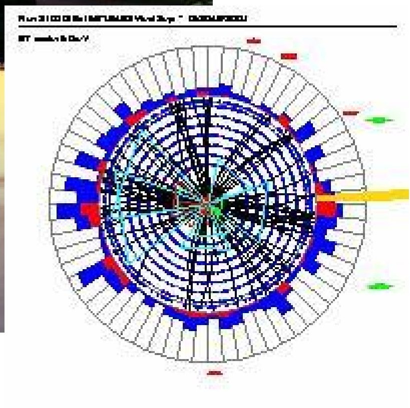
DØ Recent Results



Yury Shcheglov, PNPI,
February 2006, Repino

Outline

- **Collaboration and main physics goals**
- **DØ detector**
  - Muon system and Calorimeter
  - Vertex detector
  - Trigger system
  - Detector operation
- **Main Physics results**
  - Top Quark physics
  - QCD studies
  - Electroweak physics
  - Search for $B_s \to 2\ \mu$ Decay
  - Study of B_s Mixing
  - Extra dimensions search
  - Search for SUSY
  - Higgs search
- **Conclusion**

Collaboration

• DØ is an international collaboration of 670 physicists from 19 nations who have designed, built and operate a collider detector at the Tevatron

Institutions: 84 total, 35 US, 49 non-US

Collaborators:

• 50% from non-US institutions (note strong European involvement)

• Petersburg Nuclear Physics Institute, Gatchina, Russia involved to DØ-project through design and programming of electronic readout for 50 thousands channels of mini drift tubes; operation of the Muon Forward System; QCD physics, B physics and Electroweak physics studies

Main Physics Goals

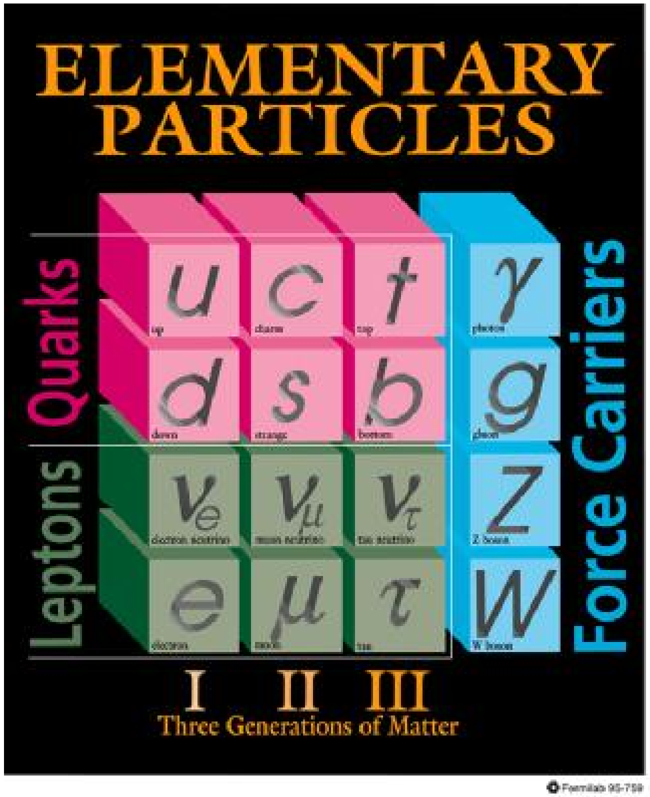
- Precision tests of the Standard Model - weak bosons physics, top quark physics, QCD, B physics
- Search for particles and forces beyond the S M - SUSY Higgs, supersymmetric particles, graviton
- Does quarks sub-structure exist ?
- What is cosmic dark matter? SUSY?
- What is spacetime structure? Extra dimensions?
- To reach these goals seven main physics groups are working on DØ:

SM testing

- B physics group
- Top quark group
- Electroweak group
- QCD group
- Higgs group

SUSY, Extra dimensions search

- New phenomena group



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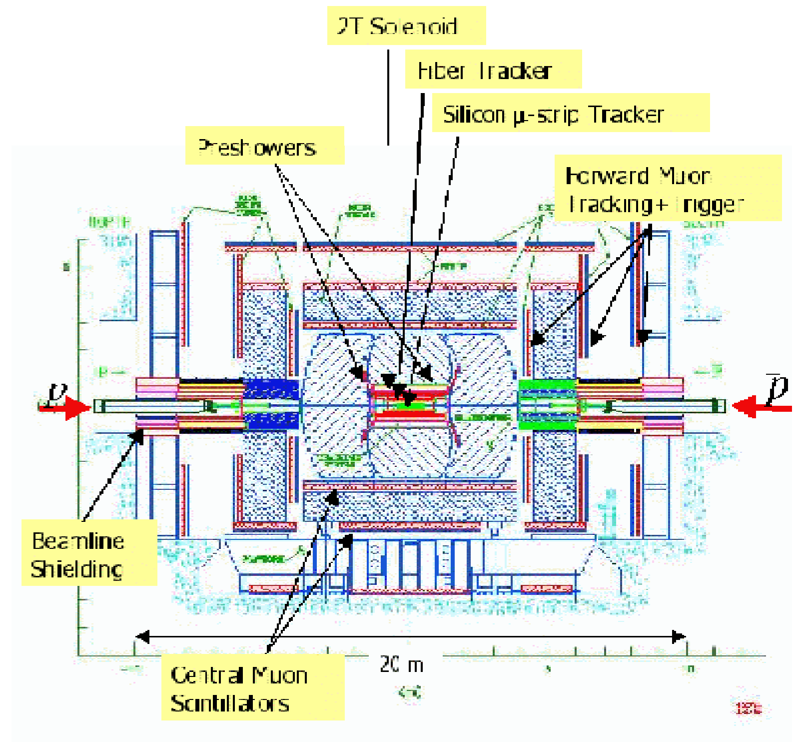
DØ - detector

