Search for Compositeness in Dimuon Channel at DØ

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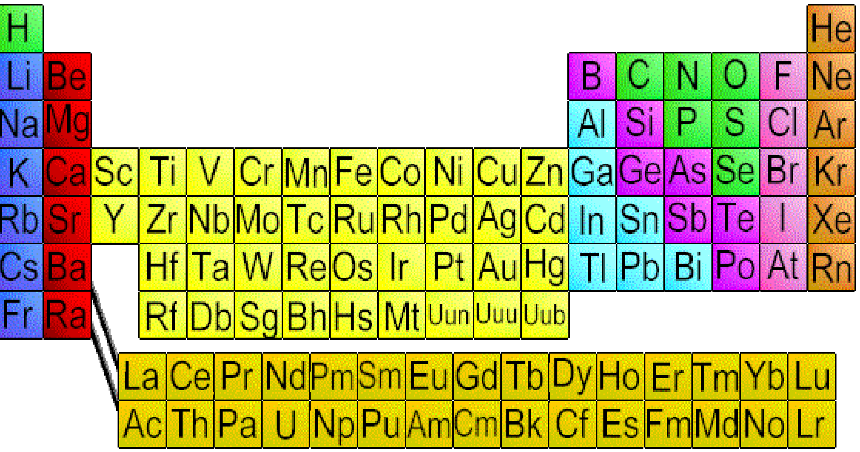
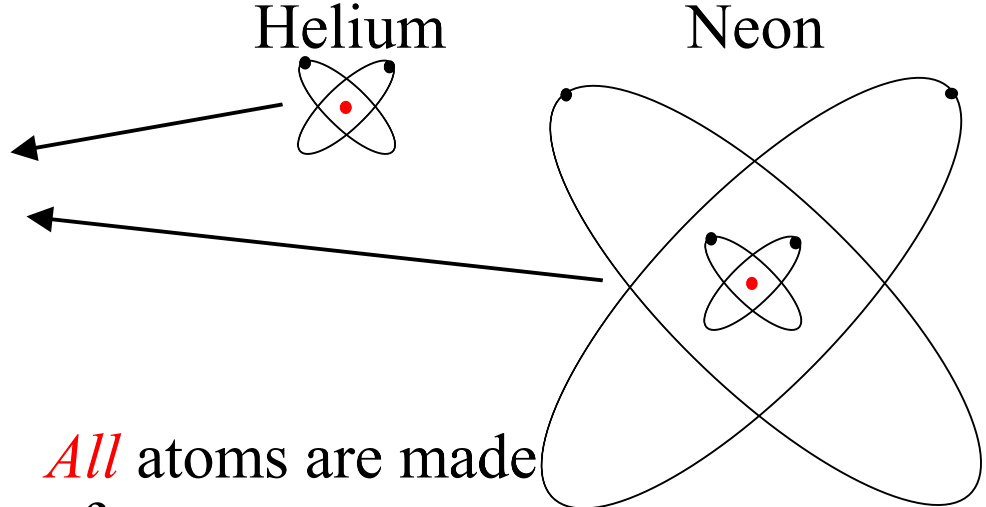
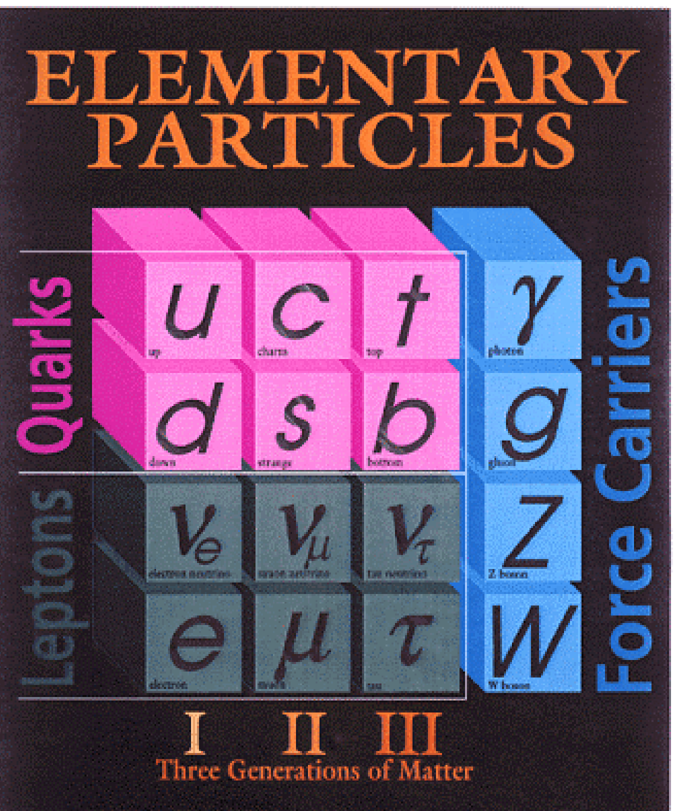
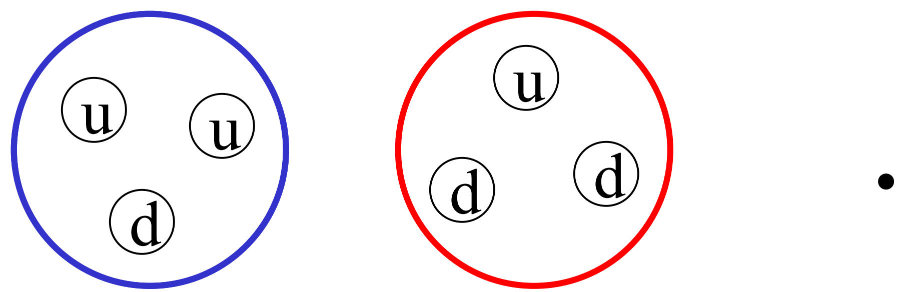
Periodic Table





All atoms are made of protons, neutrons and electrons

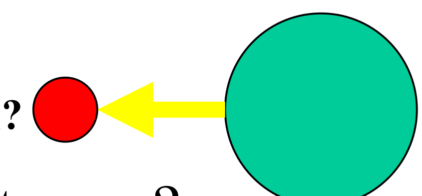




Proton Neutron Electron

What are quarks and leptons made of?

Preon?



Generation? Compositeness?

Quark-Lepton Compositeness

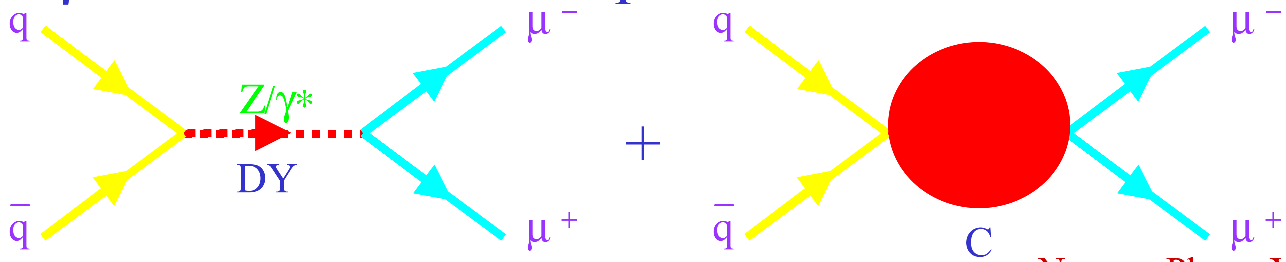
- Drell-Yan process:
  $p\bar{p} \rightarrow q\bar{q} \rightarrow \gamma^*/Z \rightarrow l^+l^-$
- When $\hat{s}^{1/2} < \Lambda$ (a characteristic energy scale), departure from SM may be observed as deviations from Drell-Yan scattering.
- Differential cross-section with contact interaction:

$$\frac{d\sigma^{\Lambda}}{dm} = \frac{d\sigma}{dm}(DY) + \beta I + \beta^2 C$$

contact interaction (C)

interference term (I)

where $\beta = 1/\Lambda^2$ and m is dilepton invariant mass.



