Jets and α_s in DIS

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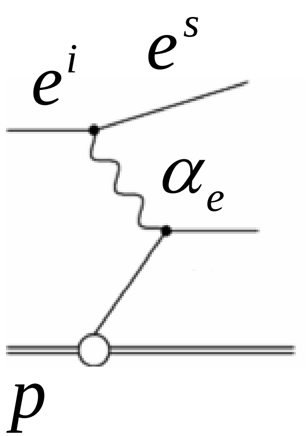
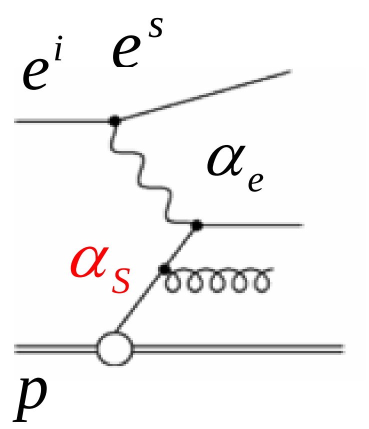
- Motivation
- Jet Cross Sections
- α_s extraction

On behalf of the H1 collaboration

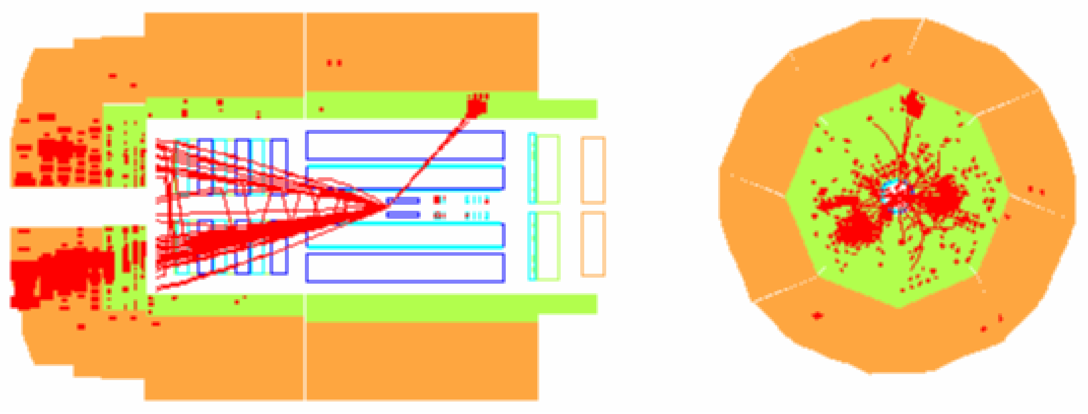
JETS IN DIS AT HERA

- HERA is an electron (positron) – proton collider
- High P_T multi jet production sensitive to pQCD parameters: α_S but also to proton PDF





JET CROSS SECTIONS

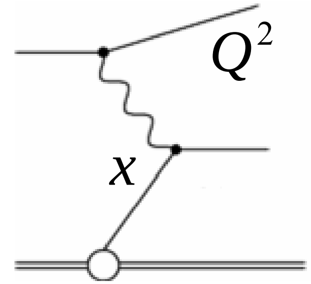


ANALYSIS PHASE-SPACE

ÉCOLE POLYTECHNIQUE

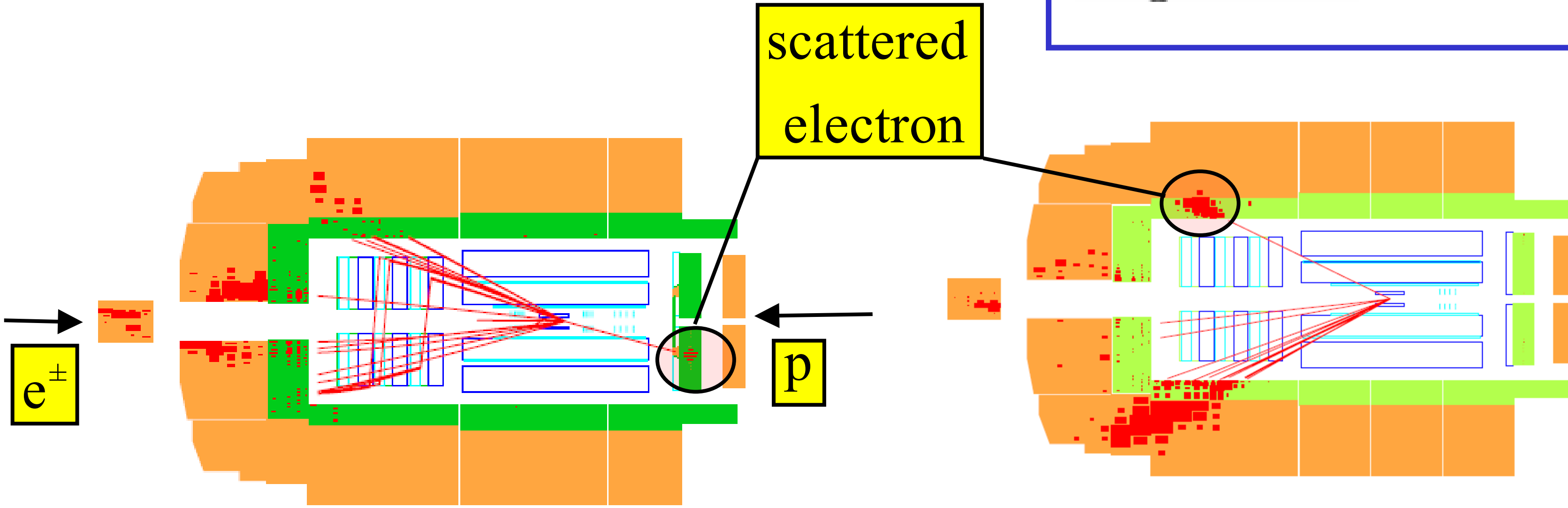
Event sample:

- High Q2: HERA I+II - 395.0 pb^{-1}
- Low Q2: HERA I – 43.5 pb^{-1}



$\sqrt{s} = 319$ GeV

$Q^2 = xys$



Low Q^2

$5 < Q^2 < 100$ GeV2

$0.2 < y < 0.7$

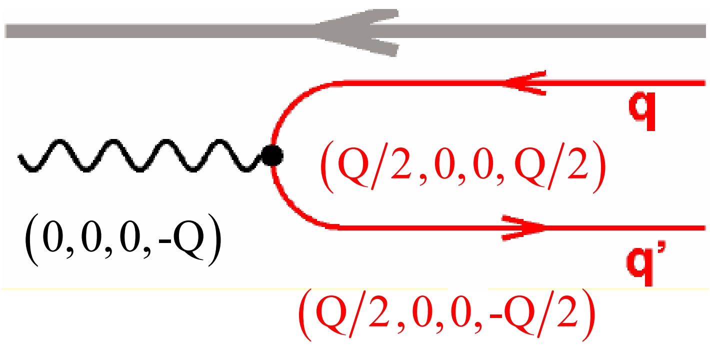
High Q^2

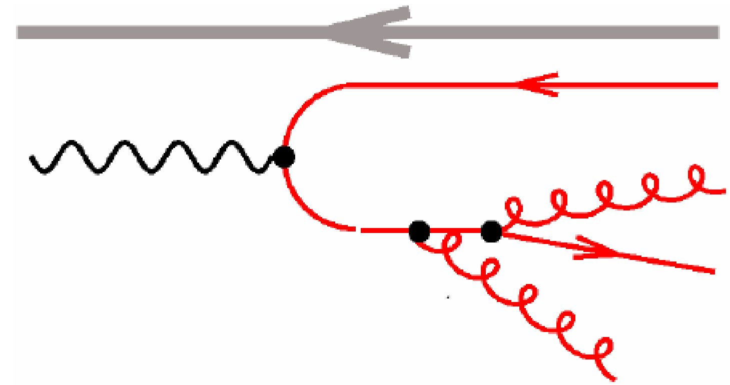
$150 < Q^2 < 15000$ GeV2

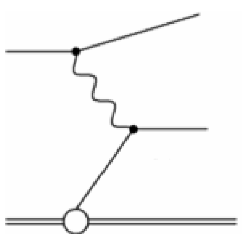
$0.2 < y < 0.7$

JET RECONSTRUCTION

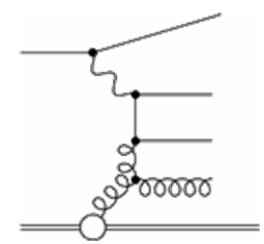
Jets are reconstructed with longitudinally invariant kT algorithm with a P_T recombination scheme (massless jets). It is collinear, infrared safe and factorisable.







