay properties of Σ^*
  to M=1.52(1.54), σ=0
- detector resolution ~ 5MeV
- acceptance $\varepsilon \approx 5\ \%$



H1 preliminary
H1 prel.
int. window = ± 10 MeV
int. window = ± 16 MeV
95 % C.L.
5<Q²<10 GeV²
10<Q²<20 GeV²
20<Q²<100 GeV²
σU.L.(θ+->K0p(p̄))[pb]
M(K0Sp(p̄))[GeV]

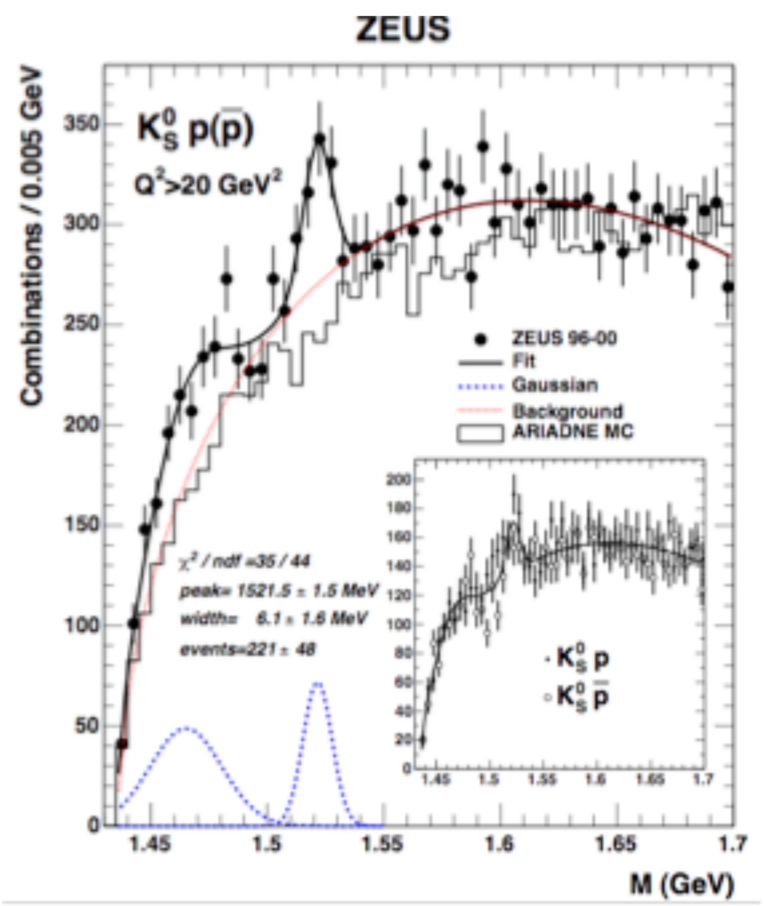
Zeus observation:
$Q^2>20$ GeV^2, $0.04<y<0.95$, $p_t>0.5$, $|\eta|<1.5$

Statistical significance ~ 4.6 σ

Mass = $1521.5 \pm 1.5^{+2.8}_{-1.7}$ MeV

Width = 6.1 ± 1.5 MeV
(exp res 2MeV)

$\sigma(ep \to eK^0pX) = 125 \pm 27^{+36}_{-28}$ pb
(preliminary)

