Determination of the PDF Uncertainties in the DØ Squark and Gluinos Analysis

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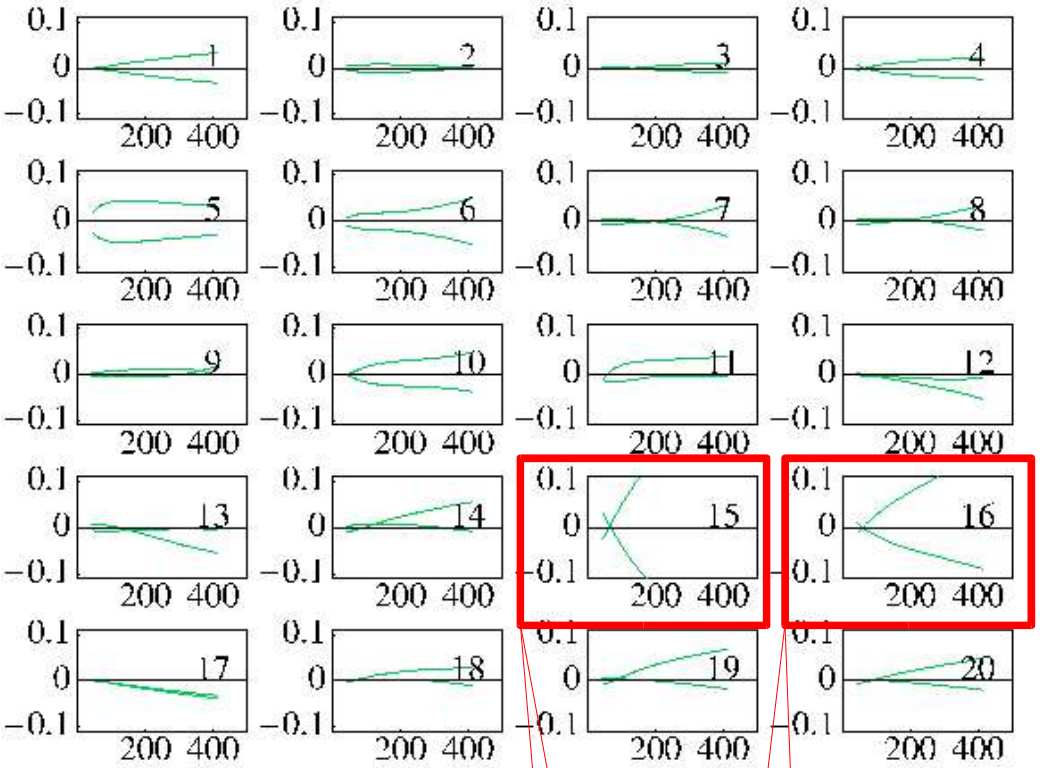
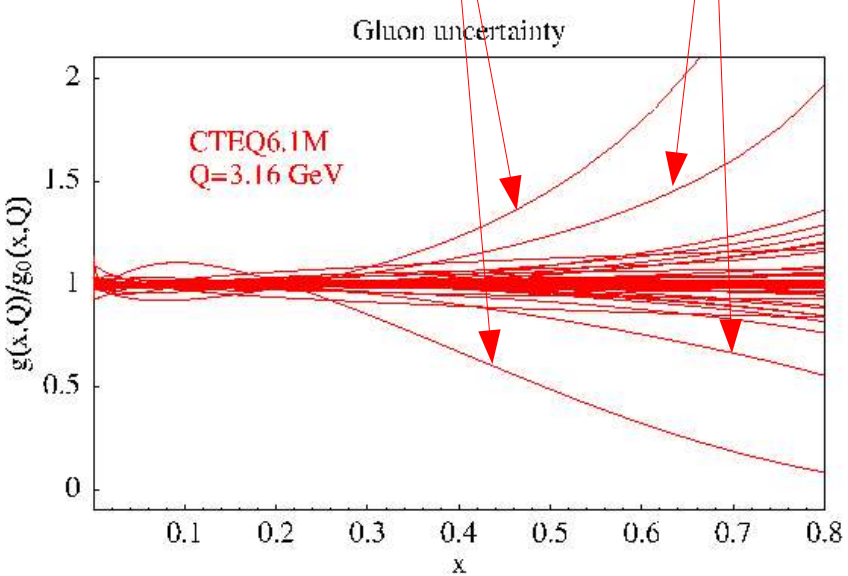
- PDF uncertainties on the squark-gluino cross section
- PDF uncertainties on the squark-gluino selection efficiencies
- <u>I am not a PDF expert :</u>
  - I followed advices available in the D0 note 4618: "Conclusions of Mini-Workshop on PDF uncertainties and related topics", V. Buescher, J.-F. Grivaz, T. Nunnemann, M. Wobisch
- One of the basic principle, separate:
  - the effect of the PDF on the signal efficiencies => treated as a systematic uncertainty in the limit computation
  - the effect of the PDF on the signal cross section => the nominal signal cross section should be decreased by this PDF uncertainty when computing the limit

