fastNLO v2

Application and Implementation in the H1Fitter

The fastNLO Collaboration

Daniel Britzger, Thomas Kluge, Klaus Rabbertz, Fred Stober,Markus Wobisch

(DESY, Liverpool, KIT, KIT, Louisiana Tech University)

H1Fitter user's meeting

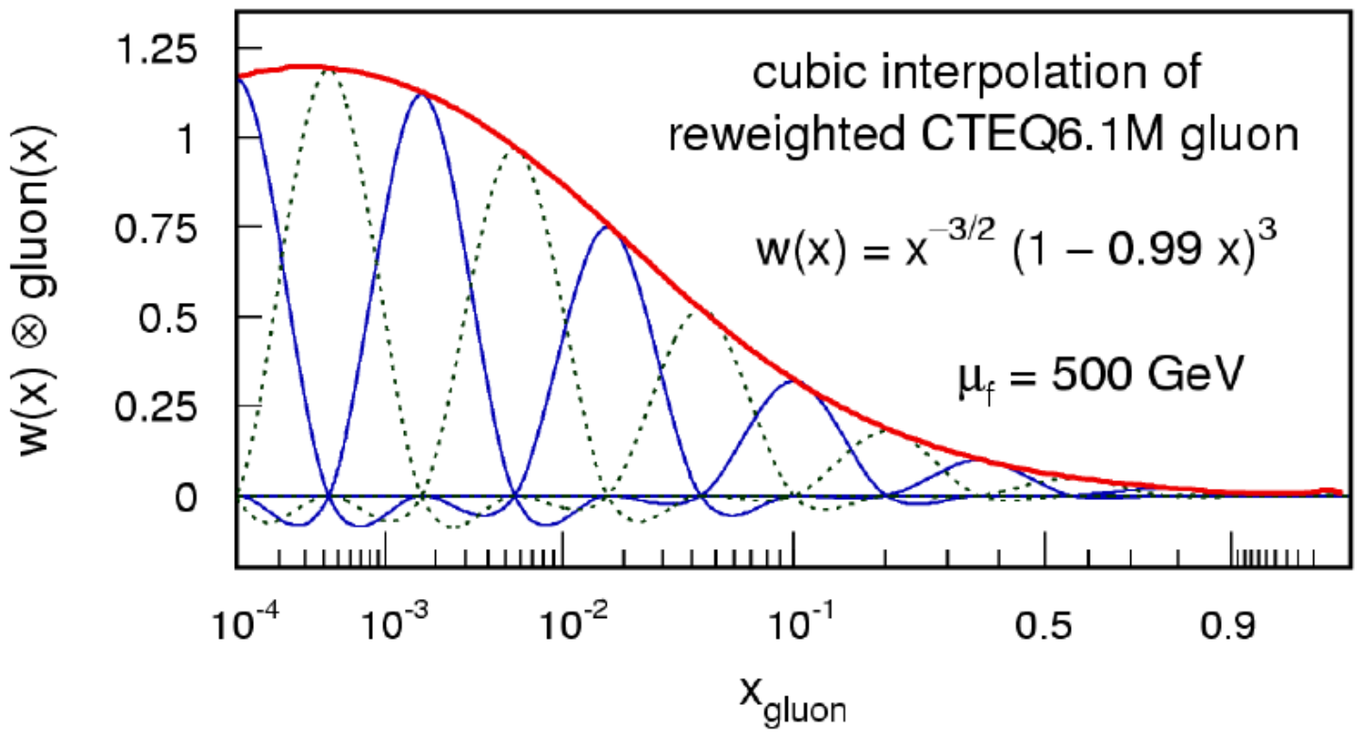
12. 12. 2011

FastNLO concept

- Jet cross sections are very slow to calculate
  -> Need of method for **very fast repeated calculation** of cross sections

- **FastNLO** factorizes the cross section calculation for an **a-posteriori** inclusion of pdf's and alpha_s for e.g. jet-production

- Introduce **set of n discrete** $x_{(i)}$'s
  with $x_n < .. < x_i < .. < x_0 = 1$
- Around each $x_{(i)}$ define **eigen function** $E^{(i)}(x)$ with:
  $E^{(i)}(x_i) = 1$, $E^{(i)}(x_j) = 0$ $(i \neq j)$, $\Sigma_i E^{(i)}(x) = 1$ for all x
- single pdf is replaced by a linear combination of eigenfunctions
- integrals are replaced by sums
- Better: Usage of **bi-cubic interpolation** and **pdf reweighting**



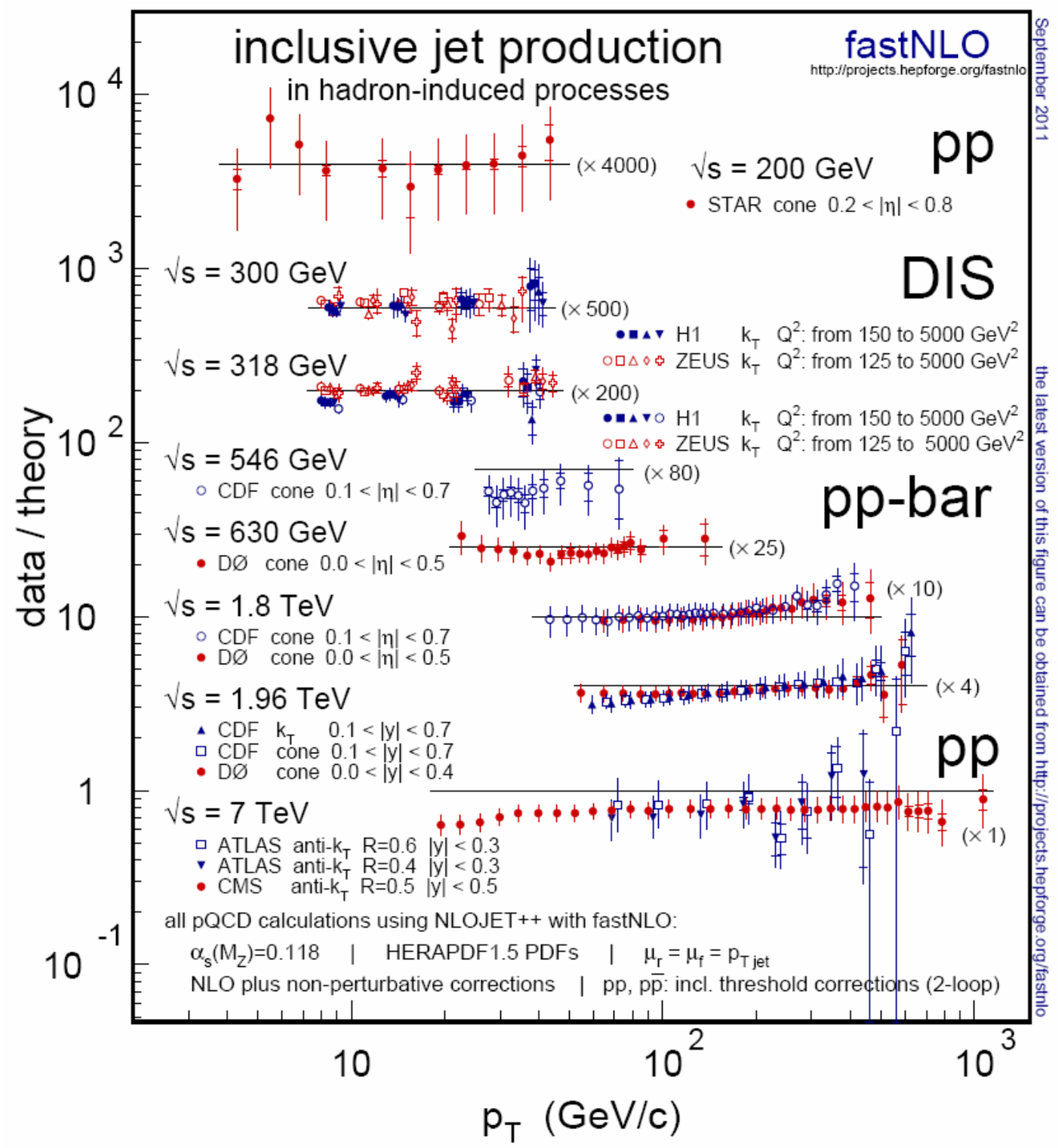
Example: Comparision of jet cross sections

- **Comparision of jet data**
  - STAR @ RHIC
  - H1 and ZEUS @ HERA
  - CDF and D0 @ TeVatron
  - CMS and ATLAS @ LHC

- Data/theory plot
- Compatible with NLO pQCD

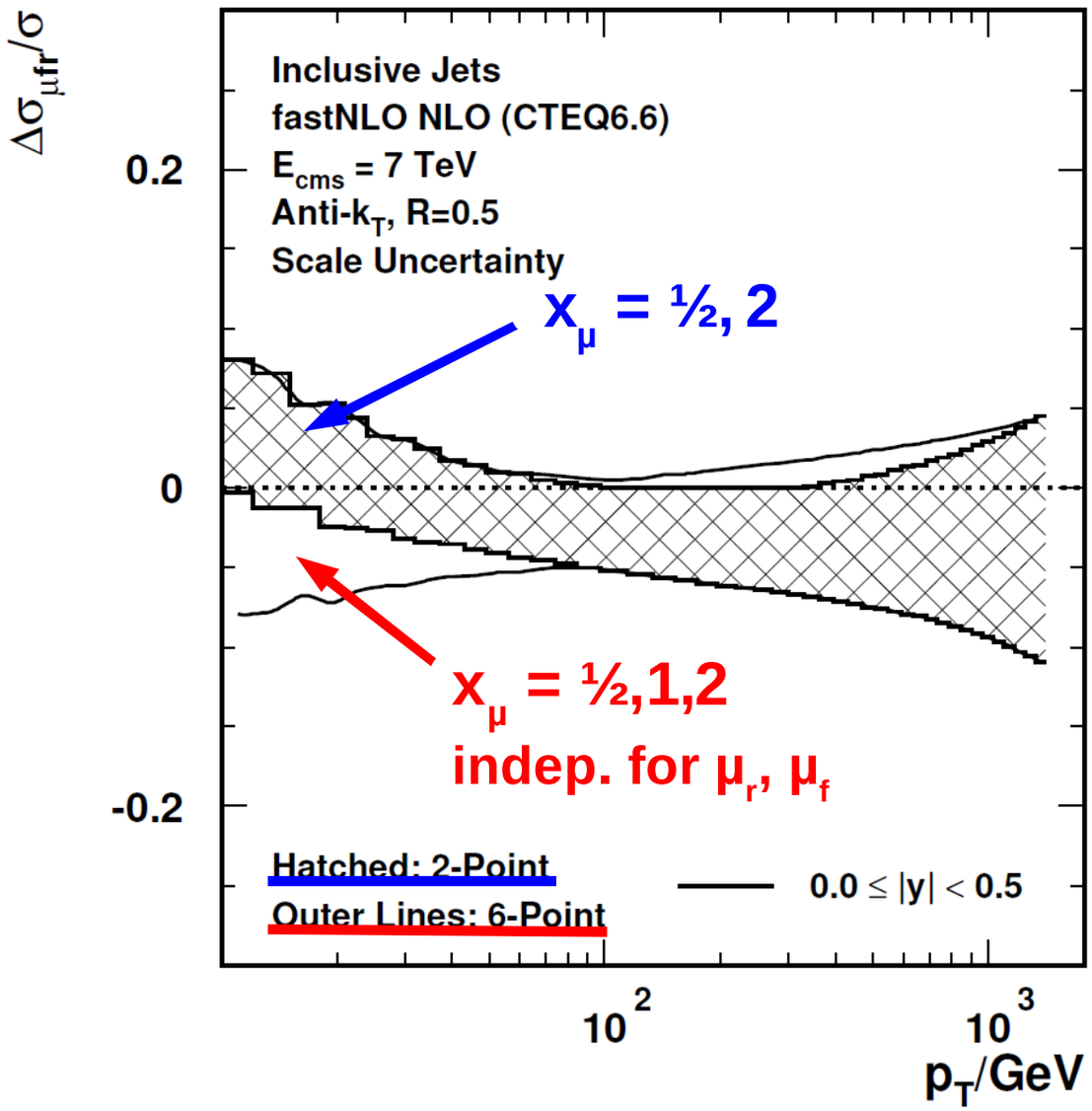
- First measurements from LHC

fastNLO, arXiv:1109:1310v1, 2011



Scales in FastNLO

- FastNLO tables come with 3 (4) simultaneous **scale variations tables**
  - e.g. 0.5, 1.0, 2.0 times the nominal scale
- **A posteriori scale variation** of the renormalizatoin scale allows study of **asymetric scale** variations
  - e.g. 6-points: (1/2,1/2), (1/2,1), (1,1/2), (1,2), (2,1), (2,2)
  - avoiding of rel. 'factor' 4.



