Searches for New Physics at DØ

---- selected topics

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On behalf of the DØ Collaboration

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Introduction

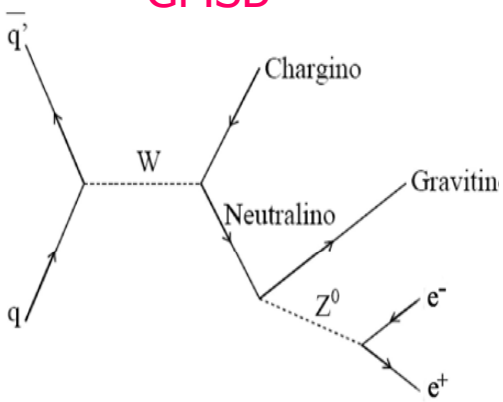
- the Standard Model (SM) is believed to be a low energy approximation of more general underlying theory
- Supersymmetry (SUSY) is a popular candidate, but no discovery yet
- New physics maybe different from SUSY
- A variety of new physics theories beyond SM (BSM), many non-SUSY possibilities, tested at DØ
- This talk covers selected topics of searches on
  - Long-lived neutral particles
  - Charged massive stable particles
  - Leptoquarks (all generations)
- All quoted limits are at 95% Confidence Level (CL)

Long-lived Particles

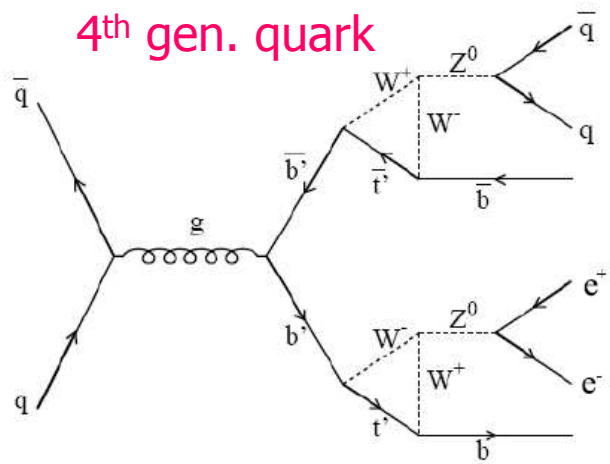
Signature: pair of EM showers from a significantly displaced vertex

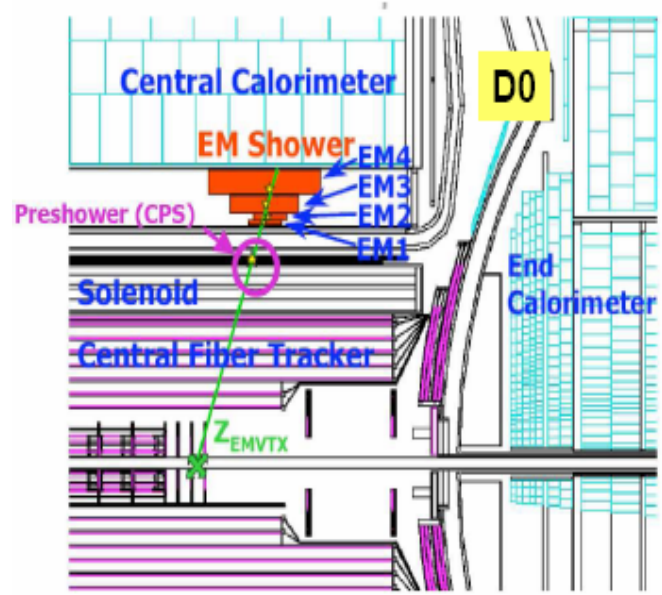
- Long-lived neutralino (χ^0) in gauge-mediated SUSY breaking (GMSB) models
- Long-lived 4th generation quark (*b'*)
- Long-lived *v*-mesons in the Hidden Valley Models, decay into electron pair

GMSB



4th gen. quark





Analysis strategy

- Two isolated EM clusters with p_T > 20 GeV & |η |< 1.1
- 5 measured positions in EM Cal. and CPS define object direction & vertex
- Construct discriminating variable R_S, related to the vertex radius

Long-lived Particles

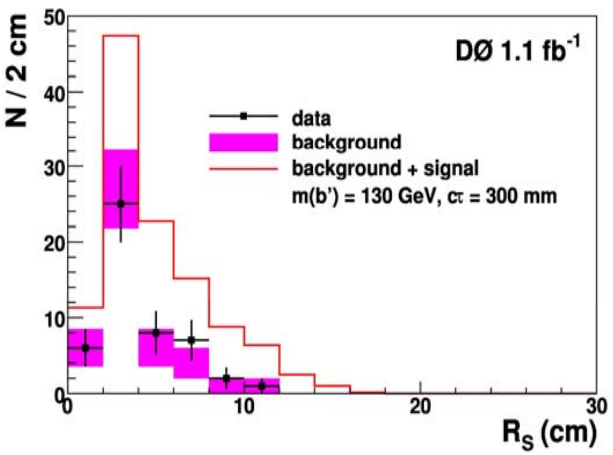
1.1 fb^{-1}

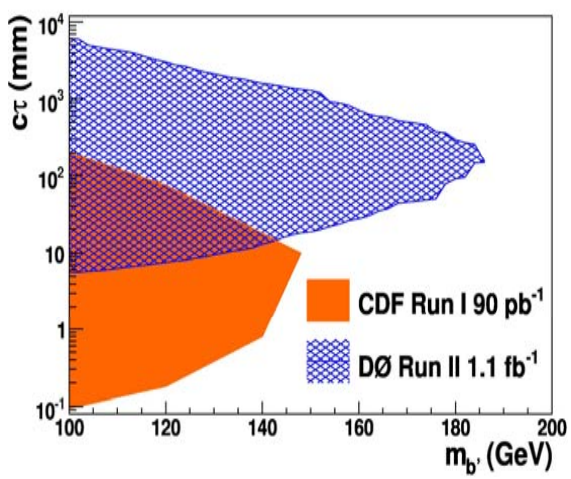
Analysis strategy (cont'd)