CTEQ6.1M.xx PDF Sets

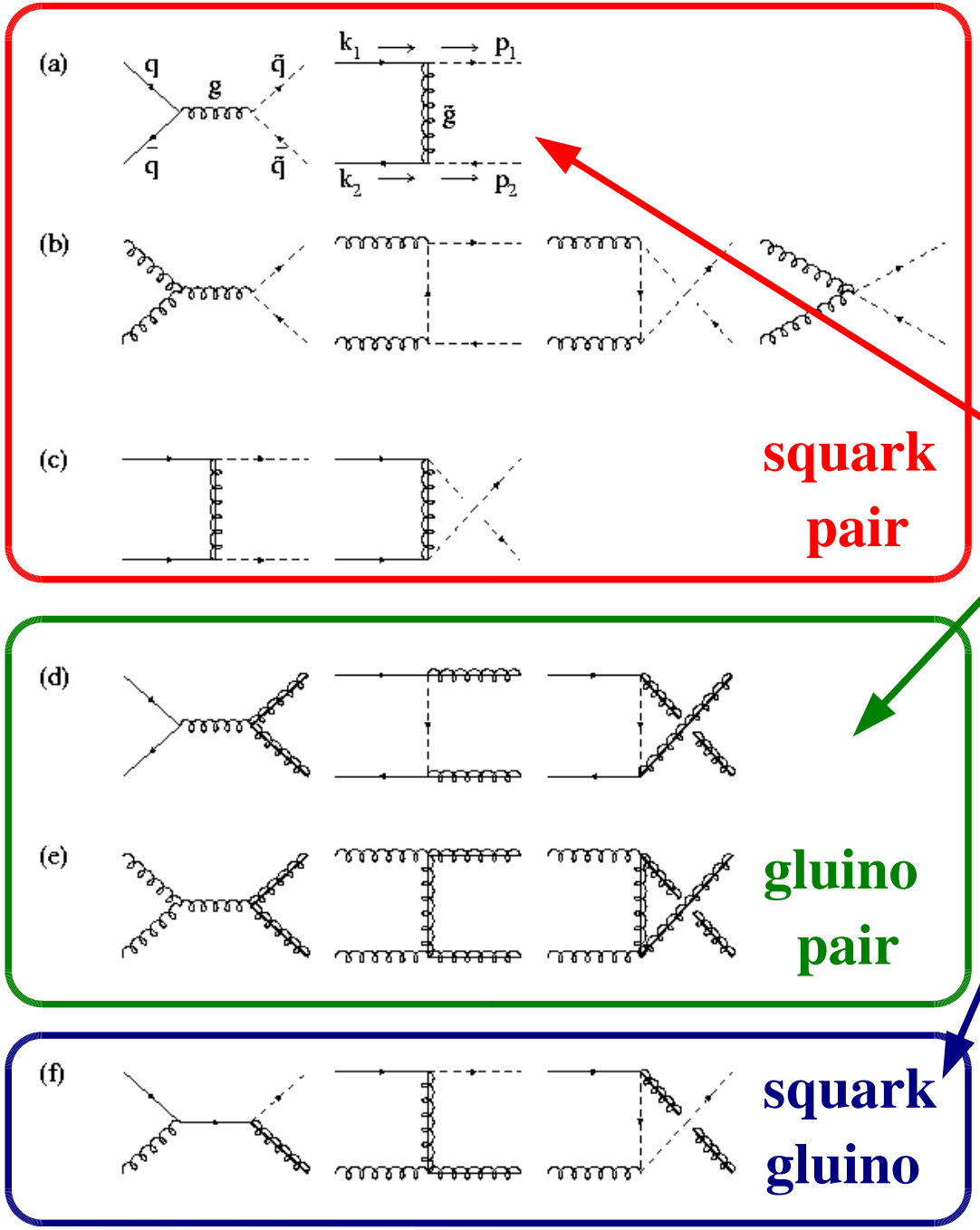




Figures from
Stump *et al.*, JHEP (0310), 2003
(hep-ph/0303013)

- CTEQ6L1 and the 41 CTEQ6.1M PDF sets were used:
- CTEQ6L1 : LO PDF
- CTEQ6.1M (or CTEQ6.1M.00) is the nominal NLO PDF. It is slightly different from CTEQ6M
- CTEQ6.1M.xx with xx=01-40: 40 up and down PDF sets along 20 eigenvector directions:
  - 01/02 corresponds to +/- for the 1st eigenvector
  - ...
- The large uncertainty using eigenvector 15 (PDF sets 29 and 30) comes from the very poor knowledge of the gluon at high-x

Squarks & Gluinos Production



diagrams from prospino preprint : hep-ph/9610490

- A lot of diagrams (only at tree level here), to produce squark/gluino pairs at the TEVATRON
- And, diagrams involving gluons in the initial state can represent a large fraction of the total squark-gluino cross section
- squark-antisquark are produced mainly by quark-antiquark interaction
- PYTHIA LO cross sections for gluino pair production at large m0:

  m0=500, m1/2=80, tan(beta)=3, A=0, mu<0

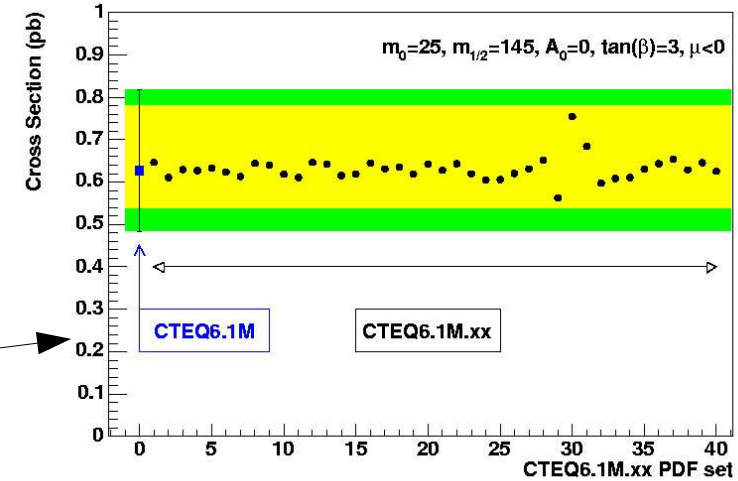
  - σ (gg->gluino-gluino) = 0.184 pb^{-1}
  - σ (qqbar->gluino-gluino) = 0.976 pb^{-1}
- And for intermediate m0 values, the squark-gluino production can represent more than 50% of the total squark/gluino cross section, and there is always one gluon in the initial state in that case

