Cross-section Measurement in Dilepton Channel @ D0

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for D0 collaboration

3rd Top Workshop @ Grenoble :
from the TeVatron to ATLAS
October 24, 2008

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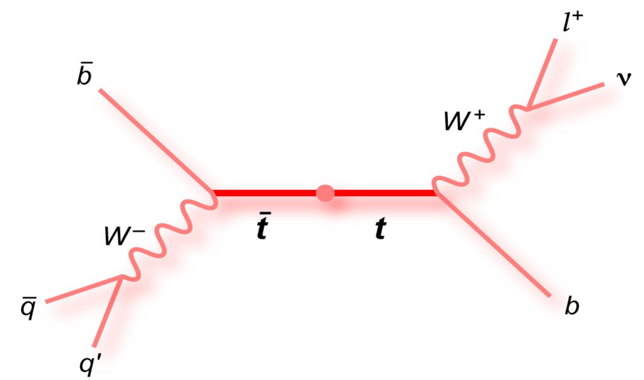
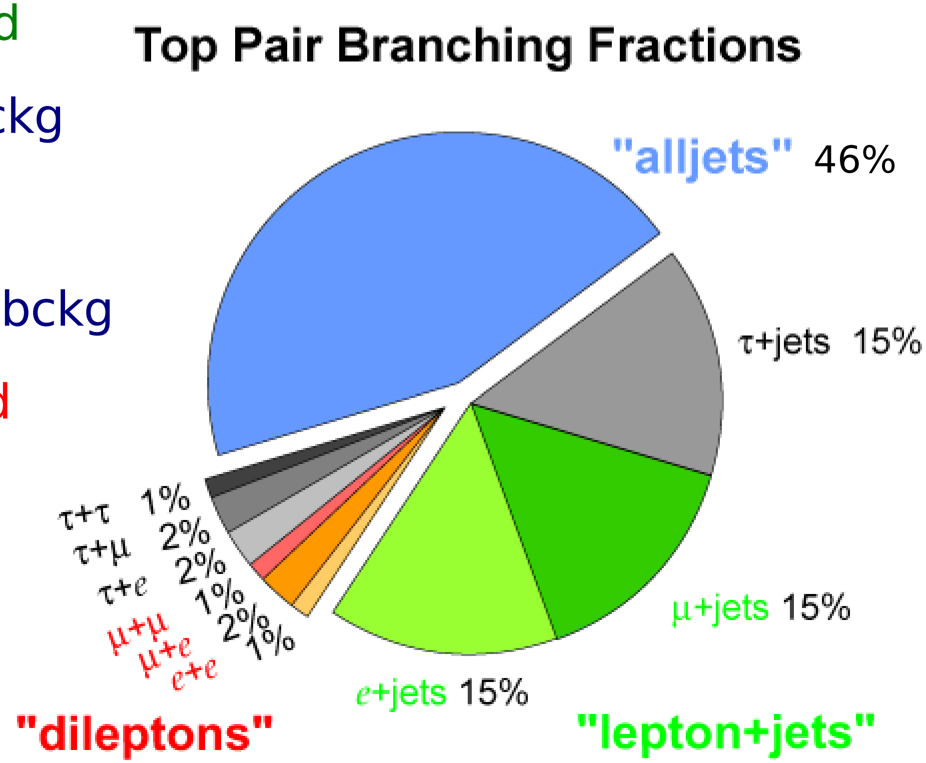
Why Cross-section?

- Comparison with a theoretical calculations: SM test, probe of the new production mechanism (e.g. resonance production)
  - N. Kidonakis and R. Vogt, arXiv:hep-ph/0805.3844: NLO + NNLO soft gluon correction, $\sigma = 7.39^{+0.57}_{-0.52}$ *pb*, m_t = 172 GeV, CTEQ 6.6
  - M. Cacciari, S. Frixione, M. M. Mangano, P. Nason and G. Ridolfi, arXiv:hep-ph/0804.2800: NLO + next-to-leading threshold logarithm correction, $\sigma = 7.61^{+0.30}_{-0.53}$ (scales) $^{+0.53}_{-0.36}$ (PDFs) pb, m_t = 171 GeV, CTEQ 6.5
  - S. Moch and P. Uwer, arXive:hep-ph/0804.1476, NNLO (approx), $\sigma = 7.8 \pm 0.6$ pb, m_t = 171 GeV, CTEQ 6.5
  - Errors ~ 8%, depends how the scale uncertainty is defined
  - Run I, 2E = 1.85 TeV, L ~ 100 pb^{-1}: $\delta\sigma/\sigma$ ~ 25%
  - Run II, 2E = 1.96 TeV, L ~ 1000 pb^{-1}: $\delta\sigma/\sigma$ ~ 10%
- Sample definition for the properties measurements
- Important background for the new phenomena and Higgs search
- Allow to extract the top mass from the cross-section dependence with a “clean” definition of a top mass from the theoretical point of view.