- <u>On tree level</u> : quark backscattered with no E_T
- <u>At $O(\alpha_S)$</u> : 2 hard QCD jet with significant E_T well separated from the proton remnant



JET OBSERVABLES

Inclusive jets: Individual jet counting for all events.
Hypothesis: Independent Individual parton emission.

Low Q^2

$E_T > 5\,\mathrm{GeV}$

$-1.0 < \eta^{Lab} < 2.5$

High Q^2

$E_T > 7\,\mathrm{GeV}$

$-0.8 < \eta^{Lab} < 2.0$

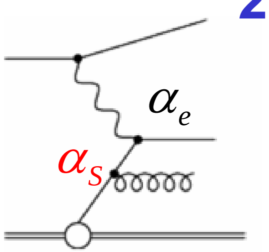
Multi-jets: Event counting with more than *n* jets. Sensitive to α_S^{n-1}.

$E_T > 5\,\mathrm{GeV}$

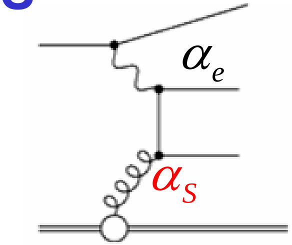
$-0.8 < \eta^{Lab} < 2.0$

$M_{12} > 16\,\mathrm{GeV}$

2-JETS

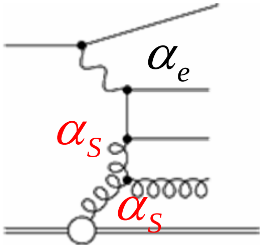


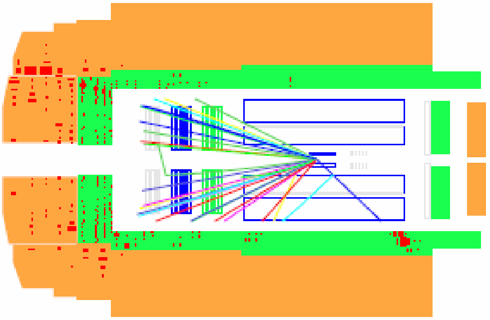
Boson Gluon Fusion

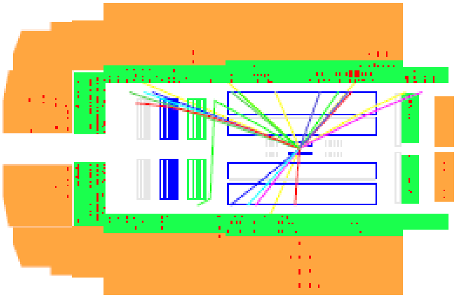


QCD Compton

3-JETS







MEASUREMENT OF THE CROSS SECTIONS

Low Q^2

$$\sigma_{Incl.\,jets} = f\left(Q^2, E_T^{Breit}\right)$$

High Q^2

Jet multiplicity

$$\frac{\sigma_{Incl.\,jets}}{\sigma_{NC}} = f\left(Q^2, E_T^{Breit}\right)$$

Multi-jet rates

$$\frac{\sigma_{2\,jets}}{\sigma_{NC}} = f\left(Q^2, E_T^{Breit}\right) \qquad \frac{\sigma_{3\,jet}}{\sigma_{NC}} = f\left(Q^2\right)$$

DATA CORRECTION

- **Acceptance correction**: < 20 % bin by bin acceptance with DJANGO-CDM and RAPGAP-MEPS
- **QED radiative correction**: 5-10 % with HERACLES
- **Z exchange**: significant at High Q^2 with LEPTO

Normalized cross sections at high Q^2 ⇒

- Normalization errors – cancel completely
- Correlated errors – cancel partially

NLO CALCULATIONS

NLO CALCULATIONS

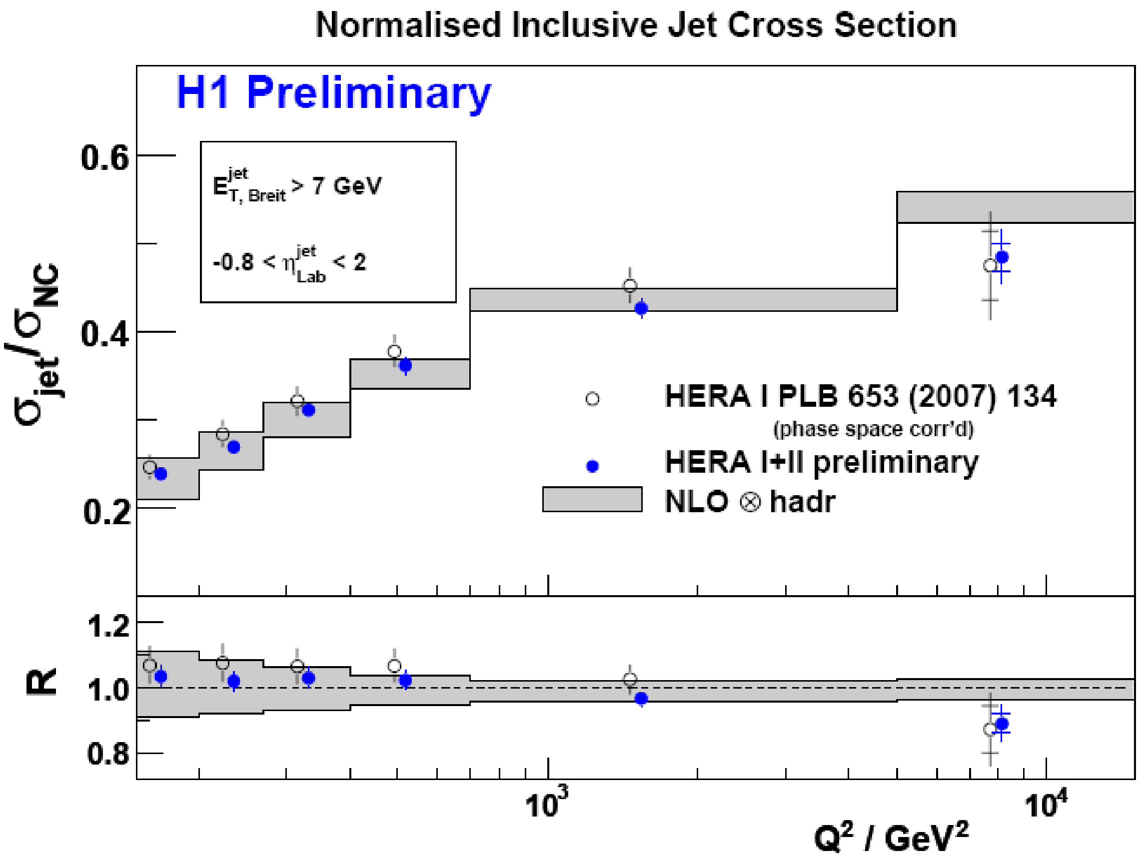
- **NLOJET++**: Integration of pQCD at NLO matrix element for jets
- **DISENT**: DIS NC cross section at NLO
- **FastNLO**: Interface for a fast PDF convolution and α_S running
- **Hadronisation Corrections**: DJANGO and RAPGAP (JETSET – Lund String fragmentation). Cross checked with HERWIG (Cluster model).

THEORETICAL UNCERTAINTIES:

- Scales (μ_R and μ_F) : estimated conventionally by variation by factors 0.5 and 2.
- PDF parameterization : dependence estimated with CTEQ65M

Observable	μ_R	μ_F	PDF	α_S
Inclusive jets	$\sqrt{Q^2+E_T^2}/2$	Q	CTEQ65M	0.118
2-, 3-jets	Q			

JET MULTIPLICITIES*



- Statistics: 6 times more data

Dominant at High Q^2 or E_T

- Hadronic energy scale:

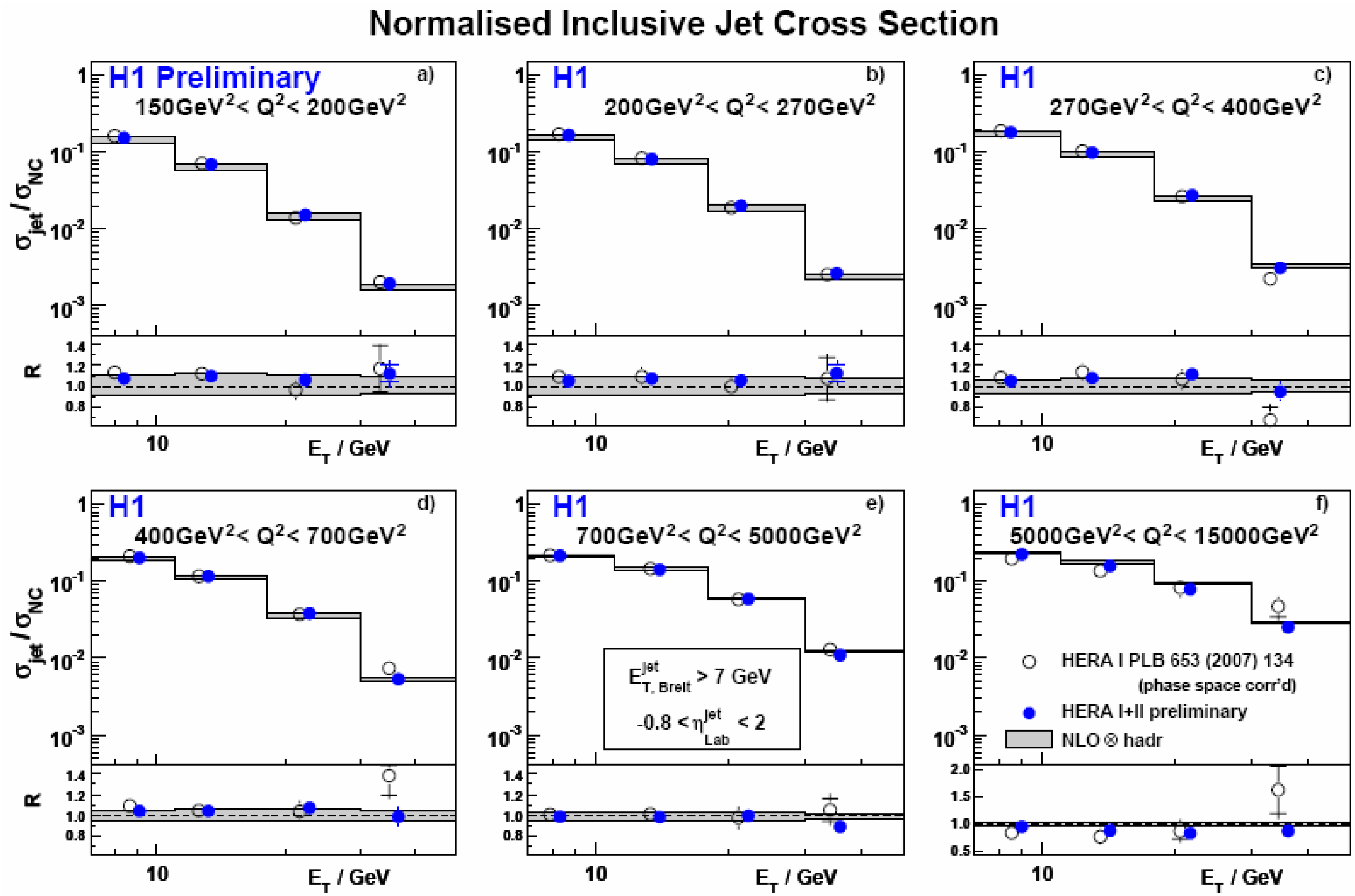
$2 \rightarrow 1.5\%$

1-3% effect on cross sections

- Accurate measurement (~3 %) well described by NLO QCD prediction
- Significant errors improvement in HERA I-II analysis compared to HERA I published

* Normalized inclusive jet cross section with HERA II data preliminary for EPS 07 conference

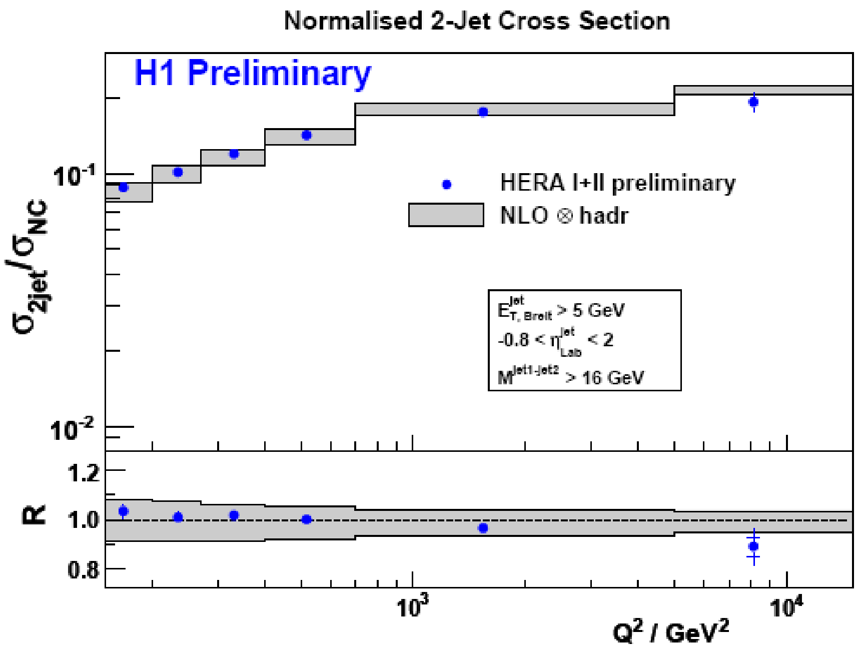
INCLUSIVE JET MULTIPLICITIES*

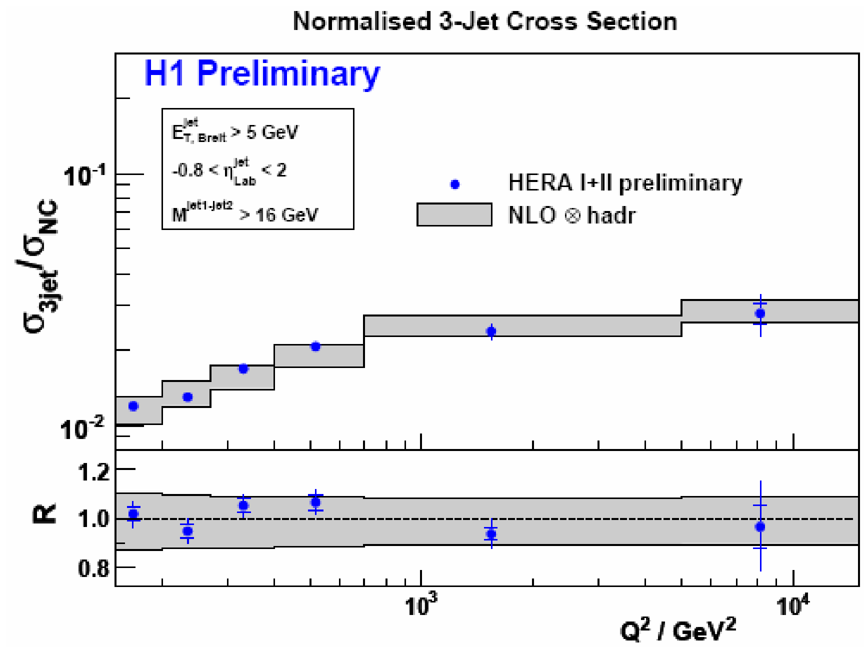


- Accurate measurement (2-6 %) well descibed by NLO QCD prediction over the overall available phase space.
- Experimental uncertainty smaller than the theoretical (5-10 %).

* HERA II normalized inclusive jets with HERA II data preliminary for EPS 07 conference