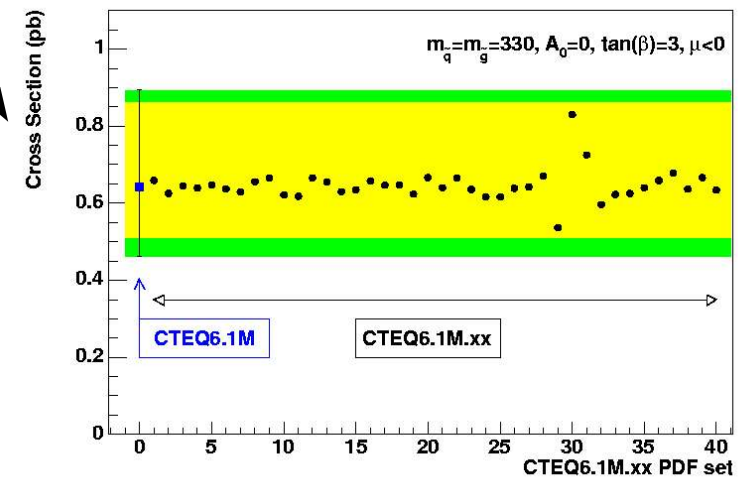
Squark-Gluino Cross Sections (I)

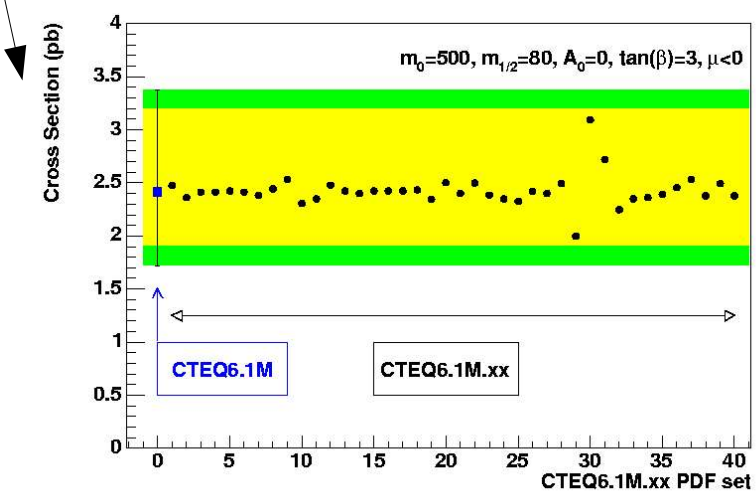
- In this study, use PROSPINO2 to compute the squark-gluino LO and NLO cross sections
- PROSPINO2 is now using “Les Houches Accord” input cards by default:
  - I used a simple program which runs ISAJET for a mSUGRA point : m0,m1/2,A0,tan(beta),sign(mu) and generate a “Les Houches Accord” input card
  - => I am sure that the mSUGRA points for which I have computed the cross sections, or, for which I have generated events in a p17 release for this study, have exactly the same masses spectrum than the p14 MC samples I used in the squark-gluino analysis
- Check that PROSPINO and PROSPINO2 give the same cross sections with the same input card, PDF and scale
- PROSPINO2 does not use LHAPDF by default, but everything was written such that it is very straightforward to use the CTEQ6.1M.xx PDF sets:
  - download the CTEQ6.1M.xx PDF tables in a PROSPINO subdirectory
  - when calling the function which computes the PDF, just put iset =xx in argument where xx = CTEQ6.1M.xx

Squark-Gluino Cross Sections (II)

- I took the 3 benchmark points of the squark-gluino analysis:
- tan(beta)=3, A=0, mu<0:
  - m0=25, m1/2 =145 : mainly squark-antisquark
  - Msquark=Mgluino=330 GeV : intermediate
  - m0=500, m1/2=80 : mainly gluino-gluino
- Compute the total squark-gluino cross section:
  - nominal cross section:
  - renormalization and factorization scale = Q
  - using CTEQ6.1M
  - to determine the PDF uncertainty:
  - renormalization and factorization scale = Q
  - and for the 40 CTEQ6.1M.xx PDF sets
  - => quadratic sum of the differences wrt the nominal cross section : yellow band on these plots
  - to determine the scale uncertainty:
  - using CTEQ6.1M
  - and scale = 2Q (down), Q/2 (up)
- Finally, combine quadratically the PDF and scale effects: green band on these plots