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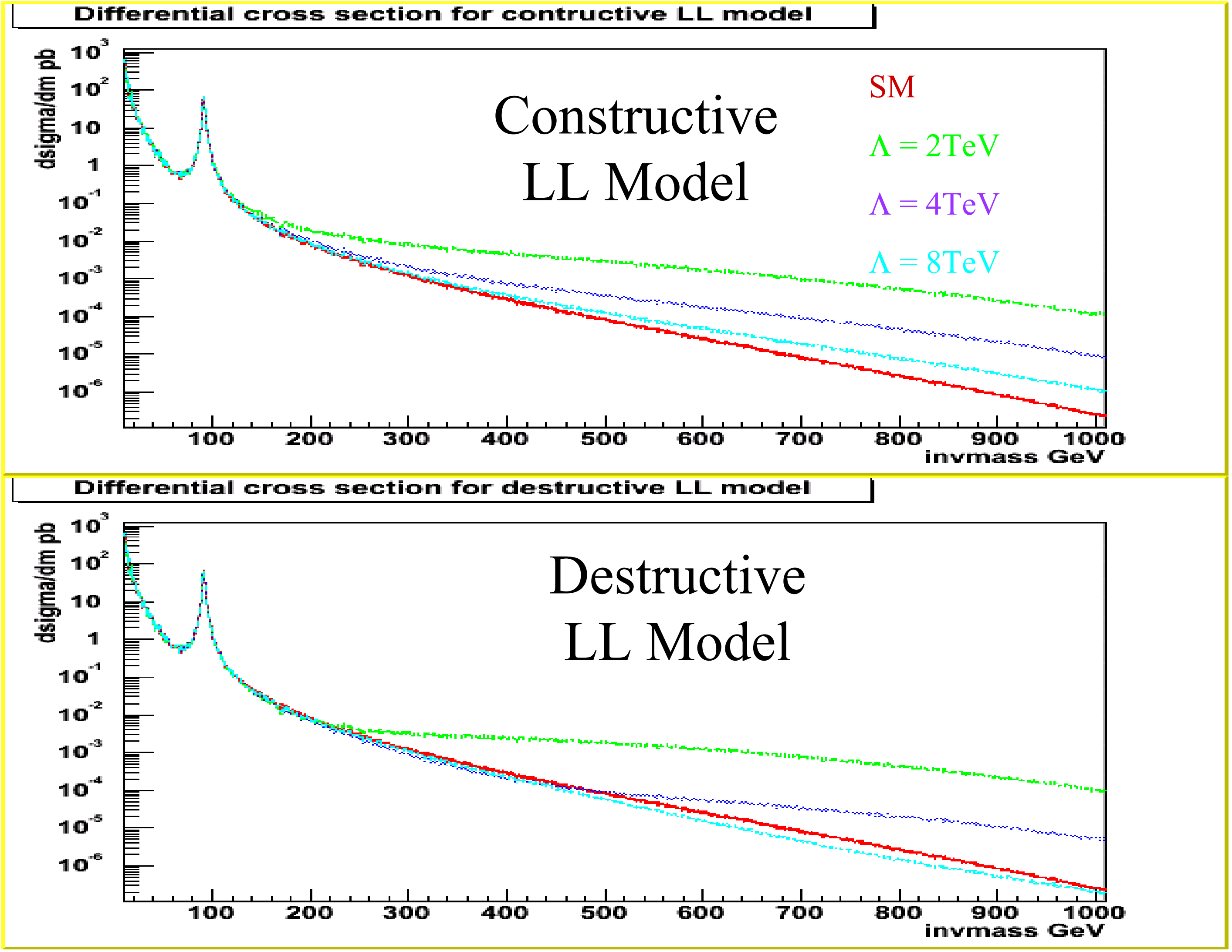
Dimuon Channel Analysis



dσ/dm pb

$\mu^+\mu^-$ Mass (GeV/c^2)

L quark helicity and L lepton helicity

q

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Data Sets and Selections

- Good dimuon events are selected from the entire data set collected until November 2003.
- Tracks associated with both muons are required to have at least 1 hit in the silicon part as well as more than 8 hits in the scintillation fiber part of the Central Tracker.
- Cosmic rays are removed from the data set.
- Dimuon invariant mass > 50 GeV
- Both muons are required to be isolated from jet.
- The integrated luminosity is 170 pb^{-1} for appropriate triggers.

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Monte Carlo

- Using the Fast Monte Carlo PMCS
- Fine tune PMCS by fitting the observed mass distribution around the Z-peak (70 GeV < Mass < 120 GeV) to the function

$$\sigma\left(\frac{1}{p}\right) = \frac{\sqrt{A^2 p^2 + B^2}}{p}$$

- and get A = 0.0025 and B = 0.037
- Use the same η, p_T and mass cuts as in data.
- Simulate all the efficiencies but isolation in the MC.
- Next-to-leading order corrections are added at high mass because the base generator (Pythia) is leading order.

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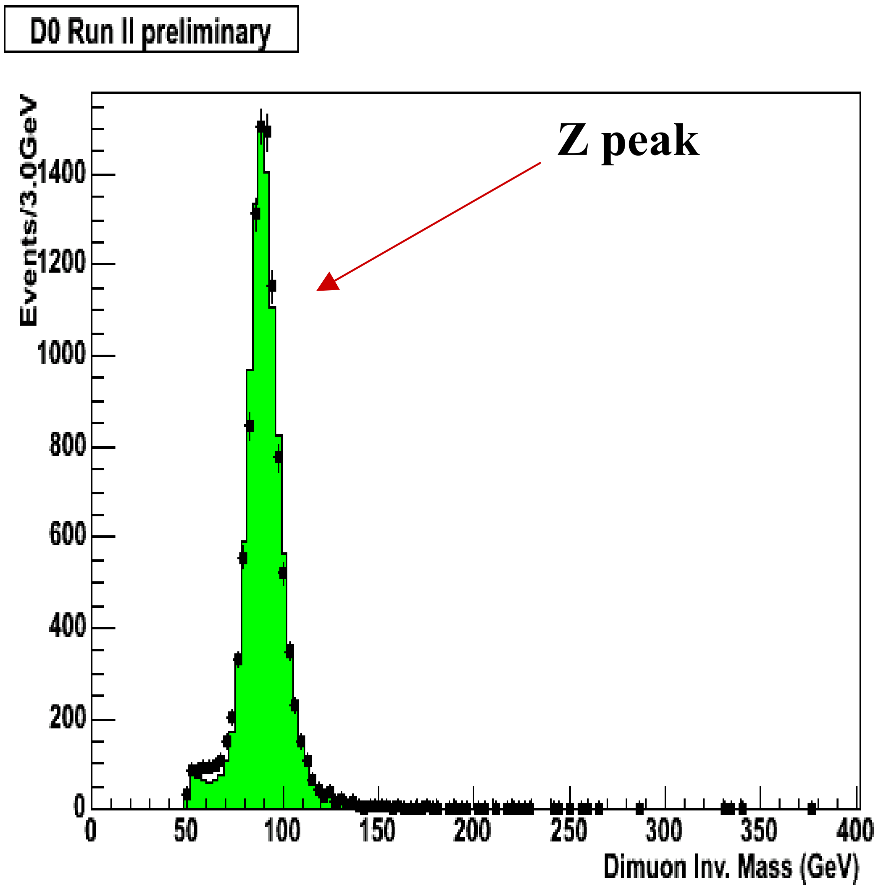
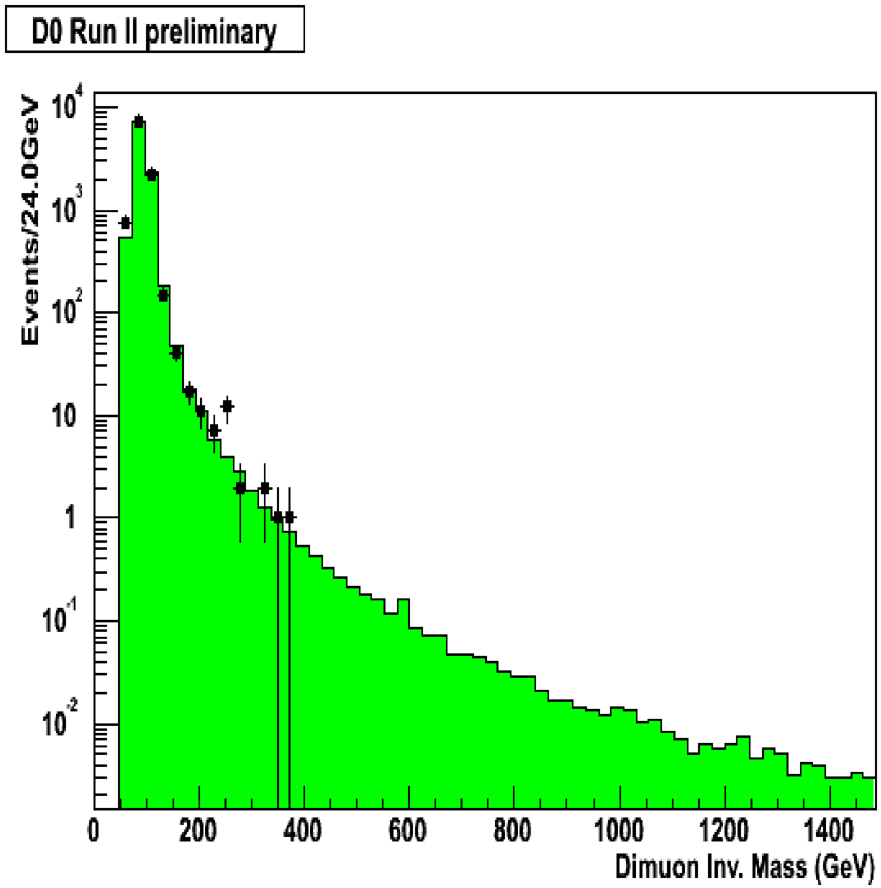
Data and MC comparison