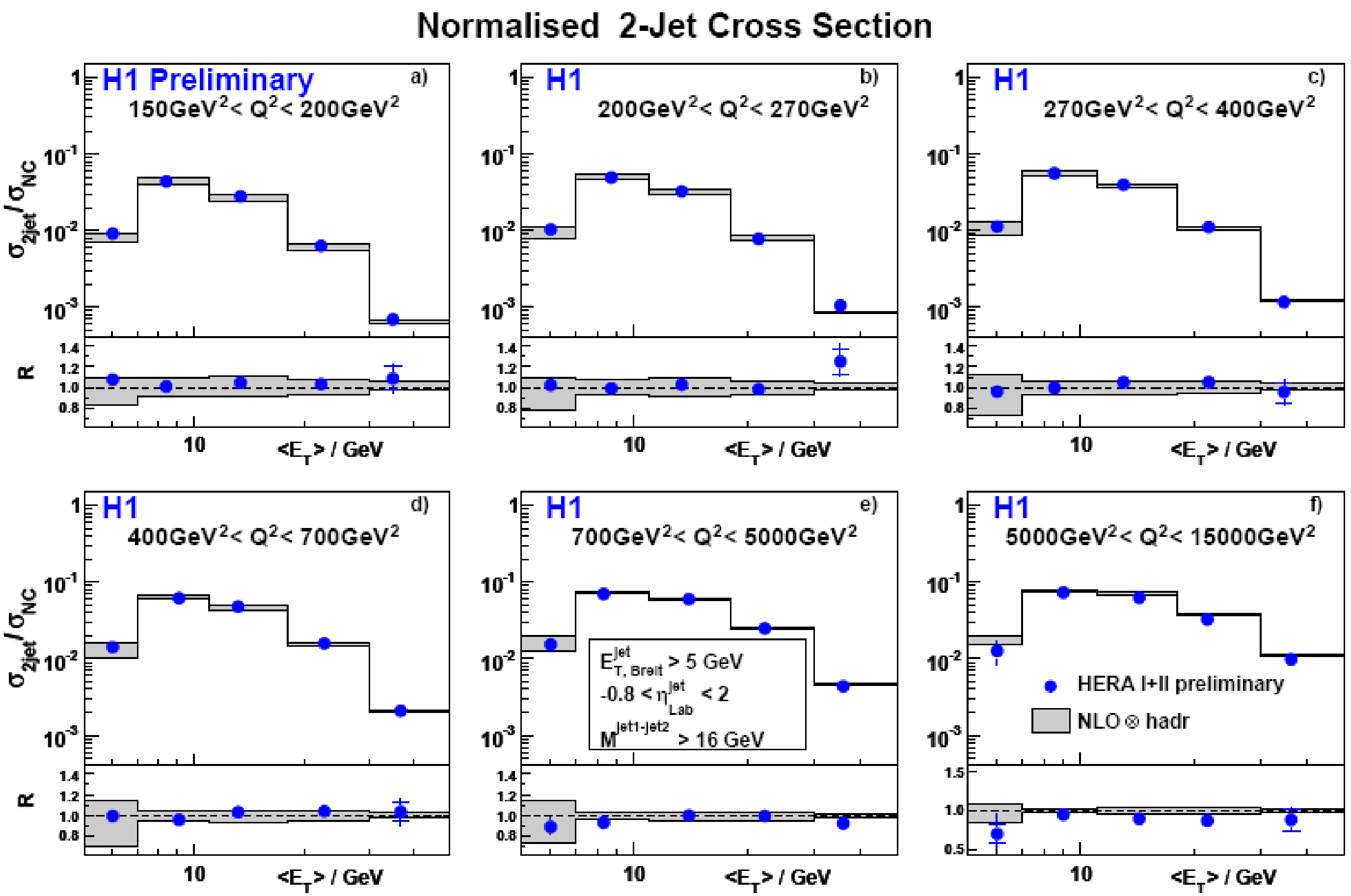
MULTI-JET RATES





- Accurate measurement well described by NLO QCD prediction.
- 3-jets rates dominated by statistical errors and model dependence, but still more precise than NLO QCD prediction

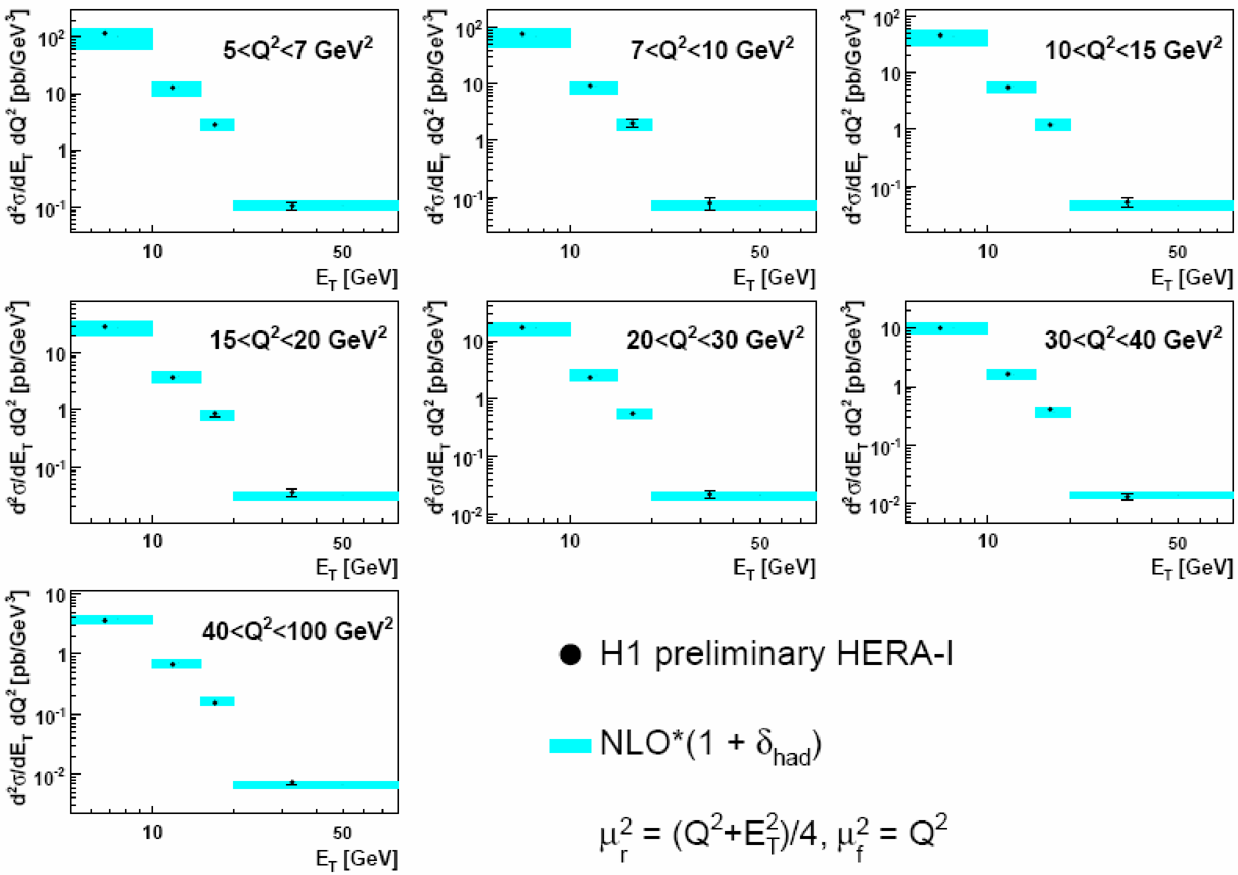
2-JET RATES



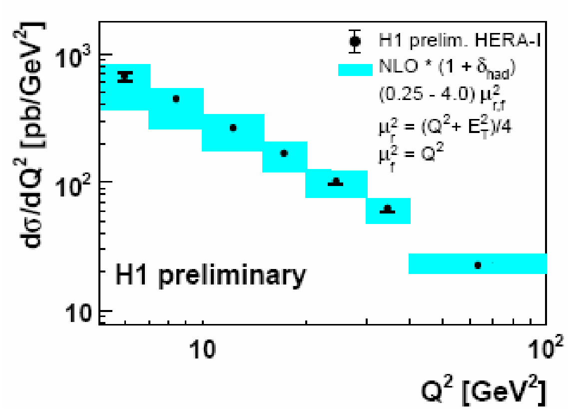
- Similar behaviour and quality of description than for inclusive jets: this observables are similar and correlated.
- Lower $<E_T>$ bin is strongly suppressed by M_{12} cut.

LOW Q^2 INCLUSIVE JET PRODUCTION*

H1 Inclusive Jet Cross Sections $\frac{d^2\sigma}{dQ^2 dE_T}$



Inclusive Jet Cross Sections $\frac{d\sigma}{dQ^2}$



Accurate measurement (5-10 %) well described by QCD NLO (theory calculated with CTEQ6). Small predictive power of NLO calculations.

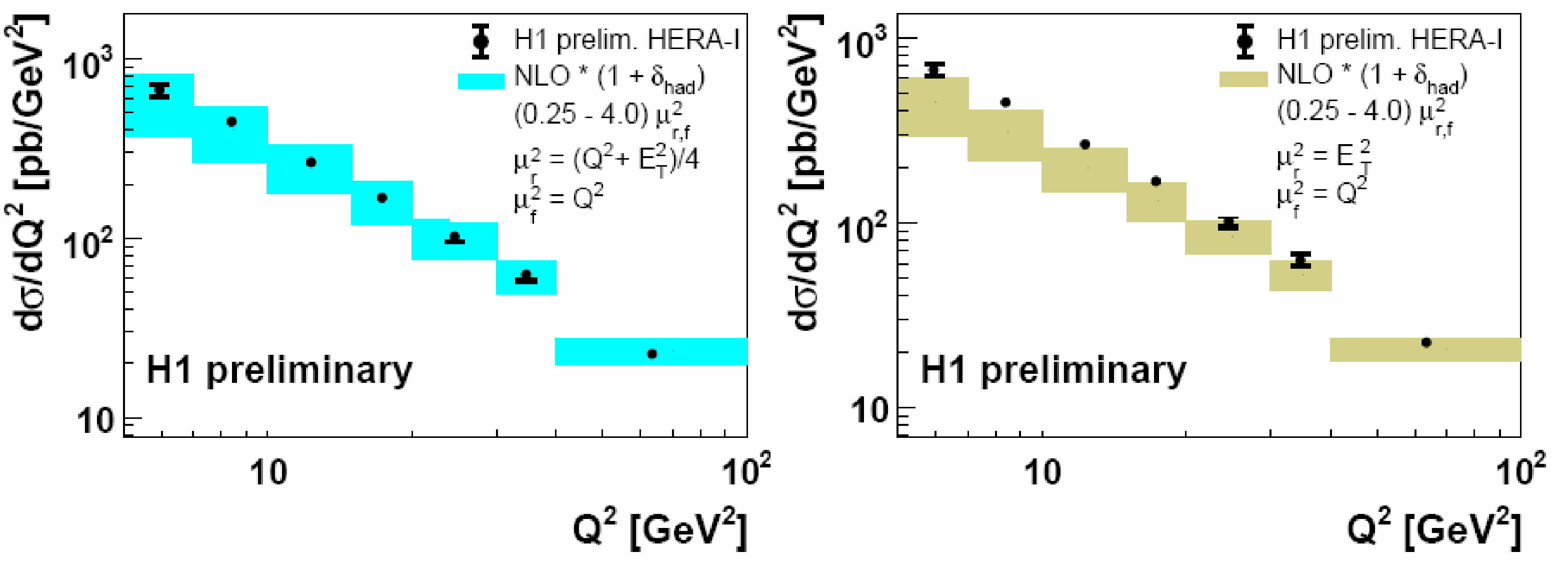
* Inclusive jet cross section preliminary for DIS 07 conference