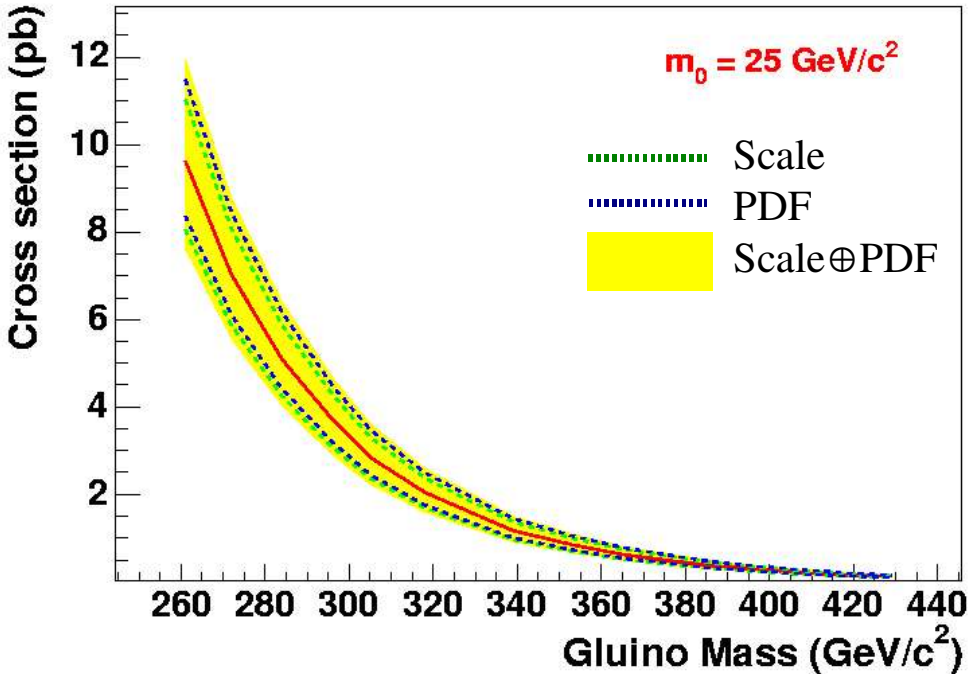


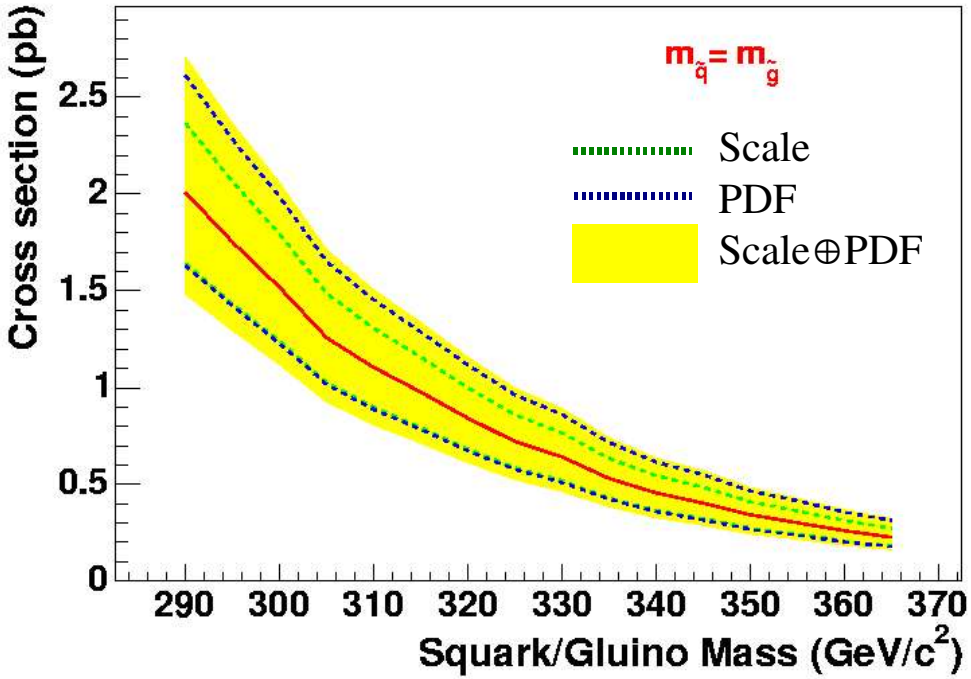


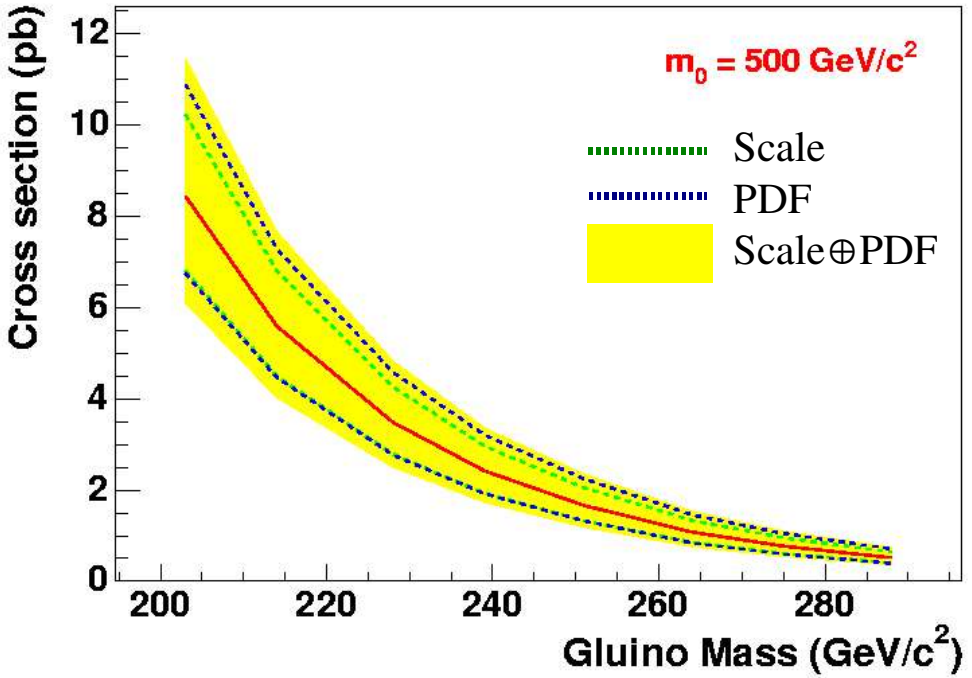


Squark-Gluino Cross Sections (III)

- Repeat this for all the mSUGRA points I use in the squark-gluino analysis : some examples here
- Effect of the scale: +/- 15-20%
- Effect of the PDF: asymmetric and reaches -30 +50% for m0=350, m1/2=100
- PDF effect comes mainly from the eigenvector 15
- PDF effect is very important for 250<m0>400, when, gluons are often involved in the hard process
- At very large m0: σ (qqbar->gluino-gluino) > σ (gg->gluino-gluino), the PDF effect decreases