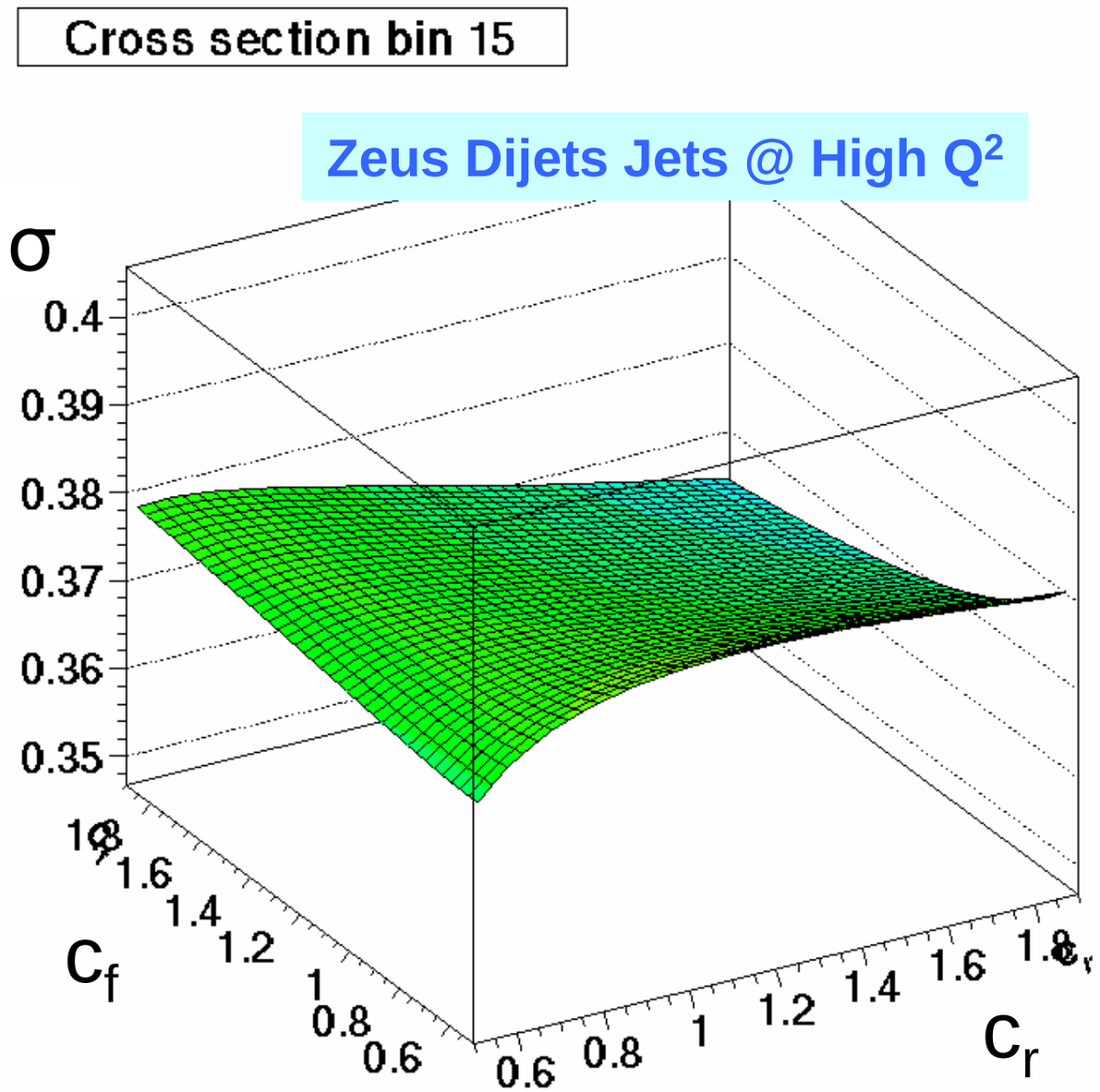
- **Improvements in v 2.0**
  - scales get own dimension
  - bicubic interpolation of scale-value to scale nodes
  - typically 6 scale nodes
  - examples already for
    - CMS incl. jets
    - D0 3-jet mass
    - …

New concept 'multidimensional scale table'

- **Improve FastNLO concept**
  - Store scale **independent** weights
  - Store several 'scale' look-up tables, e.g.:
    - pt
    - Q

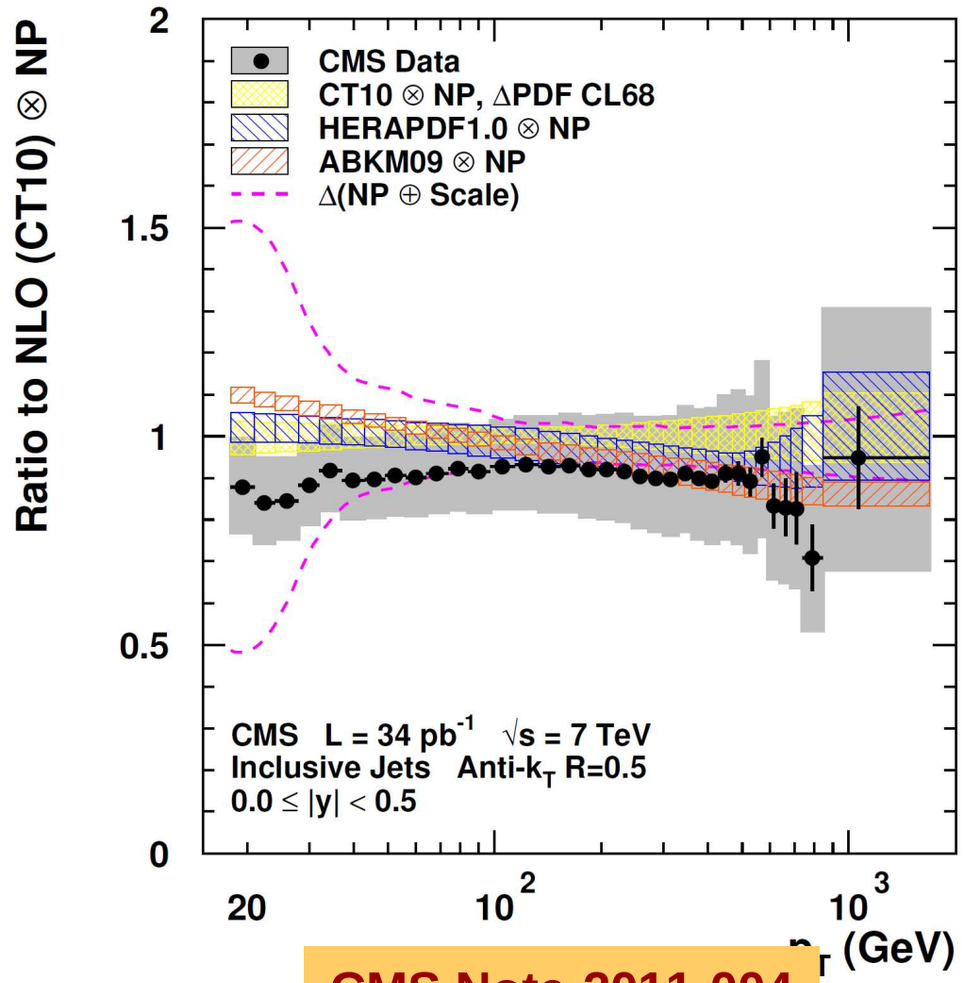
- When evaluating FastNLO cross section:
  - User can **choose every scale composition** from previously stored scales
  - e.g. $\mu_r^2 = (Q^2 + pt^2) / 2$
  - $\mu_r^2 = Q^2$
  - …
- Also a-posteriori scale variation for μ_r and μ_f are thus **independently possible** through
  - $\mu_r^2 = c_r \times (Q^2 + pt^2) / 2$
  - $\mu_r^2 = c_f \times Q^2$
  - …
- New possibilities for scans of scale dependence

- Examples exist for almost **all DIS** tables
  - accuracy > 0.005% compared to nlojet++ CS
- pp and ppbar concept proven
  - much larger tables



More features of FastNLO v2.0

- **Technicals**
  - Automatic scan of smallest x-value
  - flexible #x-nodes per bin
  - scale gets own dimension
  - Arbitrary number of dimensions for binning of observable
- **Units**
  - publication units e.g. pb/GeV
  - absolute units [pb]
- **Additional contributions**
  - **Correction factors**
    - non-perturbative corrections
    - with errors
  - **Data**
    - including arb. no. of correlated and uncorrelated errors
    - Correlation matrix
  - **Electroweak corrections** (calculated?)
  - **New physics contributions**
  - **Threshold corrections**
    - tables are available
  - Normalization options
- **Converting tool for v1.4 tables**
- **New concept of 'multidimensional scale table'**
  - store multiple scales
  - user can **compose** scales a-posteriori from all included variables
  - speed-up implemented for 'one-scales' (e.g. in pdf fits)
  - automated equidistant x-binning in a function of x



CMS Note-2011-004

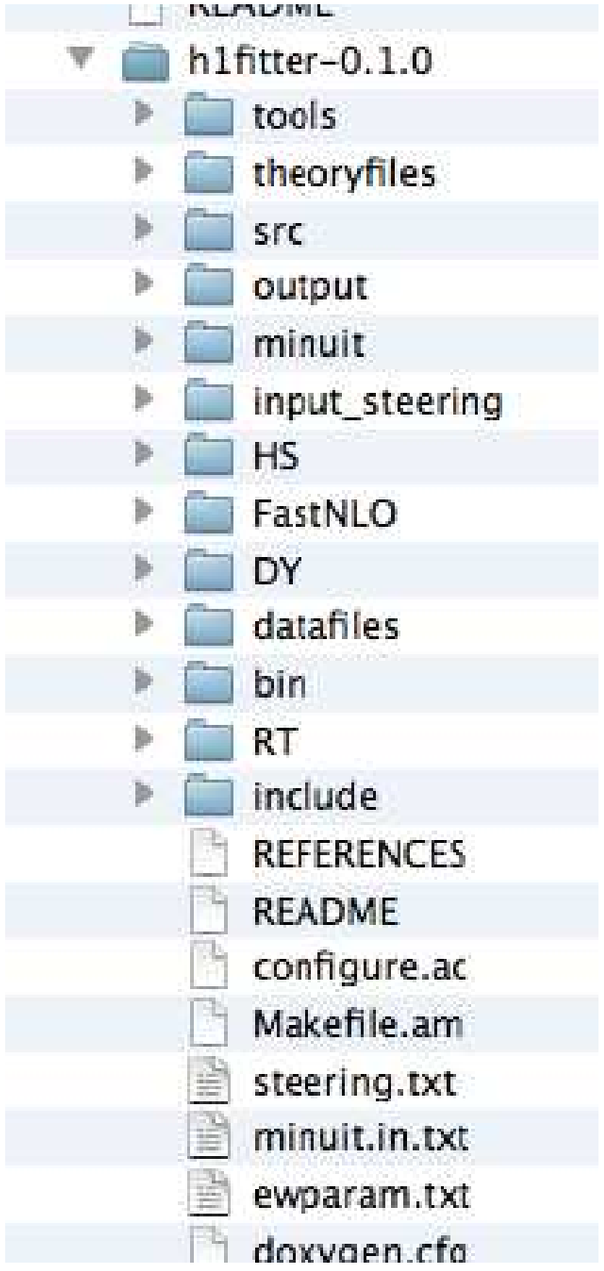
Release of v2.0

- **Release still this month !!!**
- **Easy installation**
  - autotools
  - No further dependencies (exc. LHAPDF)
  - No ROOT
  - No CERNLIBS
- **C++ and fortran reading tools**
  - both 'universal' for all v2.0 tables

What's on today's door?

FastNLO in H1Fitter

FastNLO in H1Fitter



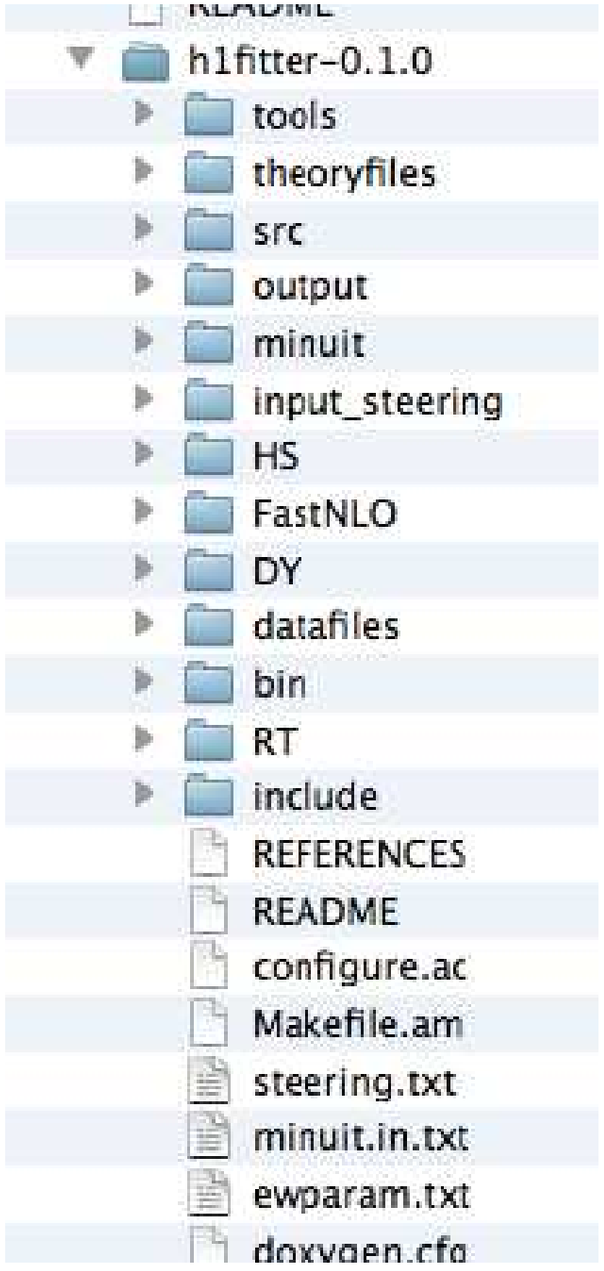
- FastNLO classes
  - FastNLOReader.cc
  - FastNLOBlockB.cc
  - Alphas.cc
- Wrapper
  - FastNLOInterface.cc

- FastNLOInterface
  - map<int, FastNLOReader*> gFastNLO_array;
  - fastnloinit_(const char *s, const int *idataset, const char *thfile)
  - fastnlocalc_(const int *idataset, double *xsec)

- Data card

```
&Data
   Name = 'CMS inclusive jets'
   Reaction  = 'FastNLO jets'

   NDATA = 176
   NColumn = 10
   ColumnType ='Bin'         , 'Bin', 'Bin' , 'Bin', 'Bin', 'Bin', 'Bin'
,'Sigma'          , 'Error','Error'
   ColumnName = 'EtaBinNumber', 'pt' , 'ymin','ymax', 'pt1', 'pt2',
'NPCorr','Sigma', 'stat' ,'uncor'
   NInfo   = 1
   DataInfo = 7000.,
   CInfo    = 'sqrt(S)'

   IndexDataset = 77
   TheoryInfoFile = 'theoryfiles/fnl2342b.tab'
   TheoryType     = 'FastNLO'
   Percent   = True, True
&End
1 19.4 0 0.5 18 21 1.4 1.97e+07 0.6 12.85
```

