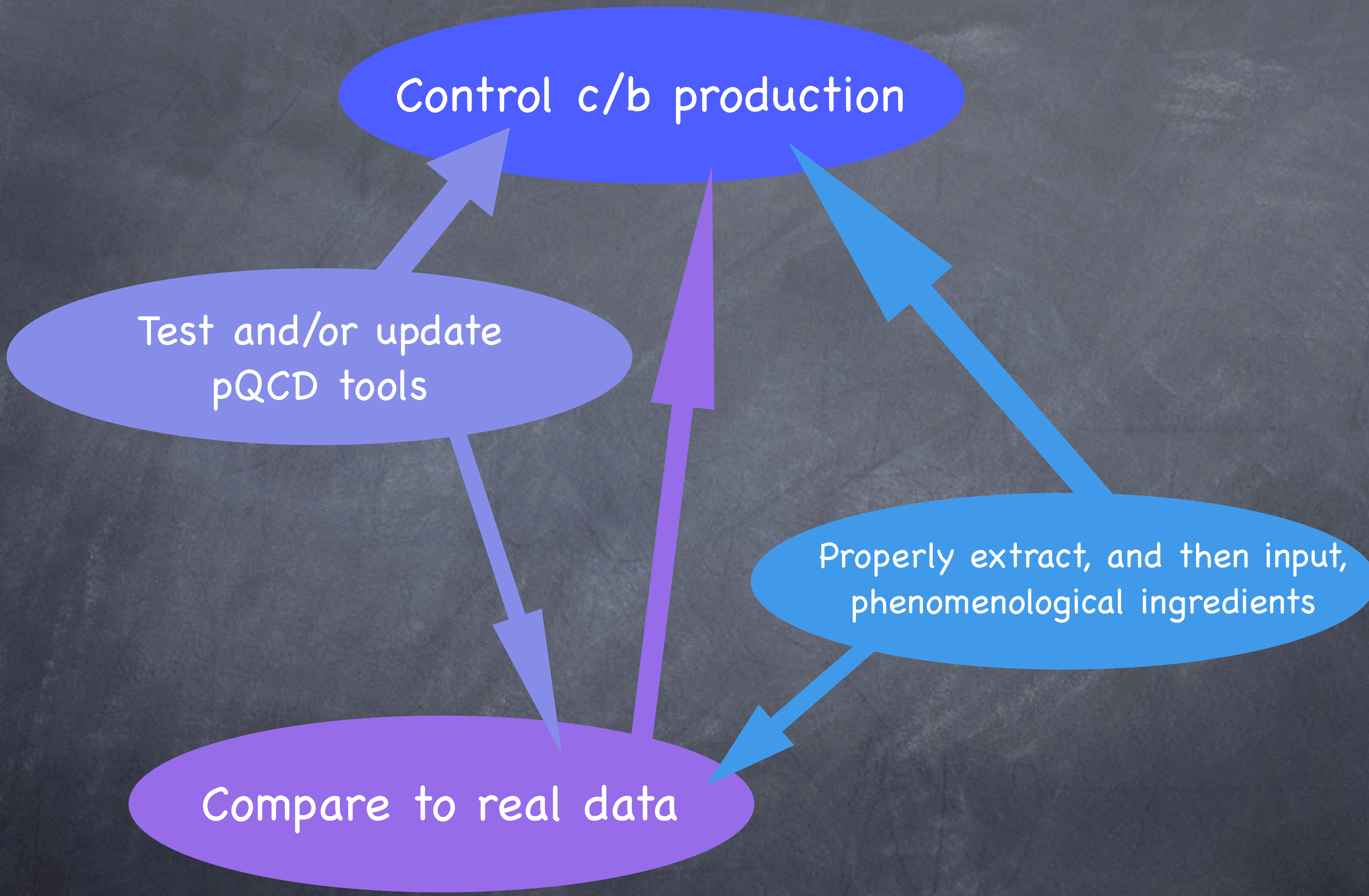
CERN, 11/10/2004

HERA-LHC Workshp
Charm and Bottom

MC, Massimo Corradi, Andrea Dainese, Andreas Meyer,
Maria Smizanska, Ulrich Uwer, Christian Weiser
+ all people who gave talks