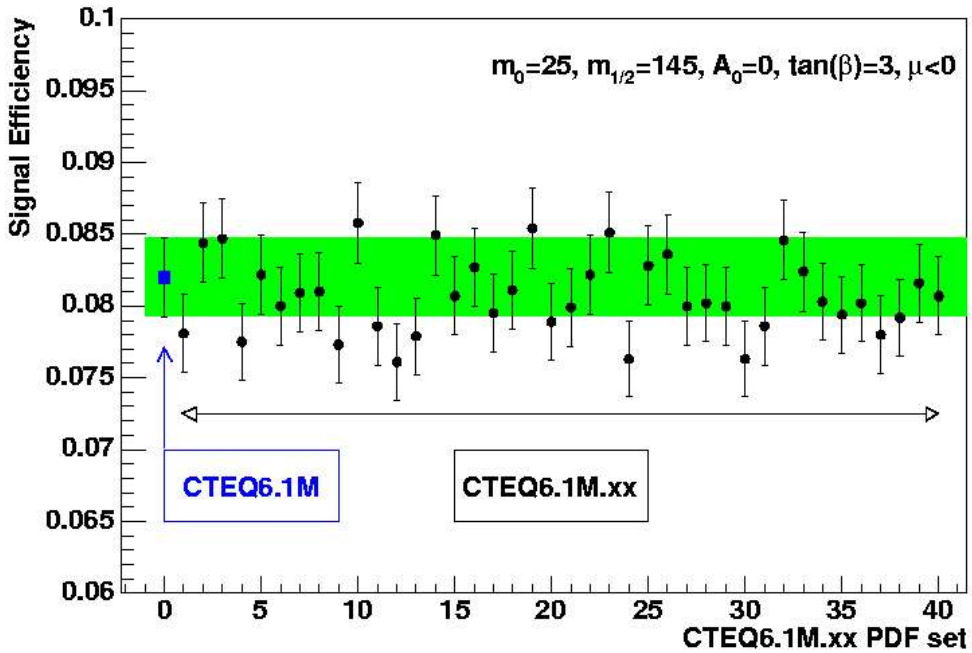






Squark-Gluino Efficiencies (I)

- In p17.09.01, we can generate events with PYTHIA and "any" PDF set using LHAPDF
- Generate 10,000 events for the 3 benchmark points, for the 42 CTEQ6 PDF (CTEQ6L1, CTEQ6.1M, CTEQ6.1M.xx) => 1,260,00 events !! this study is performed at the generator level...
- Produce p18.03.00 CAF trees which contain only the MC information and particles jets
- Adapt the squark-gluino analysis cuts ("dijet", "3-jets" and "gluino" analyses) to perform the final selections but at the generator level:
  - same cuts on jet pT, eta ...
  - replace MET by MHT computed from particle jets
  - some cuts cannot be applied (jet track confirmation)
- Determine signal efficiencies using the different PDF sets



- Example here for m0=25, m1/2=145:
- we do not see anything, the statistical uncertainty is too large
- => use the reweighting technique described in the D0 note 4618
  - use the events generated with CTEQ6L and apply the event weights as defined on the next slide
  - because, the same events are used, the statistical dispersion will disappear

Event Re-weighting wrt CTEQ6.1M.xx PDF Sets

x1,f1,Q1 and x2,f2,Q2 are available in the MCevtInfo Branch of CAF trees

xx = 01-40 stands for one of the 40 CTEQ6M.xx PDF sets

$$W(i)=\frac{PDF\ CTEQ61.M.xx(x1,f1,Q)*PDF\ CTEQ61.M.xx(x2,f2,Q)}{PDF\ CTEQ6L(x1,f1,Q)*PDF\ CTEQ6L(x2,f2,Q)}$$

CTEQ6L because my MC sample was generated using CTEQ6L

Use LHAPDF interface to compute the PDF (fortran code)

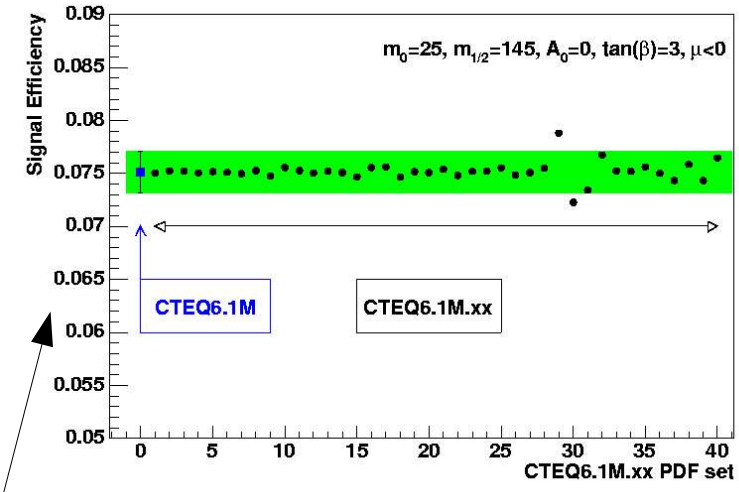
$$Efficiency=\frac{\sum_{i=1}^{i=n} W(i)}{\sum_{i=1}^{i=Ngen} W(i)}$$

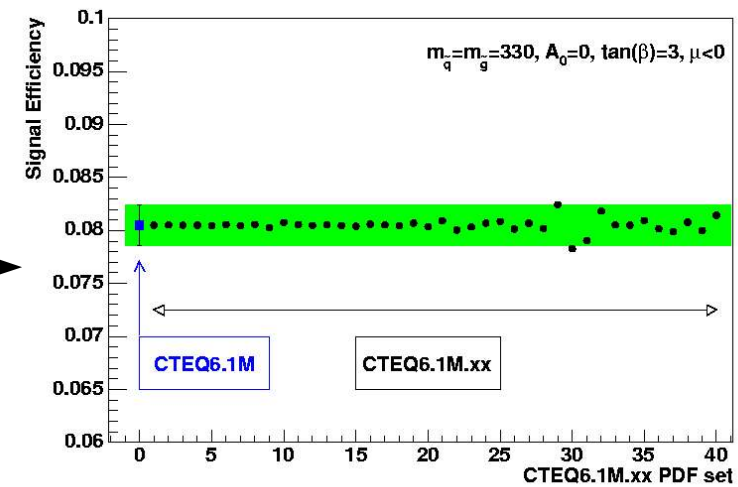
"n" means events satisfying the analysis cuts