Technicals



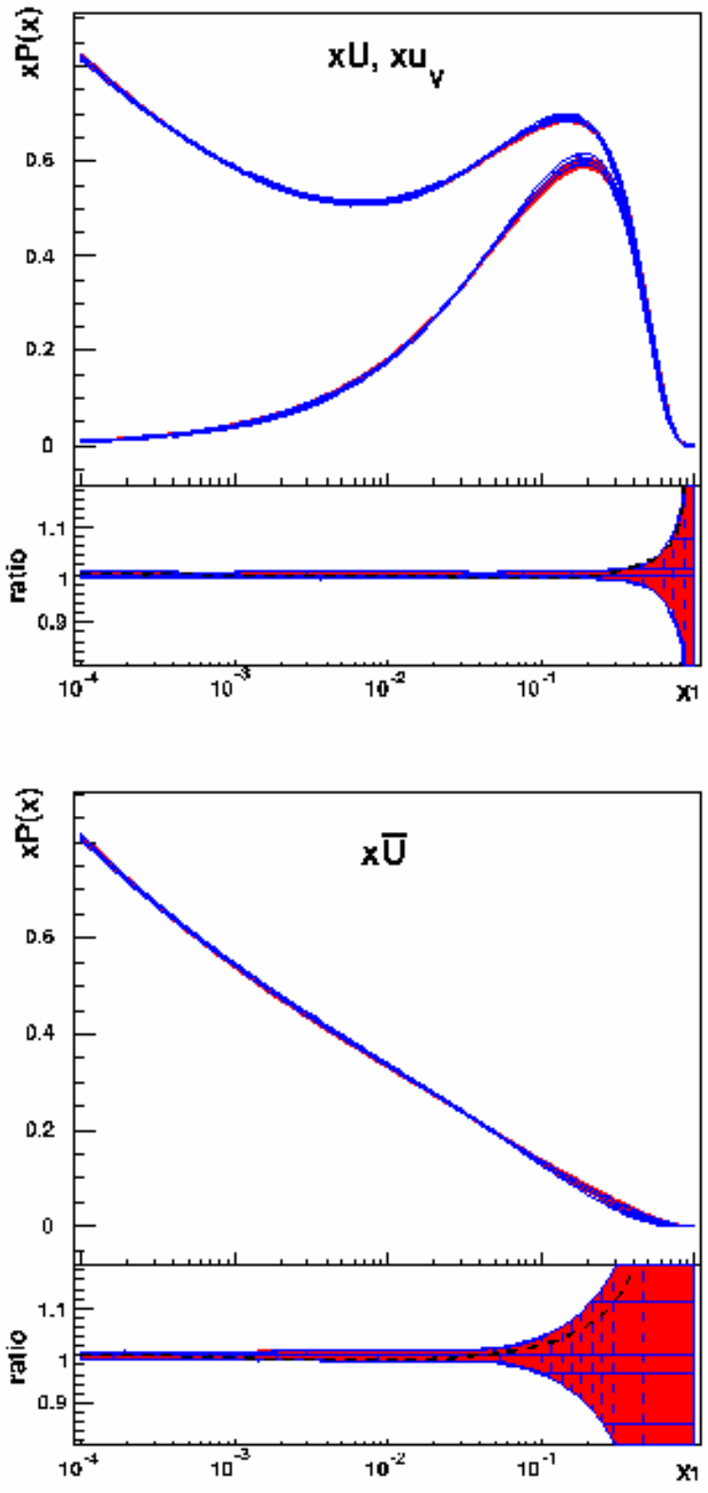
- **FastNLOInterface**

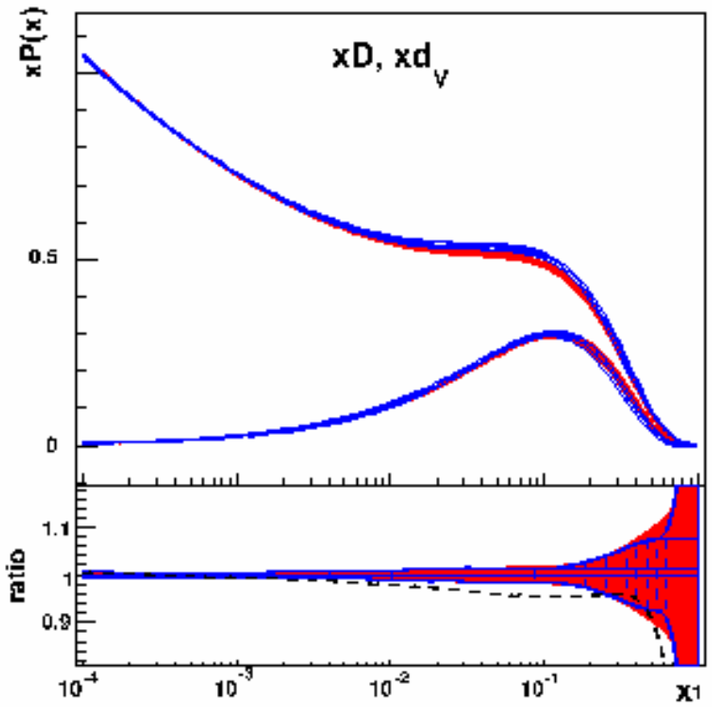
```
fnloreader = new FastNLOReader( thfile );

fnloreader->SetPDFInterface(FastNLOReader::kH1FITTER);
fnloreader->SetAlphasEvolution(FastNLOReader::kQCDNUMInternal);
fnloreader->SetScaleVariation(iscale);

// switching non-pert corr off
fnloreader->SetContributionON(FastNLOReader::kNonPerturbativeCorrection,0,false);
fnloreader->SetContributionON(FastNLOReader::kNonPerturbativeCorrection,1,false);

fnloreader->SetUnits(FastNLOReader:: kPublicationUnits);

gFastNLO_array.insert(pair<int, FastNLOReader*>(*idataset, fnloreader) );
```

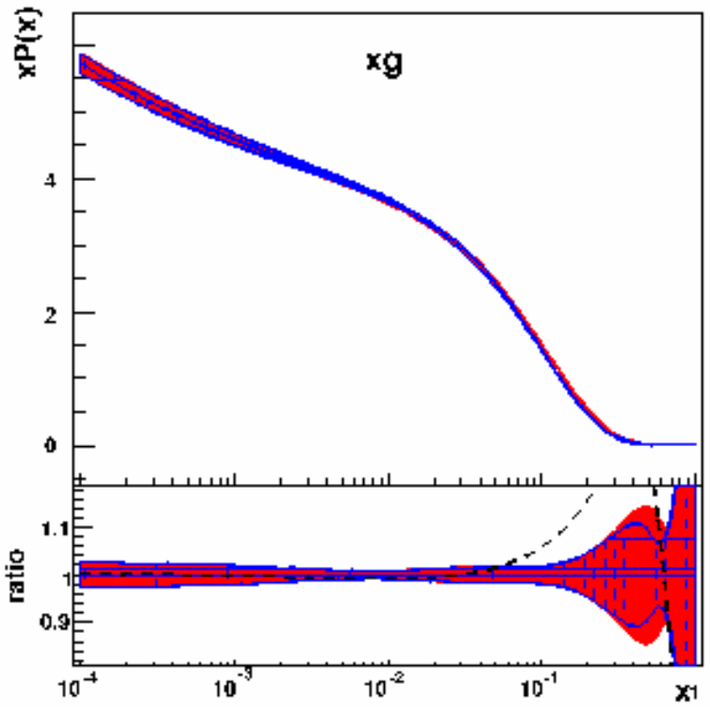
- **Features**
  - use **consistent alpha_s evolution than QCDNUM** (nf, th. matching, n-loop, MZ)

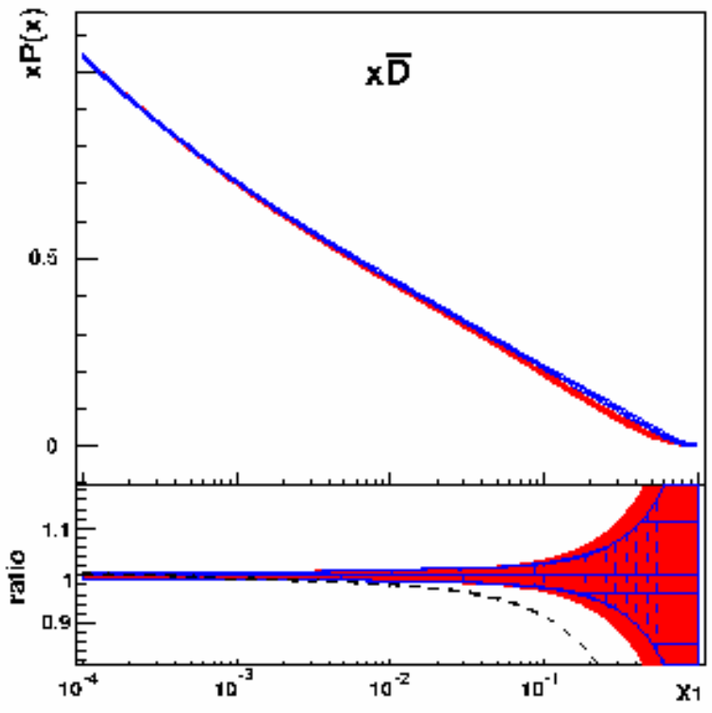
- **Necessary for input card**
  - Set scale information
  - CS in publication units or absolute units???
    - H1Fitter rule??
  - Threshold corrections ON/OFF

Results HERAPDF1.0 vs. HERAPDF1.0 + CMS incl. jets









HeraPDF1.0 + CMS

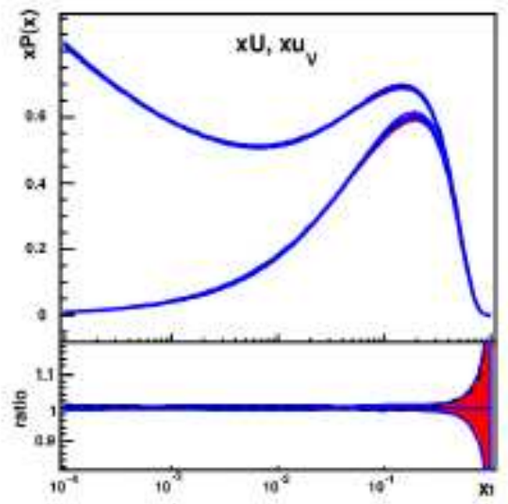
HERAPDF1.0 Reference

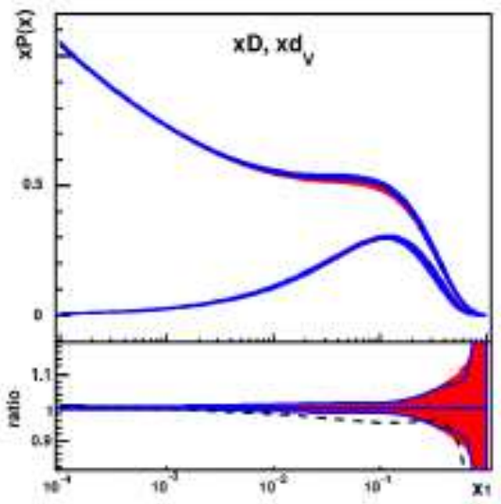
output.HERAPDF10.ref.NLO.bands

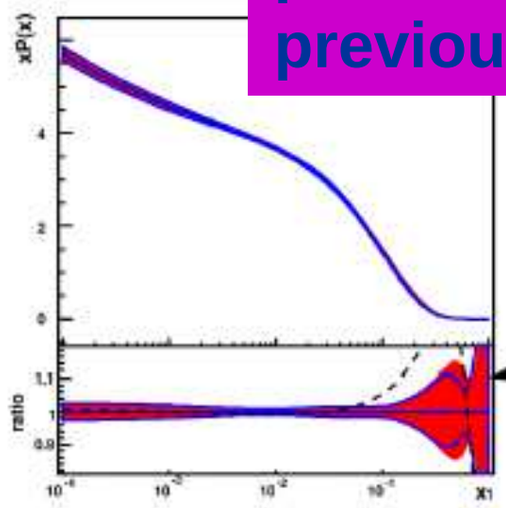
Q^2 = 4.00 GeV^2

CMS jets impact on PDF experimental uncertainty

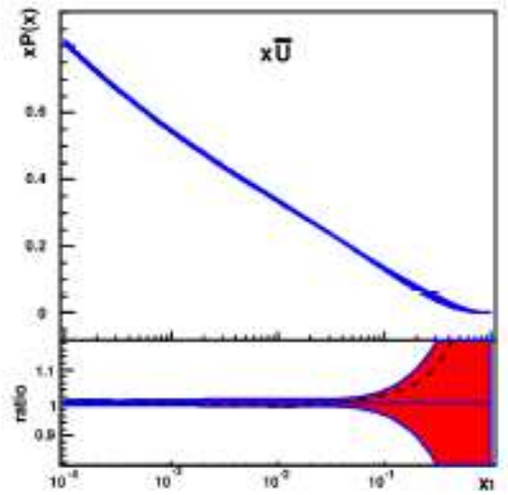
perfectly consistent with previous fit by K. Nowak

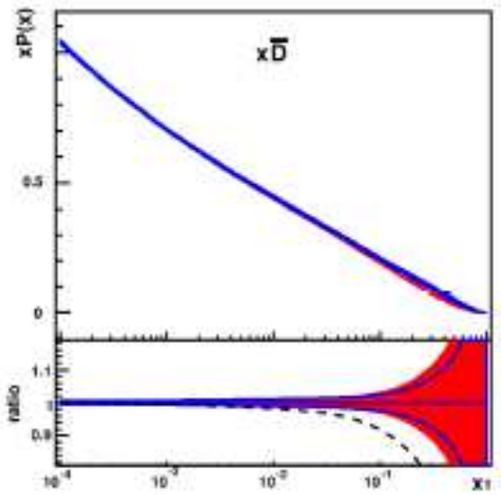






effect from CMS jets inclusion





Scenario 1

No CMS jets

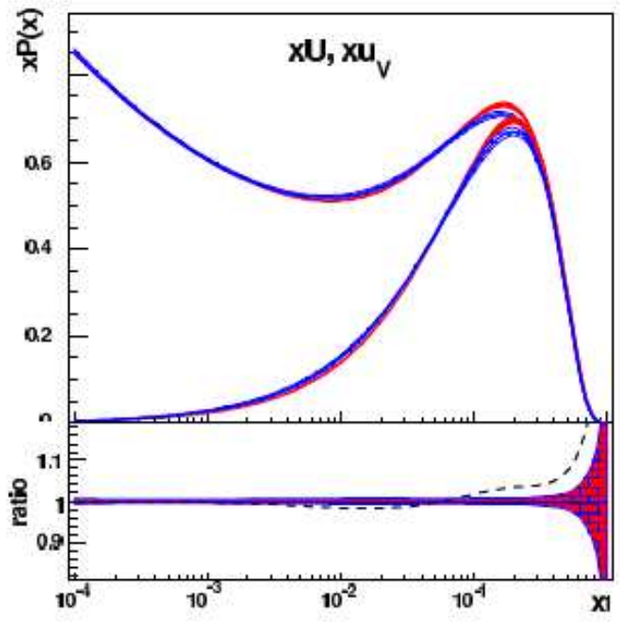
$Q^2 =$ 4.00 GeV^2

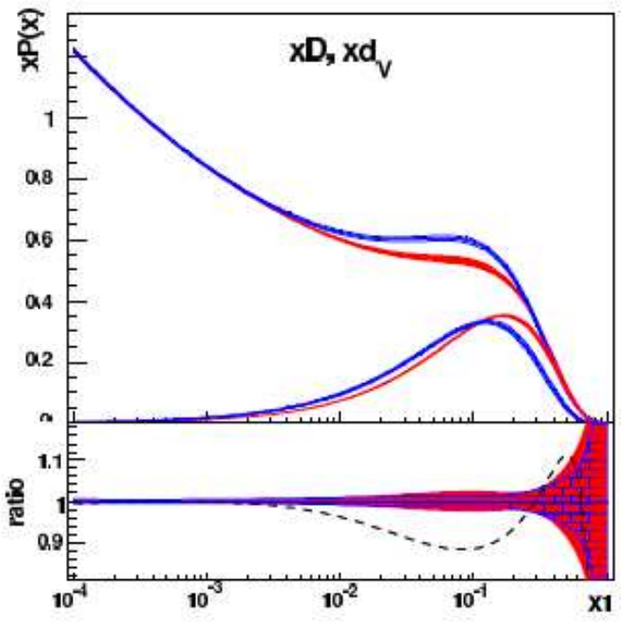
Experimental error decreased for high-x gluon