Matteo Cacciari
LPTHE - UPMC Paris

(Very personal) view of Workshop's TODO
(or, perhaps, WISHFOR) list


Control c/b production
Test and/or update pQCD tools
Properly extract, and then input, phenomenological ingredients
Compare to real data

Control c/b production

Test and/or update pQCD tools

- NLO calculations
- Resummations, matched calculations, HQ PDFs
- massless vs. massive
- small-x issues

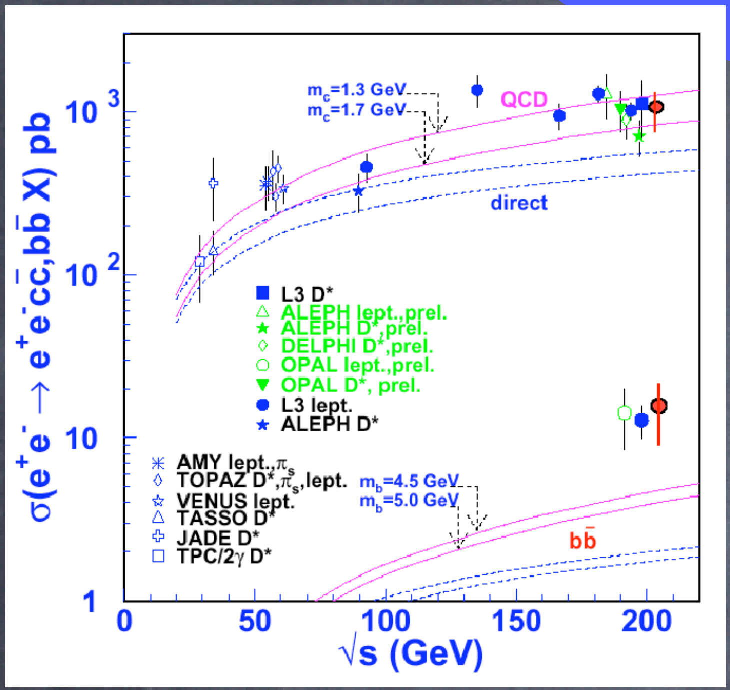
Control c/b production

- light flavours, gluon and photon PDFs -> WG1 (hint: the photon ones are by now pretty aged)
- Heavy Quark fragmentation functions (see also talk by M. Corradi)

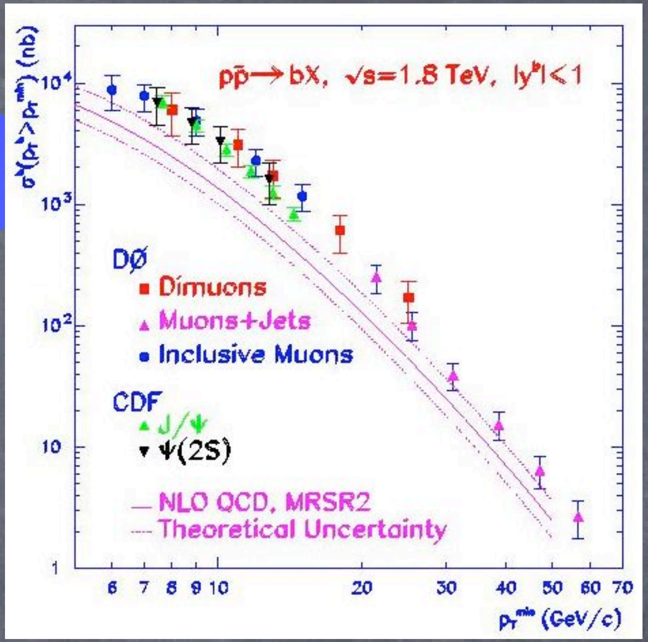
Properly extract, and then input, phenomenological ingredients