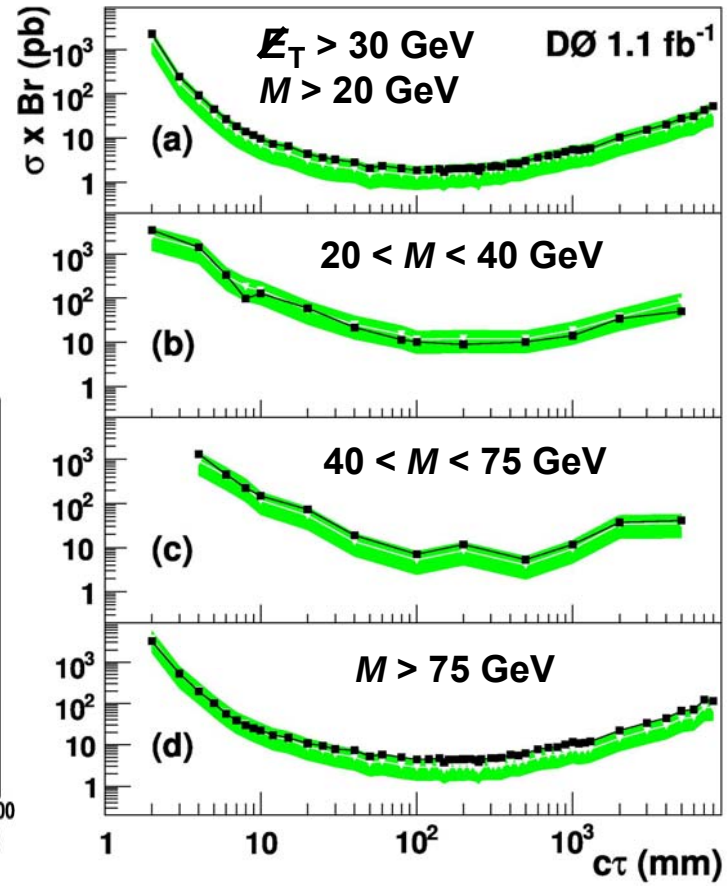
- $R_S > 0$ for LLP, but symmetric around zero for prompt ***ee/γγ***
- BKGD is estimated using negative R_S
- Divide data into 3 $M_{ee/\gamma\gamma}$ bins
- No excess is observed, model-independent Xsection limits derived, also mass of 4th generation quark (*b'*)

arXiv:/0806.2223 [hep-ex], submitted to PRL

Selection	$R_S > 0$	$R_S < 0$
$20 < M < 40$ GeV	38	47
$40 < M < 75$ GeV	191	190
$M > 75$ GeV	49	45
$M > 20$ GeV, $\not{E}_T > 30$ GeV	7	6







Charged Massive Stable Particles (CMSP)

CMSPs predicted in several extensions of SM, *e.g.*

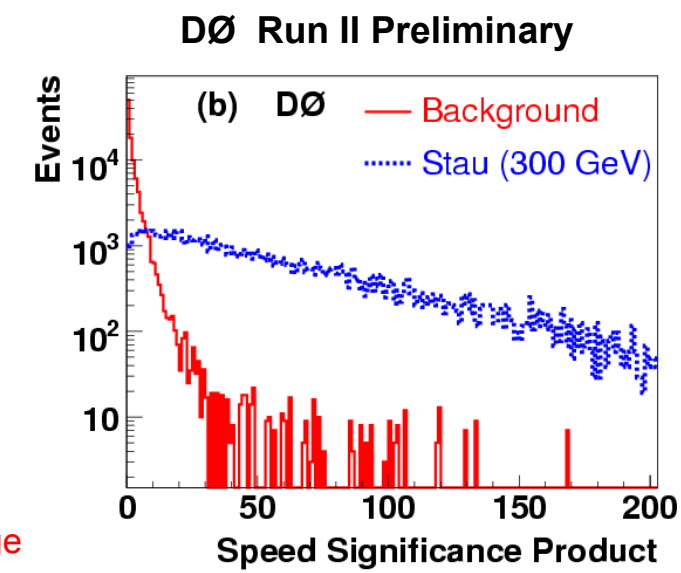
- The lightest scalar tau lepton (stau), predicted by GMSB models
- The lightest chargino, predicted by AMSB models

Experimental signature

- Charged: leaves track in the detector
- Massive: moves slowly, large time-of-ight (TOF) & dE/dx
- Stable: no decay within detector, registers in muon system (muon-like)

Event Selection for CMSP pair production

- 2 isolated "muon"s, with track matched & pT > 20 GeV
- Cosmic ray "muon" rejection:
  - Pseudo-acolinearity of two "muon"s:
    $\Delta\alpha_{\mu\mu} = |\Delta\varphi_{\mu\mu} + \Delta\theta_{\mu\mu} - 2\pi| > 0.05$
  - Time difference between muon layers
- Two "muon"s' p_T asymmetry required to be small
- Measure "muon" speed $\boldsymbol{v}$ using scintillation counters, calculate speed significance: $Sig.(v) = (1-\boldsymbol{v}_{average})/\boldsymbol{\sigma}_{average}$
- Cut on speed $\chi 2$ & speed significance



CMSP – stau Search

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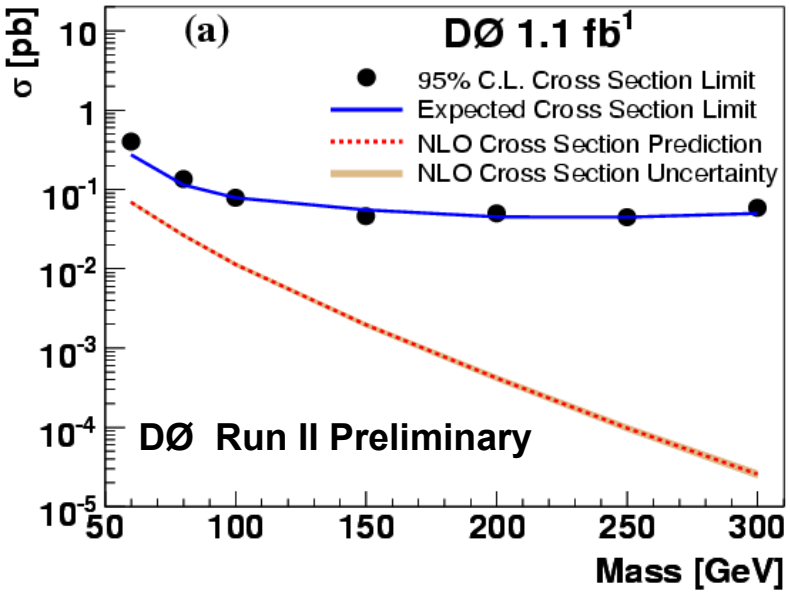
Event selection (cont'd)

- Construct likelihood function *L(x)* using: $M_{\mu\mu}$ & *Sig.(v1)*$_*$*Sig.(v2)*
- Cut on the discriminant: *D=L*(S)/(*L*(S) + *L*(B)) is optimized to get the best sensitivity
- No excess observed, Xsection limits derived for 3 different signal scenarios