- Top quark has a very short life-time ~ 10^{-25} sec ⇒ decay before hadronisation
- In SM $|V_{tb}| \sim 1 \Rightarrow Br(t \to Wb) \sim 100\%$
- Dileptons:
  - e, μ, τ → e (μ) : ~ 6.5%, low background
  - τ → had + e (μ) : ~ 3.6%, reasonable bckg
- Leptons + jets,
  - e, μ, τ → e (μ) + jets ~ 35%, reasonable bckg
  - τ → had + jets ~ 9.5%, high background
- All jets ~ 46%, high bckg





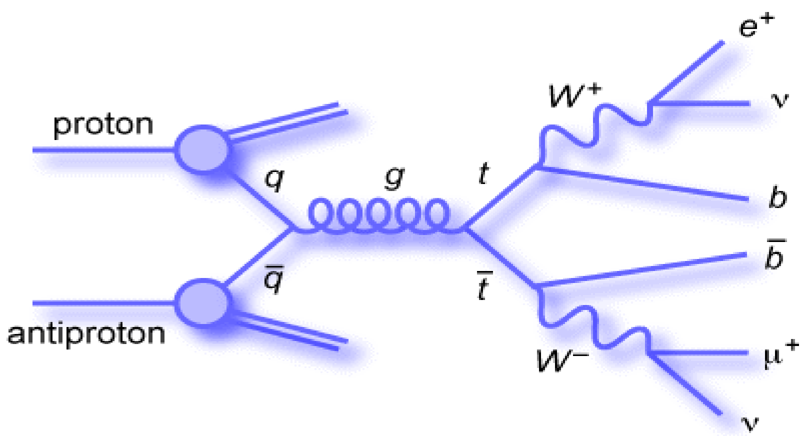
Cross-Section Measurement

$$\sigma = \frac{N_{observed} - N_{background}}{\varepsilon(m_t)\int L\,dt}$$

Top mass dependent efficiency!

- Efficiency for all physics processes estimated from MC: Pythia or Alpgen (generator) + Pythia (showering). In the second case a MLM matching algorithm avoids double counting of final states.
- Real “zero bias” events are superposed on detector simulation to reproduce all detector effects, including luminosity dependence.
- Available statistics = (delivered luminosity *x* cross-section - poor quality data) *x* trigger efficiency (channel dependent)
- Selection optimized for each individual channel in order to obtain the best possible precision.
- $N_{observed}$ - $N_{background}$ is calculated with event counting techniques or using signal/ background fit of the discriminating variable shape.
- The final result is a combination of several channels.

Dilepton Signature



tt⇒e track bb νν

tt⇒μ track bb νν

tt⇒ee bb νν

tt⇒eμ bb νν

tt⇒μμ bb νν

tt⇒eτ bb νν

tt⇒μτ bb νν

electron: isolated cluster in EM calo, p_T>15 GeV, track match, $|\eta| \in$ 0 – 1.1, 1.5 – 2.5

muon: track in muon system, track in central tracker isolated in calo and tracker p_T>15 GeV, $|\eta| < 2$

jet: dR=0.5 cone, JES corrected for muons from b-quark decays, p_T > 20 GeV (at least), $|\eta| < 2.5$