• Main parts of the detector – central tracker, preshower detectors, calorimeter, muon system and toroid (1.8 T)
• Run II upgrade – central tracker and forward muon system was completely replaced:
-Silicon microstrip tracker and scintillating fiber tracker were installed and located within 2T solenoidal magnet
- 50000 mini drift tubes were used for the new muon forward system



• During Run II Tevatron is operated with 36 bunches of protons and antiprotons with a bunch spacing of 396 ns and at an increased center-of-mass energy of 1.96 TeV (Run I, 1.8 TeV)

• Luminosity was increased by more than a factor of ten to greater than $1{\cdot}10^{32}$ cm^{-2} s^{-1}

Muon System

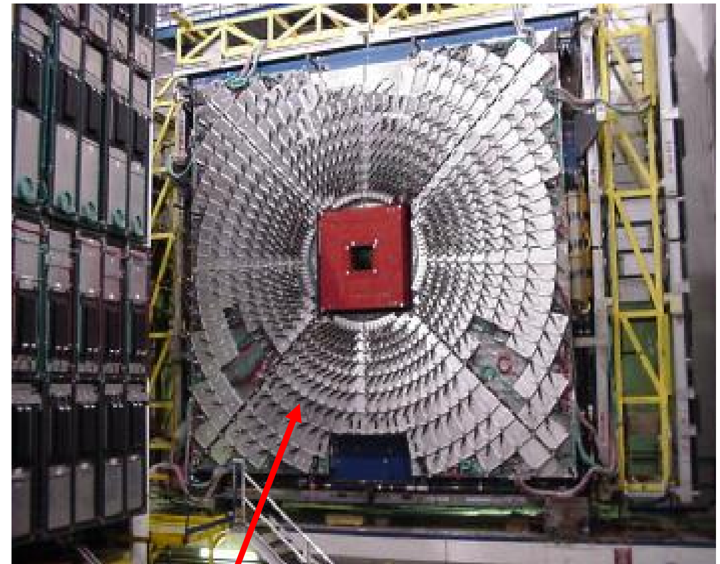
• Three layers of scintillator planes for triggering and three layers of drift tubes for a muon track reconstruction, for both the Central and Forward Muon System

• Main part of Forward Muon System was designed and produced in JINR - mini drift tubes and amplifier discriminator boards, IHEP - scintillators, PNPI - electronic readout front-ends for mini drift tubes

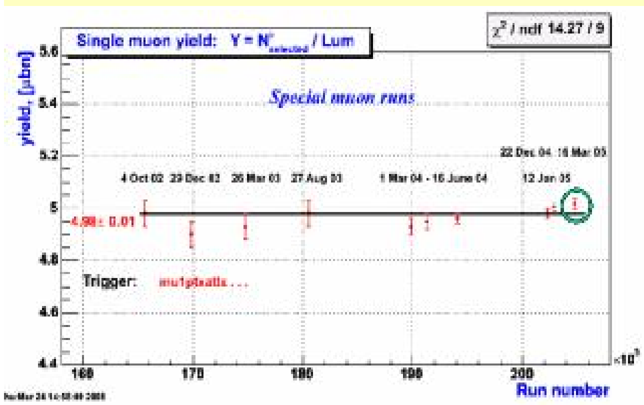
- 50 thousands of drift tubes with 400 micron space resolution cover an area 590 m^2

- 5000 scintillators provide fine pixel structure, which helps to get 1 ns time resolution for all muon tracks

Good stability of all muon system over all operation period !



Forward Muon Scintillators System



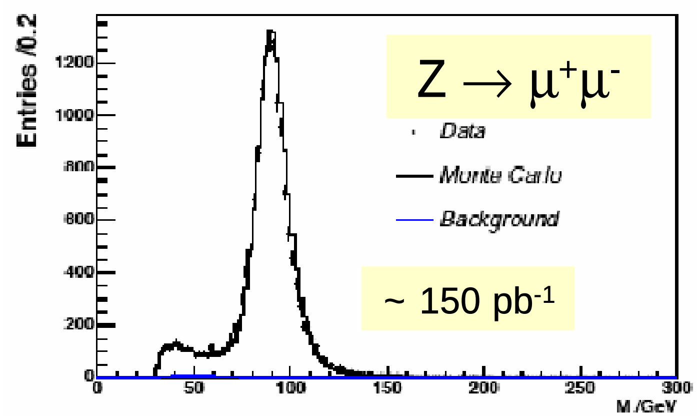
Acceptance:

Central Muon System

$|\eta| < 1.0$

Forward Muon System

$1.0 < |\eta| < 2.0$



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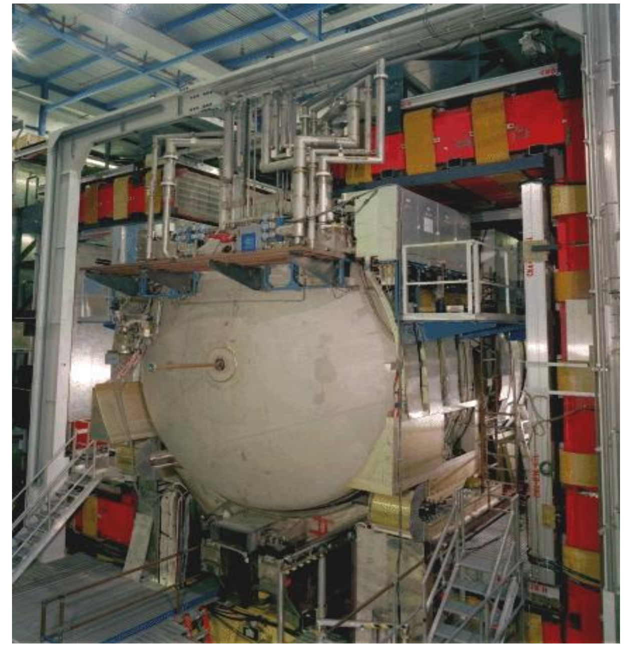
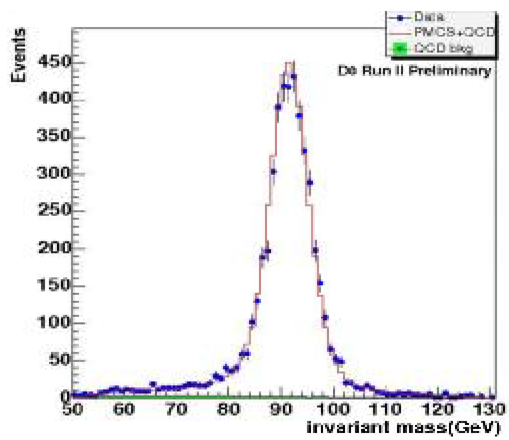
Calorimeter

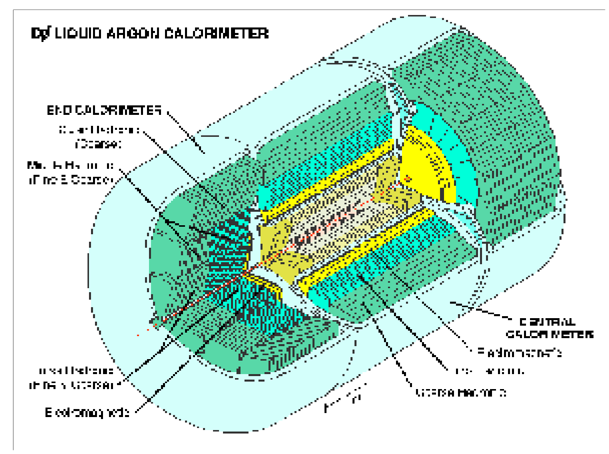
- Uranium/liquid-argon calorimeter . Detector temperature 90 K
- Two main parts: electromagnetic and hadronic
- The electron drift time across the 2.3 mm liquid argon gap is 450 ns
- Stable and reliable operation
- Less then 0.1% of non-working channels



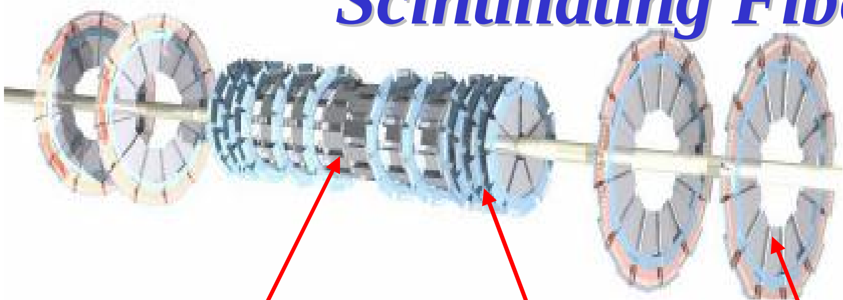


Z0 – boson peak in dielectron channel

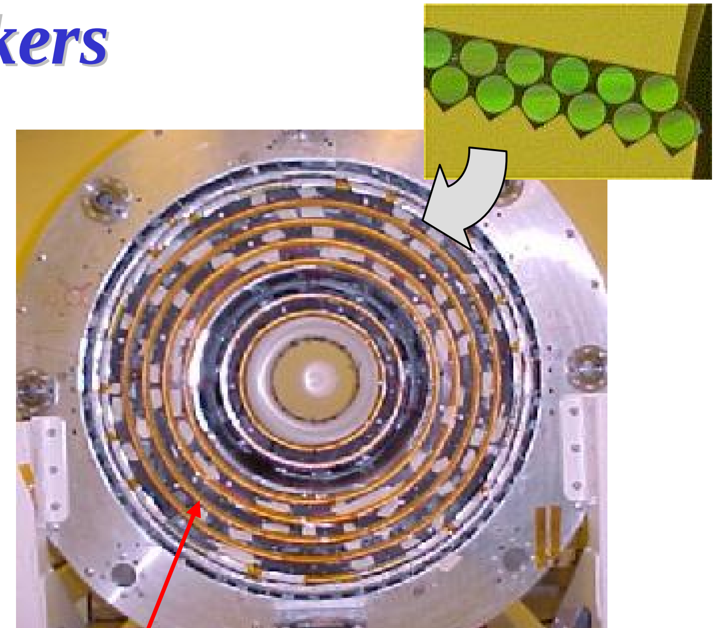
- Central calorimeter (CC) covering pseudorapidities up to $|\eta| < 1.1$
- Two end calorimeters (EC) extend coverage to $1.1 < |\eta| < 4.2$
- CC and two EC housed in separate cryostats

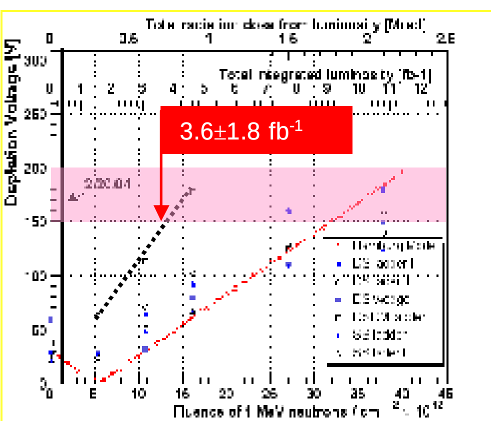


Silicon Microstrip and Scintillating Fiber Trackers



- 6 barrels (modules)+12 F disks + 4 H disks
- Barrel has 4 layers axial and stereo strips
- Radiation dose: no substantial changes in depletion voltage up to now
- Big contribution to design and adjustment from the Moscow State University
- Next DØ upgrade: new silicon tracker Layer 0