Dots are data and histograms are MC





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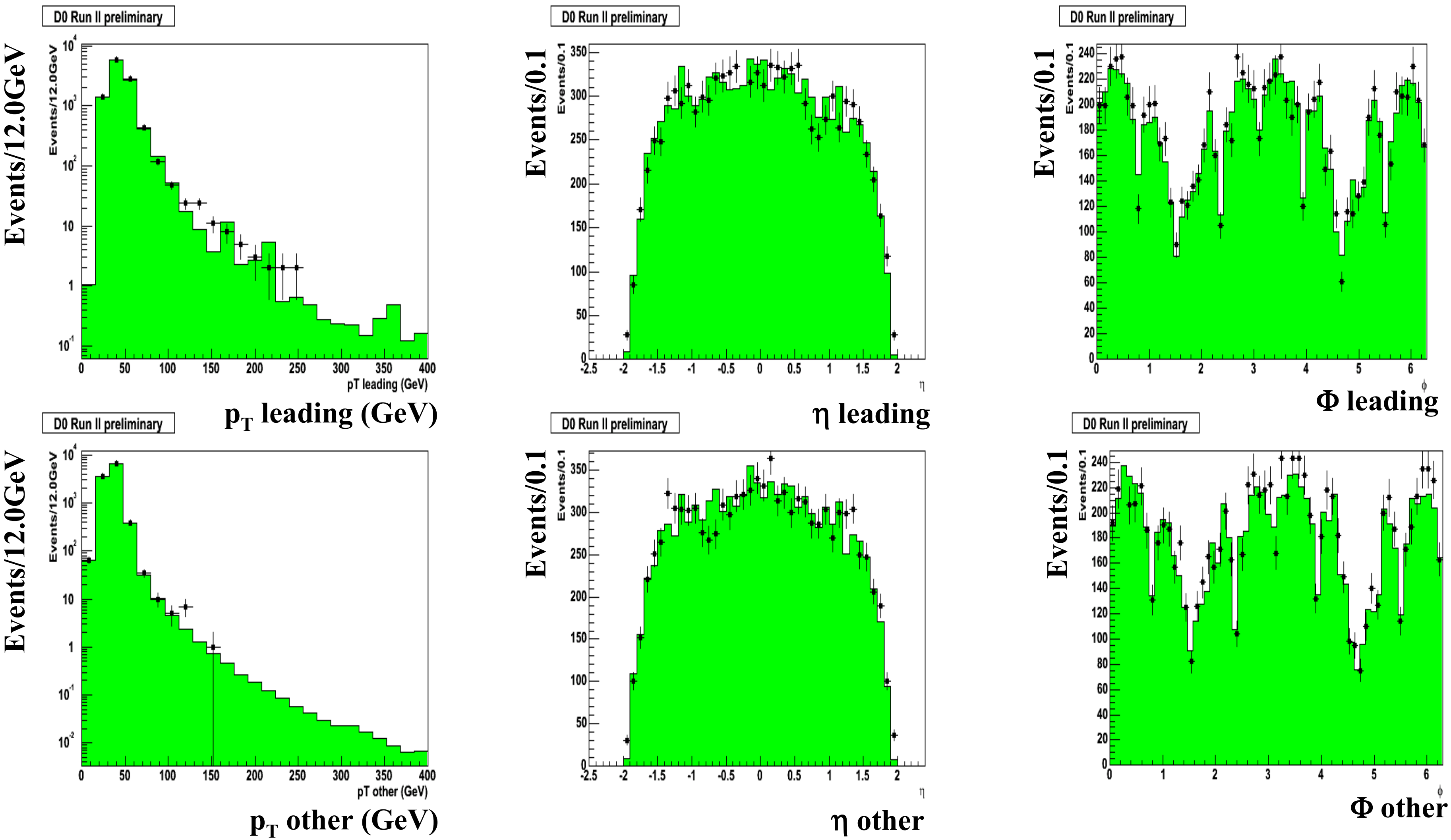
Data and MC comparison

Dots are data and histograms are MC

DØ RunII preliminary



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Dimuon Channel Analysis

Mass bin GeV	Data events	Background	Efficiency
60 - 75	647	7.095 ± 2.580	0.384 ± 0.063
75 - 105	8837	97.890 ± 35.596	0.193 ± 0.037
105 - 120	591	6.501 ± 2.363	0.816 ± 0.138
120 – 160	183	2.046 ± 0.744	0.377 ± 0.058
160 – 200	30	0.352 ± 0.128	0.361 ± 0.064
200 – 240	16	0.187 ± 0.068	0.360 ± 0.066
240 – 290	11	0.125 ± 0.045	0.384 ± 0.067
290 – 340	3	0.045 ± 0.016	0.386 ± 0.068
340 – 400	1	0.011 ± 0.004	0.401 ± 0.068
400 – 500	0	0.006 ± 0.002	0. 408 ± 0.068
500 – 600	0	0.002 ± 0.0007	0.411 ± 0.068
600 - 1000	0	0.001 ± 0.0004	0.413 ± 0.068

$\mu^+\mu^-$ events from $\tau^+\tau^-$ and $b\bar{b}$ DY Production

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Cross Section Measurement

- The dimuon data agrees with SM prediction.
- Likelihood function:

$$P(N_{obs} \mid N_{exp}) = \frac{e^{-N_{exp}} N_{exp}^{\ N_{obs}}}{N_{obs}!}$$

where $N_{exp} = (\sigma_{DY} * L + b)$ expected number of events and N_{obs} observed number of events.

- Bayes theorem of posterior probability $P(N_{exp}|N_{obs})$:

$$P(N_{exp} \mid N_{obs}) = \frac{P(N_{obs} \mid N_{exp}) P(b, \varepsilon, L, \sigma_{DY})}{Z}$$

$$P(b, \varepsilon, L, \sigma_{DY}) = P(b)P(\varepsilon)P(L)P(\sigma_{DY})$$

Cross Section Measurement

where $$P(\sigma_{DY}) = \frac{1}{\sigma_{max}} \quad \text{if } 0 < \sigma_{DY} < \sigma_{max}$$

$$= 0 \quad \text{otherwise}$$

- Z: $$\int_0^\infty db \int_0^\infty dL \int_0^1 d\varepsilon \int_0^\infty d\sigma P(N_{exp} \mid N_{obs}) = 1$$

- Posterior probability for σ_{DY} given N_{obs}:

$$P(\sigma_{DY} \mid N_{obs}) = \frac{1}{Z} \int_0^\infty db \int_0^\infty dL \int_0^1 d\varepsilon \, \frac{e^{-N_{exp}} N_{exp}^{N_{obs}}}{N_{obs}!} P(b)P(L)P(\varepsilon)P(\sigma)$$

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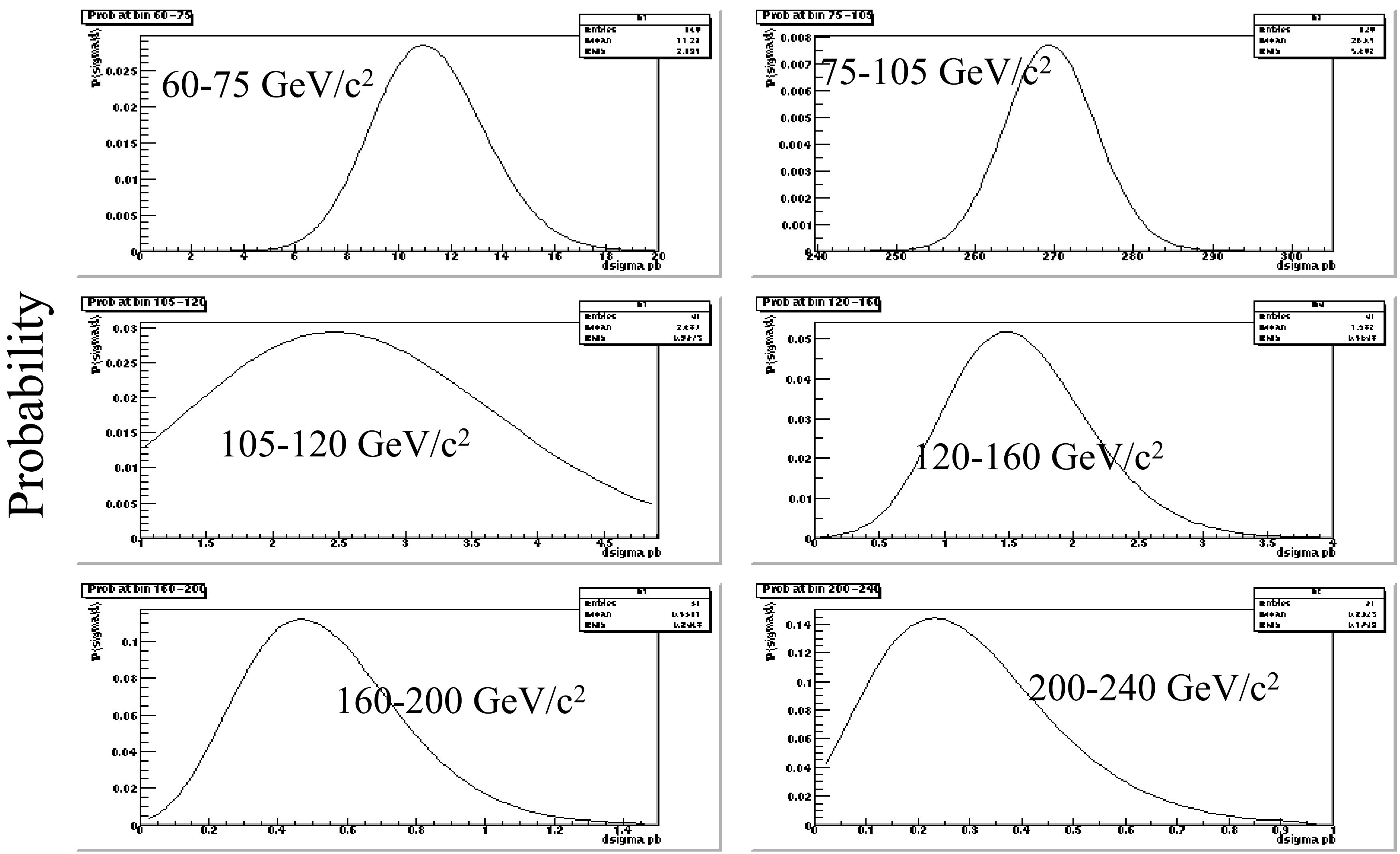
Distribution of posterior probability densities