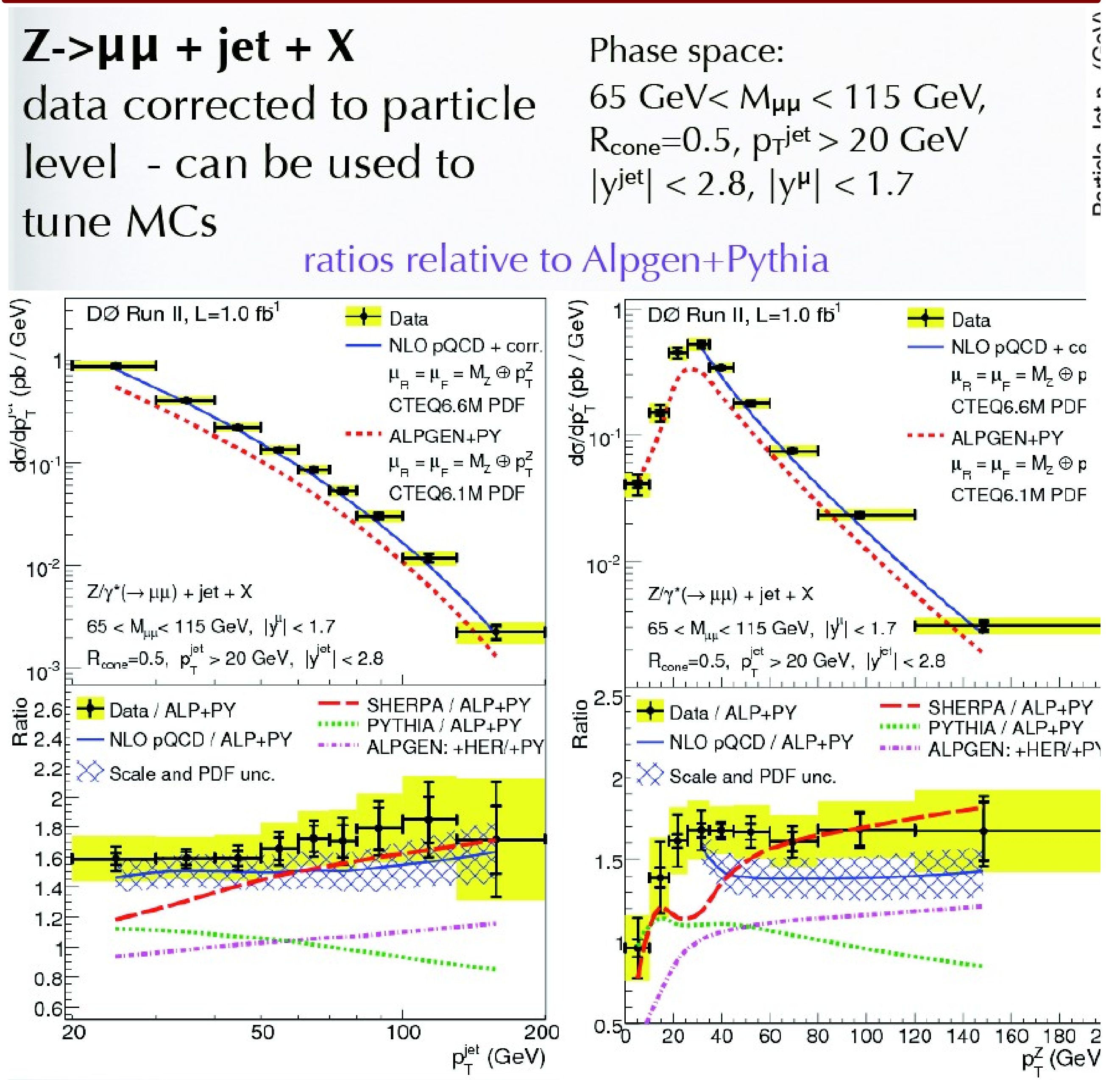
MET: corrected for electrons, muons, jets

- Explore all channels to maximize acceptance
- Explicitly remove overlaps by vetoes
- 1 fb results

MC stimulation and Z background normalization

- Use Alpgen (ME generation) + Pythia (parton showering) for ttbar, Z+jets
  - Generate samples with a different number of parton bins
  - Sum them together according to the alpgen cross-sections
  - Scale sum of the all parton bins with the ratio N(N)LO cross-section / sum of Alpgen cross-section.
- Z p_T distribution is reweighted according to data for each jet multiplicity bin

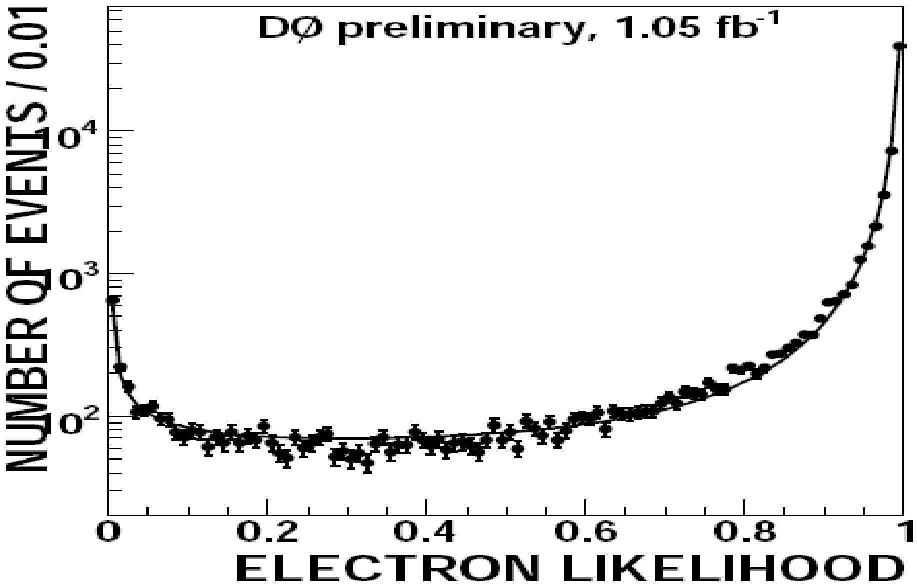
Sabine Lammer's Physics at LHC08 presentation