Scalar Tau Leptons

Mass (GeV)	Signal Acceptance	Predicted Background	Observed Events
60	$0.047 \pm 0.001 \pm 0.001$	$20.4 \pm 1.8 \pm 4.3$	27
80	$0.111 \pm 0.002 \pm 0.009$	$24.7 \pm 2.0 \pm 3.4$	27
100	$0.147 \pm 0.002 \pm 0.012$	$22.3 \pm 1.9 \pm 2.0$	22
150	$0.171 \pm 0.002 \pm 0.013$	$13.1 \pm 1.4 \pm 1.9$	11
200	$0.159 \pm 0.002 \pm 0.014$	$7.9 \pm 1.1 \pm 1.5$	8
250	$0.140 \pm 0.002 \pm 0.014$	$5.4 \pm 0.9 \pm 0.8$	5
300	$0.119 \pm 0.002 \pm 0.014$	$4.0 \pm 0.8 \pm 0.5$	5

pair production Xsection limits



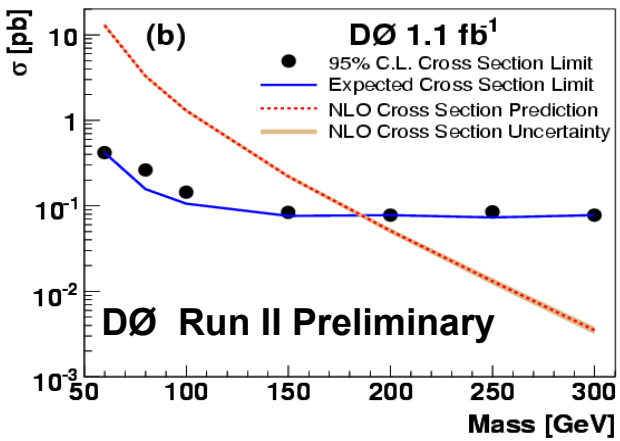
CMSP – Charginos Search

1.1 fb^{-1}

gaugino-like charginos

Mass (GeV)	Signal Acceptance	Predicted Background	Observed Events
60	$0.026 \pm 0.001 \pm 0.004$	$17.5 \pm 1.7 \pm 2.2$	17
80	$0.062 \pm 0.001 \pm 0.005$	$16.2 \pm 1.6 \pm 1.2$	23
100	$0.090 \pm 0.001 \pm 0.009$	$16.7 \pm 1.6 \pm 1.1$	20
150	$0.108 \pm 0.002 \pm 0.010$	$11.6 \pm 1.3 \pm 0.9$	12
200	$0.095 \pm 0.001 \pm 0.010$	$8.2 \pm 1.1 \pm 0.6$	9
250	$0.075 \pm 0.001 \pm 0.009$	$4.8 \pm 0.8 \pm 0.5$	5
300	$0.059 \pm 0.001 \pm 0.009$	$2.9 \pm 0.7 \pm 0.3$	2

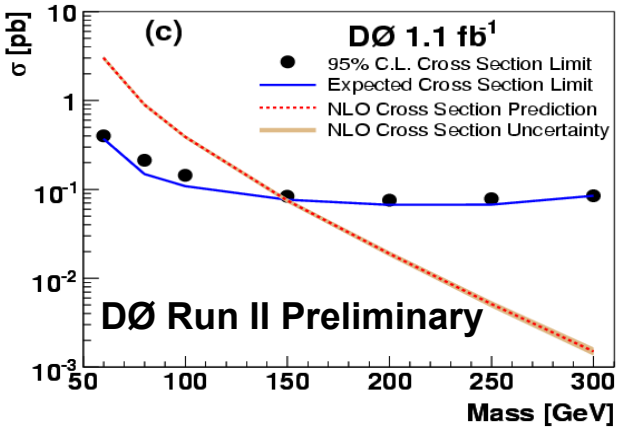
***M < 185 GeV* excluded**



higgsino-like charginos

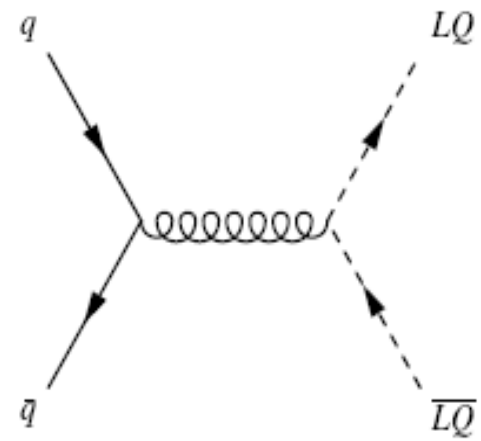
Mass (GeV)	Signal Acceptance	Predicted Background	Observed Events
60	$0.027 \pm 0.001 \pm 0.003$	$16.2 \pm 1.6 \pm 1.3$	17
80	$0.067 \pm 0.001 \pm 0.006$	$17.8 \pm 1.7 \pm 1.7$	23
100	$0.096 \pm 0.001 \pm 0.008$	$18.9 \pm 1.7 \pm 2.2$	22
150	$0.116 \pm 0.002 \pm 0.010$	$12.4 \pm 1.4 \pm 1.6$	13
200	$0.102 \pm 0.001 \pm 0.011$	$7.7 \pm 1.1 \pm 0.3$	8
250	$0.083 \pm 0.001 \pm 0.011$	$4.9 \pm 0.9 \pm 0.6$	5
300	$0.064 \pm 0.001 \pm 0.009$	$3.2 \pm 0.7 \pm 0.5$	3

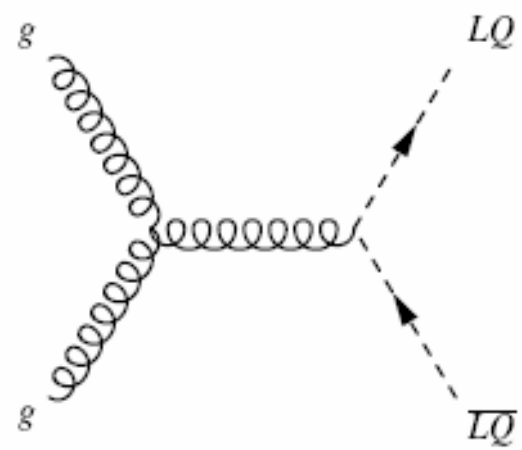
***M < 145 GeV* excluded**



Searches for LeptoQuarks

- Leptoquarks (LQ) are hypothetical bosons allowing lepton-quark transitions
- Predicted by several extensions of the SM, *e.g.* GUT, Technicolor, Compositeness
- have both baryon & lepton quantum numbers
- $Q_{em} = \pm 1/3, \pm 2/3, \pm 4/3$
- Spin-0 (scalar) and spin-1 (vector)
- 3 generations of LQ, each only couples to a quark and a lepton in the same generation
- β is coupling (LQ, $l^{\pm}$, q) & $1 - \beta$ is (LQ, v, q')
- LQs are pair-produced at Tevatron
- Xsection for scalar LQ only depends on M_{LQ} and α_s