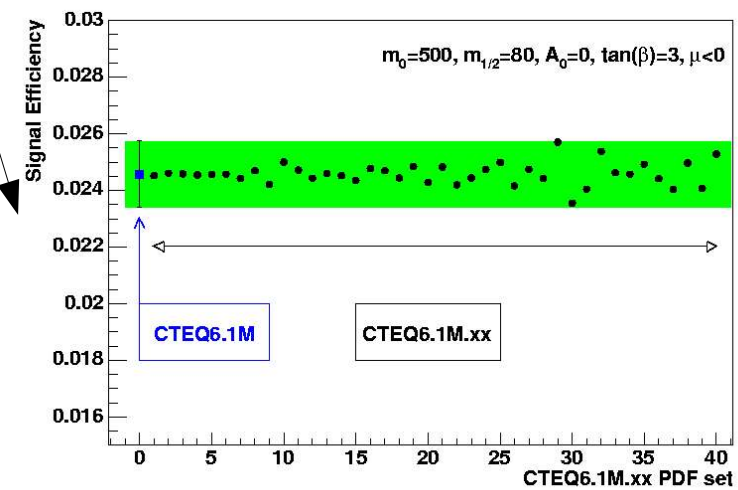
"Ngen" = number of events generated

Squark-Gluino Efficiencies (II)

- And now it works
- Here again, the eigenvectors 15 and 16 are dominating
- The systematic uncertainty is defined doing the quadratic sum of the differences wrt CTEQ6.1M. They are found to be :
  - +5.9 -4.8% for m0=25, m1/2=145 applying the “dijet” analysis
  - +3.3 -3.6% for Msq=Mgl=300 applying the “3-jets” analysis
  - +8.0 -6.0% for m0=500, m1/2=85 applying the “gluino” analysis