$\gamma\gamma \to Q\bar{Q}$

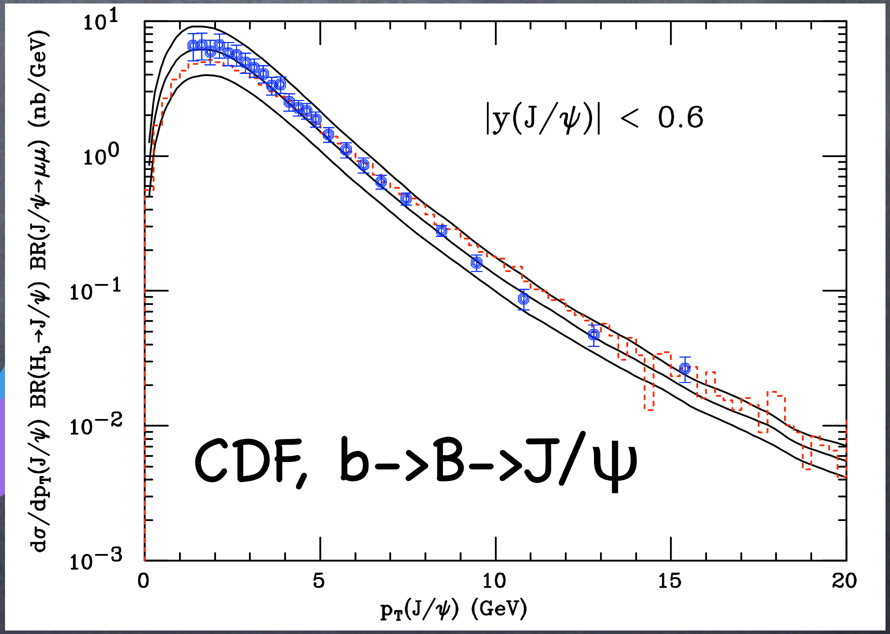
Control c/b production



Total cross sections are not really measured



Neither are b-quark distributions



Compare to real data

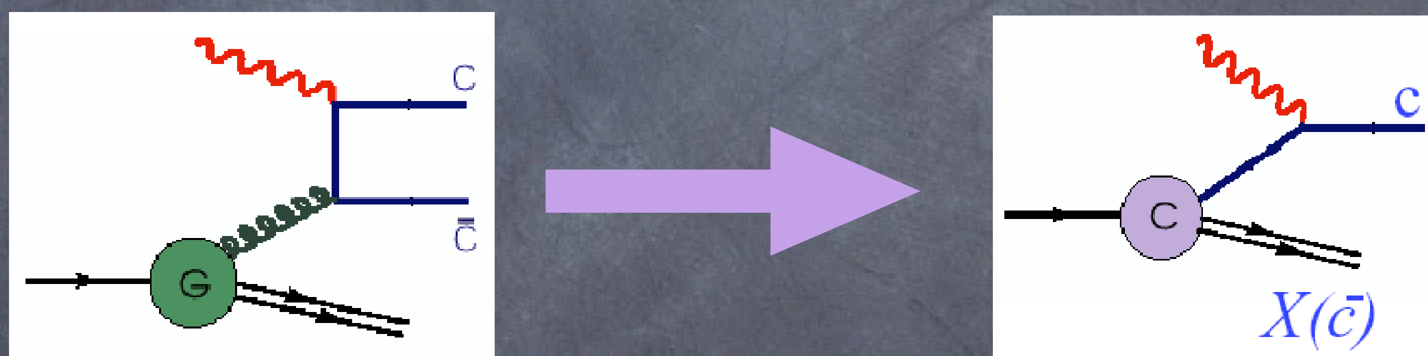
Things work better with real particles

Control c/b production

PDF's

Test and/or update
pQCD tools

NLO calculations are by now mature QCD. They do however contain `new' items, like heavy quark PDFs:



An NLO diagram can be approximated by a heavy quark PDF term, and the HQ PDF is CALCULABLE in pQCD:

$$c(x,\mu) = \frac{\alpha_s(m)}{2\pi} \log \frac{\mu^2}{m^2} \int_x^1 g(x/z,m) P_{cg}(z) \frac{dz}{z} + O(\alpha_s^2)$$

Bonus: evolution RESUMS to all order the large logarithms log(Q/m)