σ (pb)

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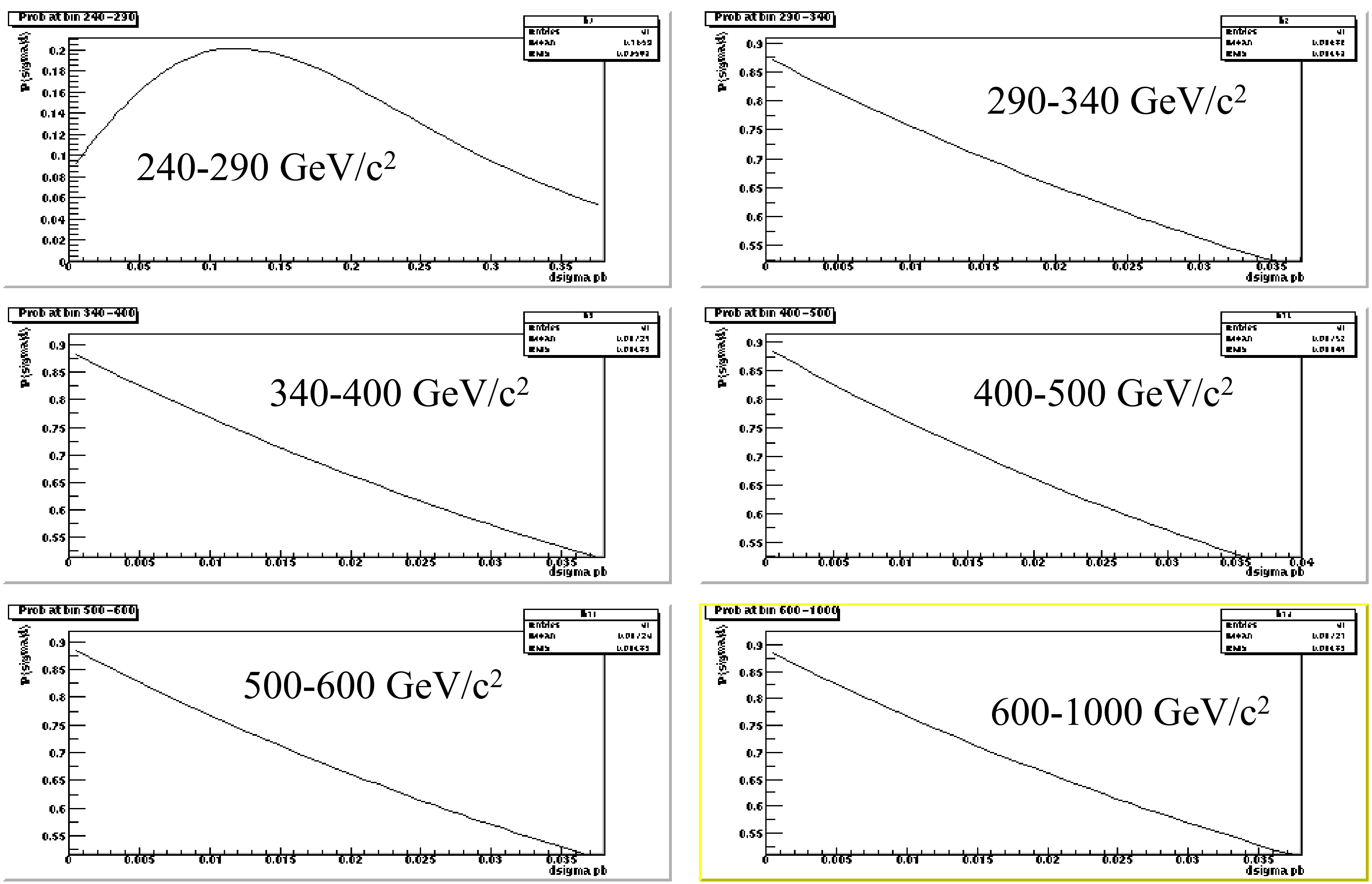
Distribution of posterior probability densities

Probability



σ (pb)

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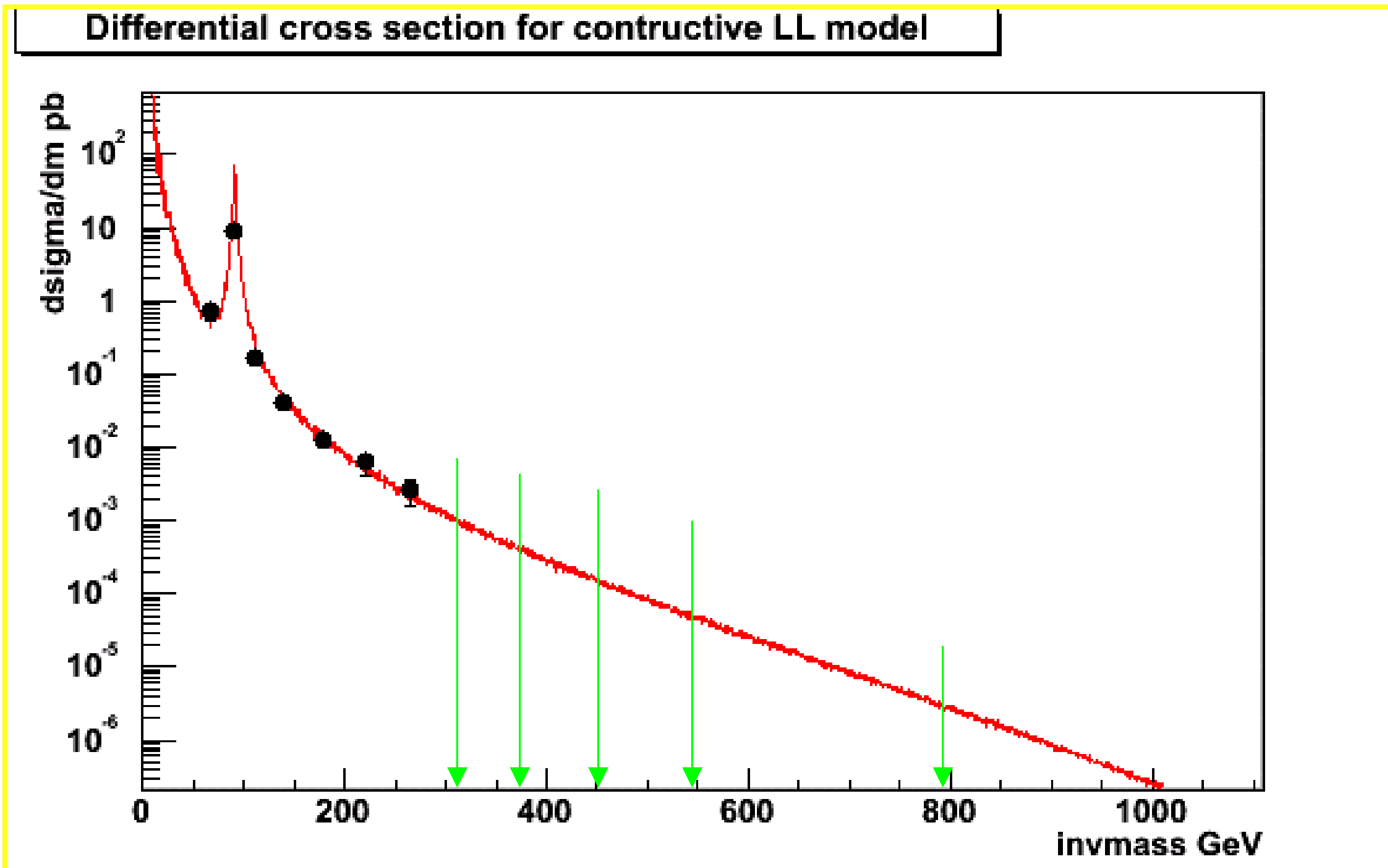
Differential cross section LL