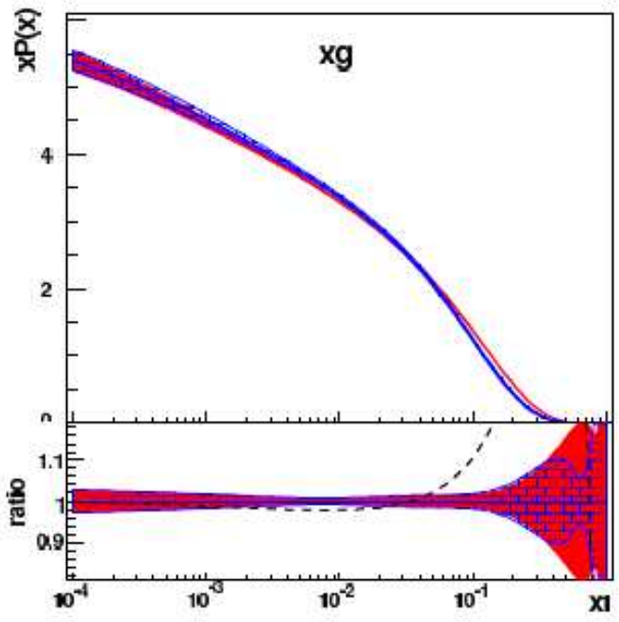
Including D0 incl. jets @ NNLO

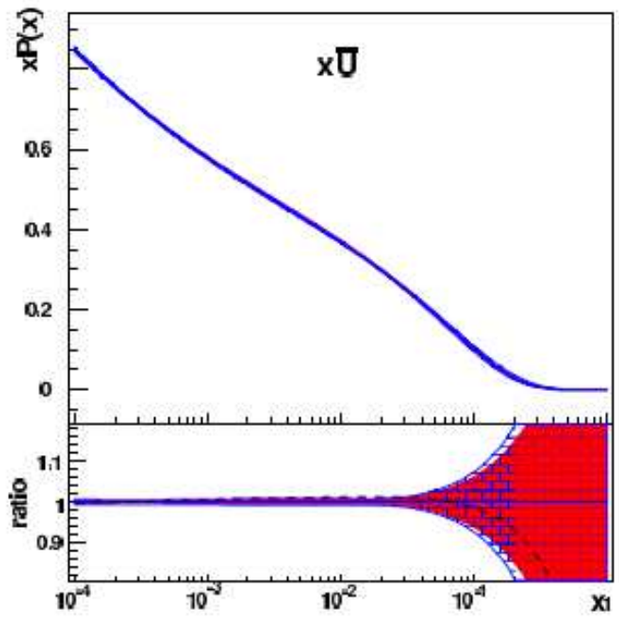
D0, arXiv:0802.2400

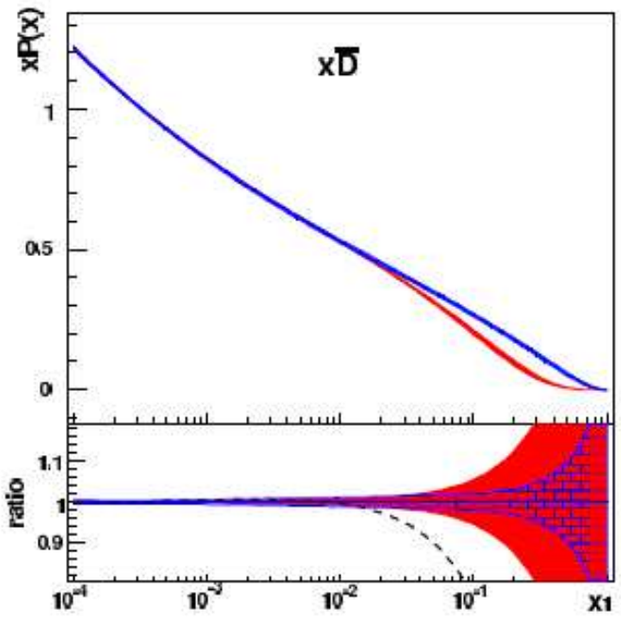
- using D0 jets
- including threshold corrections O(nnlo)











HeraPDF1.0 + D0 (incl. th. corr)

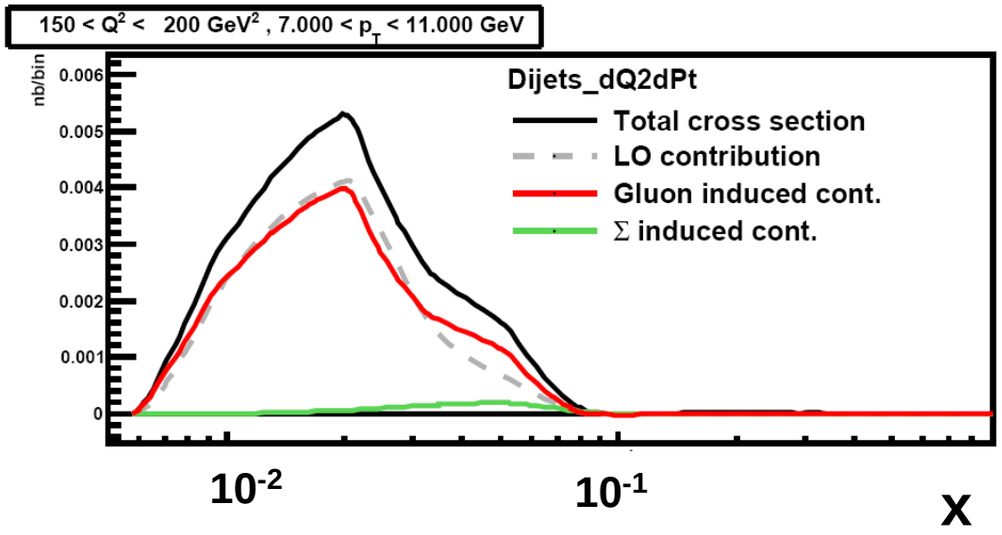
"HERAPDF1.0 @ NNLO"

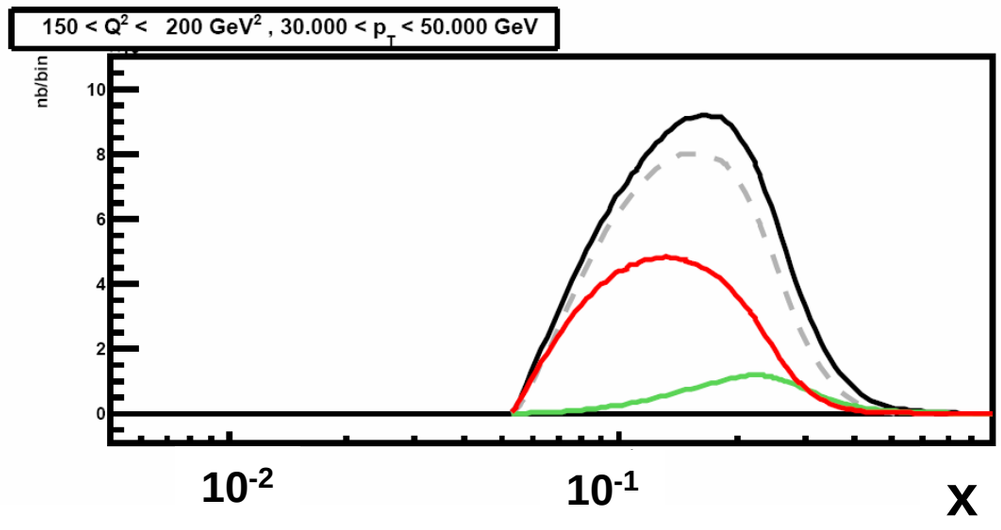
Q2 = 4 GeV2
Chi2/ndf = 752.9 / 692
Chi2/ndf (D0) = 75.0 / 110

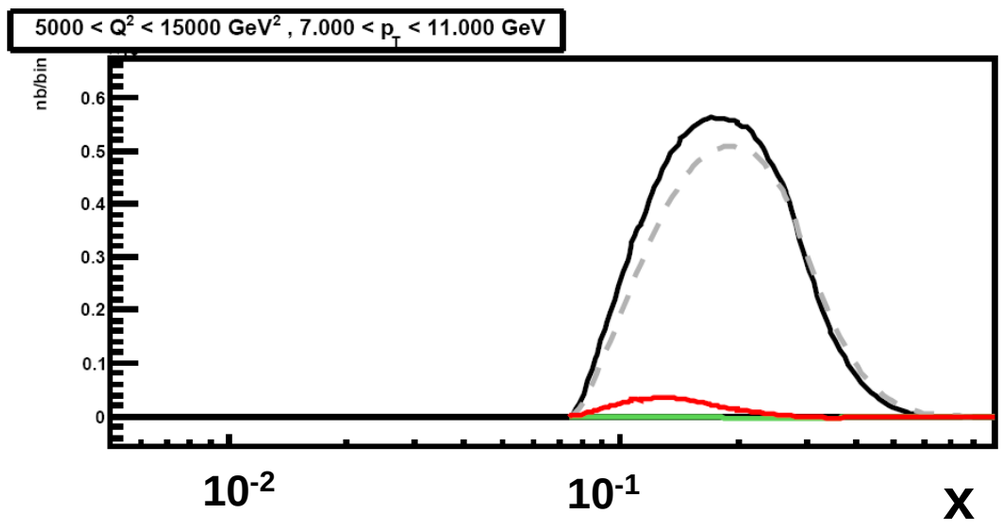
Which x-region do we test with jet data?

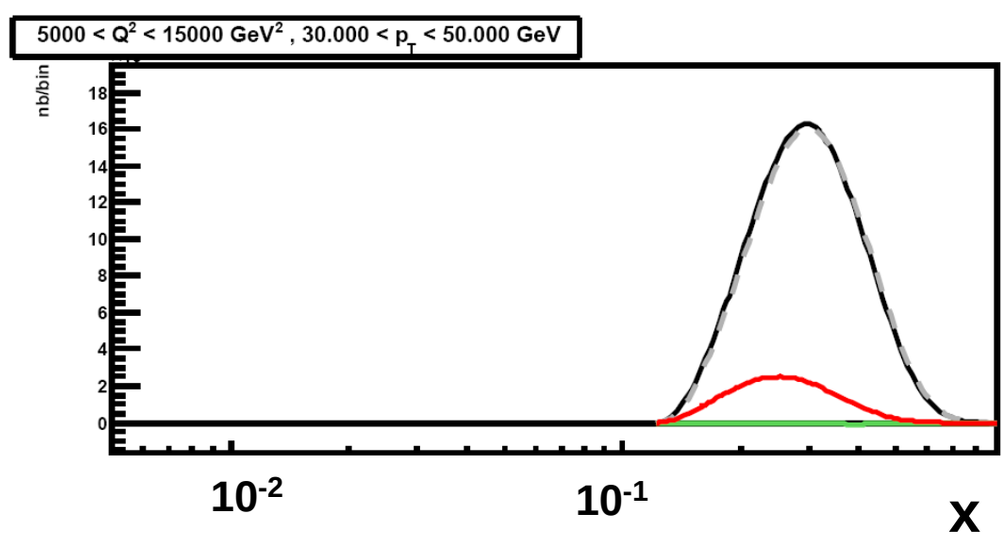
- E.g. **H1 dijets @ high Q^2**
  - four bins:
    - low and high Q^2
    - low and high <pt>
- Only three contributions in DIS
- Gluon, Delta, Sigma induced processes

- low Q^2 is mostly **gluon induced**
- High Q^2 is mostly **Delta induced**
- 'low' x-region only at low <pt> and low Q^2

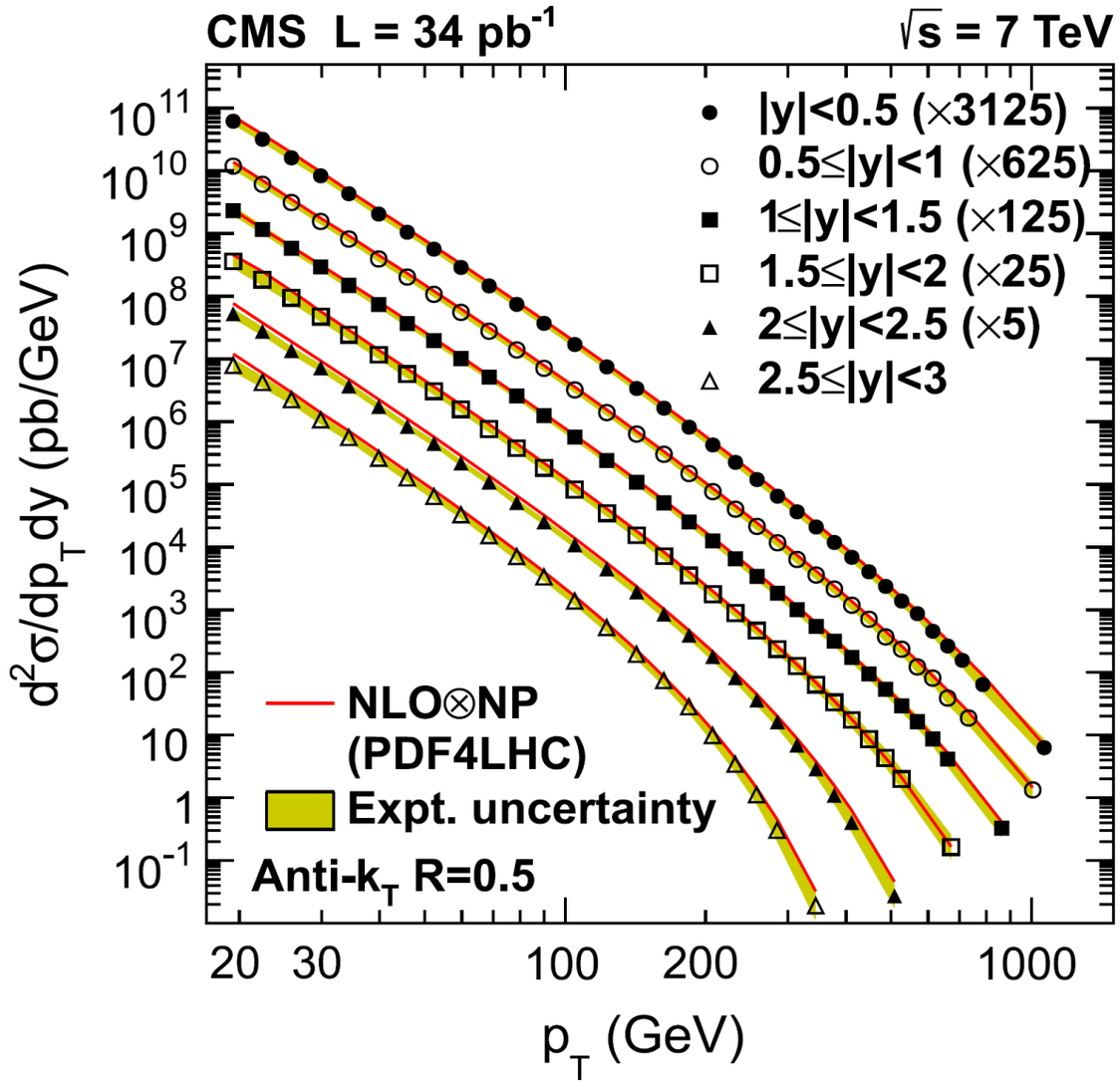








Can we do the same for CMS incl. jets?