Control c/b production

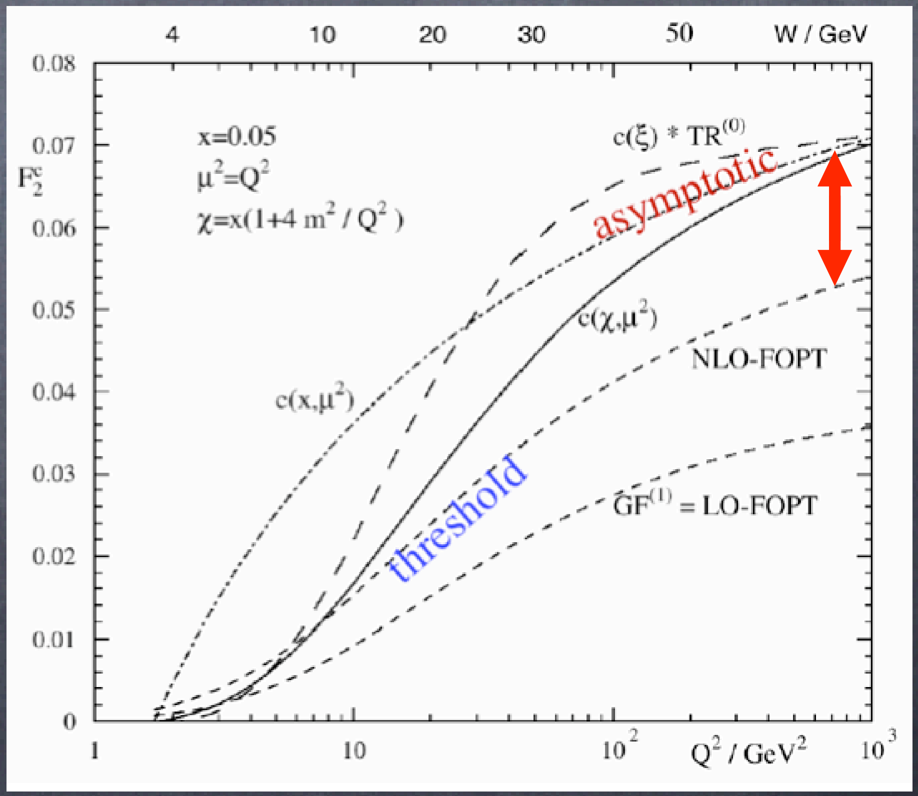
PDF's

Test and/or update
pQCD tools

HQ PDF's can be used to improve the calculation of $F_{2,c}$ and $F_{2,b}$ at Q >> m

NB.
NLO calculations are easy, PDF's ones are even easier: the challenge lies in the matching, important in the intermediate region

<-- low Q^2 high Q^2 -->



From S. Kretzer's talk, first meeting

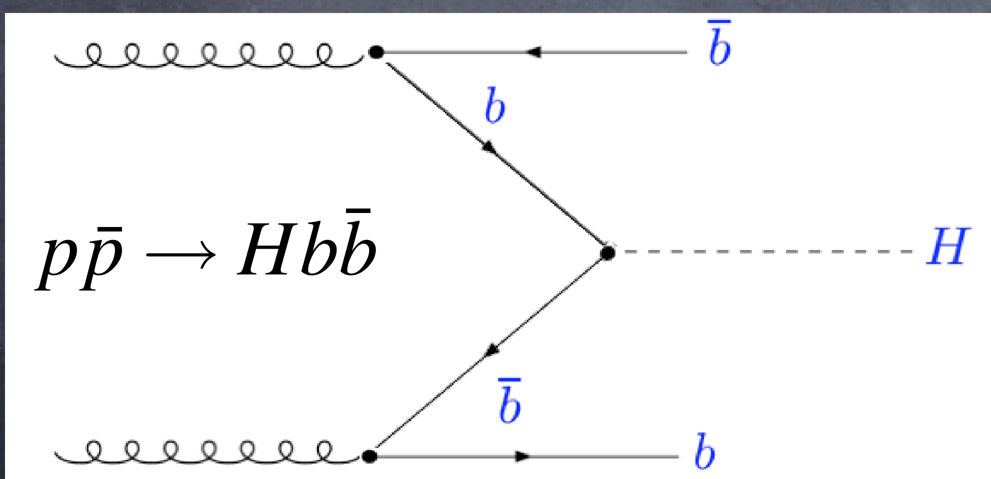
PDF's

Control c/b production

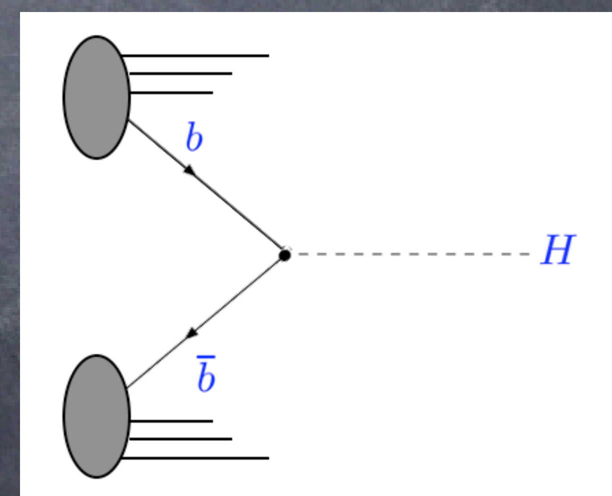
Test and/or update pQCD tools

One of the goals is to test HQ PDF's to be used in LHC processes:

NLO



LO with b PDF
(kown to NNLO)



e.g. b bbar H or Zb associated production.
See talks by F. Maltoni and A. Tonazzo this afternoon

Control c/b production

Massive
vs.
massless

Test and/or update
pQCD tools

Usually an ill-posed comparison:
what "massless"??

A full massive calculation (FO, NLO, MV, ...) contains, well, mass terms, in the form of $\alpha_s(\log(p_T/m) + c)$ and $(m/p_T)^a$ in the large p_T limit

- A CORRECT NLL resummed (massless) calculation neglects the $(m/p_T)^p$ term and reproduces, when expanded to $O(\alpha_s)$, the FO $\alpha_s(\log(p_T/m) + c)$ term
- An APPROXIMATED massless calculation neglects parts of the logarithmic structure, and cannot reproduce the fixed order heavy quark cross section when expanded
- A MATCHED calculation, besides resumming to a given logarithmic accuracy (NLL), also reintroduces the power suppressed mass terms. It is therefore predictive over the whole p_T range.

Control c/b production

Massive
vs.
massless

Test and/or update
pQCD tools

What to use where

- Small scales (p_T <= m): FO needed, matched does not give improvement
- Large scales (p_T >> m): resummed needed. Correct massless will reproduce all NLL, and allow to calculate heavy quark cross section. Approximate massless won't resum all logs, will need a phenomenological function and can only describe hadron cross sections
- In intermediate scales region (p_T >= m) a MATCHED calculation is needed. One implementation for hadron-hadron and photon-hadron collisions is the so called FONLL (MC, Frixione, Greco, Nason, http://www.cern.ch/cacciari/FONLL)

Control c/b production

Resummation

Test and/or update pQCD tools

The large log(Q/m) resummed by the HQ PDF's approach are not the only ones appearing in NLO calculations:

- threshold logarithms
- small transverse momentum logs -> $\log(q_T/m)$
- large transverse momentum logs -> $\log(p_T/m)$
- small x logs (see later)