LOW Q² INCLUSIVE JET PRODUCTION*

$\mu_R = \frac{\sqrt{Q^2 + E_T^2}}{2}$

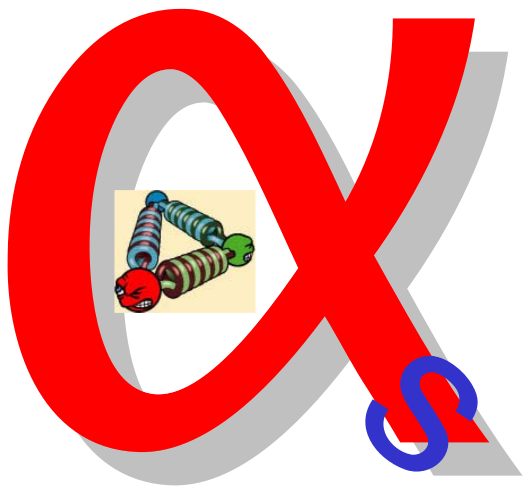
Inclusive Jet Cross Sections $\frac{d\sigma}{dQ^2}$

$\mu_R = E_T$



- The choice of a μ_R combined from Q and E_T (same that at high Q^2) improves the data description especially in the region where $Q \ll E_T$.
- Improved confidence in α_S extraction

α_s EXTRACTION



EXTRACTION PROCEDURE

ÉCOLE POLYTECHNIQUE

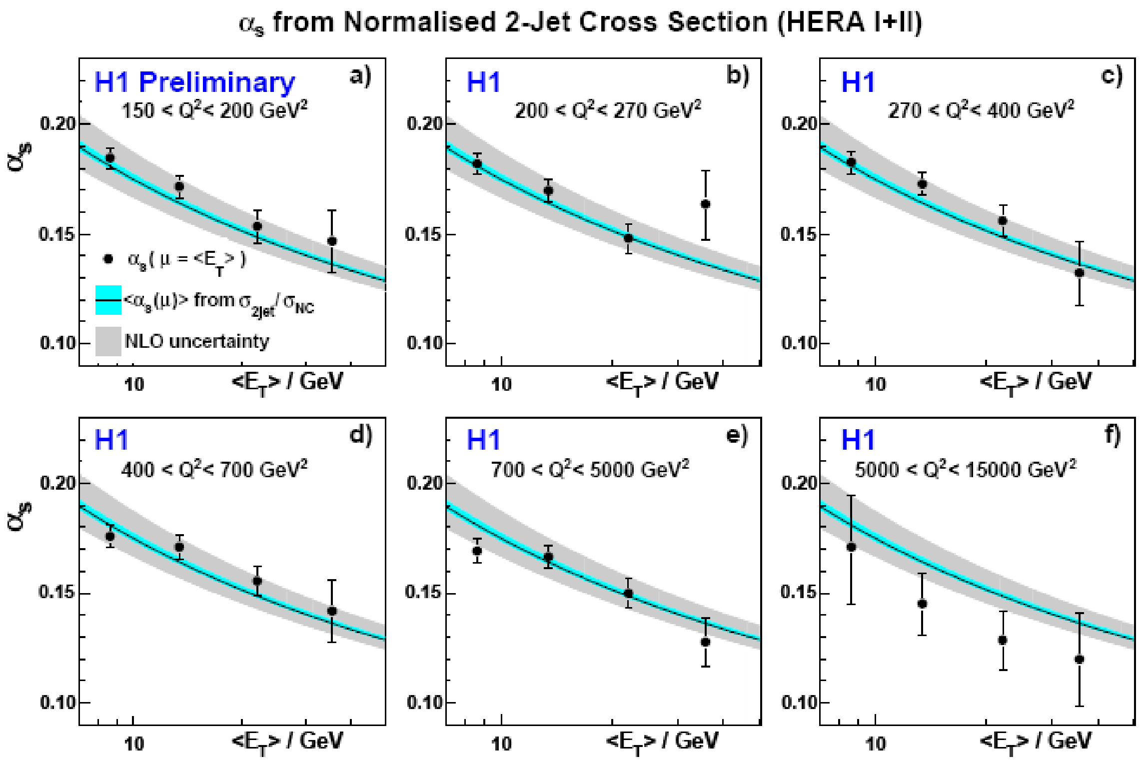
Consistency check:

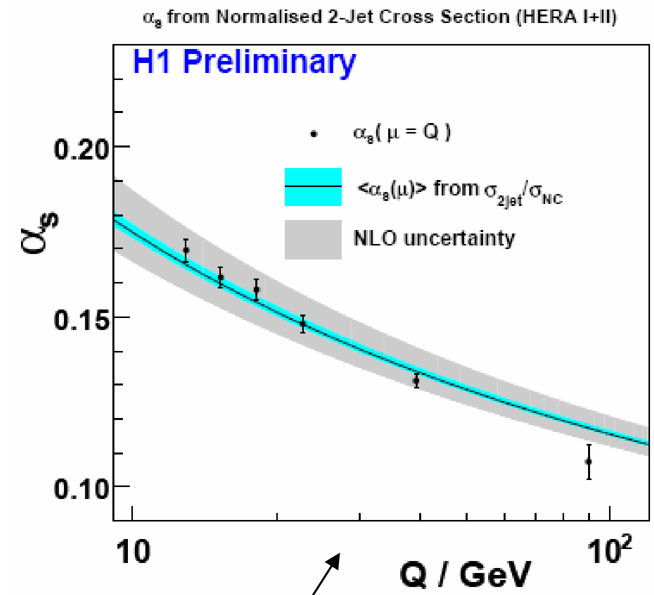
- α_S is adjusted to match the data point with NLO QCD prediction.
- α_S at μ_R scale associated to each point is ran to a common scale M_Z

Combined fit:

- χ^2 fit of NLO QCD predictions to data with $\alpha_S(M_Z)$ as free parameter.
- Hessian procedure which fit sources of correlated systematical errors such as jet energy scale. Statistical correlations are taken in account.
- Theoretical prediction errors are taken in account by an offset method: scales, hadronization corrections and PDF parameterizations are varied and $\alpha_S(M_Z)$ refitted. Resulting variations are added in quadrature.