CMS, PRL 107, 132001, 2011

- CMS inclusive jets
- 176 bins
- 6 rapidity regions

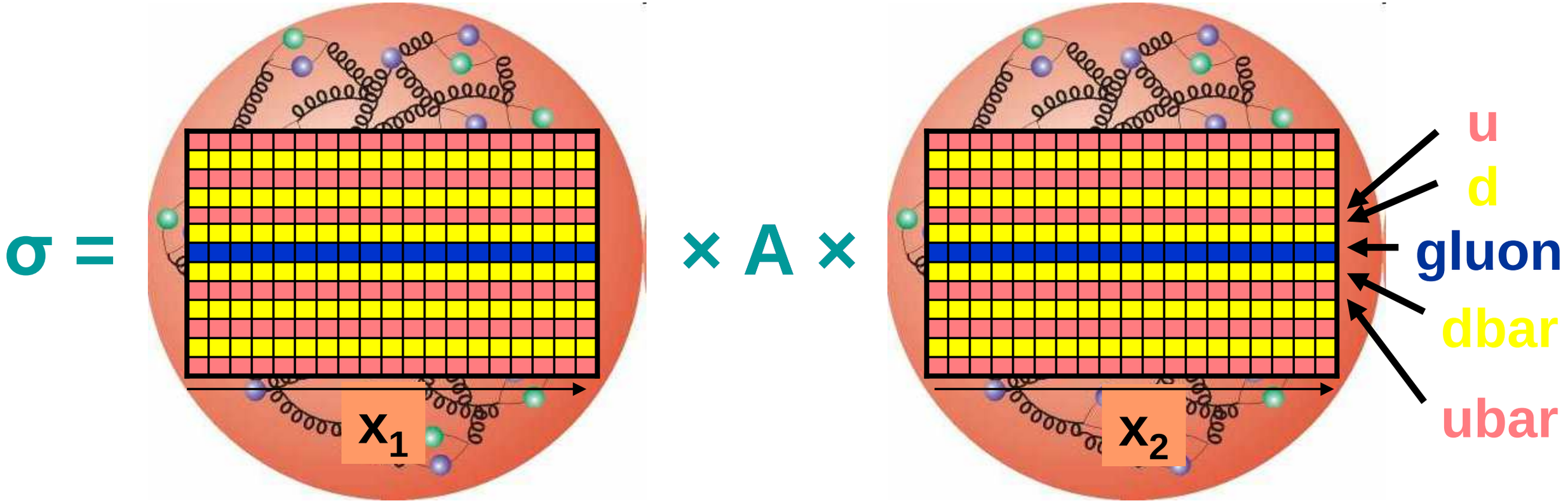
- To which 'x'-regions and to which pdfs are we sensitive to???

Can we do the same for CMS incl. jets?

- In FastNLO we replace x-integrations by sums over n_x-nodes
- Basically $13\times13\times n_x\times n_x$ contributions to the cross section
  - reduced to $7(6)\times n_x\times n_x/2$ cont. in FastNLO
- Still
  - Cross section can be written for FastNLO like

$$\sigma_{Bin} = \Sigma_{f1}\Sigma_{f2}\Sigma_{x1}\Sigma_{x2} \left(pdf(f1,x1) \times pdf(f2,x2) \times A \right)$$

  - with $A(f1,f2,x1,x2,\mu_r,\mu_f) = \sigma_{fnlo}\times \alpha_s$



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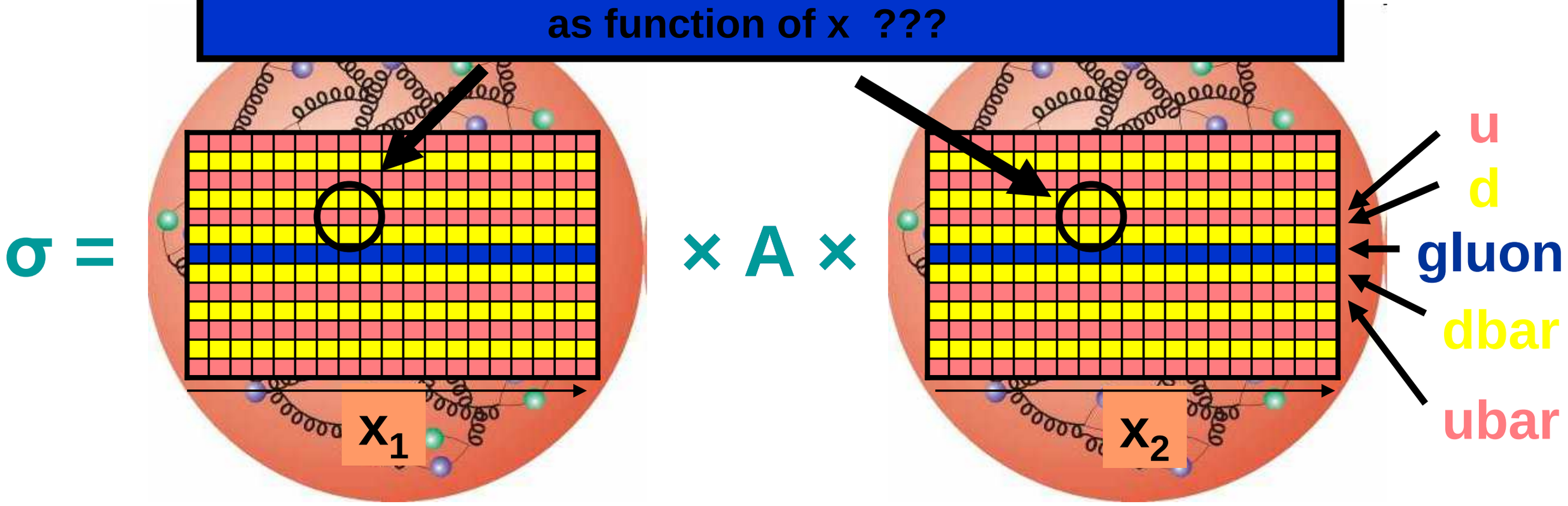
$$\sigma_{Bin} = \Sigma_{f1}\Sigma_{f2}\Sigma_{x1}\Sigma_{x2} \left(pdf(f1,x1) \times pdf(f2,x2) \times A \right)$$

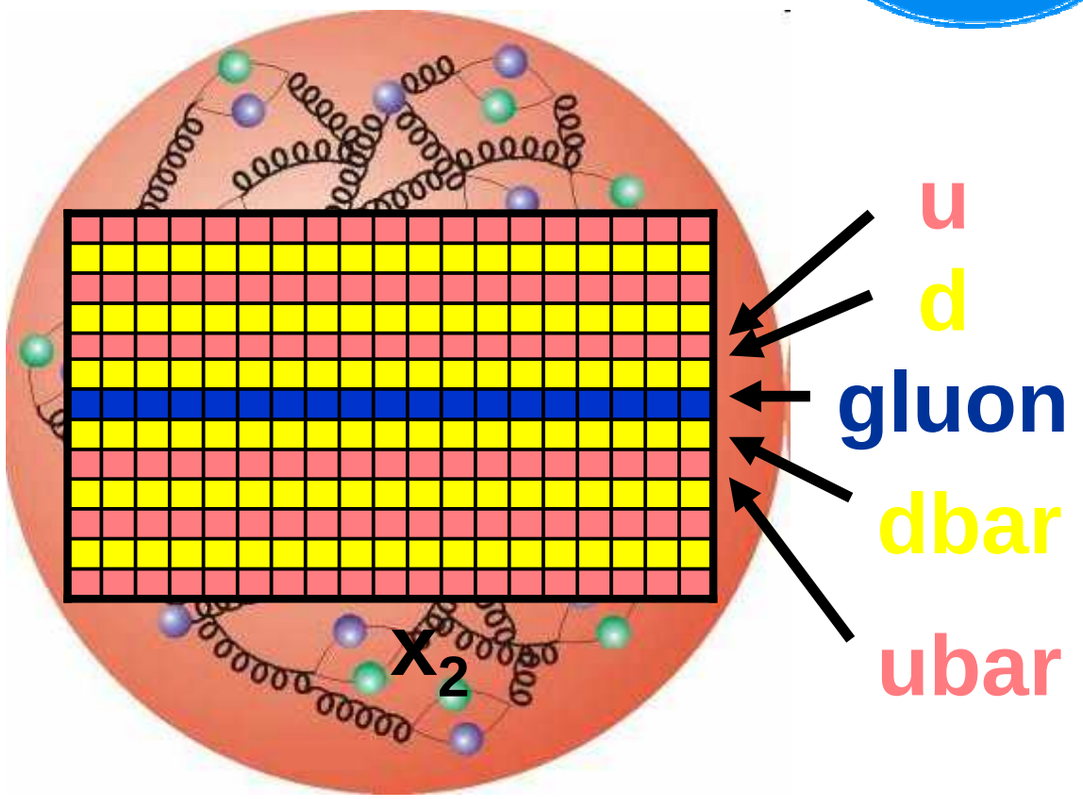
  - **How much ist the contribution to the cross section from flavor i as function of x ???**



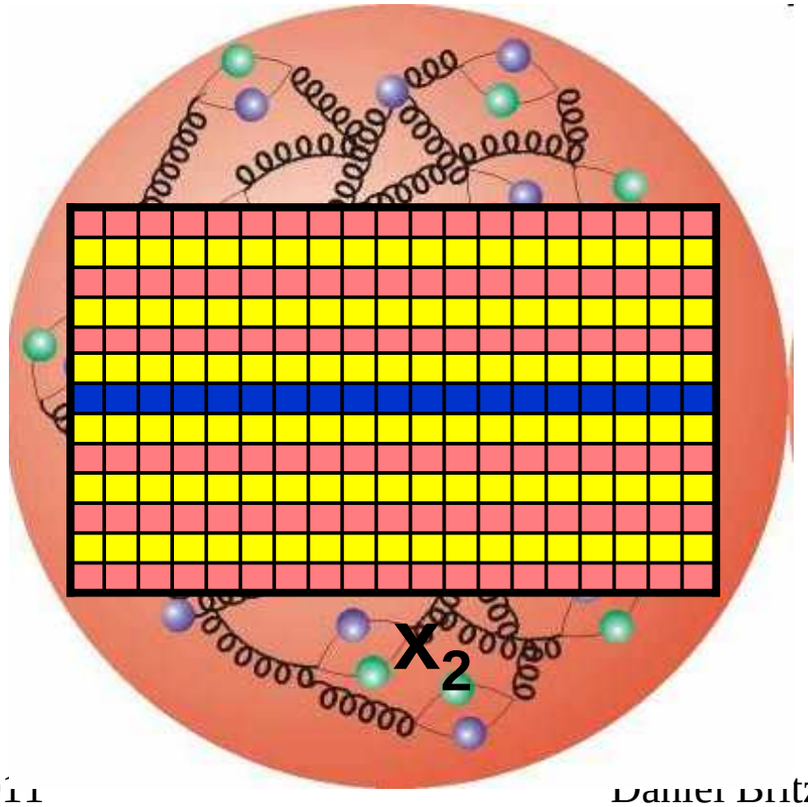
Can we do the same for CMS incl. jets?