SM tracker covering
$|\eta| < 3.0$

SF tracker covering
$|\eta| < 1.6$

Both trackers inside of 2T magnet

- 8 axial and 8 stereo fibers double layers
- VLPC based readout
  - VLPC – visible lights photon counters produced from silicon avalanche photo detectors that operate nominally at 9 K
  - is capable of detecting singles photon
- Well designed and produced
  - good light yield of 7 phe/mip
  - efficiency per layer $\varepsilon > 98\%$

Trigger System

•Tevatron operate with 36 bunch protons and antiprotons with a bunch spacing of 396 ns

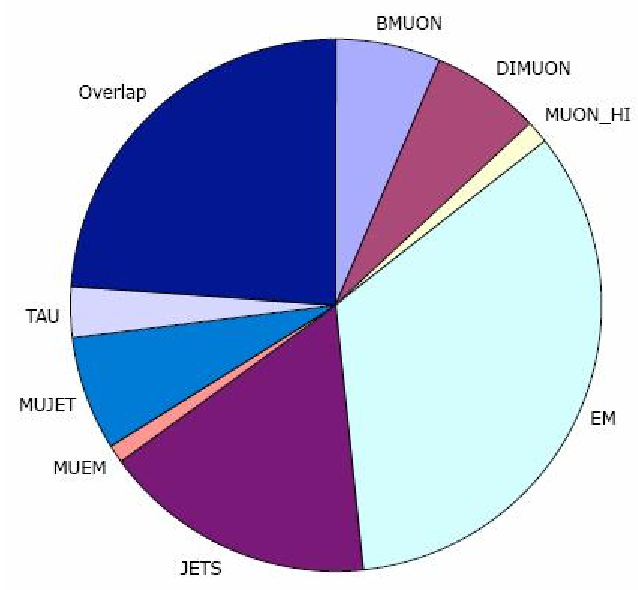
• Trigger system has to select 50Hz of events to write to tape out of 1.7MHz interactions rate. $3 \cdot 10^4$ rejections!

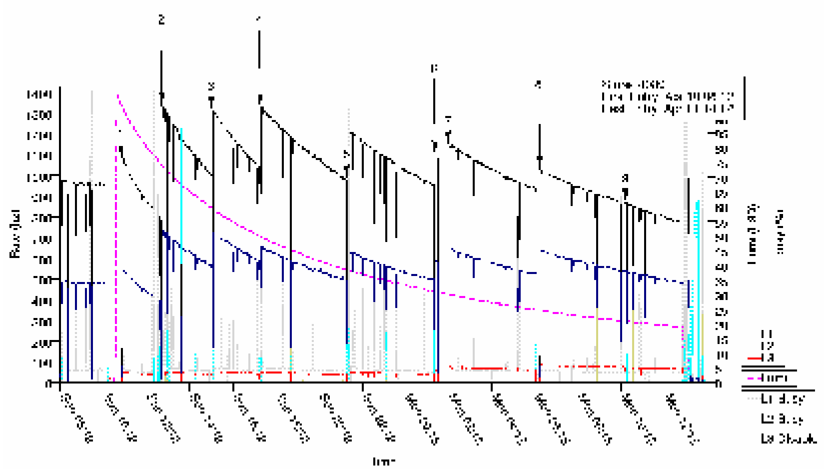
•Current DØ capabilities:

Level 1 trigger 2kHz

Level 2 trigger 1kHz

Level 3 trigger 50Hz





• L1 examines every event for interesting features in each detector subsystem
• L2 to test event for correlations between detector subsystems
• L3 provides additional rejections with access to all event parameters to enrich the physics sample

Detector operation

- Last year the experiment is operating well and recording physics data with 90% efficiency:

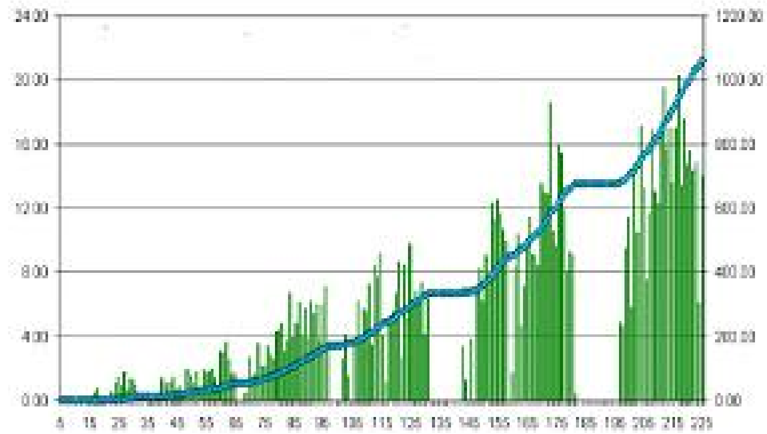
- per day 2 pb^{-1}

- per week 14 pb^{-1}

(Top quark in RUN I was discovered at 50 pb^{-1})

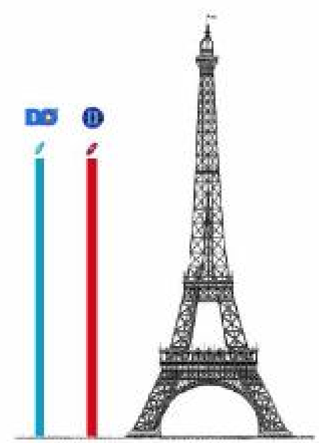
- 90% data taking efficiency due to
  - –5% are trigger system disables
  - –5% are begin/end stores, failures
- For today DØ has > 1 fb^{-1} on tape
- Most of physics results are from data collected before the end of 2004 shutdown
- More than 4 fb^{-1} are expected to be recorded before October, 2009