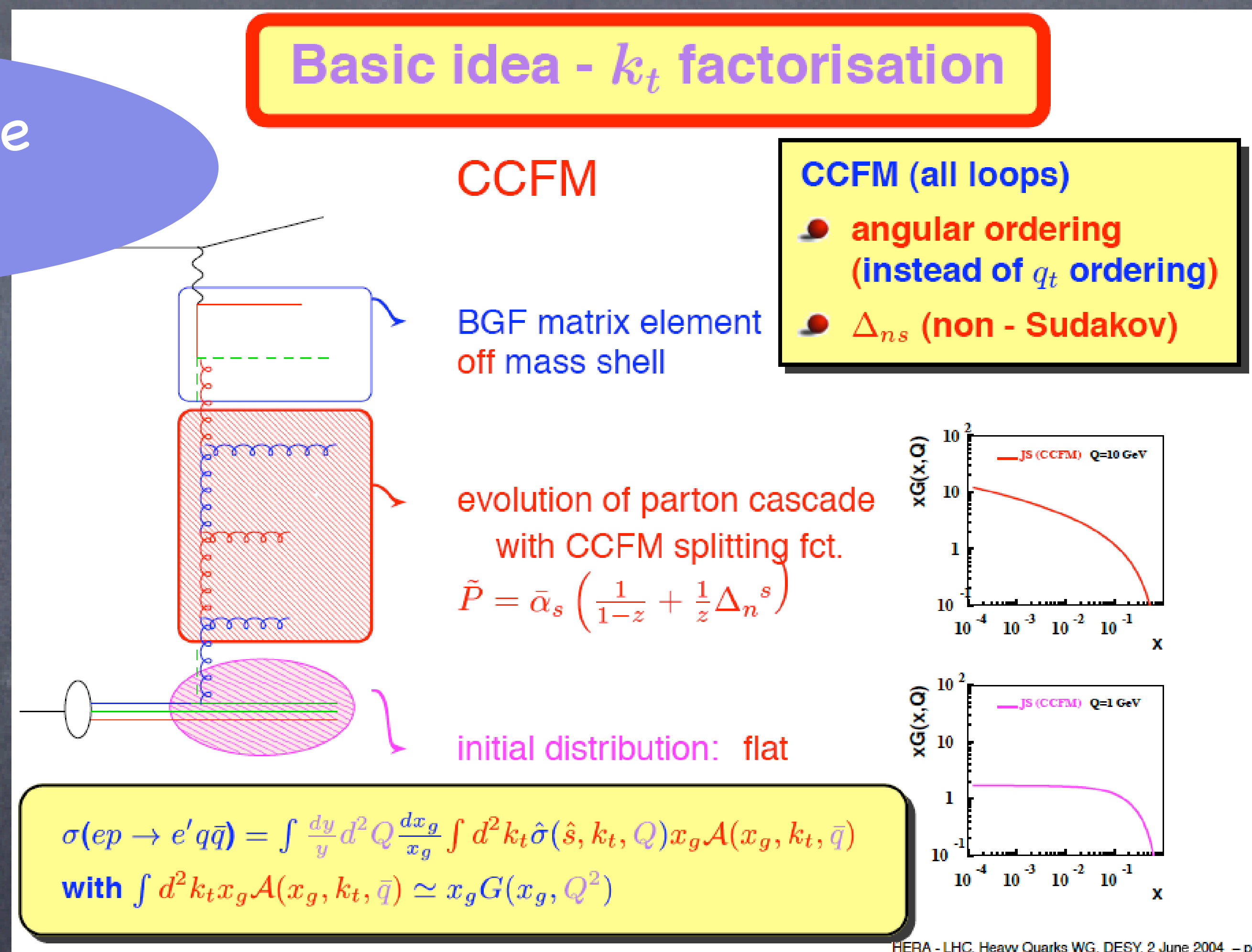
See E. Laenen's threshold/joint resummation

Usually not an issue at HERA.
See my talk later for Tevatron/LHC

Control c/b production

Small-x

Test and/or update pQCD tools



Do we need to go beyond collinear factorization?

Zotov, Jung, Baranov talks at DESY meeting. Kolhinen, Dainese, Kutak at this meeting.

A lot of work done. Most important goal right now (personal view): estimate theoretical uncertainties, as most predictions only have overall LO accuracy and may depend on further phenomenological parameters

HQ FF's

Control c/b production

Like HQ PDF's their FF's are also calculable in pQCD:

$$D_Q^Q(x,\mu_0) = \delta(1-x) + \frac{\alpha_s(\mu_0)}{2\pi}\left[\frac{1+x^2}{1-x}\left(\log\frac{\mu_0^2}{m^2} - 2\log(1-x) - 1\right)\right]_+$$

$$D_g^Q(x,\mu_0) = \frac{\alpha_s(\mu_0)}{2\pi}(x^2+(1-x)^2)\log\frac{\mu_0^2}{m^2}$$

These are however only "almost" physical: heavy quarks hadronize only a little (recall the `dead cone'), but do hadronize. The FF for a heavy hadron is therefore given by the one above plus higher twist corrections which start at order Λ/m:

Properly extract, and then input, phenomenological ingredients

$$D_i^H = D_i^Q \otimes D_Q^H$$

Non-perturbative object: needs phenomenological parametrization (Kartvelishvili et al, Peterson et al, Bowler, Collins-Spiller, MC-Gardi, ...) and CAREFUL determination from data (see M. Corradi's talk)

NB: if perturbative FF is missing/incomplete, LARGE perturbative corrections must be parametrizied by the non-perturbative form, squashing the genuine (and SMALL) non-perturbative ones.

Control c/b production

TODO

- Devise HERA measurements (differential, not extrapolated) which can test the resummations, especially those for the HQ PDF's
- Work
- Improve the analysis/extraction/comparison of the non-perturbative part of the HQ fragmentation functions
- Work
- If small-x phenomenology is to play an important role, theoretical uncertainties must be better known
- Work
- Monte Carlo tuning/validation. MC@NLO for HERA?
- Work
- Work and work more