$\Delta\sigma/\Delta M$ (pb/GeV/c^2)

M (GeV/c^2)

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Limit calculation of Λ

- Conditional probability for the observed event distribution to be d_0, given the expected event distribution is d_Λ:

$$P(d_O \mid d_\Lambda) = \prod_{k=1}^{n} \frac{e^{-N_\Lambda^k} {N_\Lambda^k}^{N_O^k}}{N_O^k!}$$

- Bayes theorem:

$$P(d_\Lambda \mid d_O) = \frac{P(d_O \mid d_\Lambda) P(b, L, \varepsilon, \Lambda)}{Z}$$

- Posterior probability that the compositeness scale is Λ:
$P(\Lambda|d_O) =$

$$\frac{1}{Z}\int_0^\infty \mathrm{d}b \int_0^\infty \mathrm{d}L \int_0^1 \mathrm{d}\varepsilon \prod_{k=1}^{n}\left[\frac{e^{-N_\Lambda^k} {N_\Lambda^k}^{N_O^k}}{N_O^k!} e^{-\frac{1}{2}\left(\frac{\varepsilon^k-\varepsilon_m^k}{\delta\varepsilon^k}\right)^2} e^{-\frac{1}{2}\left(\frac{b^k-b_m^k}{\delta b^k}\right)^2}\right] e^{-\frac{1}{2}\left(\frac{L^k-L_m^k}{\delta L^k}\right)^2} P(\Lambda)$$

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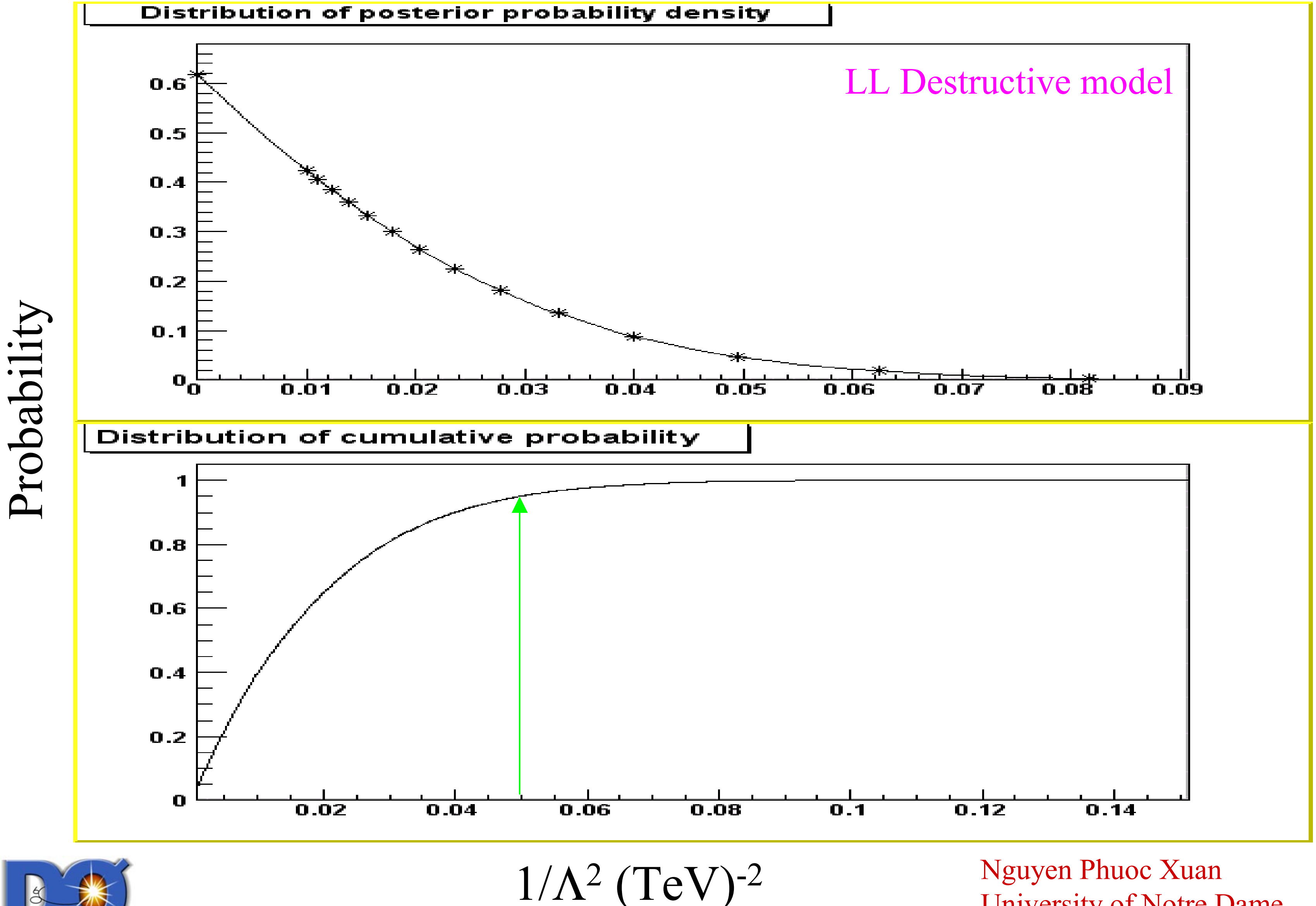
Limit calculation of Λ



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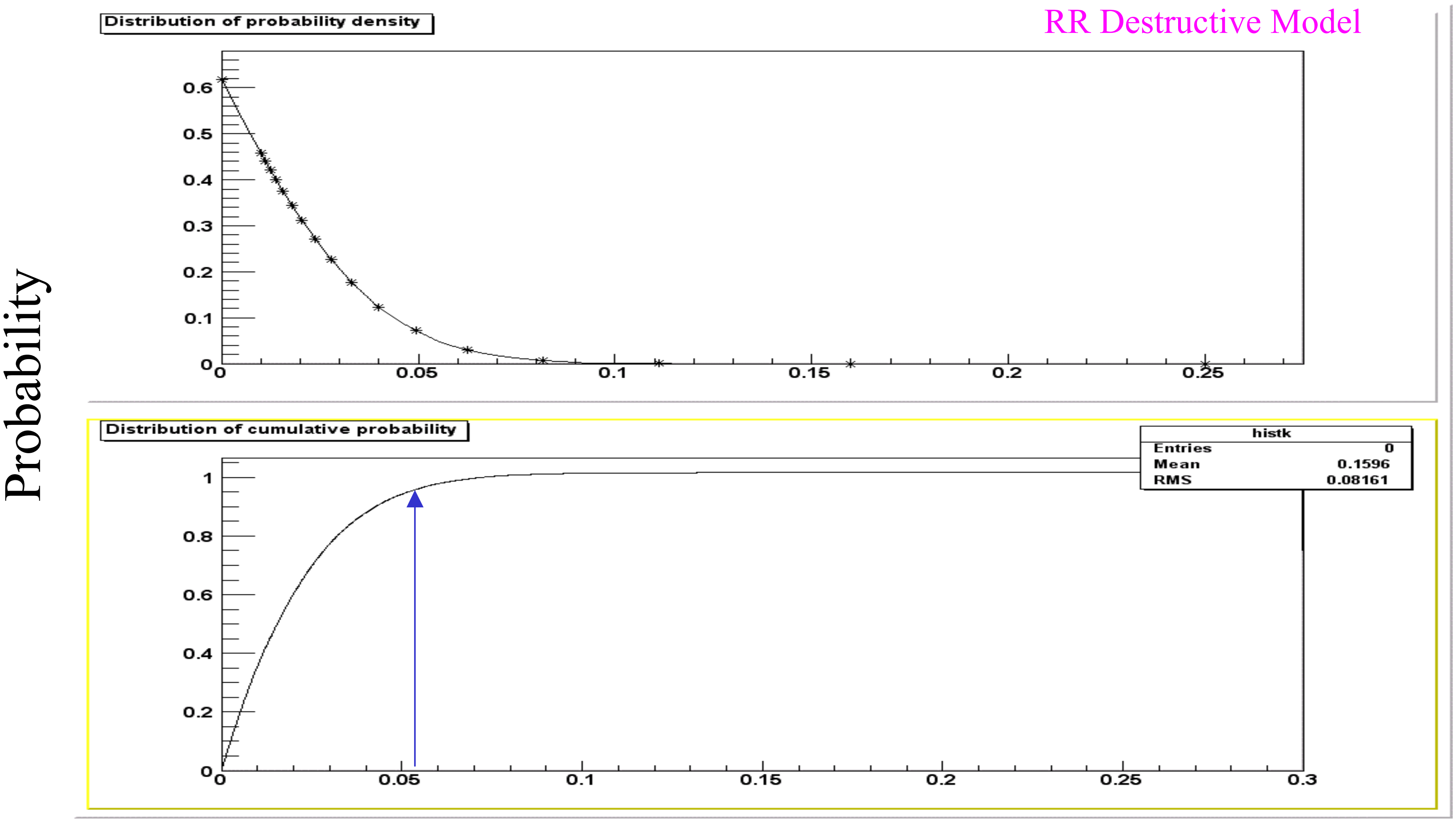
Limit calculation of Λ