Collider Run II integrated luminosity



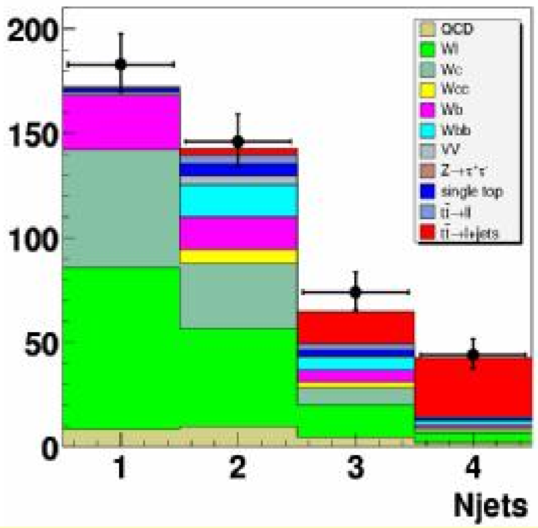
Weekly integrated luminosity
Run II integrated luminosity

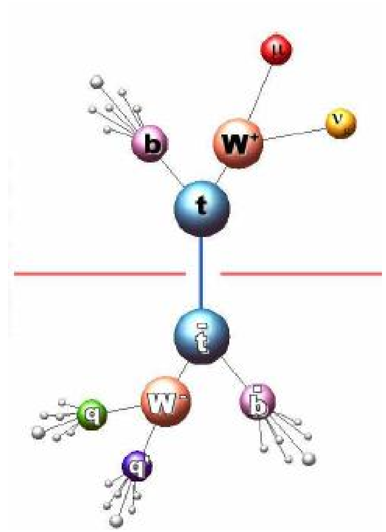
	p17 reprocessing
Luminosity	470 pb^{-1}
Events	1G
Rawdata 250kB/Event	250TB
DSTs 150kB/Event	150TB
TMBs 20kB/Event	20TB
Time 50s/Event	20,000months
(on 1GHz Pentium III)	3400CPUs for 6mths
Remote processing	100%

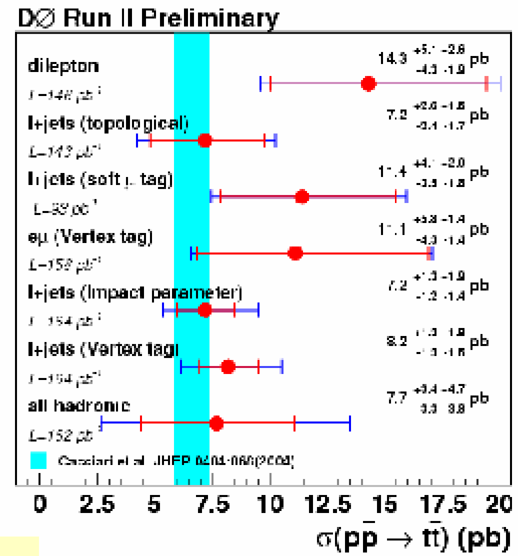


- But already a stack of CDs of all DØ Run II data as high as the Eiffeltower!

Top Quark Production Cross Section







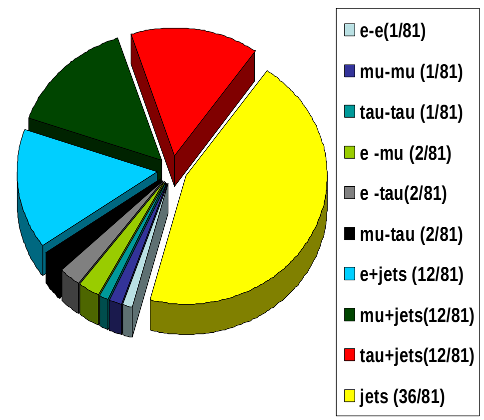
- The most heavy six t-quark was discovered on Tevatron in 1995
- In triggering and analysis select events with high P_t leptons,

high E_t multiple jets, large missing E_t , displaced vertex for b-jets

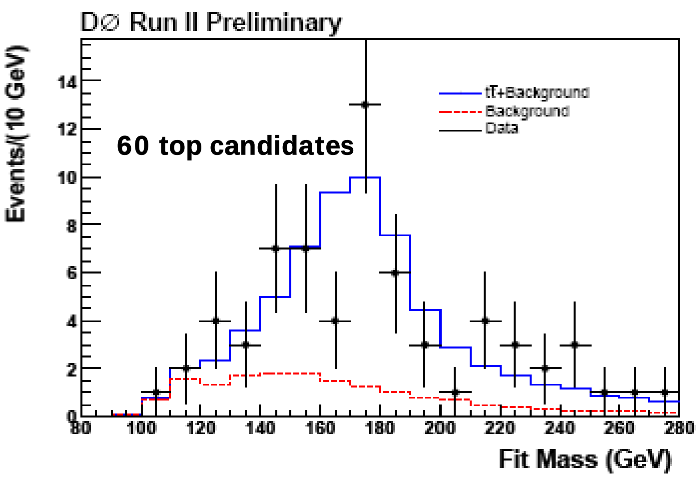
•"Di-lepton" mode has low backgrounds: di-bosons, Drell-Yan, but low statistics: 5% for **e**, **μ** decays

•"Lepton+jets" very productive mode, 6 times more decays then dilepton mode with main background W+jets; good purity after b - tagging