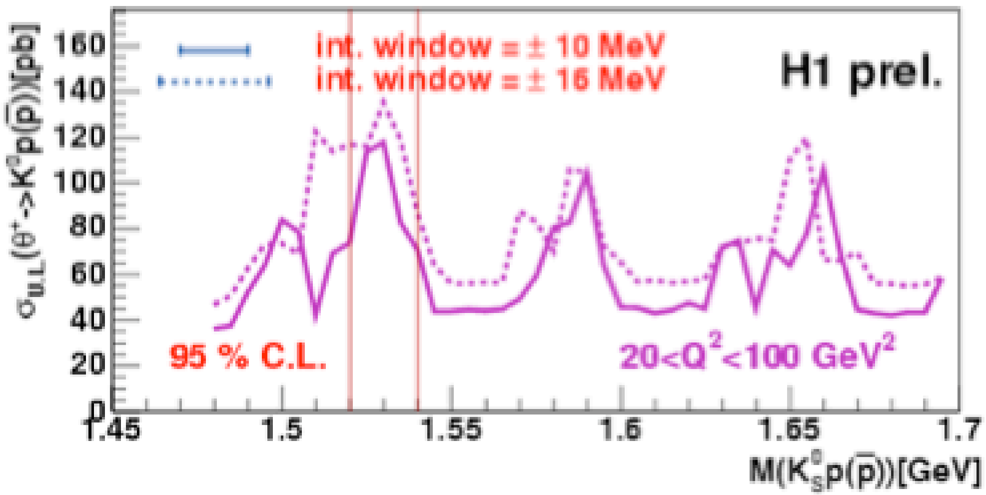


There are differences in the analysis
particle ID, phase space etc...

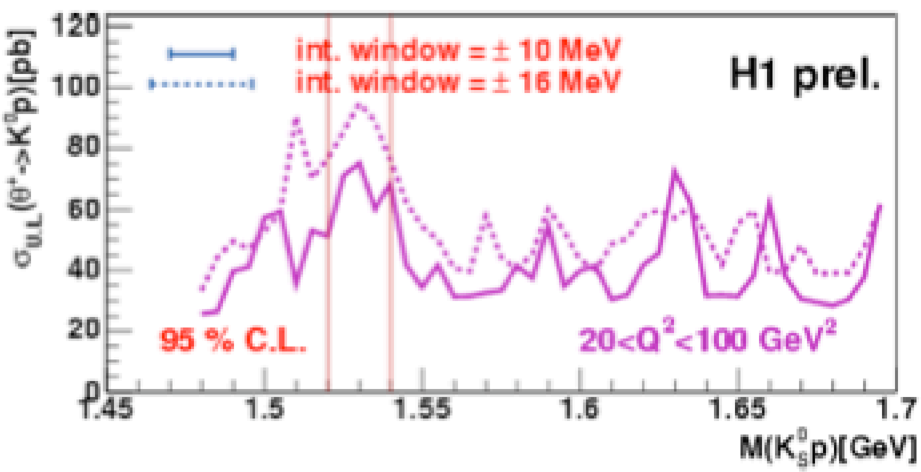
Upper Limit (95%C.L.) on $\sigma(ep \to e\theta X \to e\, K^0 p(\bar{p})X)$: low p selection

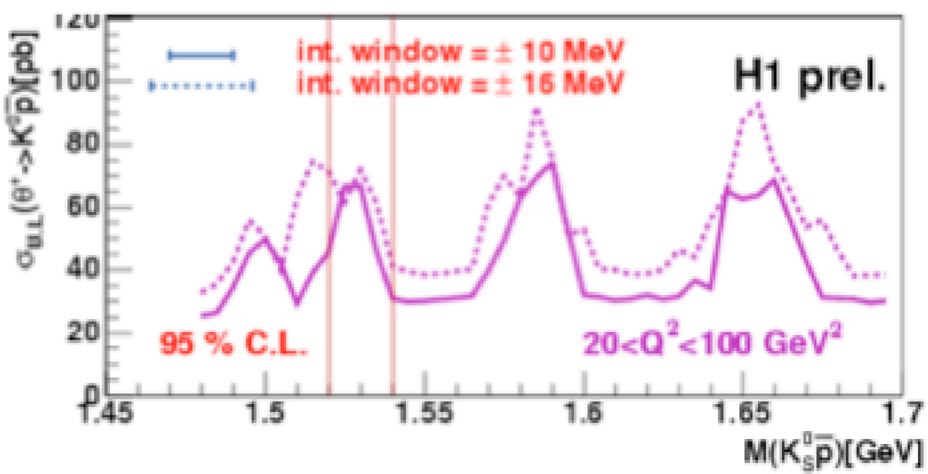
low-momentum dE/dx selection
$20<Q^2<100$ GeV^2
$0.1 < y < 0.6$

M=1.52 GeV $\sigma_{U.L.}\sim 100$ pb



H1 limits not in contradiction with ZEUS





Summary

- HERAII upgrade a success
- Competitive measure of α_s from 2/3 jet ratio
- Charm pentaquark better understood
- NO strange pentaquark seen in H1
- In all cases more data needed $\rightarrow$HERAII

Backup