α_s FROM 2-JET RATES





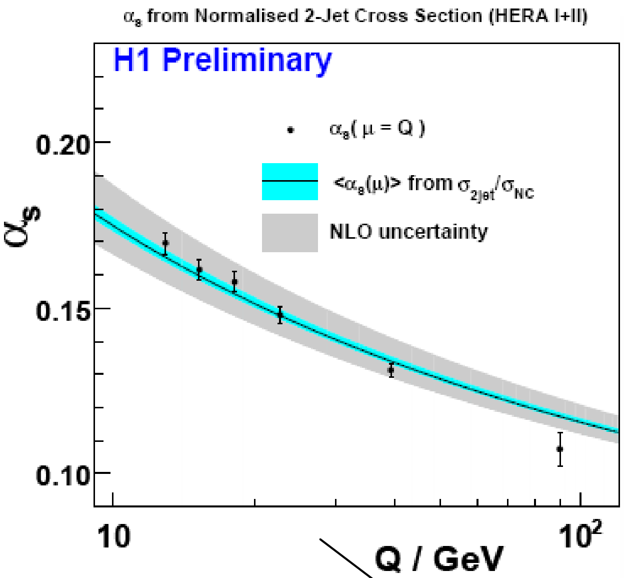
Inside each Q2 bin the running of $\alpha_S(E_T)$ is verified

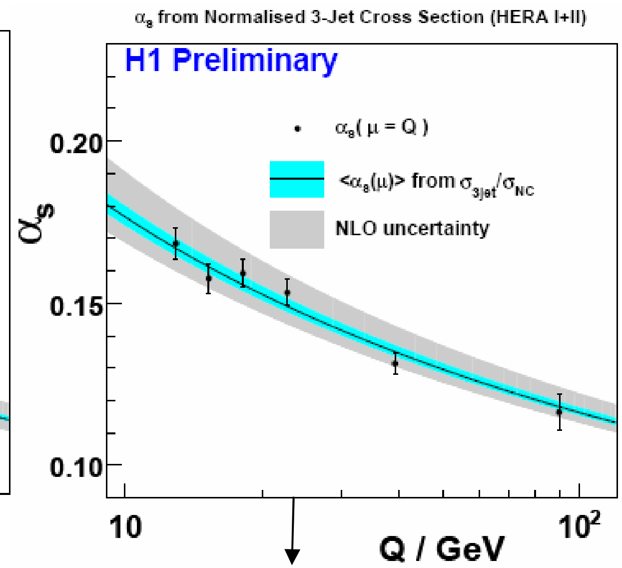
→ Combined fit inside each Q2 bin of $\alpha_S(M_Z)$; Test of $\alpha_S(Q)$ running

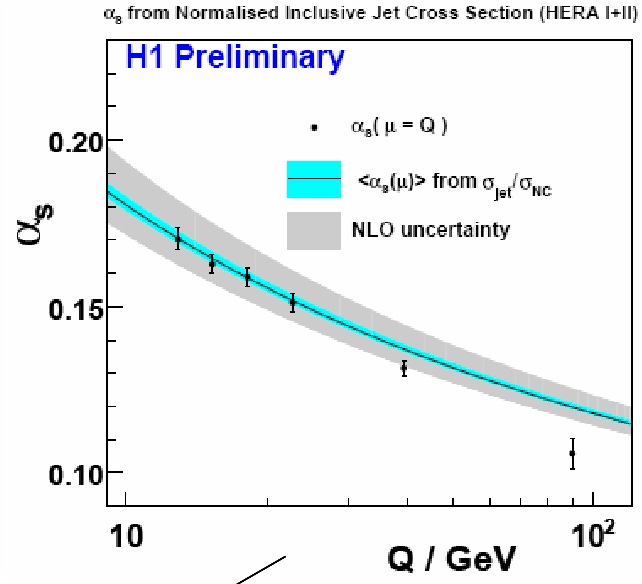
→ Combined fit of $\alpha_S(M_Z)$ from all 24 points

αS FROM HIGH Q2 JET RATES

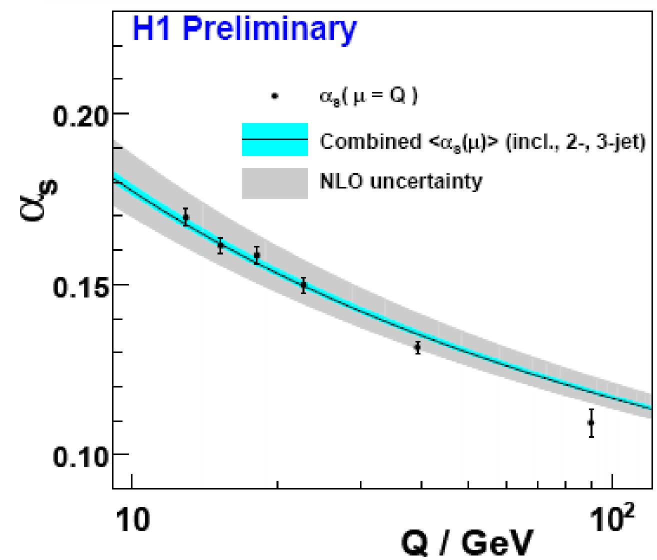
1 - Individual extraction from each jet observable





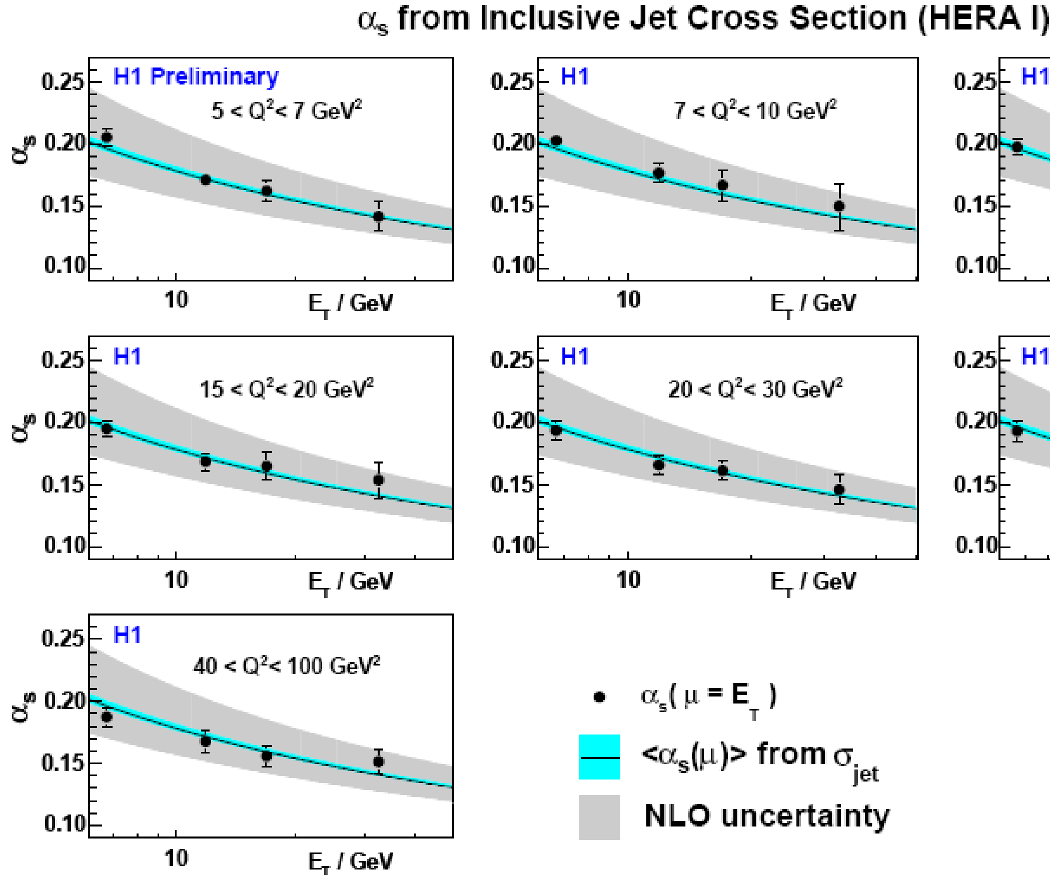


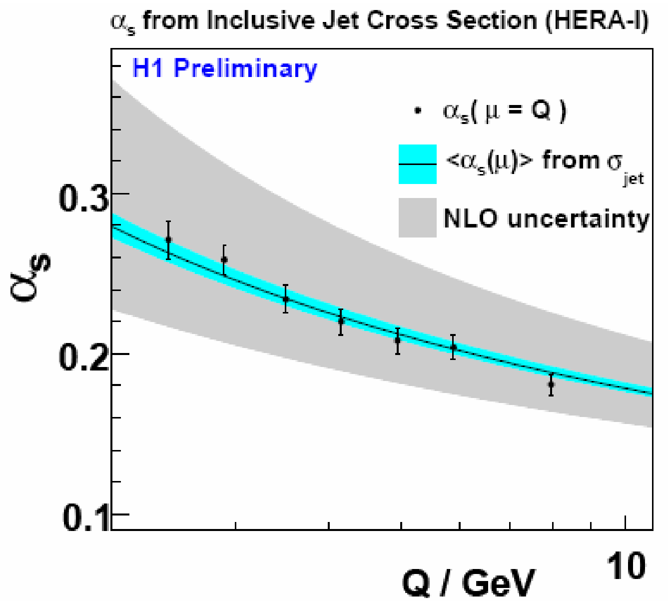
2 - $\alpha_S(Q^2)$ running verified for each observable