$\square \times A \times$

$f_i \mid x_{1,i}$



+



$\times A \times \square$

$f_i \mid x_{1,i}$

x-dependent contributions

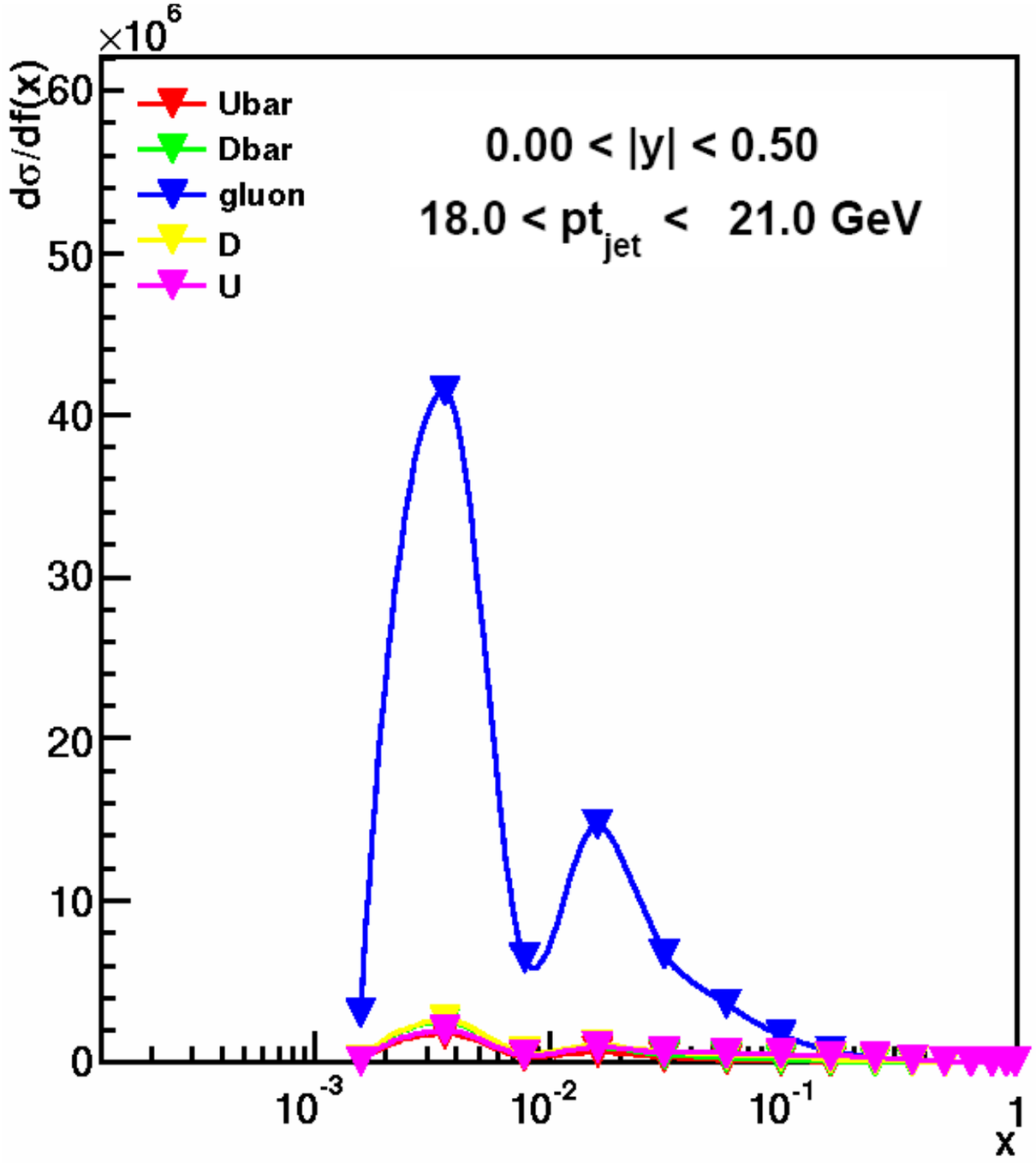
CMS inclusive jets

Low pt region

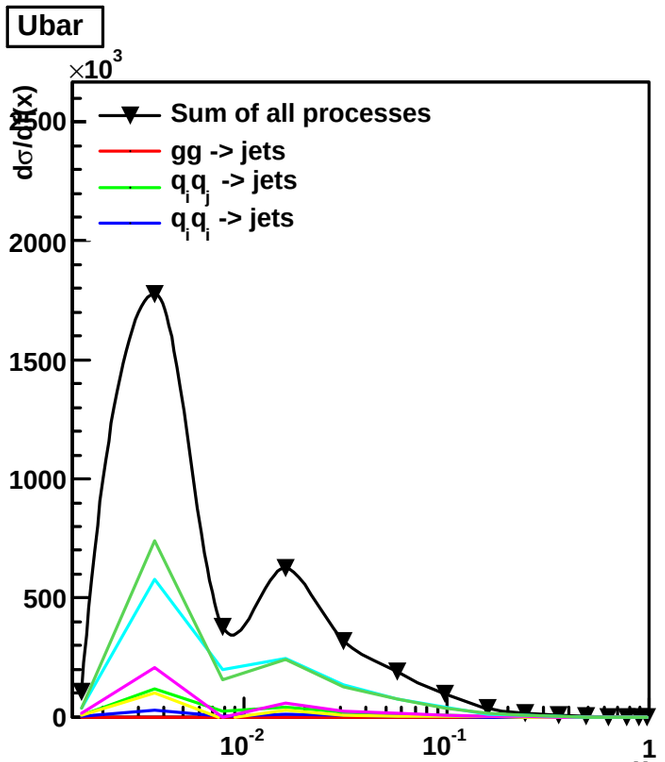
Central rapidity

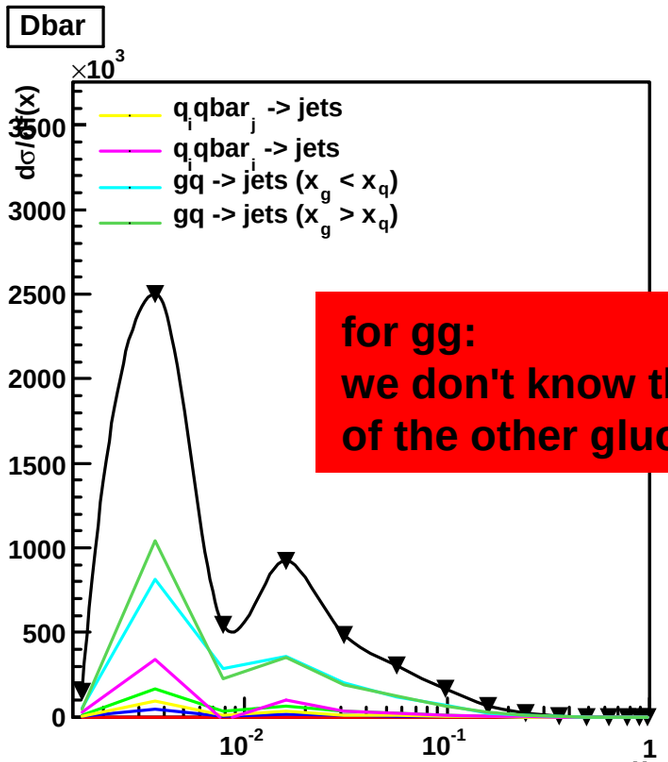
- 'Integral' of all contributions is $2\sigma_{bin}$
- negative contributions from cancellations (?)

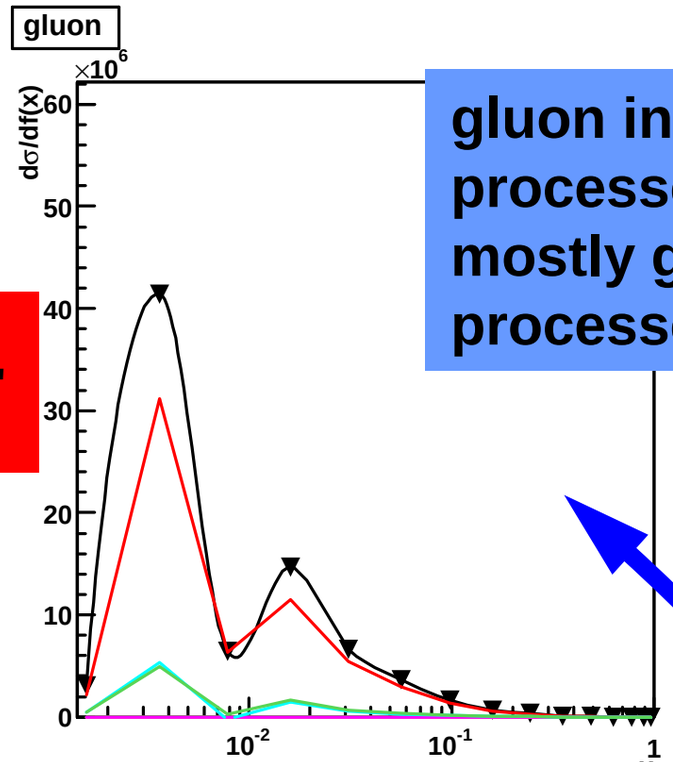
- This Bin
  - testing PDFs up to 10^{-3}
  - no sensitivity to high x region
  - process mostly gluon dominated
    - but what kind of gluon process?



What kind of contributions?



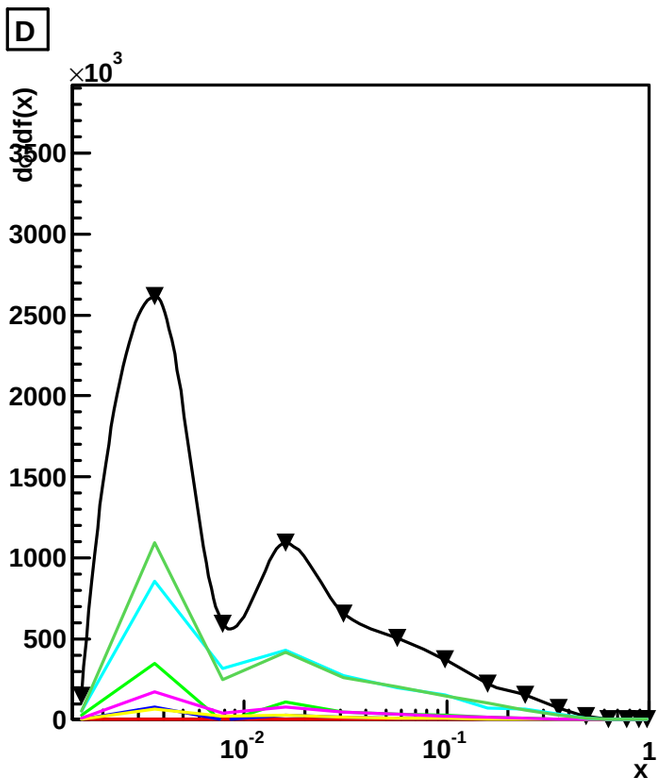


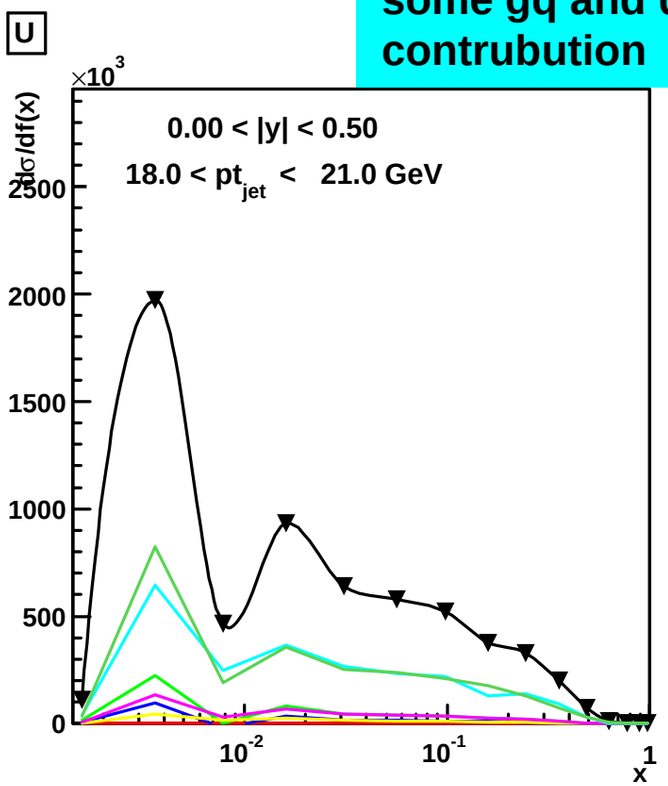


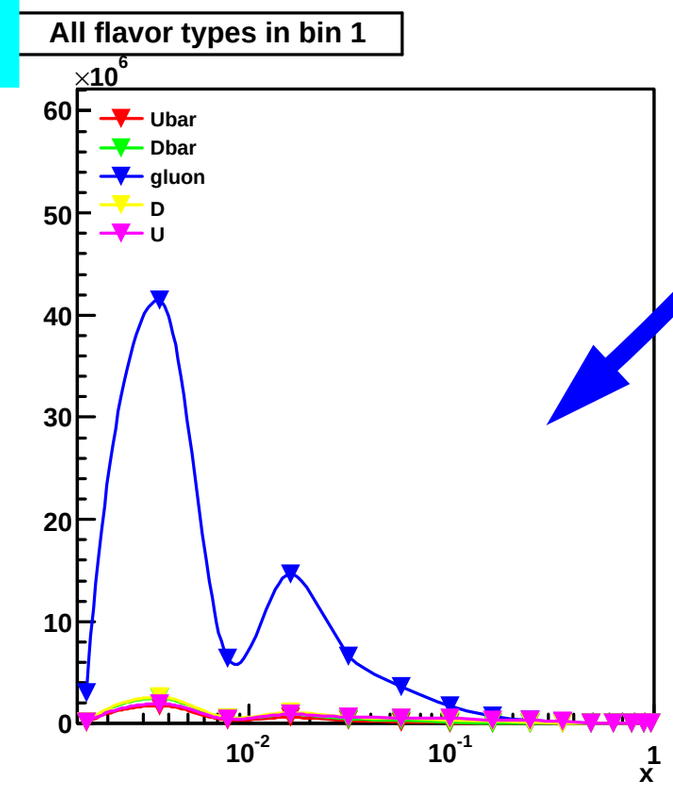
for gg:
we don't know the 'x'
of the other gluon