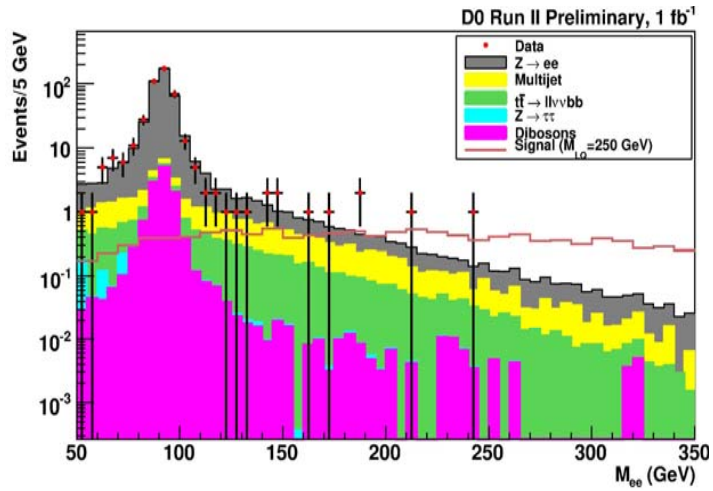


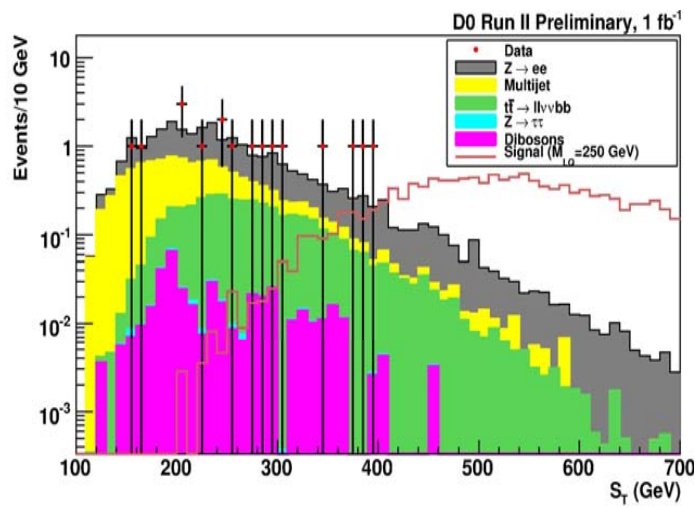
1st Generation: $LQ_1LQ_1 \rightarrow ejej$ (β=1)

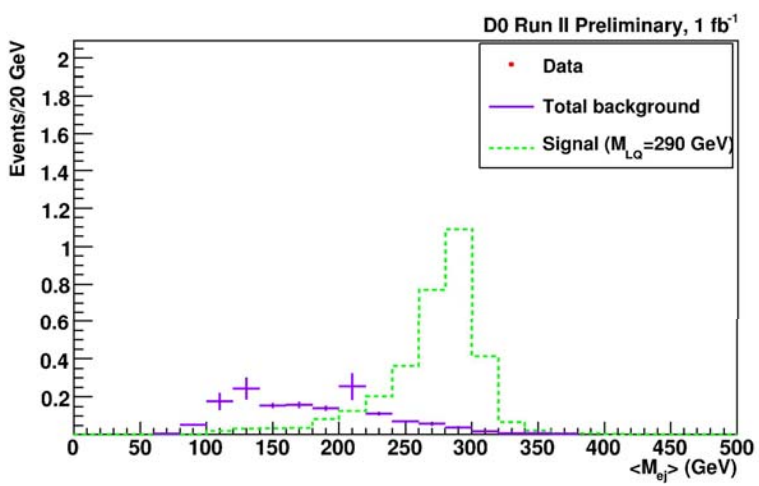
1 fb^{-1}

Analysis strategy:

- Two electrons with p_T > 25 GeV
- at least one electron within $|\eta|$< 1.1
- Two jets with E_T > 25 GeV and $|\eta|$< 2.5
- M_{ee} > 110 GeV
- $S_T = p_T^{e1}+p_T^{e2}+p_T^{jet1}+p_T^{jet2}$ > 400 GeV
- No excess observed
- *e* & *jet* are paired such that M_{ej}^1 & M_{ej}^2 difference minimal
- $< M_{ej} >=(M_{ej}^1+M_{ej}^2)/2$ used to set the limits
- Interpret results in both scalar & vector LQ

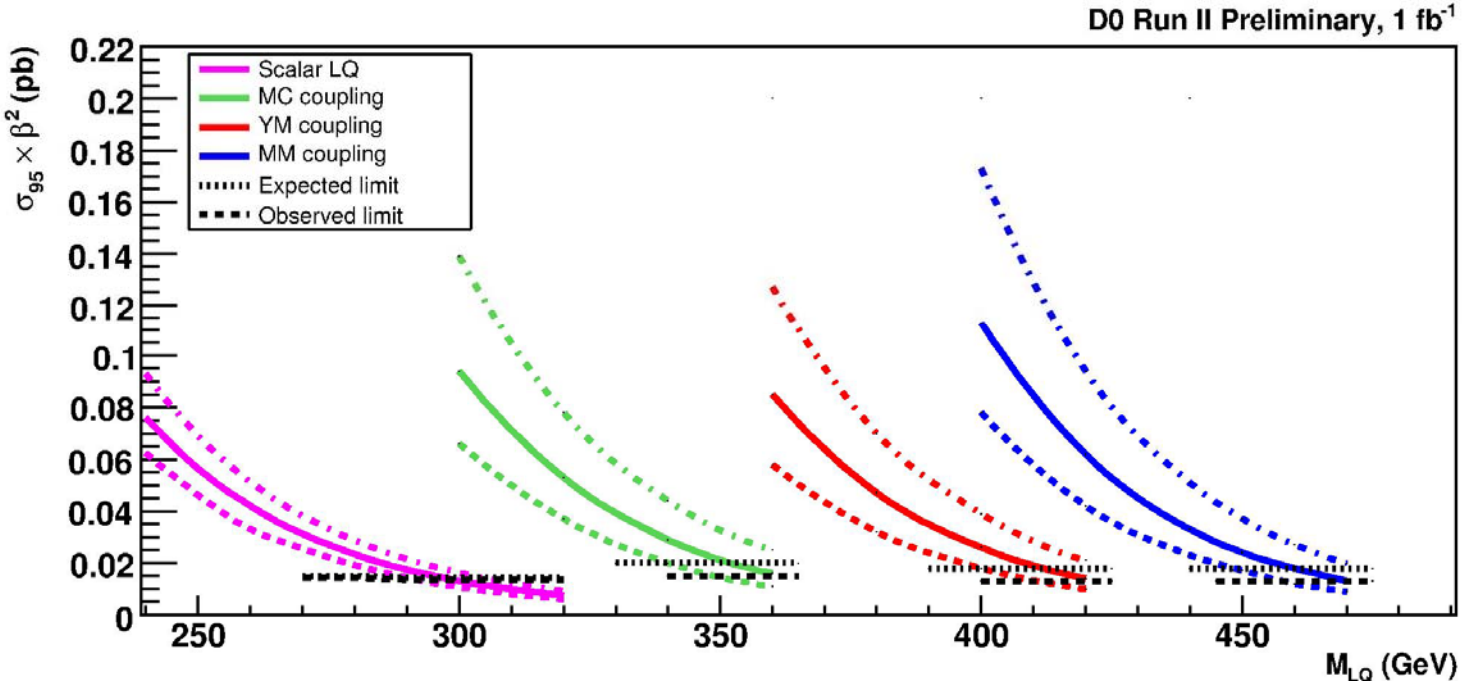






1st Generation: $LQ_1LQ_1 \rightarrow ejej$ (β=1)