3 - Combined extraction with 54 experimental points

α_S FROM LOW Q^2 INCLUSIVE JETS



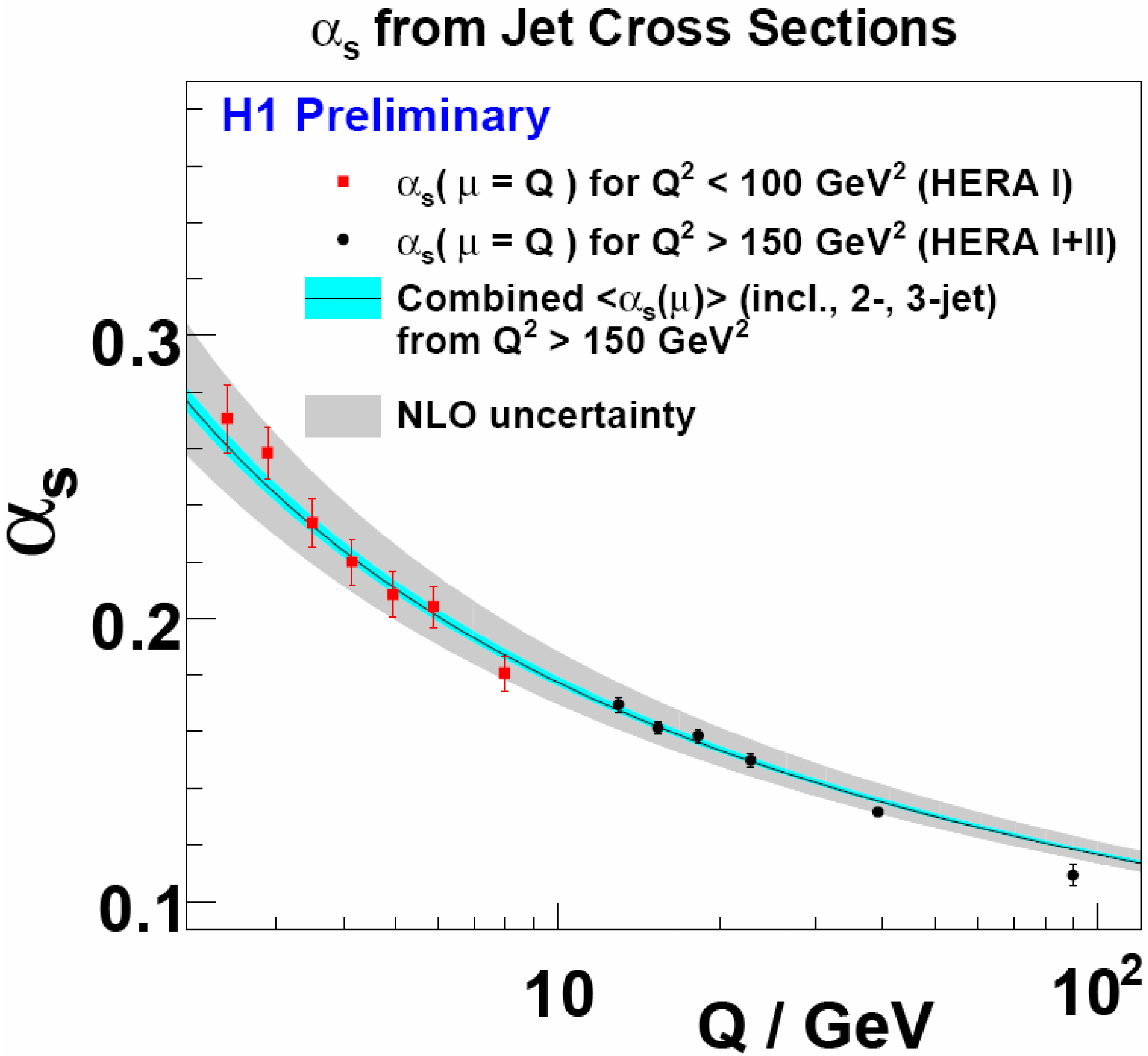


- Fit procedure identical to high Q^2
- Running of α_S with Q^2 and E_T is verified
- Experimental errors dominated by theoretical

SYNOPSIS OF α_s EXTRACTIONS

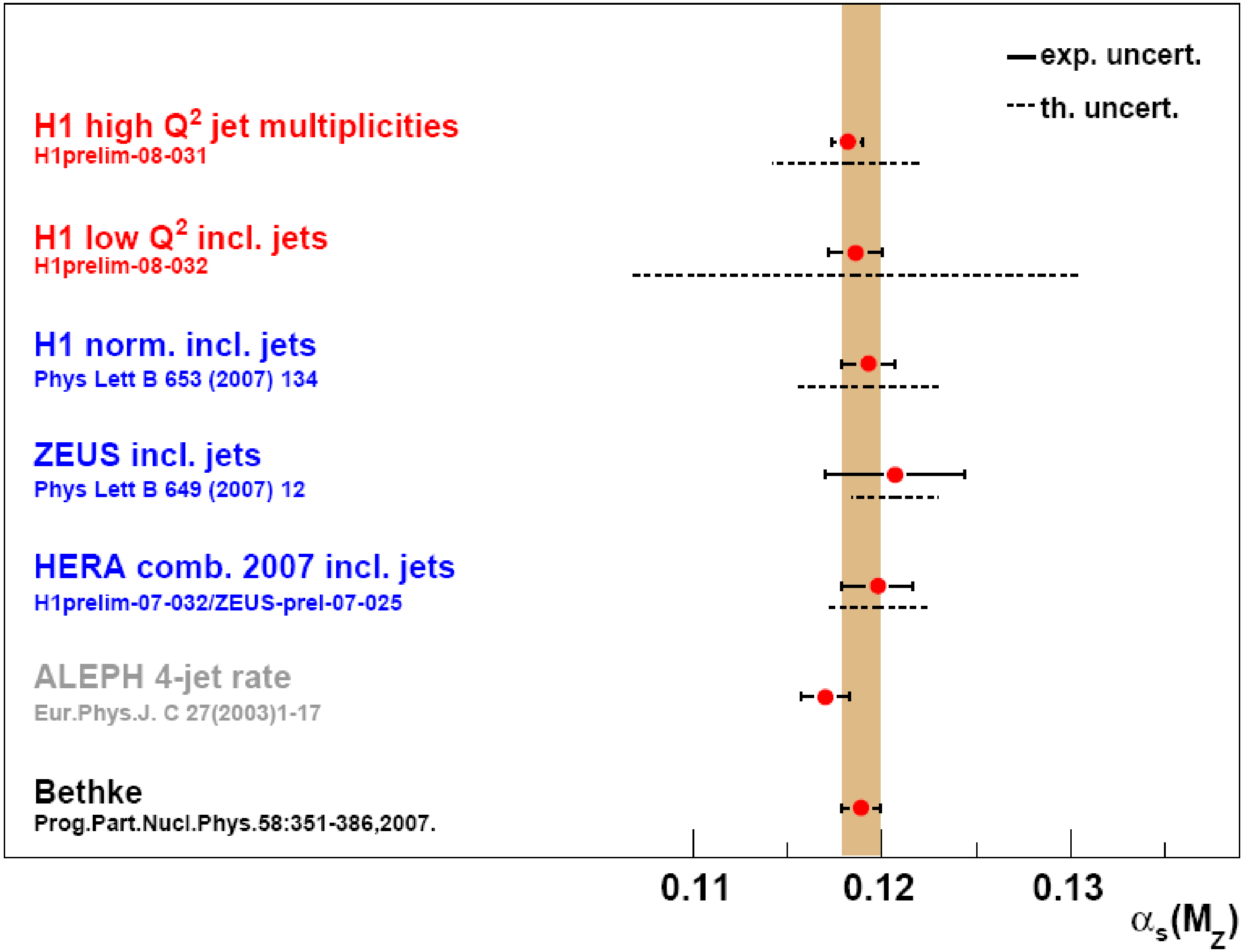
Observable	α_S	Exp. error	Theory err. Scales	Theory err. PDF	X^2/NDF
$\frac{\sigma_{3JET}}{\sigma_{NC}} = f(Q^2)$	**0.1179**	0.0014	+0.0056 - 0.0034	0.0009	4.53/5
$\frac{\sigma_{2JET}}{\sigma_{NC}} = f(Q^2, \langle E_T \rangle)$	**0.1171**	0.0010	+0.0048 - 0.0036	0.0018	28.1/23
$\frac{\sigma_{JET}}{\sigma_{NC}} = f(Q^2, E_T)$	**0.1196**	0.0010	+0.0049 - 0.0036	0.0019	26.8/23
$\frac{\sigma_{IJET}}{\sigma_{DIS}} \& \frac{\sigma_{2JET}}{\sigma_{DIS}} \& \frac{\sigma_{3JET}}{\sigma_{DIS}}$	**0.1182**	0.0008	+0.0041 - 0.0031	0.0018	54.8/53
$\sigma_{IJET} = f(Q^2, E_T)$ Low Q^2	**0.1186**	0.0014	+0.0132 - 0.0101	0.0021	20.5/27