gluon induced processes are mostly gg processes

some gq and qg contrubution

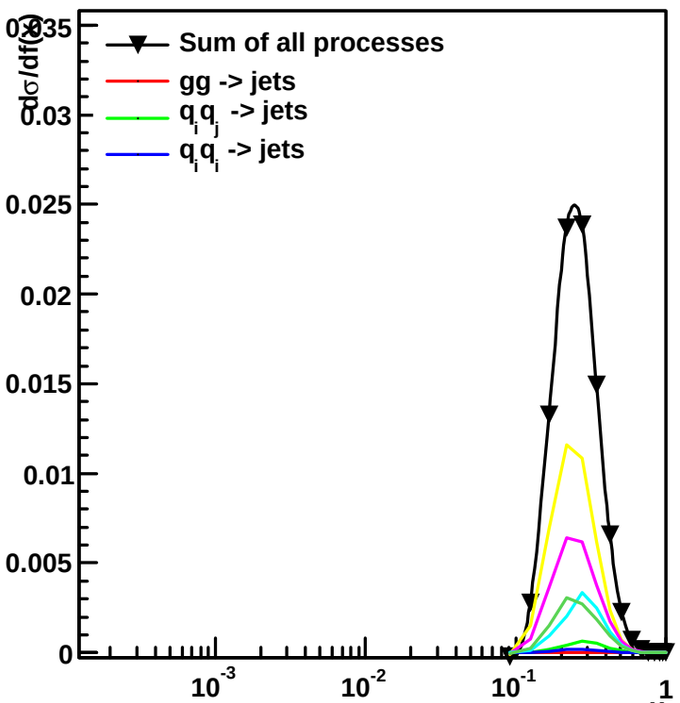




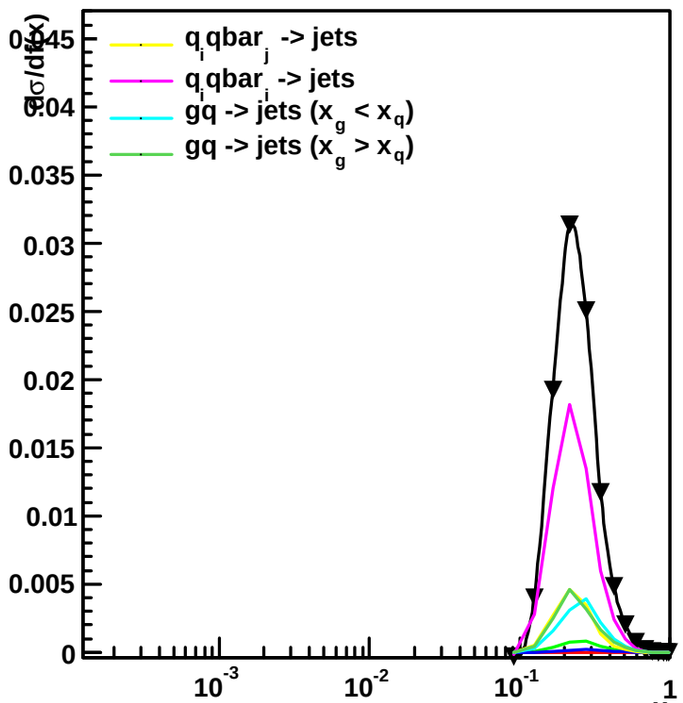


Central Rapidity - High pt Jets

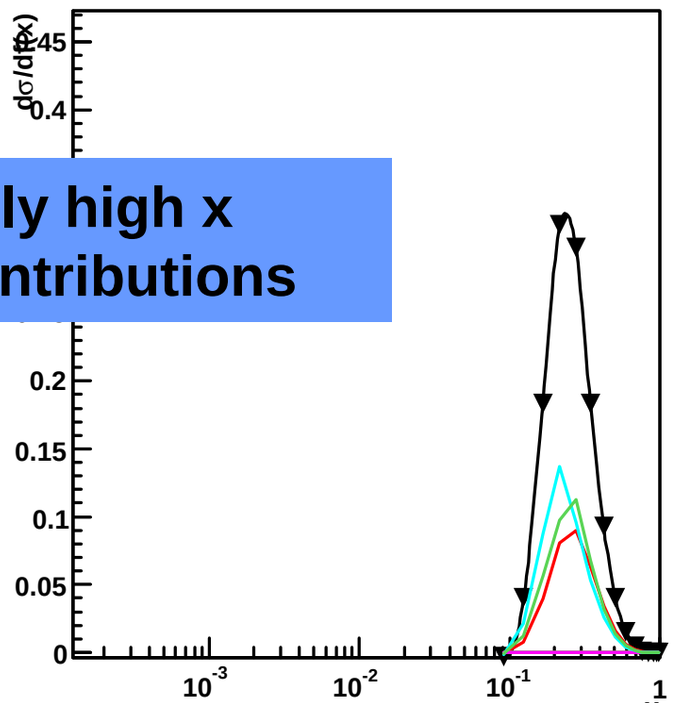
Ubar



Dbar

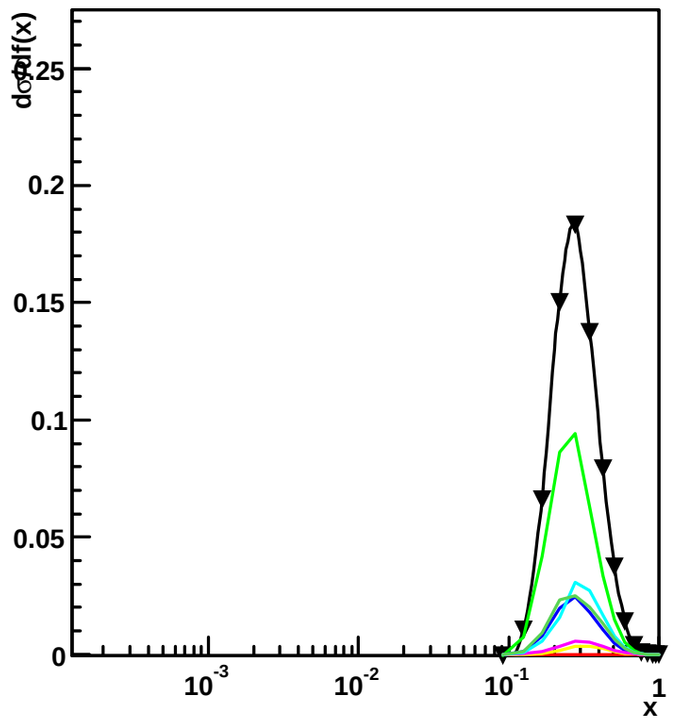


gluon

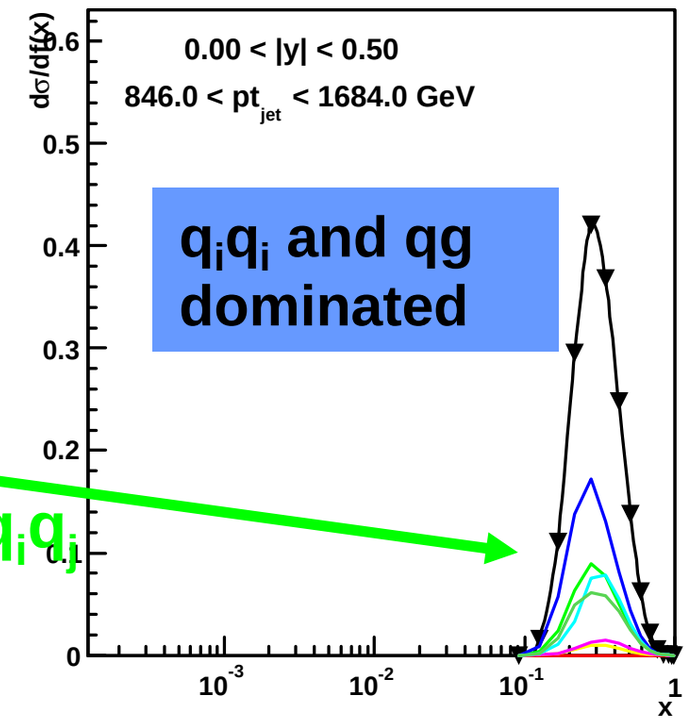


only high x contributions

D



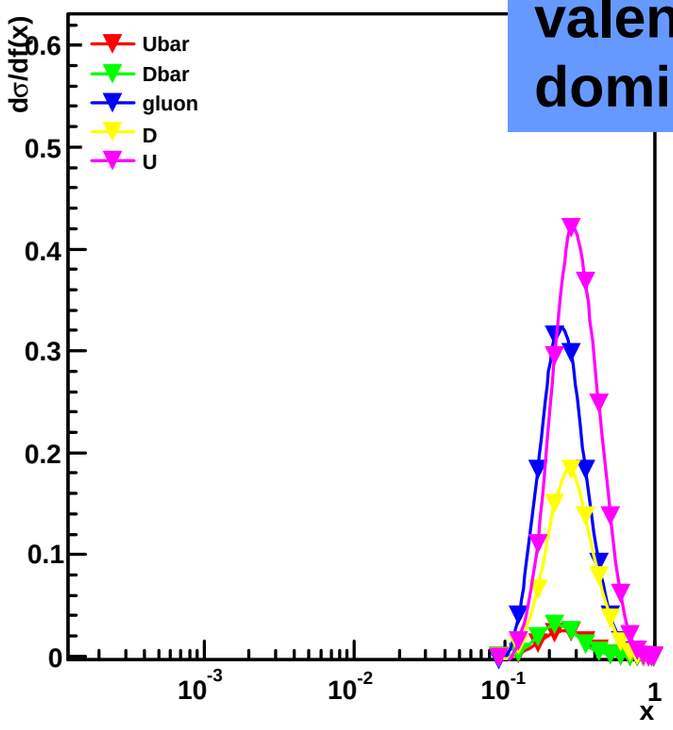
U



$q_i q_i$ and qg dominated

$q_i q_j$

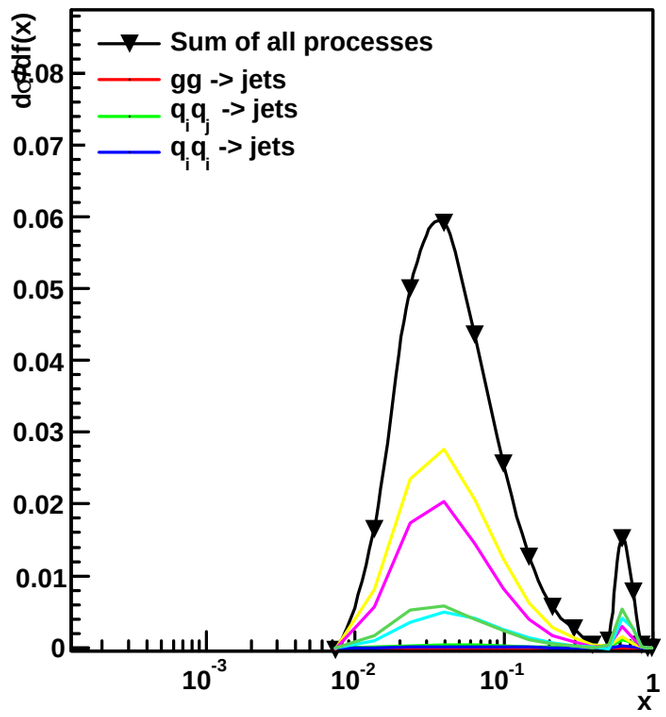
All flavor types in bin 34



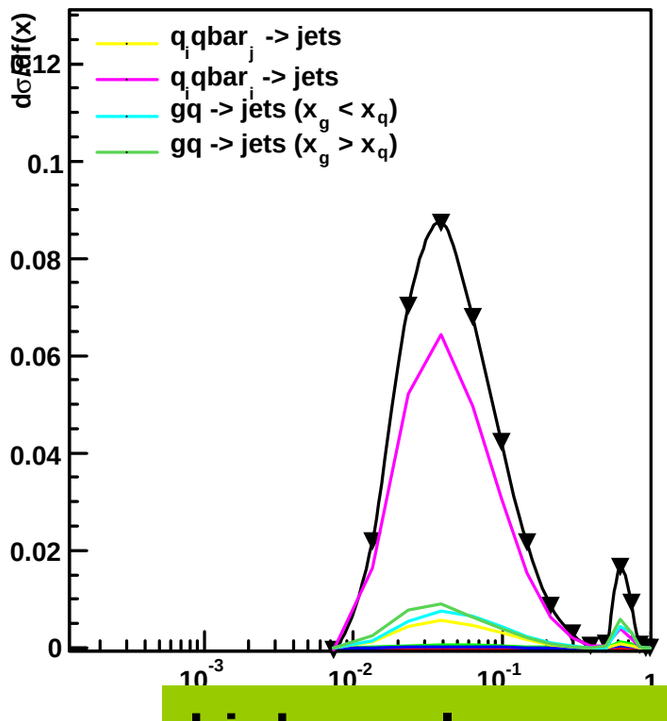
valence dominated

Forward Region - High pt Jets

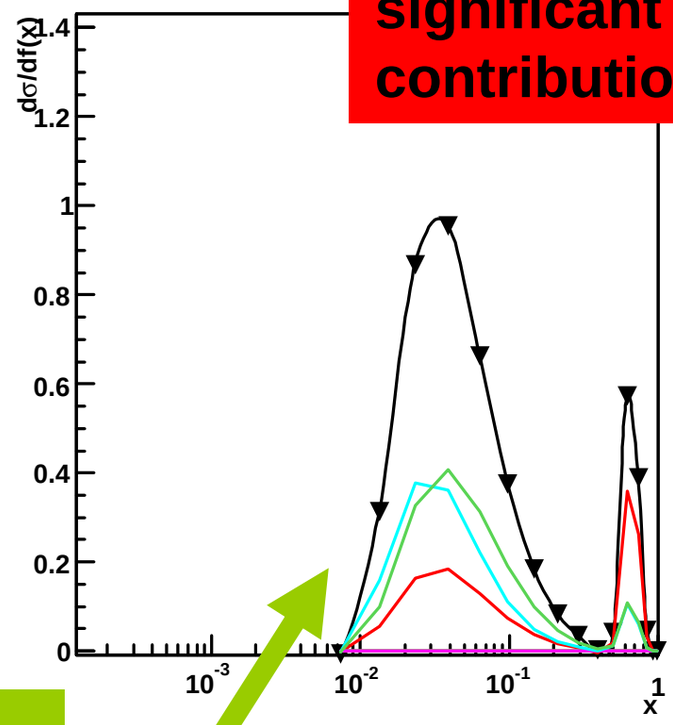
Ubar



Dbar



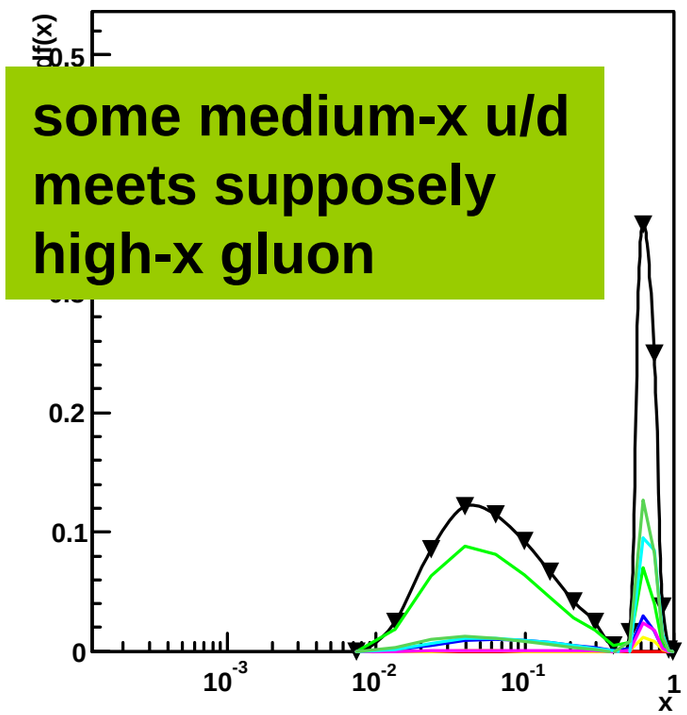
gluon



significant high-x gg contribution

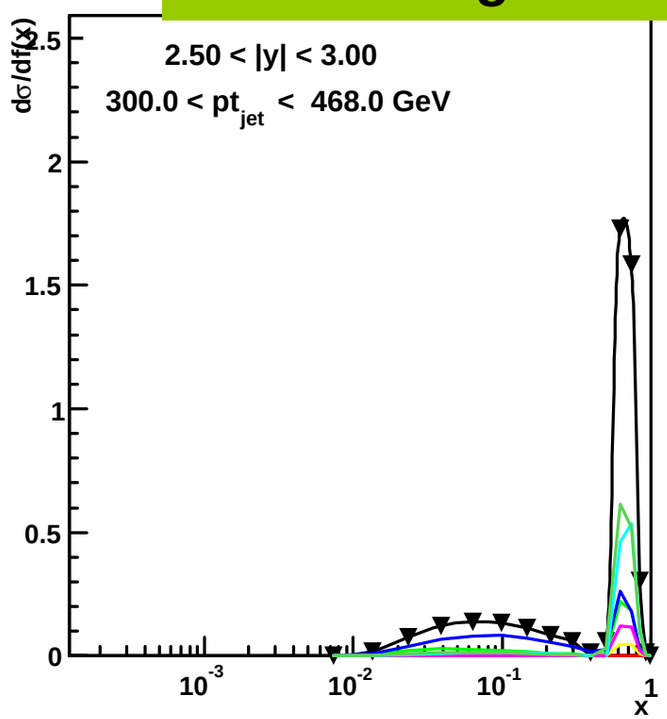
high-x valence meets medium-x gluon

D

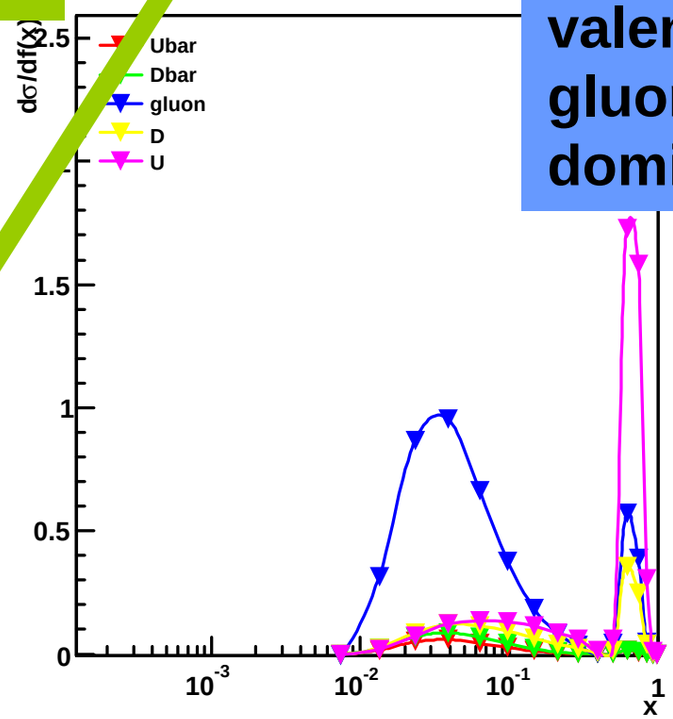


some medium-x u/d meets supposely high-x gluon

U



All flavor types in bin 176

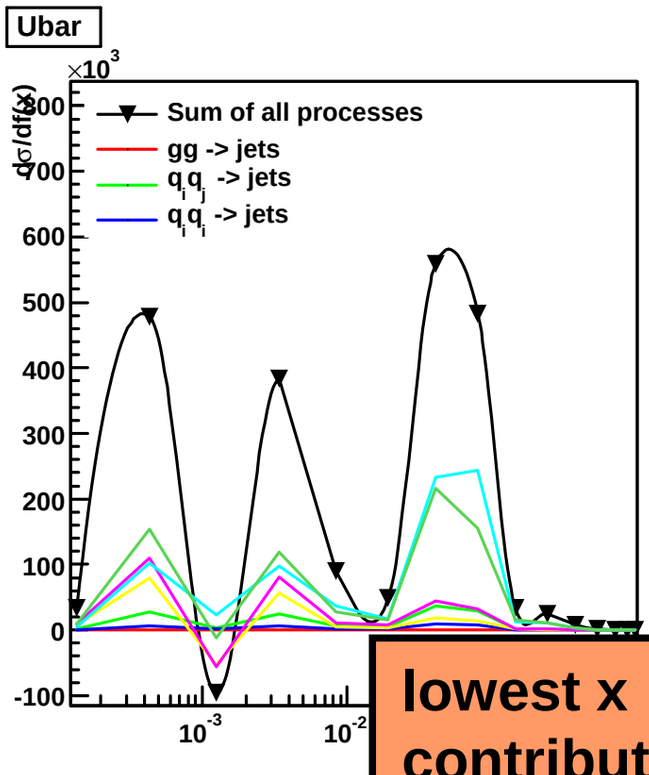


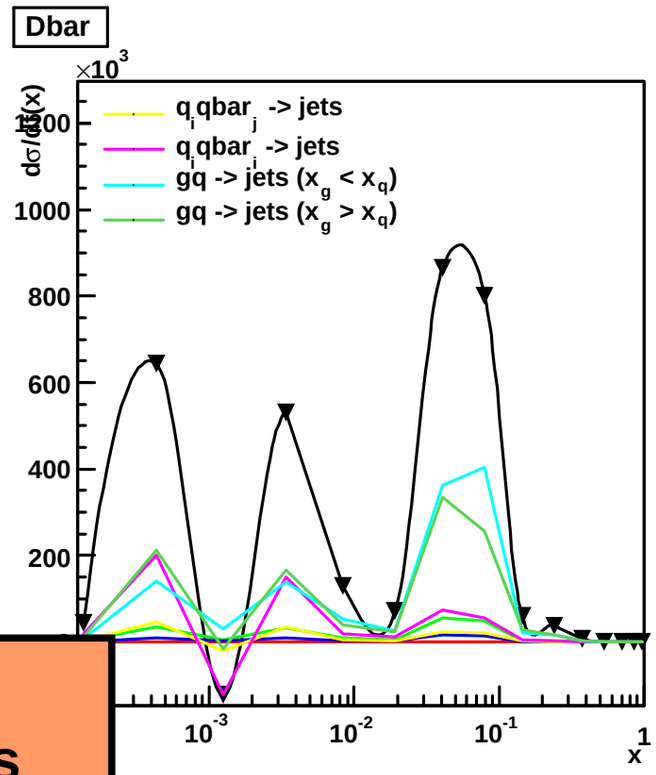
valence and gluon dominated

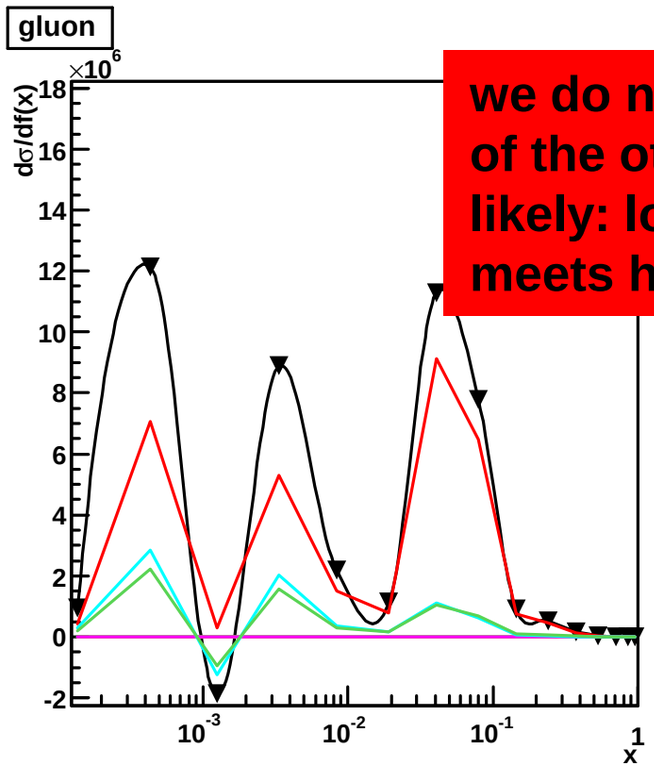
Conclusion

- **FastNLO**