1 fb^{-1}



Scalar LQ_1: M_{LQ} > 292 GeV

Vector LQ_1:

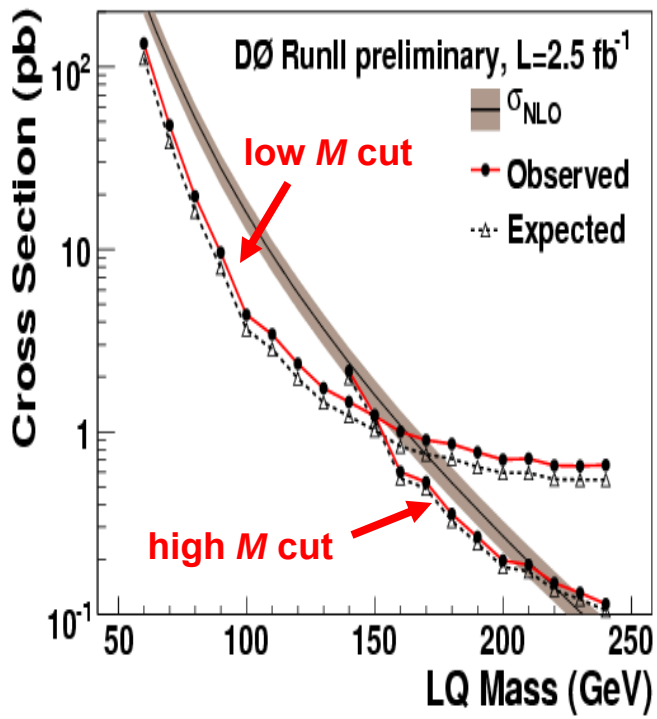
Minimal Coupling	$Q = 1/3,\ T_3 = -1/2,\ \kappa_G = 1,\ \lambda_G = 0$	M_{LQ} > 350 GeV
Yang-Mills Coupling	$Q = 1/3,\ T_3 = -1/2,\ \kappa_G = 0,\ \lambda_G = 0$	M_{LQ} > 410 GeV
Minus Minus Coupling	$Q = 1/3,\ T_3 = -1/2,\ \kappa_G = -1,\ \lambda_G = -1$	M_{LQ} > 458 GeV

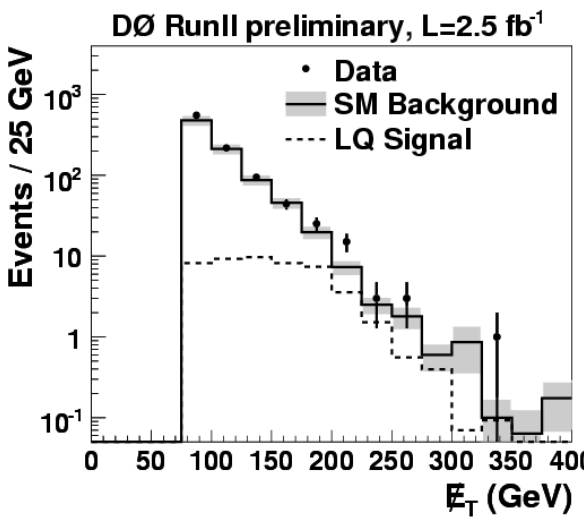
1st Generation: $LQ_1LQ_1 \rightarrow \nu j \nu j$ (β=0)

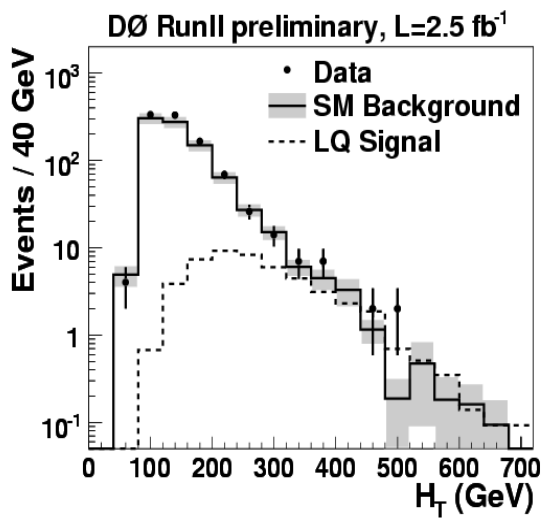
2.5 fb^{-1}

Analysis strategy:

- Two leading jets with E_T > 35 GeV & $|\eta|$< 0.8
- Large missing transverse energy $\not{E}_T$ >75 GeV
- good $\not{E}_T$ and jets separations
- Veto on events with isolated leptons & 3rd jet
- Optimized cuts on $\not{E}_T$ and $H_T = |\Sigma_{jets}\, p_T|$ for low/high M_{LQ}
- Scalar LQ_1: **M_{LQ} > 214 GeV for β= 0**







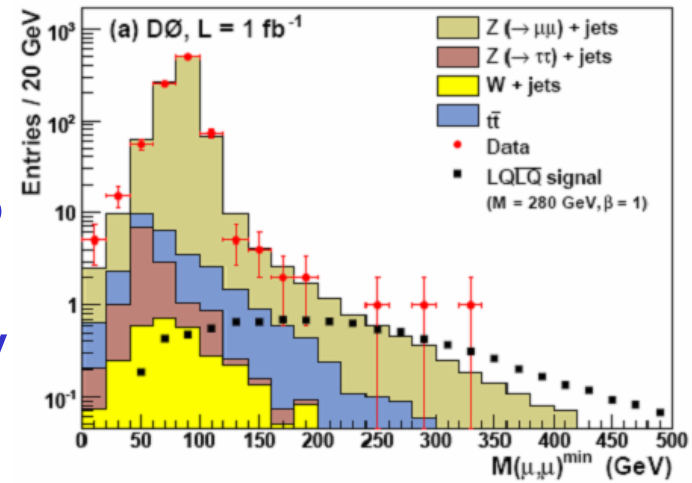
2nd Generation: $LQ_2LQ_2 \rightarrow \mu j \mu j$ (β=1)