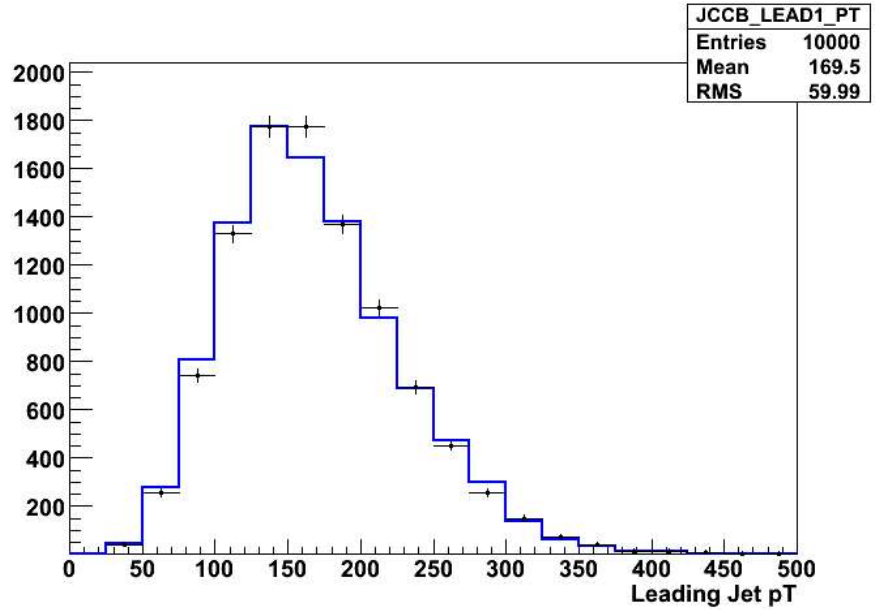


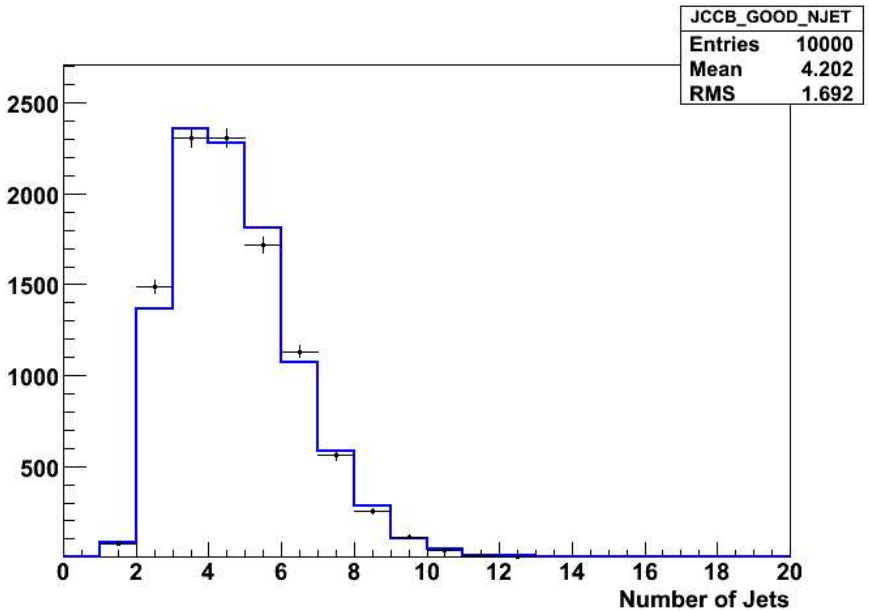


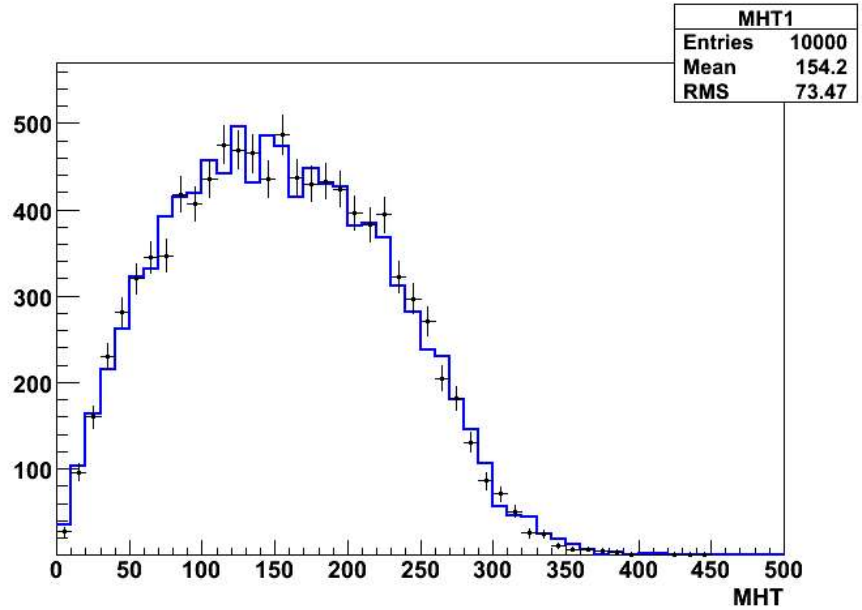


Squark-Gluino Efficiencies (III)

- Squark gluino signals generated directly with :
  - CTEQ6L1 : backpoints with error bar
  - CTEQ6.1M.29 : blue line