$1/\Lambda^2$ (TeV)$^{-2}$

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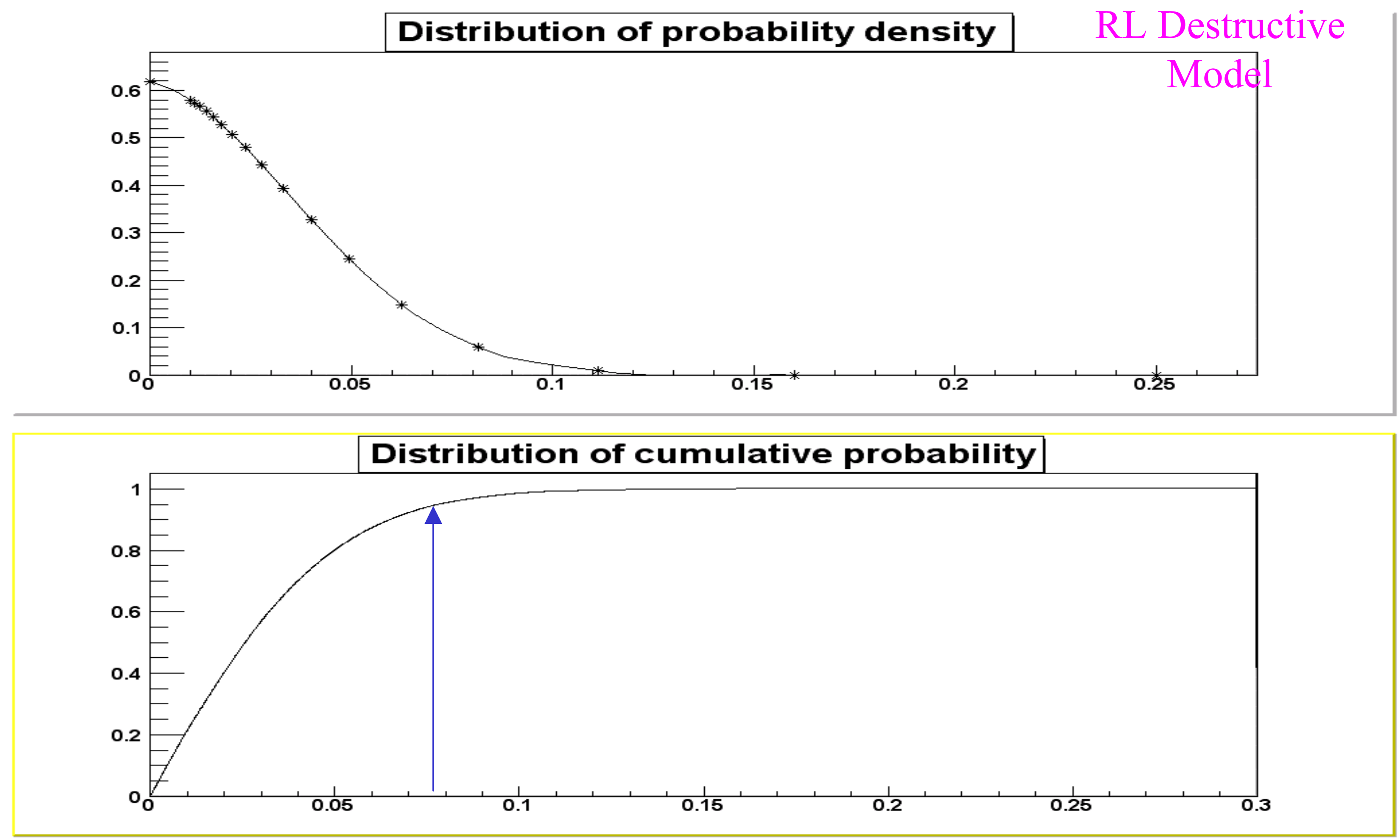
Limit calculation of Λ

Probability



$1/\Lambda^2$ (TeV)$^{-2}$

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Run I e^+e^- Results

$$CL = \int_{\Lambda_{\lim}}^{\infty} d\Lambda \, P(\Lambda \mid d_o)$$

- Run I 95% CL lower limit

	LL	LR	RL	RR	LL+RR	LR+RL	LL-RR	RL-RR	VV	AA
Λ^+(TeV)	3.3	3.4	3.3	3.3	4.2	3.9	3.9	4.0	4.9	4.7
Λ^-(TeV)	4.2	3.6	3.7	4.0	5.1	4.4	4.5	4.3	6.1	5.5

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Run II $\mu^+\mu^-$ Results

- Run II 95% CL lower limit

	LL	LR	RL	RR
Λ^+(TeV)	3.38	4.10	3.90	3.46
Λ^-(TeV)	5.58	4.81	4.92	5.67

← Projected, not measured

- Limits are obtained from 1-dimensional mass distribution
- Analysis will be extended to a 2-dimensional study of mass vs. scattering angle

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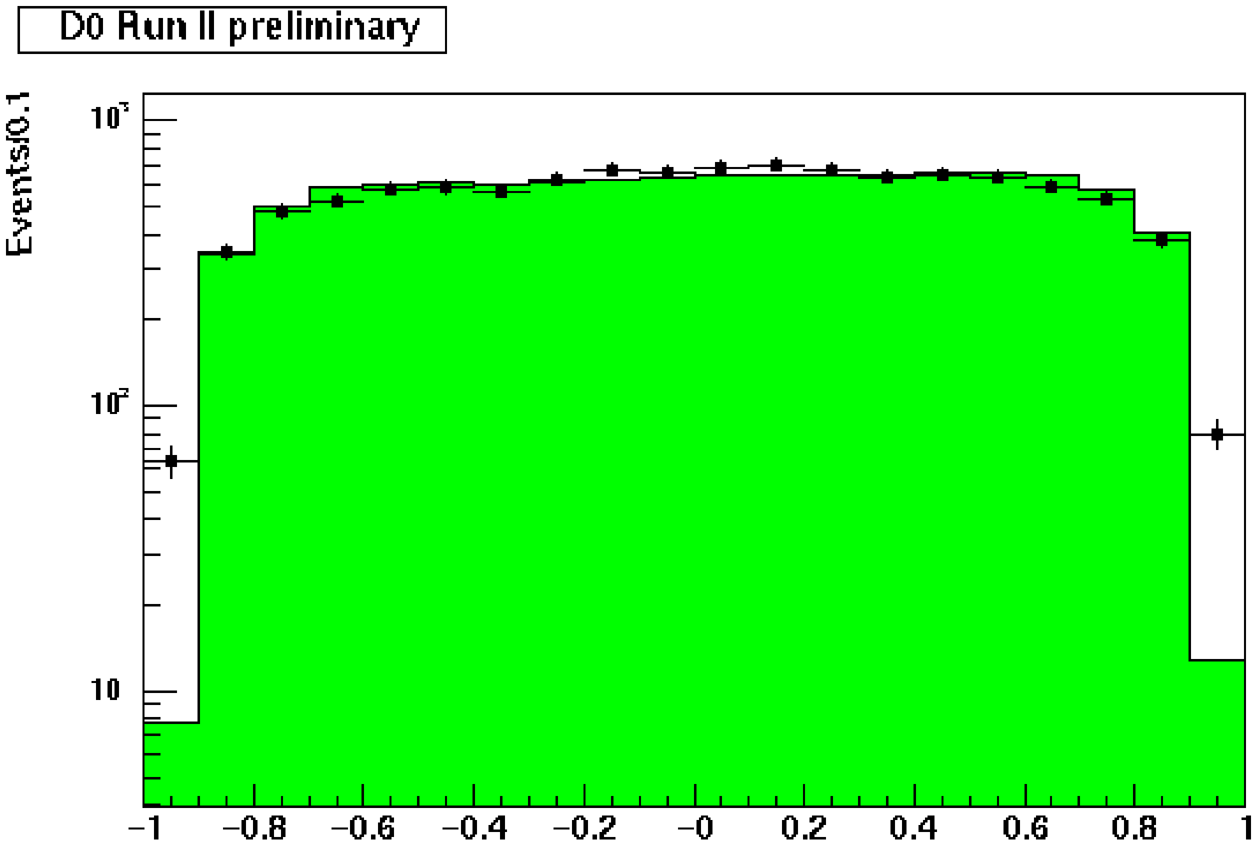
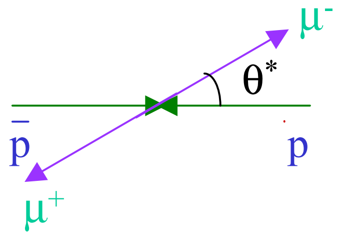
Dσ/dcos(θ*) analysis