1 fb^{-1}

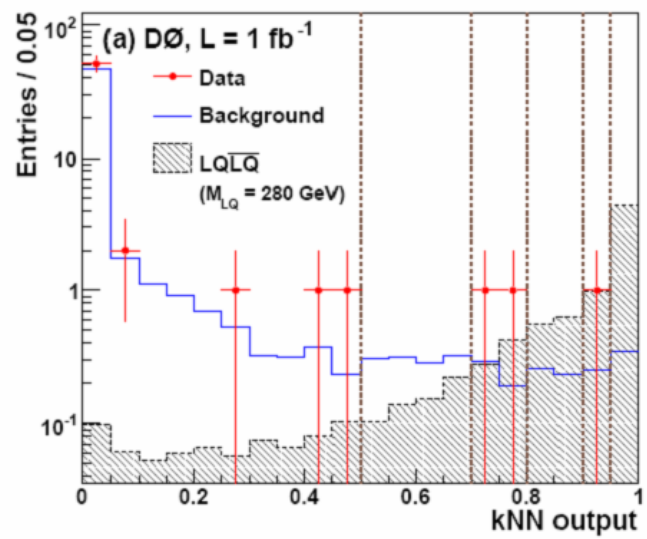
Analysis Strategy:

- Two muons with p_T > 20 GeV
- Two jets with E_T > 25 GeV and $|\eta|$< 2.5
- $M_{\mu\mu}$> 50 GeV
- $S_T = p_T^{\mu_1} + p_T^{\mu_2} + p_T^{jet_1} + p_T^{jet_2}$> 200 GeV
- $M_{\mu\mu}^{min}$ > 100 GeV
- S_T, $M_{\mu\mu}^{min}$ & $M(\mu_i, jet_i)$ as inputs to a multivariate classier, using the k-Nearest-Neighbors (kNN) algorithm.
- Data consistent with BKGD expectation
- kNN distributions used for limit setting (modified frequentist)

DØ Run II Preliminary



DØ Run II Preliminary



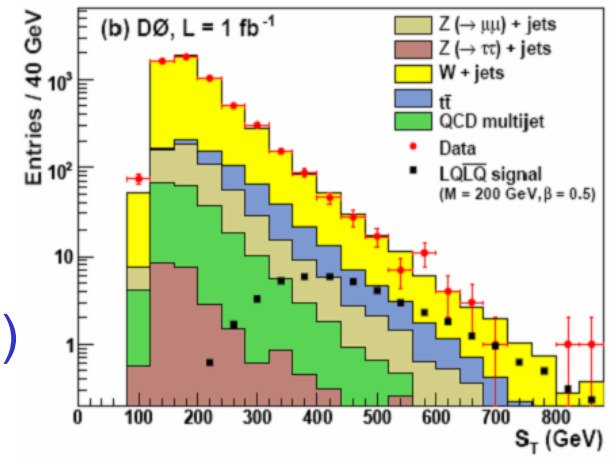
2nd Generation: $LQ_2LQ_2 \rightarrow \mu j \nu j$ (β=0.5)

1 fb^{-1}

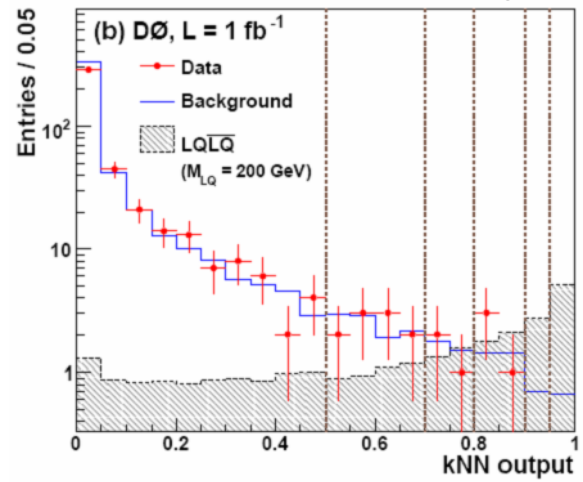
Analysis Strategy:

- Exactly one muon with p_T > 20 GeV
- Two jets with E_T > 25 GeV and $|\eta|$ < 2.5
- $\not{E}_T$ > 30 GeV
- $M_T(\mu, \not{E}_T) = (2p_T^{\mu}\not{E}_T[1-\cos\Delta\varphi(\mu, \not{E}_T)])^{-1/2}$ > 50 GeV
- $S_T = p_T^{\mu} + p_T^{jet1} + p_T^{jet2} + \not{E}_T$ > 200 GeV
- Inputs to kNN: S_T, $M_T(\mu, \not{E}_T)$, $M(\mu, jet_i)$ & $M_T(\not{E}_T, jet_i)$
- No excess observed, kNN outputs for limits setting
- $\mu j \mu j$ & $\mu j \nu j$ combined to derive the Xsection limits
- **M_{LQ} > 316 GeV (β=1) & M_{LQ} > 270 GeV (β=0.5)**

DØ Run II Preliminary



DØ Run II Preliminary



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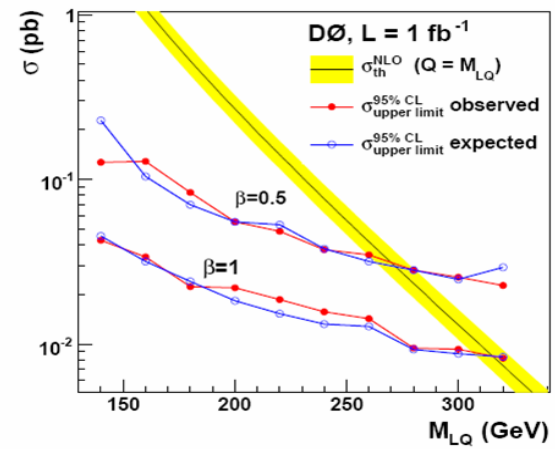
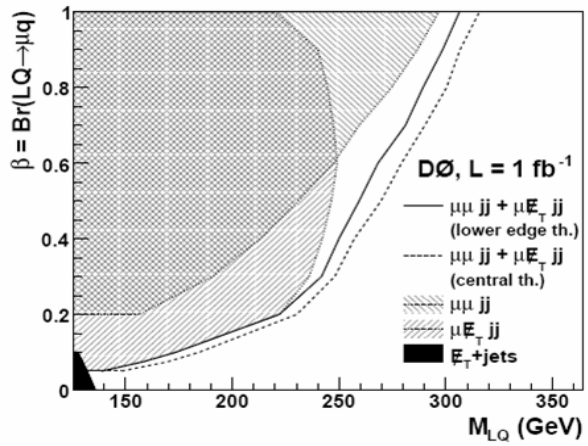