  - v2.0 is (almost) released
  - new v2.0 tables become available
  - v1.4 tables are converted into 'new' table format
  - new concept for multidimensional scale tables
- **FastNLO + H1Fitter**
  - C++ version (pre-release) is implemented in H1Fitter
  - universal interface to all FastNLO tables
    - pp, ppbar, DIS tables
  - Alpha_s evolution is identical with QCDNUM
  - NNLO fits with jet data (incl. thr. corr.) is principally possible
- **Todo**
  - Some parameters should be implemented in steering
  - Cross sections in pb or pb/[BinWidth] in H1Fitter ?
- **Open questions**
  - Which scales should be used?
  - How to determine 'theory unc.' from scale variations
    - how to do it for multiple jet cross sections (DIS,pp,ppbar?)
  - How to treat theory uncertainty?
    - Fit with +/- scale variation -> additional pair of pdf-error-set ?

Forward Region - Low pt Jets

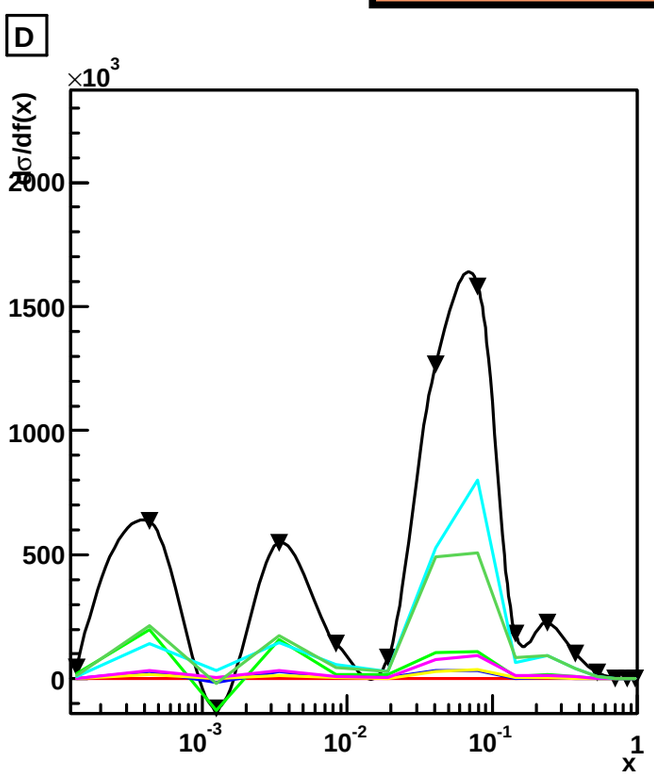


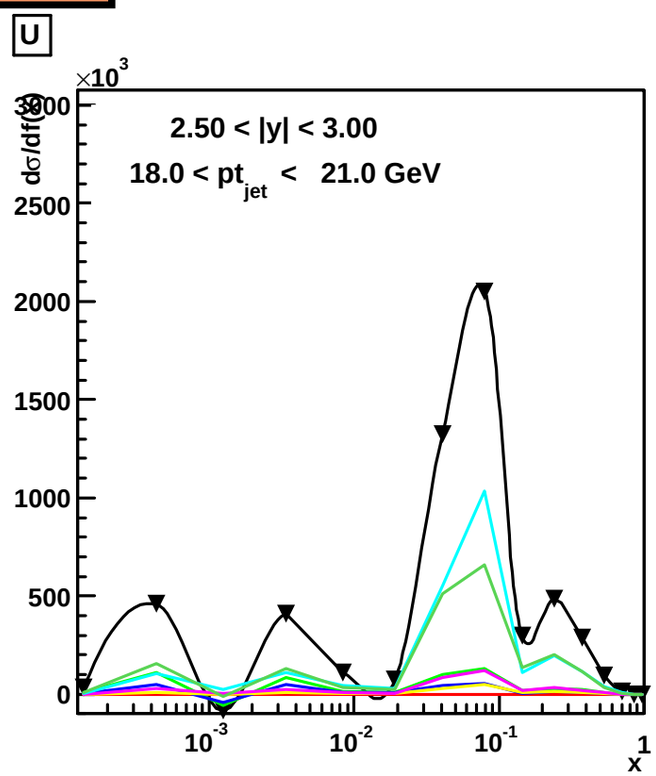


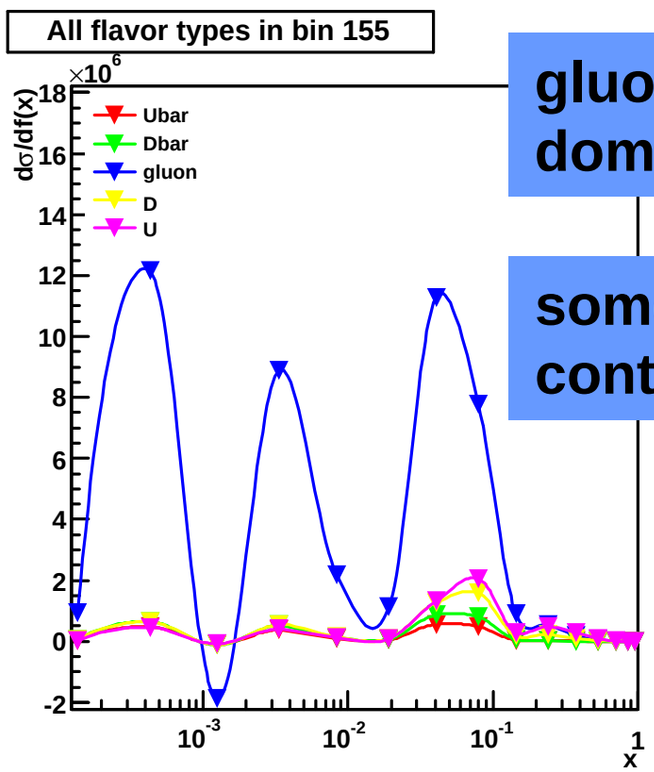


we do not know the 'x' of the other gluon likely: low-x gluon meets high-x gluon

lowest x contributions







gluon dominated

some valence contributions