- Data and Monte Carlo comparison



cos(θ*)

for all mass



$\mu^+ \mu^-$ center of mass frame

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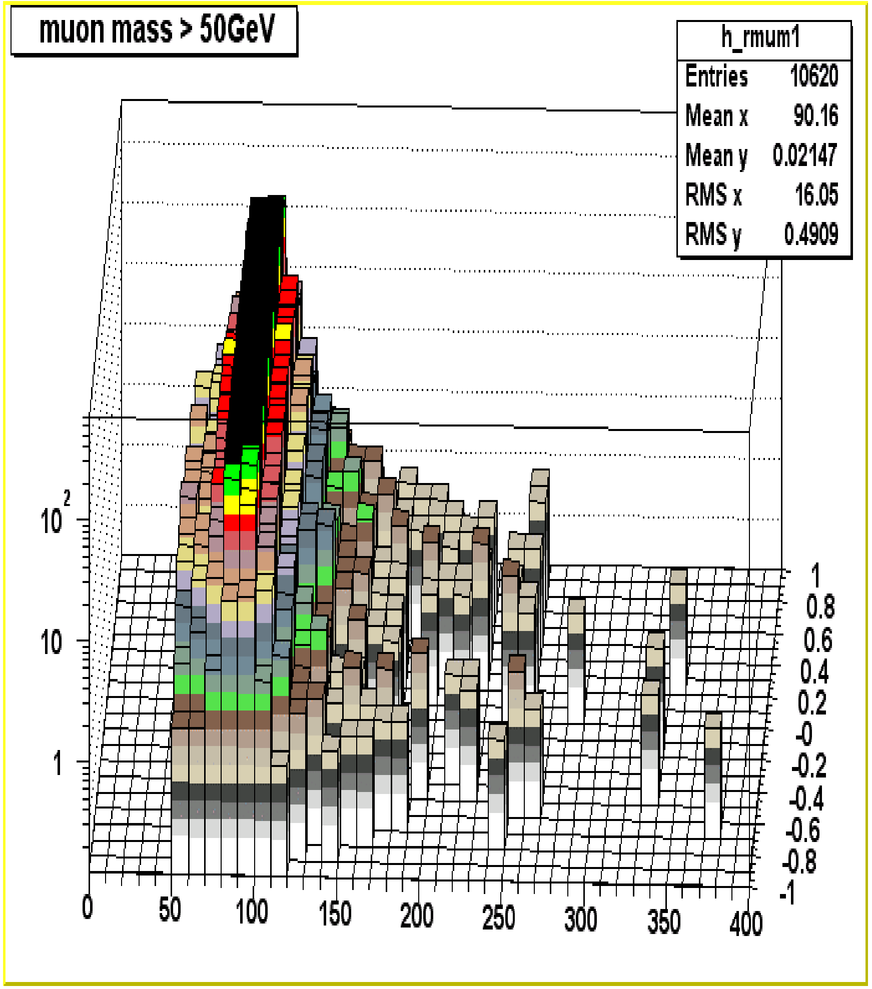
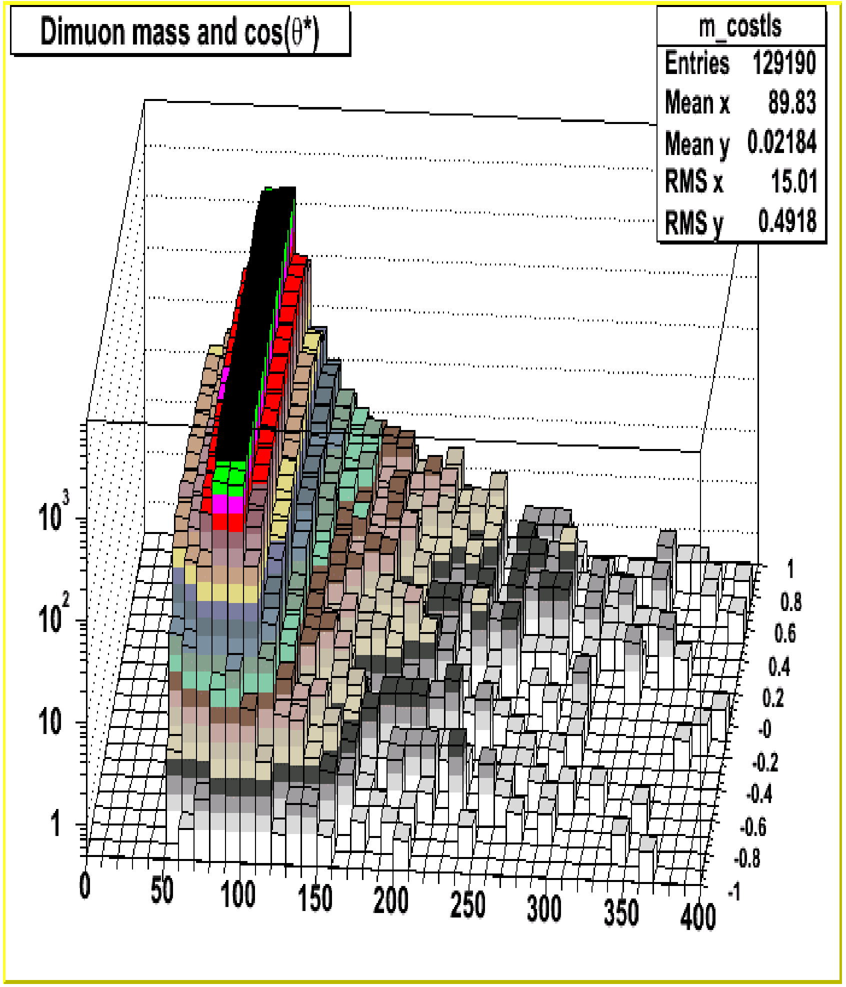
Data and MC comparison

Data



MC



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Summary and outlook

- First study of quark compositeness through dimuon channel at DØ.
- First study of quark compositeness with $d\sigma/d\cos(\theta^*)$ analysis.
- Put limits on Λ (characteristic energy scale).
- Plans:
  - This is a preliminary analysis – we need to refine the tools.
  - Repeat analysis with larger data sample.
  - Extend analysis to 2-dimensional.