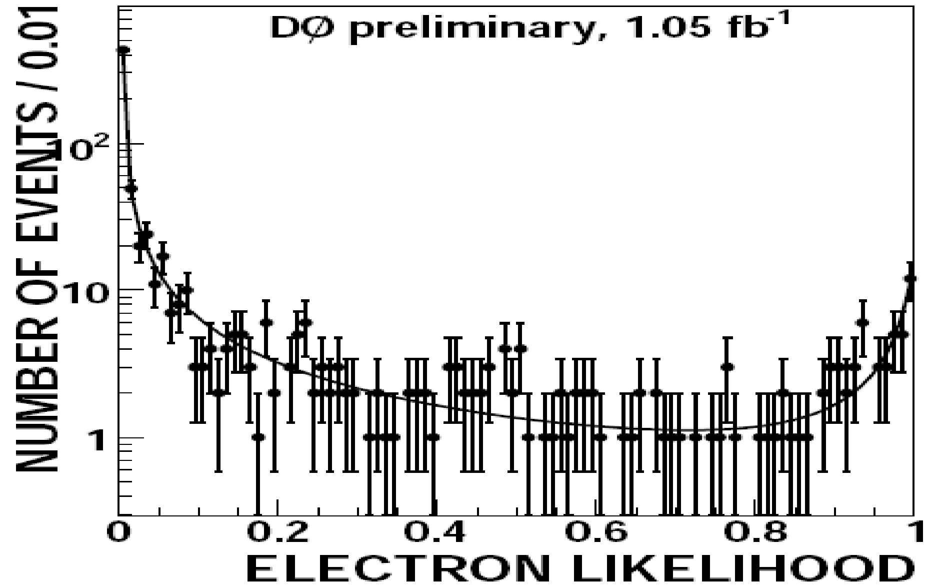


Object ID and trigger efficiencies

- The object ID and trigger efficiencies is measured in data: $Z \rightarrow ee$, $Z \rightarrow \mu\mu$, γ+jet and compared with MC
- For a perfect agreement need to introduced additional scale factors and object over-smearing. Scale factors produced for the object with "standard" selection and have dependence from the chosen parameters (p_T, η, ϕ, Z_{PV}, …). The typical average corrections are 1 – 10 %.
- Another product of this comparison are the efficiencies systematics. Usually less than several percent.

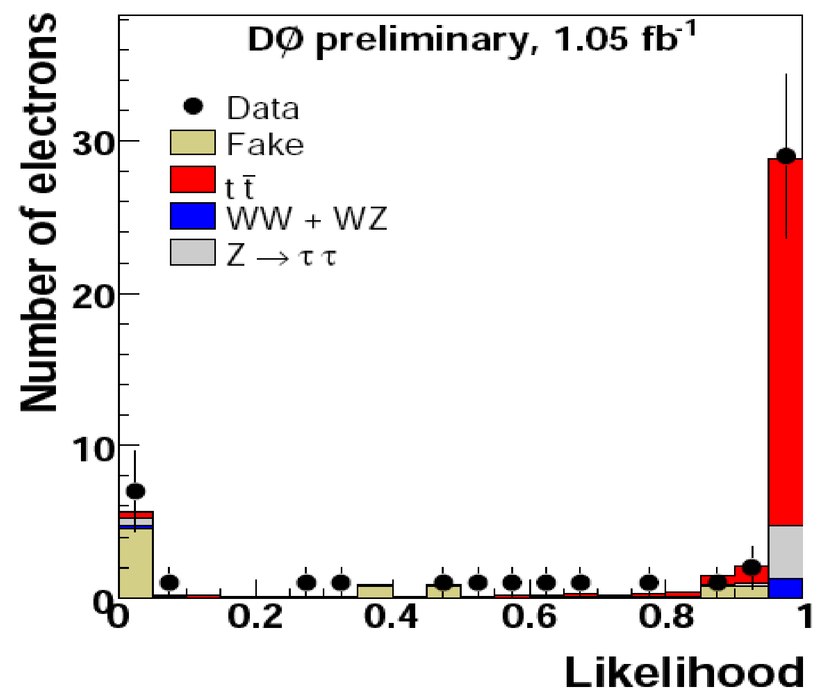
Missidentified Electron Bckg Estimation: ee, eμ





- Electron likelihood is a "quality"of the electron: matching between track and calorimeter cluster, E/P, calorimeter clusters parameters
- Define signal (Z->ee) and background samples (antiisolated muon and MET < 15 GeV) and measure likelihood shapes
- Fit distribution using unbinned likelihood fit

$$\mathscr{L} = \prod_{i=1}^{N} (n_e S(x_i) + n_{misid} B(x_i)) \frac{e^{-(n_e + n_{misid})}}{N!}$$



Fake isolated muon background: eμ, μμ

- An isolated muon can be impersonated by a muon in a jet when the jet is not reconstructed.
- Measure the fraction of muons (f_μ) that appear as isolated in a di-muon control sample dominated by fake isolated muons.
- The number of events with a fake isolated muon contributing to the final sample is estimated using the “matrix method” using two samples: the “tight” sample requires two isolated muons; the “loose" sample requires only one isolated muon.

$$N_L = N_S + N_{QCD}$$

$$N_T = N_S \frac{\varepsilon_S^T}{\varepsilon_S^L} + N_{QCD} f_\mu$$

MC

Data

Dilepton results

- Physics background estimated from MC: $Z \to ee$, $Z \to \mu\mu$, $Z \to \tau\tau$ + jets, WW, WZ, ZZ + jets
- Instrumental background is estimated from data: jets misidentified as electrons, muons from the semileptonic b-quark decays