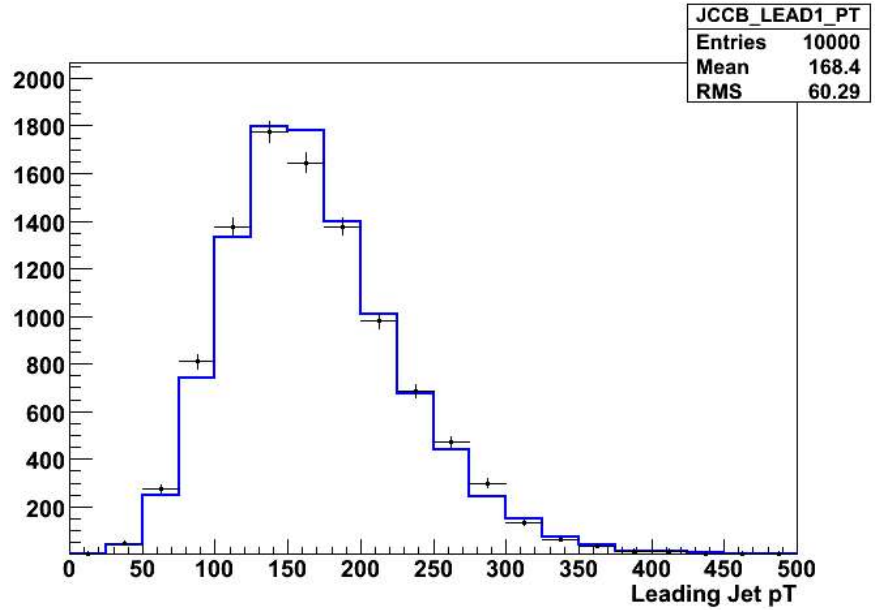


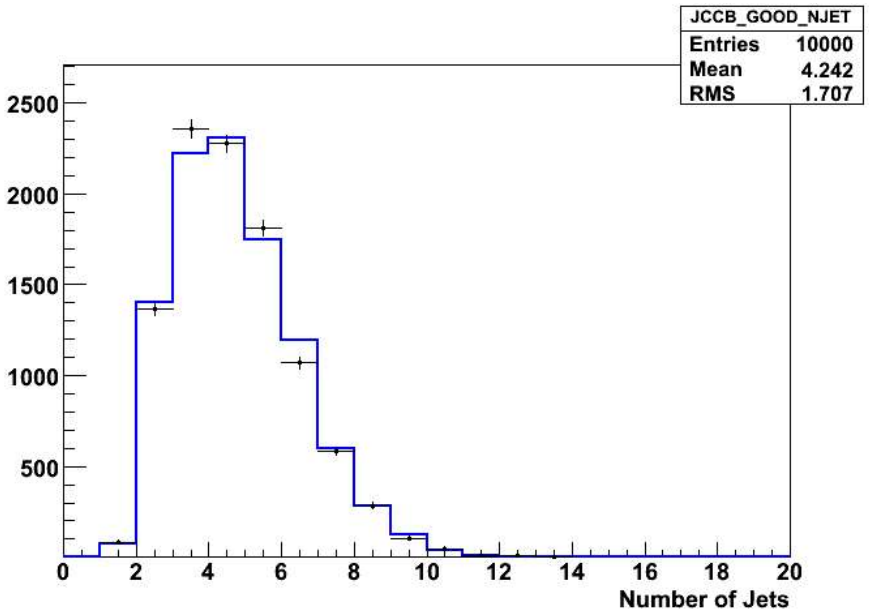


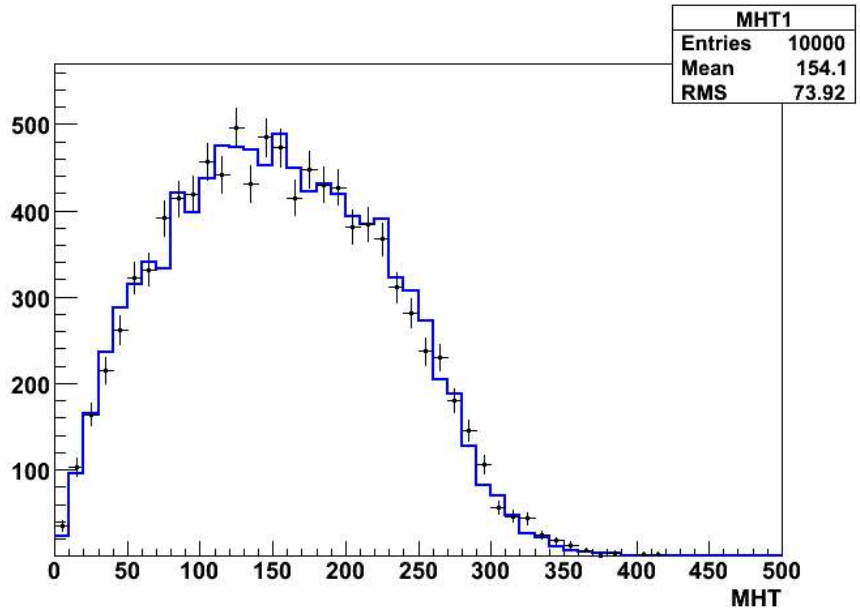


Squark-Gluino Efficiencies (III)

- Squark gluino signals generated :
  - directly with CTEQ6.1M.29 : blue line
  - with CTEQ6L1 reweighted to CTEQ6.1M.29: backpoints with error bar
- Not so much differences, need to study correlations between variables.

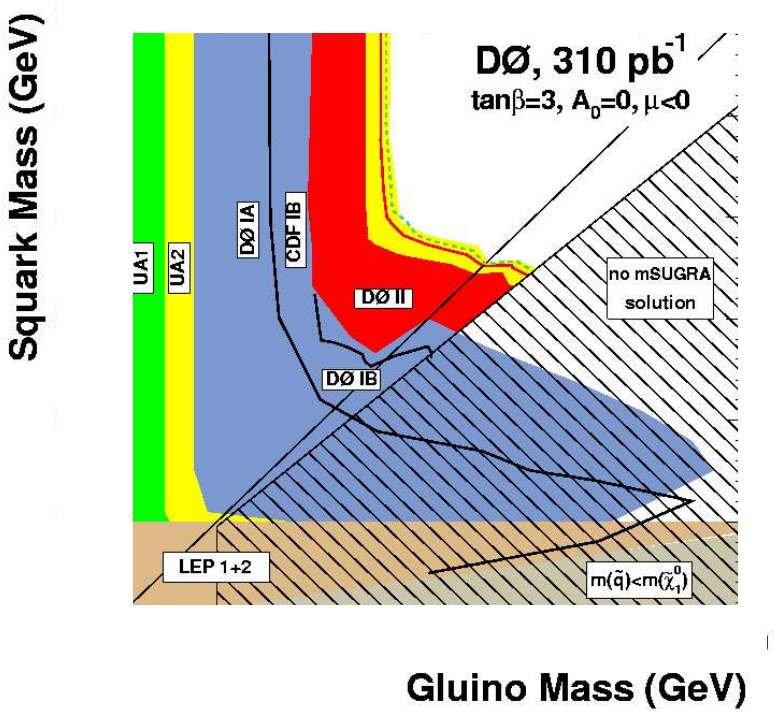




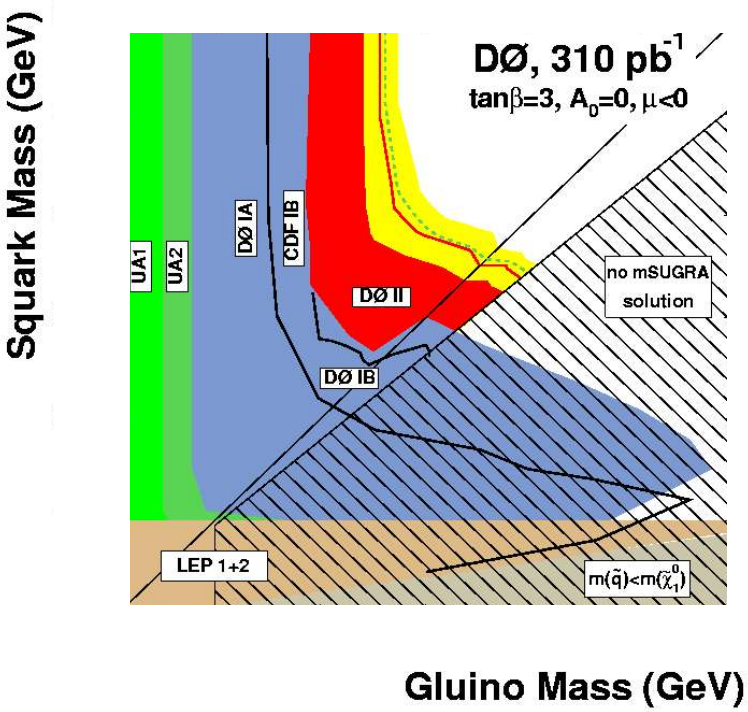


Effects on the Limits

Scale "uncertainty" only



PDF ⊕ Scale "uncertainty"



Conclusion

- PDF uncertainties for the D0 squark-gluino analyses were evaluated using the prescriptions described in the D0 note 4618:
  - signal cross section : huge effect, but finally, the combined effect of PDF and scale gives a 5-10% uncertainty on the squark-gluino mass limits
  - signal efficiencies : +8 -6%, low effect in the limit computation (other larger errors)