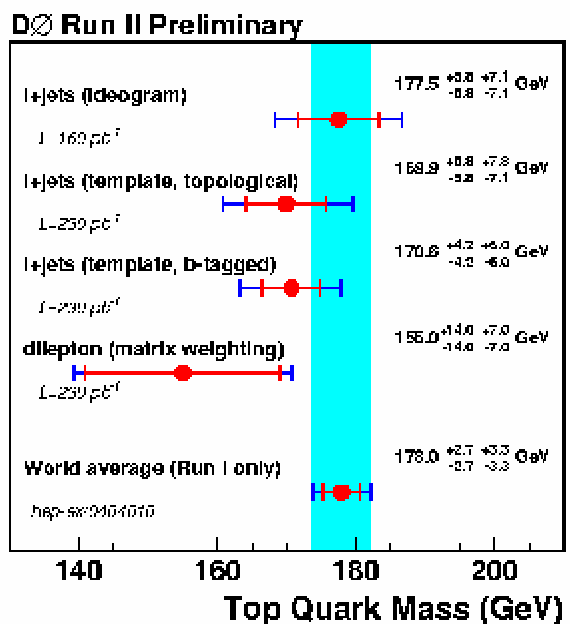
•"All jets"-44% branching, high QCD and combinatoric background

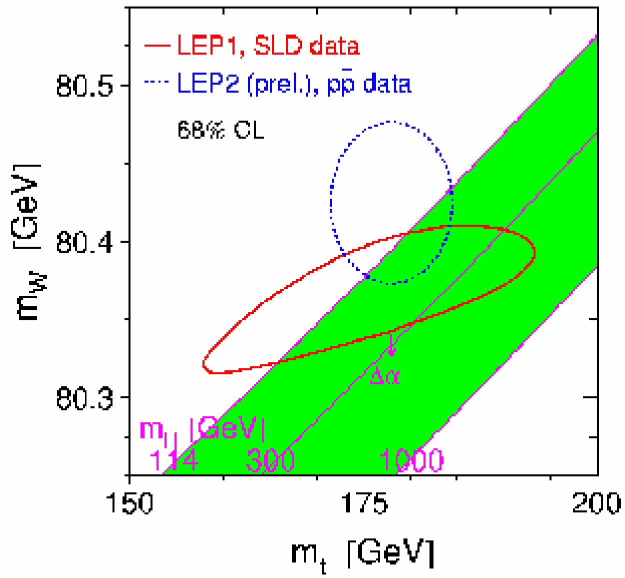


Top Quark Mass



l+jets b-tagged template method, 230pb^{-1}

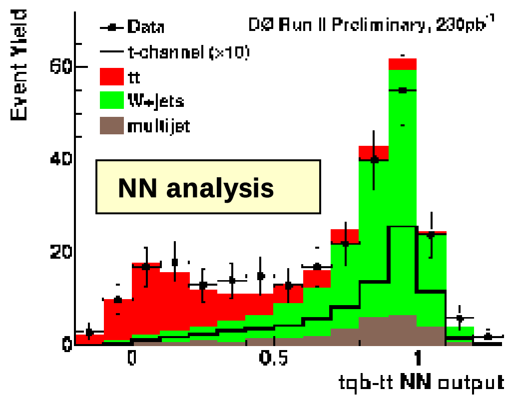


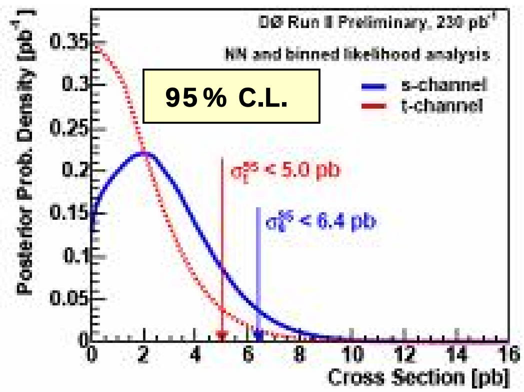


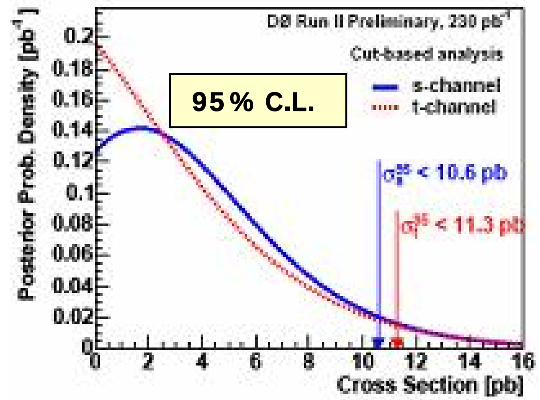
- Top quark mass is a fundamental SM parameter. Provides constrain on Higgs mass
- Different methods used to derived top quark mass: template methods and matrix element method
- Jet energy scale is the dominant systematic error. The correct jet energy calibration is very critical !