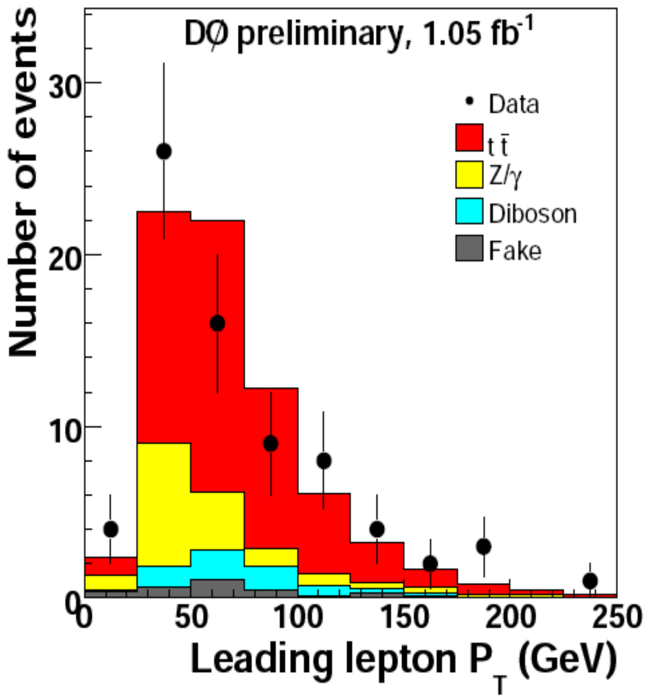
ee: veto event in Z-peak
MET > 35 (45) GeV
sphericity > 0.15

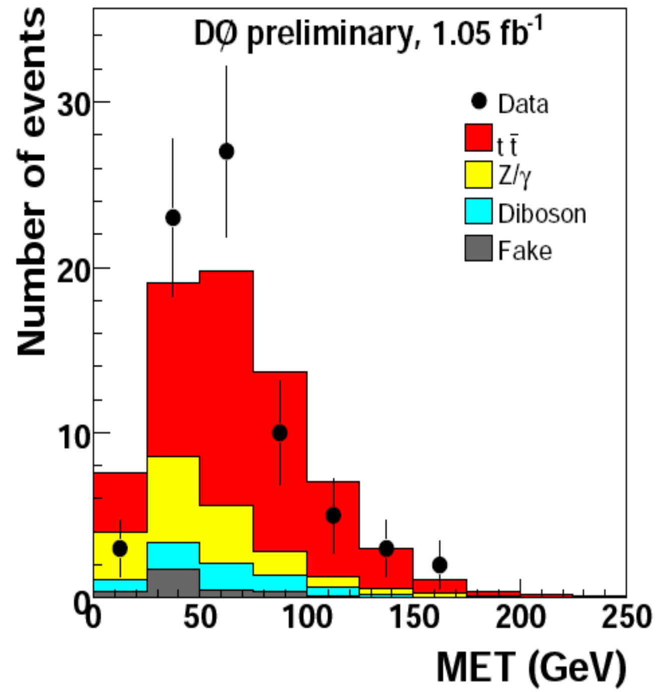
$e\mu$: p_T(jets) + p_T(leading lept) >115 GeV

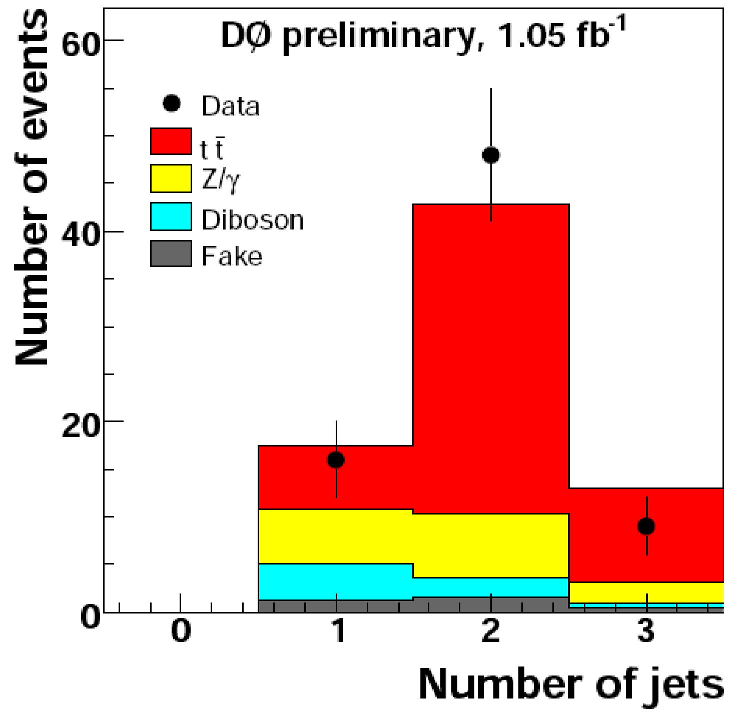
$\mu\mu$: MET > 35 GeV
muon p_T and MET vector must be separated in azimuth
χ^2 of $Z \to \mu\mu$ hypothesis >8