DØ Run II Preliminary



3rd Generation: $LQ_3LQ_3 \rightarrow \tau b \tau b$

1.05 fb^{-1}

Focus on $\tau_1 \rightarrow \mu + \nu\bar{\nu}$ & $\tau_2 \rightarrow hadron(s) + \nu$

Analysis Strategy:

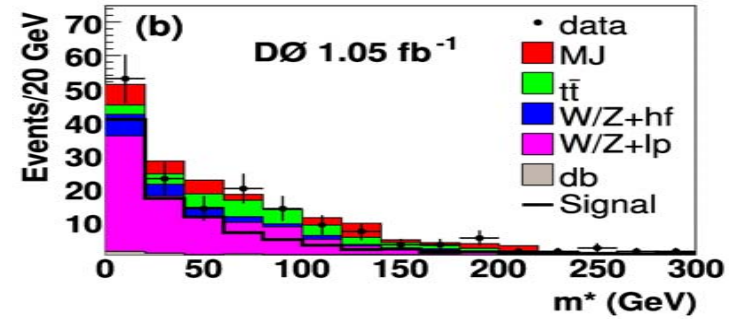
- one isolated muon with p_T > 15 GeV & |η| < 2.0
- Tau candidates are selected for 3 decay topologies:

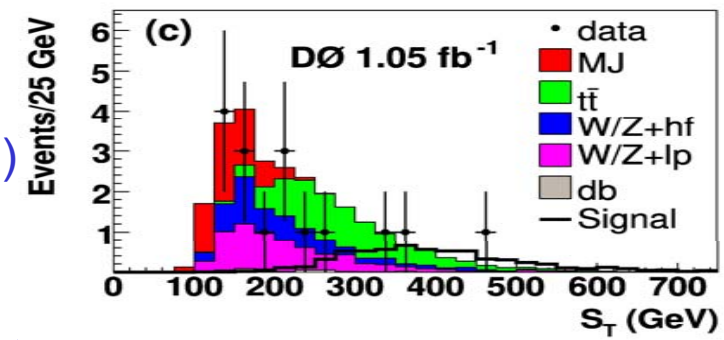
  (1) $\tau^{\pm} \rightarrow \pi^{\pm}\nu$,

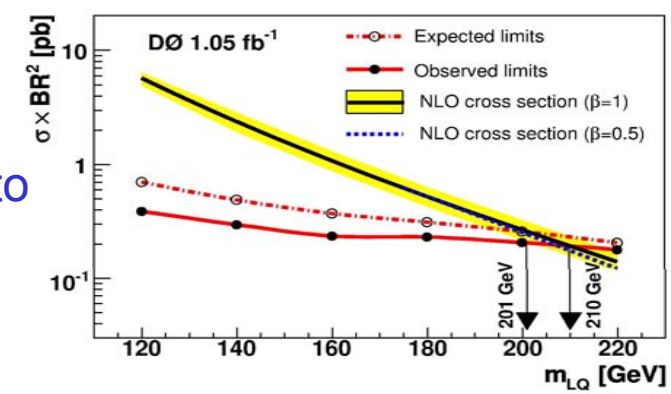
  (2) $\tau^{\pm} \rightarrow \pi^{\pm}\pi^{0\prime s}\,\nu$,

  (3) $\tau^{\pm} \rightarrow \pi^{\pm}\pi^{\pm}\pi^{\mp}(\pi^{0\prime s})\nu$.
- Tau p_T > 15 GeV (type 1 & 2) and > 20 GeV (type 3)
- A NN for each tau type to further reject fake taus
- Two jets: E_T^1> 25 GeV, E_T^2> 20 GeV & |η| < 2.5
- $m^* = \left(2E^{\mu}\not{E}_T\,(E^{\mu}/p_T^{\mu})(1-\cos\Delta\varphi(\mu,\not{E}_T))\right)^{-1/2} < 60$ GeV
- jets are b-tagged based on optimized NN cut
- two sub-samples formed: 1 b-tag or 2 b-tags
- $S_T = p_T(\mu) + p_T(\tau) + p_T(jet_1) + p_T(jet_2) + \not{E}_T$
- S_T distributions for 1 and 2 b-tag samples are used to to set limits (modified frequentist)
- **M_{LQ} > 210 GeV (β=1) & M_{LQ} > 201 GeV (β=0.5)**

arXiv:/0806.3527 [hep-ex], submitted to PRL







Summary

- New DØ results in the searches for new particles presented
- No sign of new physics beyond the SM has been observed
- New regions of the parameter space of BSM theories have been excluded
- All presented results and more are available at http://www-d0.fnal.gov/Run2Physics/WWW/results/np.htm
- With about 4 fb^{-1} collected, new possibilities are still under exploration