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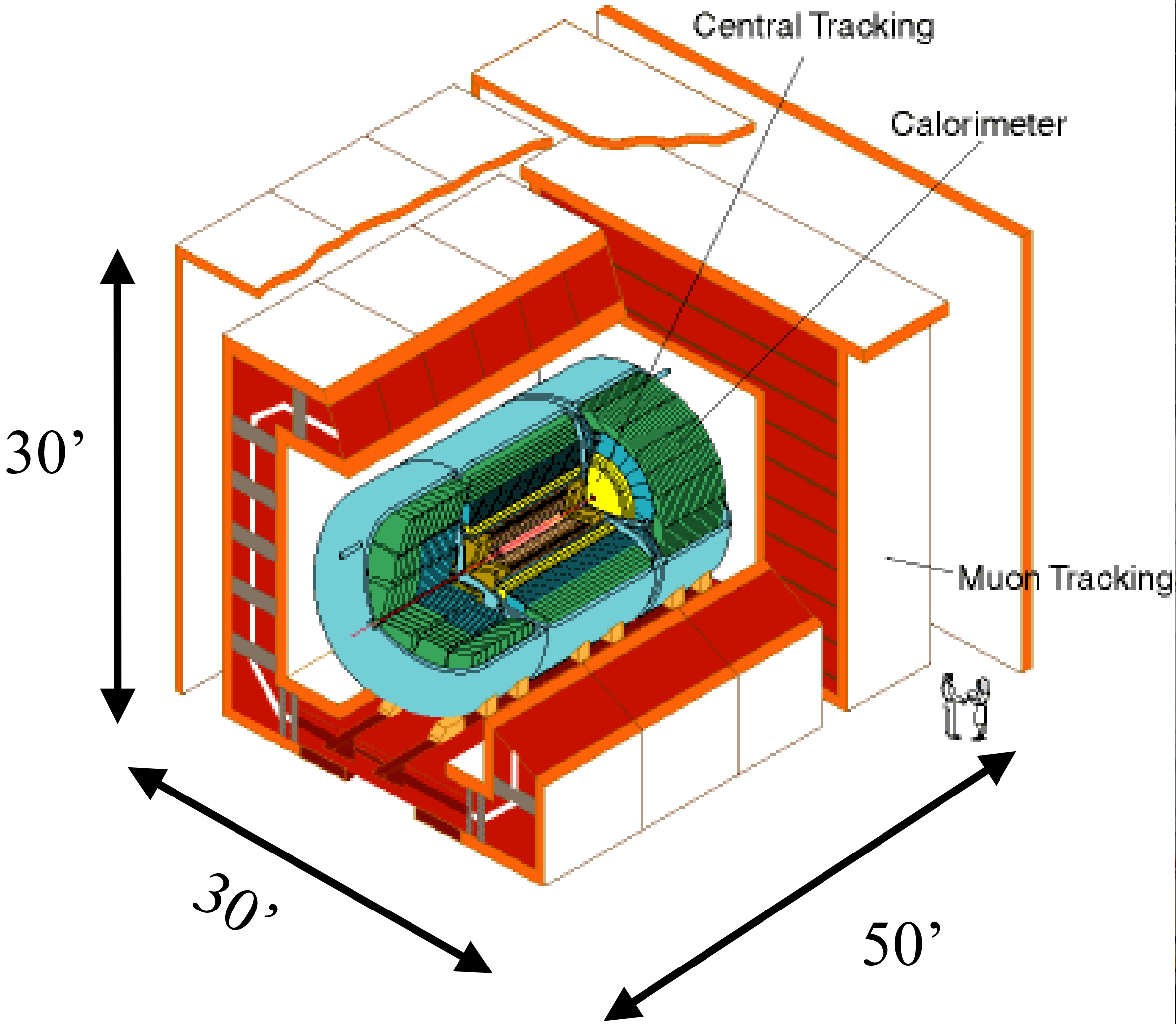
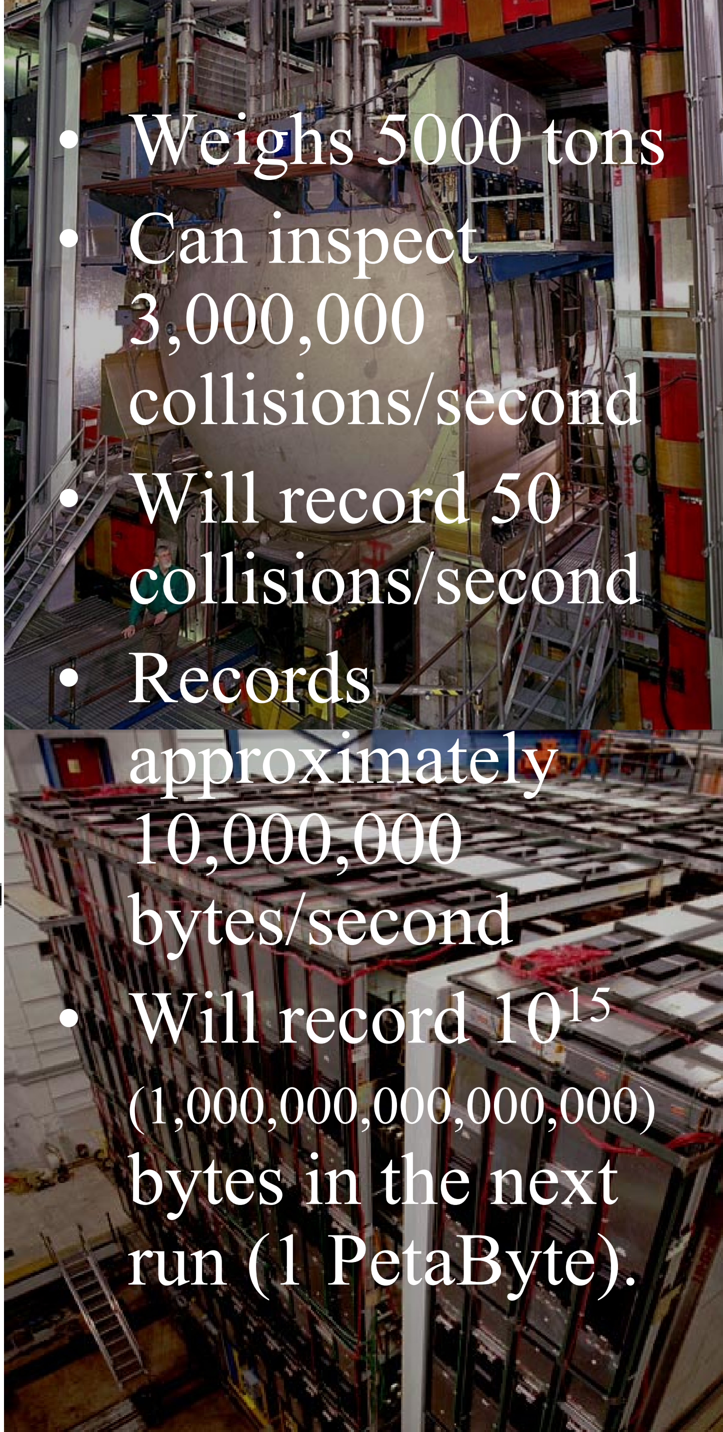
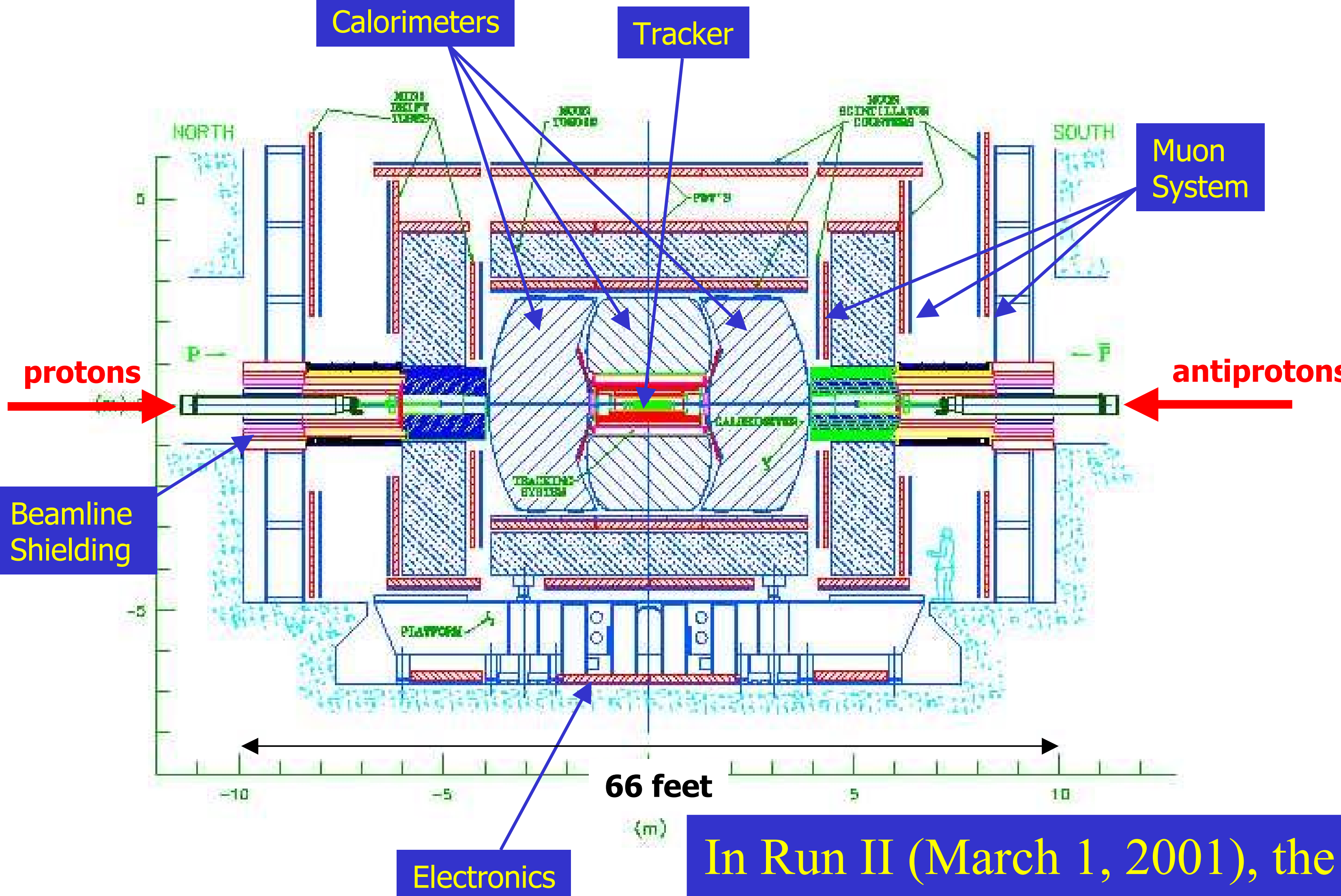
DØ Detector: Run II





- Weighs 5000 tons
- Can inspect 3,000,000 collisions/second
- Will record 50 collisions/second
- Records approximately 10,000,000 bytes/second
- Will record 10^{15} (1,000,000,000,000,000) bytes in the next run (1 PetaByte).



In Run II (March 1, 2001), the Fermilab Tevatron will deliver 10-20 times as many collisions per second as Run I.

The DØ detector required an overhaul in order to cope.