Category	ee	$\mu\mu$	$e\mu$ ($\geq$ 2 jets)	$e\mu$ (1 jet)
integrated luminosity (pb^{-1})	1036	1046	1046	1046
Z/γ^*	$2.4^{+0.4}_{-0.4}$	$2.7^{+0.4}_{-0.4}$	$3.6^{+0.7}_{-0.8}$	$5.5^{+0.8}_{-0.8}$
WW/WZ and other MC	$0.4^{+0.2}_{-0.2}$	$0.5^{+0.1}_{-0.1}$	$1.4^{+0.6}_{-0.6}$	$3.4^{+1.4}_{-1.4}$
Instrumental background	$0.2^{+0.2}_{-0.1}$	$0.4^{+0.2}_{-0.2}$	$1.8^{+0.6}_{-0.6}$	$1.2^{+0.4}_{-0.4}$
Total background	$3.0^{+0.5}_{-0.5}$	$3.6^{+0.5}_{-0.5}$	$6.7^{+1.2}_{-1.2}$	$10.2^{+1.8}_{-1.7}$
Signal efficiency (%)	$8.3^{+1.2}_{-1.2}$	$5.1^{+0.4}_{-0.4}$	$12.4^{+0.9}_{-1.0}$	$3.1^{+0.3}_{-0.3}$
Expected signal	$9.5^{+1.4}_{-1.4}$	$5.8^{+0.5}_{-0.5}$	$28.6^{+2.1}_{-2.4}$	$7.1^{+0.6}_{-0.7}$
Total Sig. + Bkg.	$12.5^{+1.5}_{-1.5}$	$9.4^{+0.7}_{-0.7}$	$35.3^{+2.8}_{-3.2}$	$17.2^{+2.0}_{-2.1}$
Selected events	16	9	32	16