α_s RUNNING OVER Q^2 RANGE



Running verified over all two orders of magnitude in Q

SUMMARY OF αS EXTRACTIONS



- New measurements from low and high Q2 jets data compatible with the world average
- High experimental precision

CONCLUSIONS

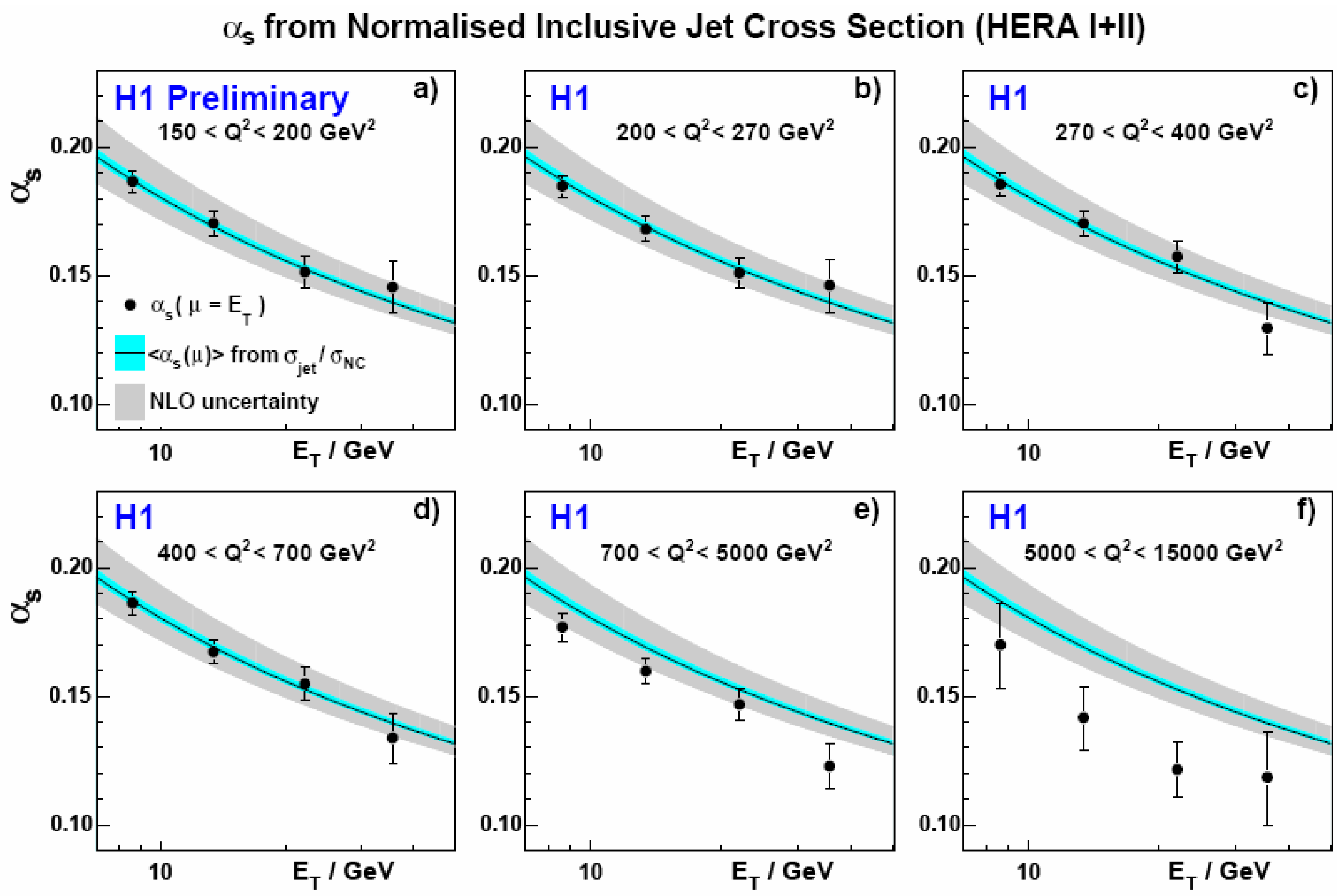
$$\alpha_S \text{ from high Q2:} \quad 0.1182 \pm 0.0008(\text{exp.})^{+0.0041}_{-0.0031}(\text{th.}) \pm 0.0018(\text{pdf})$$

$$\alpha_S \text{ from low Q2:} \quad 0.1186 \pm 0.0014(\text{exp.})^{+0.0132}_{-0.0101}(\text{th.}) \pm 0.0021(\text{pdf})$$

- Very precise α_S determination
  - Small experimental errors (high Q2: 0.7% , low Q^2: 1.2%)
  - Theoretical errors dominates (high Q2: 3.5%, low Q^2: 12%) mainly due to the μ_R.
- α_S running verified over two orders of magnitude in Q. A striking agreement between low Q^2 and high Q^2.
- NNLO calculations are necessary to exploit the full potential of those data.

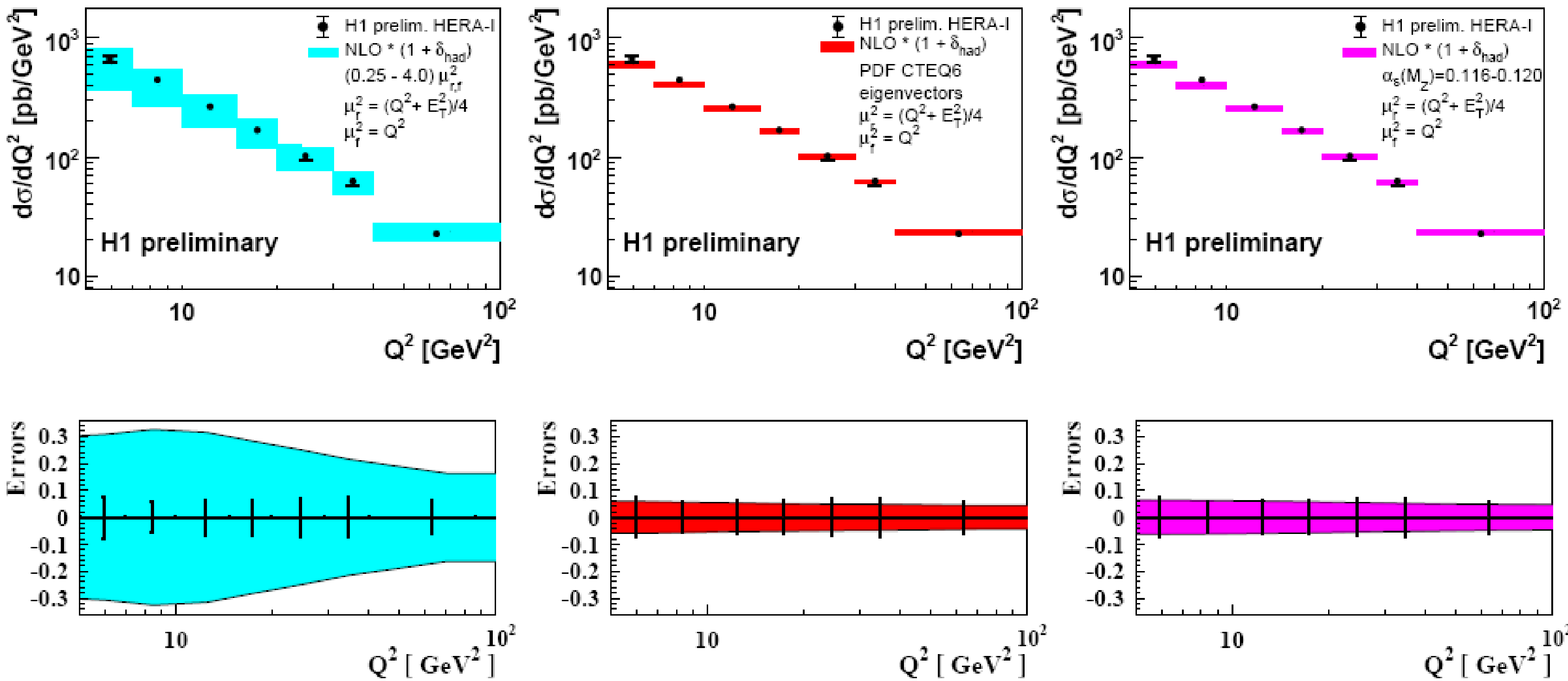
BACKUP

EXTRACTION FROM INCLUSIVE JET CROSS SECTION



LOW Q² INCLUSIVE JET PRODUCTION*

Inclusive Jet Cross Sections $\frac{d\sigma}{dQ^2}$



μ_R, μ_F dependance

PDF param. sensitivity

α_S sensitivity

- Scale dependence is the most important source of theoretical uncertainty at low Q2
- The sensitivity to the PDF and to α_S parameterizations are comparable

JET FIDUCIAL CUTS