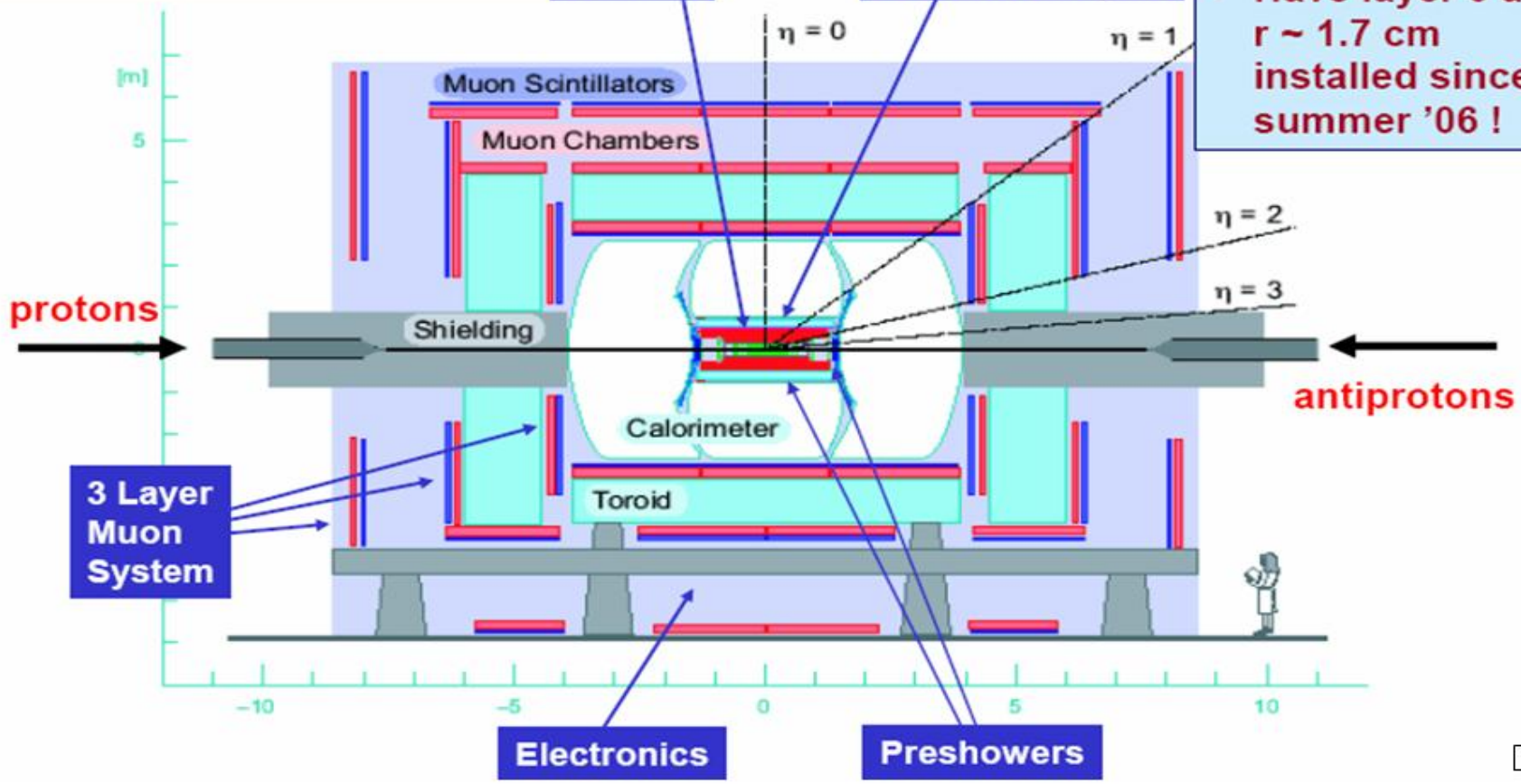
BACKUP SLIDES

DØ Detector

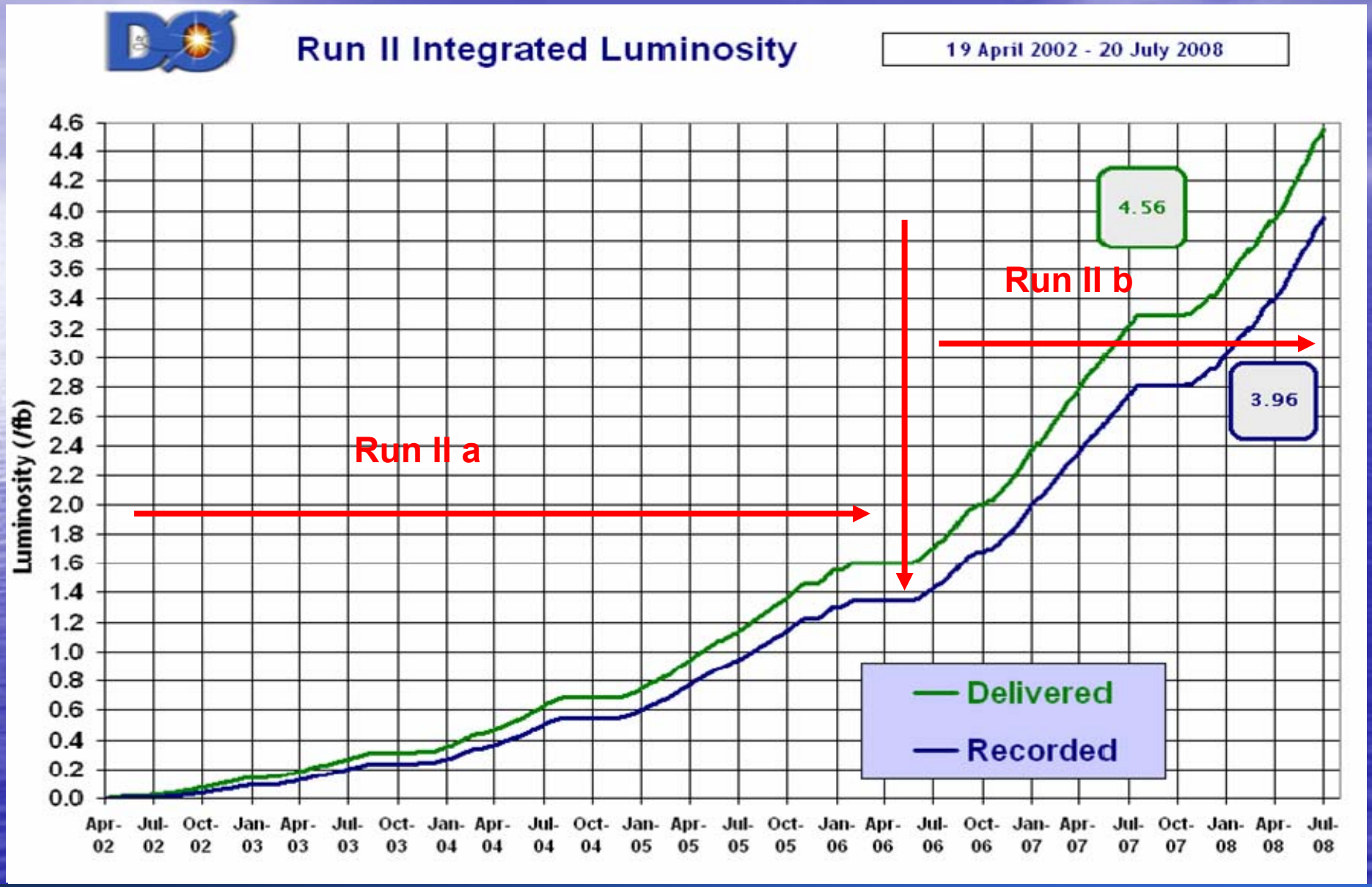
- Upgraded
  - Muon system, cal. electronics
  - DAQ, (track) trigger system
  - Displaced-vtx trigger

- New (tracking in B-field)
  - Silicon detector
  - Fiber tracker

- Have layer 0 at r ~ 1.7 cm installed since summer '06 !



DØ Dataset


Run II Integrated Luminosity
19 April 2002 - 20 July 2008
Luminosity (/fb)
4.6
4.4
4.2
4.0
3.8
3.6
3.4
3.2
3.0
2.8
2.6
2.4
2.2
2.0
1.8
1.6
1.4
1.2
1.0
0.8
0.6
0.4
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Apr-02
Jul-02
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Jan-06
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Jan-07
Apr-07
Jul-07
Oct-07
Jan-08
Apr-08
Jul-08
Run II a
Run II b
4.56
3.96
Delivered
Recorded