Dilepton results





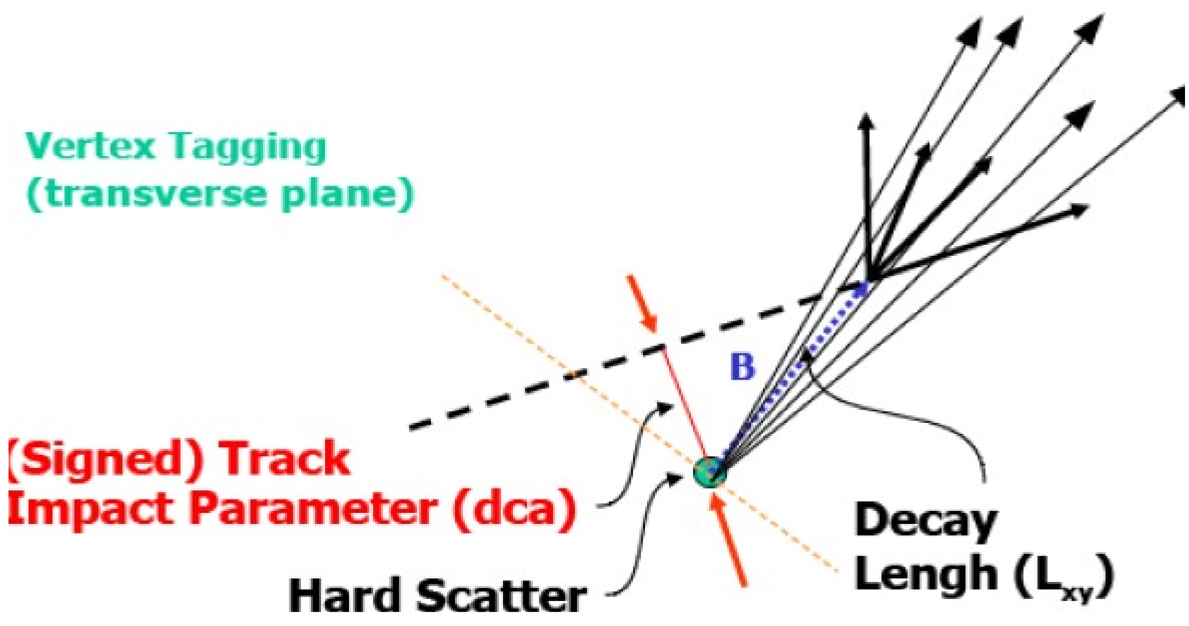


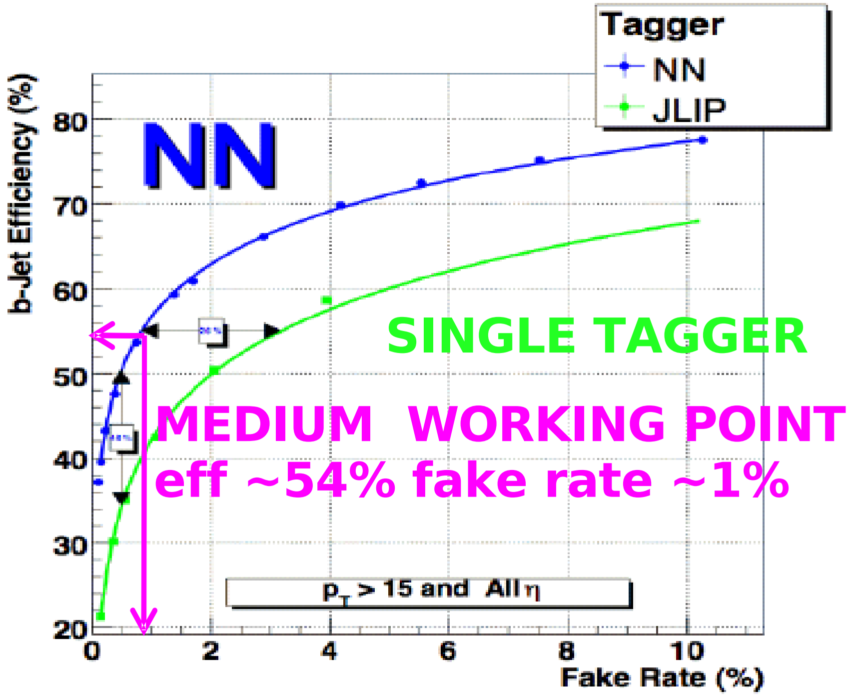
channel	ε
ee	8.3 %
$e\mu$ nj=1	3.1%
$e\mu$ nj$\geq$2	12.4%
$\mu\mu$	5.1%

$\sigma = 6.8^{+1.2}_{-1.1}$ (stat) $^{+0.9}_{-0.8}$ (syst) $\pm$ 0.4 (lumi) pb

relative error : $\delta\sigma/\sigma$ ~22% m_t = 175 GeV

b-Jet Tagging





Several mature algorithms used:

3 main categories:

- **Soft-lepton tagging**
- **Impact Parameter based**
- **Secondary Vertex reconstruction**

Combine in Neural Network:

- vertex mass
- vertex number of tracks
- vertex decay length significance
- chi2/DOF of vertex
- number of vertices
- two methods of combined track impact parameter significances

Heavy Flavor Normalization

- For the analyses with the b-quark tagging, normalization of the HF flavor is important
- Generate separately Z+bb, Z+cc samples.
- Remove heavy flavor contribution from the Z+nlp samples.
- Normalize HF sample to data using b-tagged samples.
- Normalize overall cross-section to the NNLO Z cross-section

Lepton + track

Veto for other dilepton channels is applied

- estimate rate of the events with track not from the lepton
- Use b-tagging to reduce background (at least 1 b-tagged jet)

channel	Observed	N^{bkg}	BR	$\mathcal{L}$ (pb^{-1})	ε
e+track, nj=1	4	1.58	0.1066	1035	0.25%
e+track, nj≥2	8	1.83	0.1066	1035	1.31%
μ+track, nj=1	1	1.38	0.1066	994	0.18%
μ+track, nj≥2	8	1.36	0.1066	994	1.08%

$\sigma = 5.1^{+1.6}_{-1.4}$ (stat) $^{+0.9}_{-0.8}$ (syst) ± 0.3 (lumi) pb

relative error : $\delta\sigma/\sigma$ ~34% m_t= 175 GeV

COMBINED WITH DILEPTONS

$\sigma = 6.2 \pm 0.9$ (stat) $^{+0.8}_{-0.7}$ (syst) ± 0.4 (lumi) pb

relative error : $\delta\sigma/\sigma$ ~19% m_t= 175 GeV

1 e or μ: p_T > 15 GeV

track: p_T>15 GeV, |η| < 2, isolated and separated in dR from jets and leptons

MET
μ+track: correct MET for track > 25 GeV (35 GeV)
e+track: > 20 GeV (25 GeV) outside (inside) Z peak

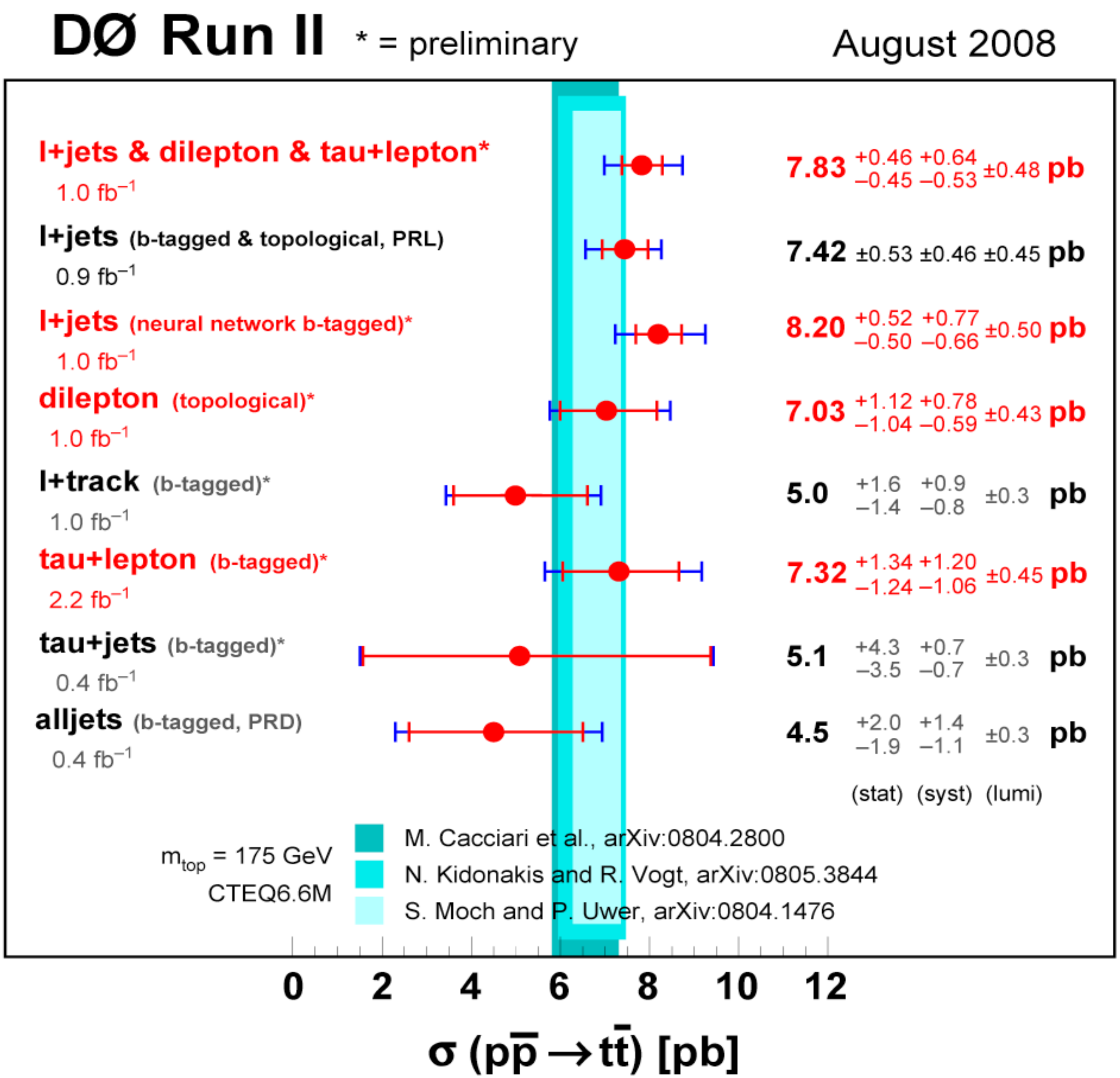
MET in Z-event hypothesis:
μ+track: > 25 GeV (35 GeV)
e+track: > 20 GeV (25 GeV) outside (inside) Z peak

Dilepton Systematics

Source	$\ell\ell$	ℓ+track	combined
Jet energy calibration	$+0.3-0.3$	$+0.1-0.1$	$+0.3-0.2$
Jet identification	$+0.1-0.1$	$+0.02-0.03$	$+0.04-0.04$
PV identification	$+0.3-0.2$	$+0.2-0.1$	$+0.3-0.2$
Muon identification	$+0.2-0.2$	$+0.06-0.05$	$+0.2-0.1$
Electron identification	$+0.6-0.5$	$+0.2-0.2$	$+0.4-0.4$
Track identification	N/A	$+0.7-0.6$	$+0.3-0.3$
Trigger	$+0.2-0.2$	$+0.3-0.2$	$+0.2-0.2$
Fakes	$+0.2-0.2$	$+0.3-0.2$	$+0.1-0.1$
b-tagging	N/A	$+0.3-0.3$	$+0.1-0.1$
MC normalization	$+0.3-0.3$	$+0.2-0.2$	$+0.2-0.2$
Other	$+0.2-0.2$	$+0.1-0.1$	$+0.2-0.2$
Subtotal	$+0.9-0.8$	$+0.9-0.8$	$+0.8-0.7$
Luminosity	±0.4	±0.3	±0.4
Total	$+1.0-0.9$	$+1.0-0.9$	$+0.9-0.8$

- There is no “main” systematics which is driving the total error. Further improvement is possible, but require laborious work on each source of systematics

Cross-Section Summary



Conclusion

- At the end of RunII one could expect to have a dilepton cross-section measurement at ~8% level limited mainly by the statistical and luminosity errors.
- The cross-section ratio between *dilepton / lepton + jets c*hannels could be measured up to ~6% precision at the end of RunII, limited by the dilepton statistical uncertainty.