All results of Run II are consistent with Run I World average

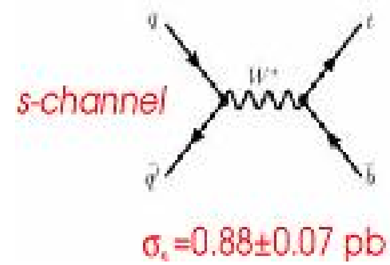
Search for Single Top Quark Production

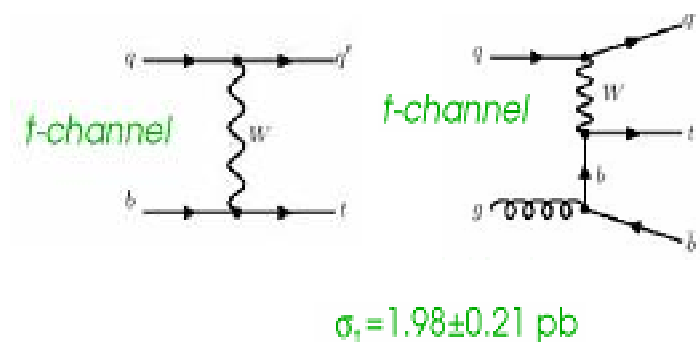




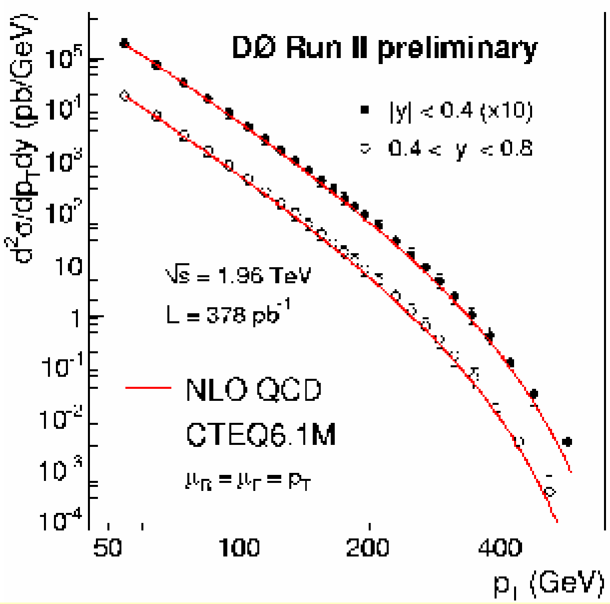


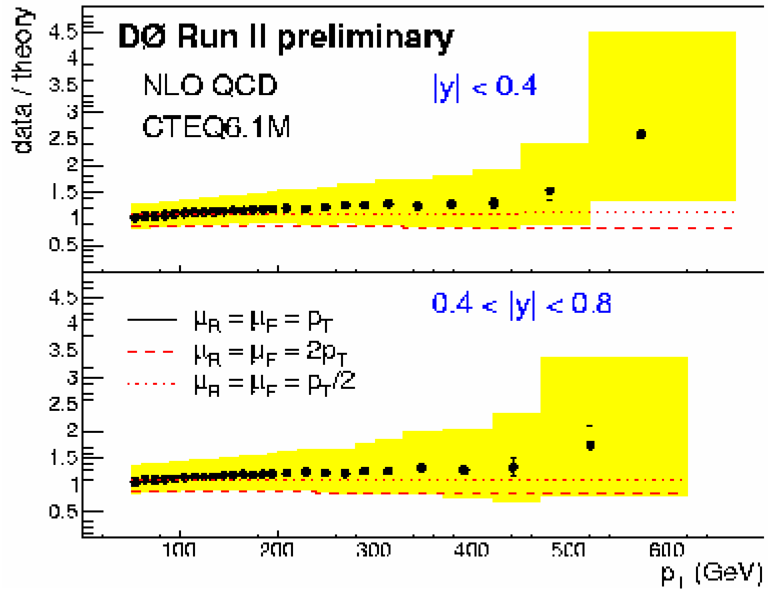
- EW production of top quark is a direct probe of $|V_{tb}|$ and search for new physics
- Events selection: similar to top pairs in l+jets mode, but with lower jets multiplicity
- Backgrounds (W+jets, tt, di-bosons) are substantial
- Results, 230 pb^{-1} : σ_t< 5.0 pb (t-channel) , σ_t < 6.4 pb (s-channel) at 95% C.L.
- Expect: new data set analyzed by the end of the year with some improvements in analysis





QCD Studies



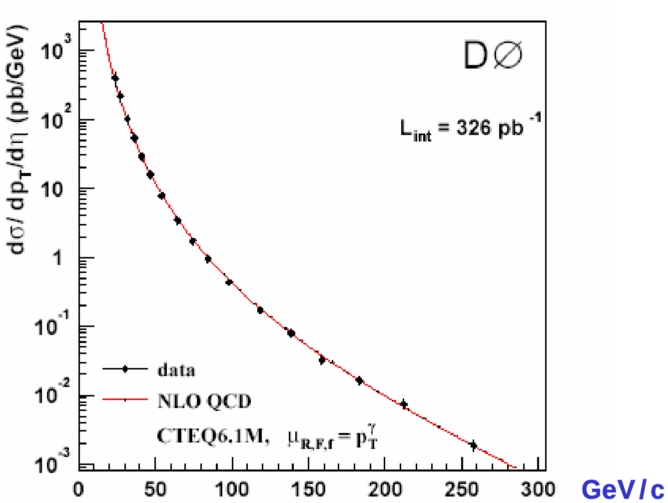


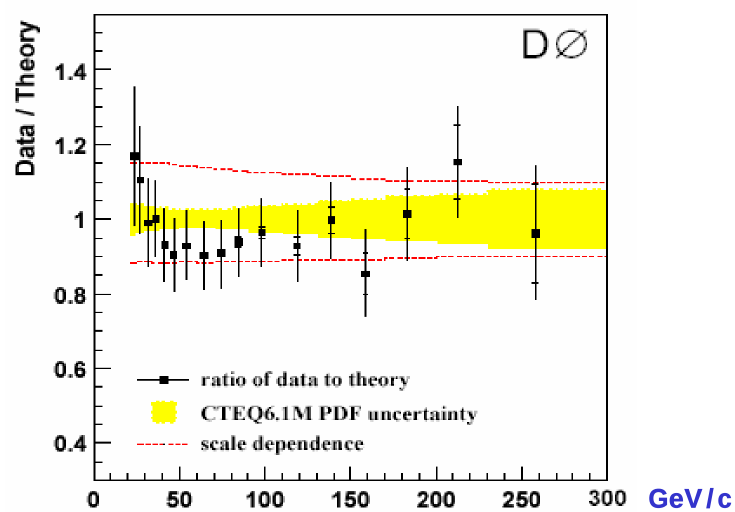
Motivation to study:

- Use QCD processes to measure proton structure. Is there quarks sub-structure exist ?
- Resolve some outstanding puzzles e.g. heavy flavor production
- Understand the backgrounds to physics beyond SM

*DØ Run II result***:** the inclusive jet Cross Section changes up to 8 of orders of magnitude. Single jets, di-jets, μ+jet cross sections under study too. *Dominant systematic uncertainty is JES . Derived from p_T balance in g+ jet events*

Inclusive photon cross section in central rapidity region, |h| < 1.6



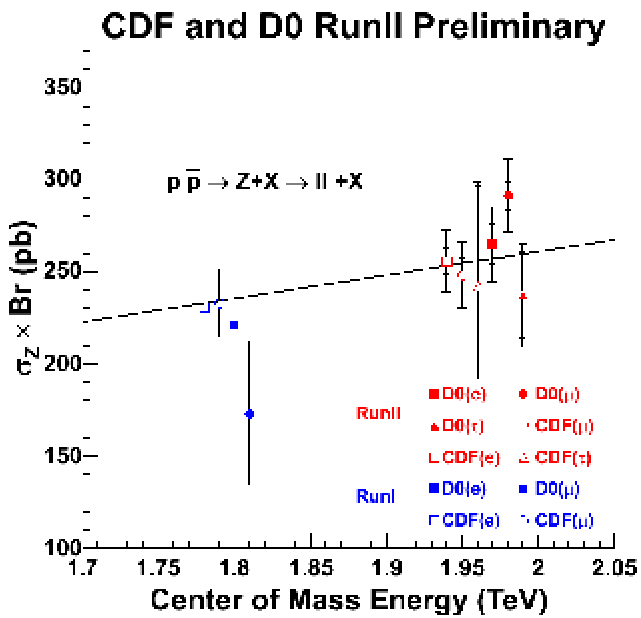


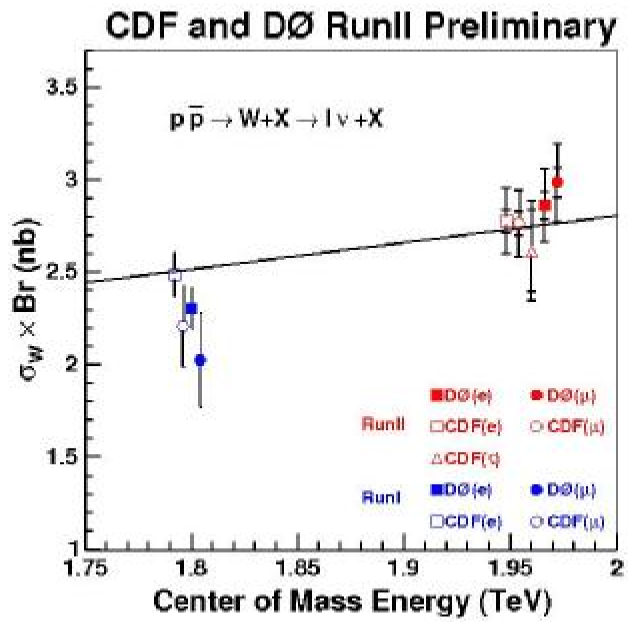
Dominant source of photon production for pT < 150 GeV is prompt Compton quark-gluon scattering. This is a very important channel for the calorimeter calibration !

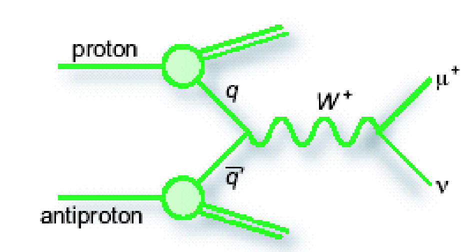
- Cross section is sensitive to the gluon PDF (Parton Distribution Function)
- Experimental uncertainties are comparable with the theoretical ones. Gamma pT values are much higher than those covered in previous experiments
- The NLO QCD predictions [by JETPHOX program] describe the data within the experimental uncertainties in the whole pT range considered, 23<pT<300 GeV, $|\eta|$ < 1.6
- These data can be used for determination of parton distributions from future global fits

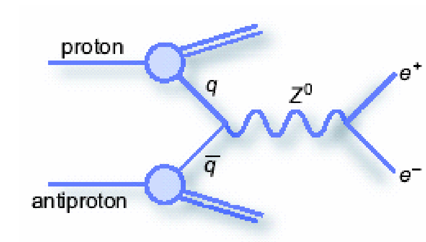
Electroweak Physics

- Search for new physics through precision measurements of electroweak parameters
- Measurement of a single and multiboson production - WW, WZ, Wγ, Zγ, WWγ and WWZ couplings & Anomalous Couplings

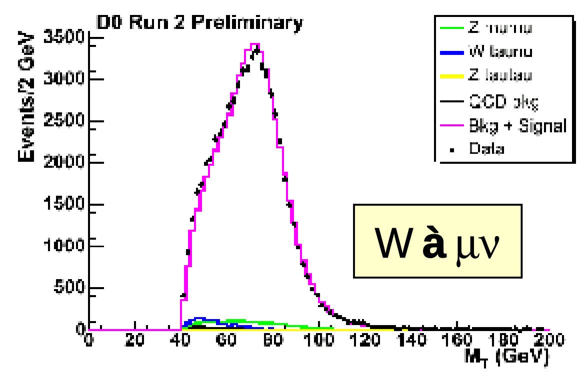








- Clean, relatively high cross section and well known signals allow to provide the test of the Standard Model
- Can be used to cross check luminosity measurements



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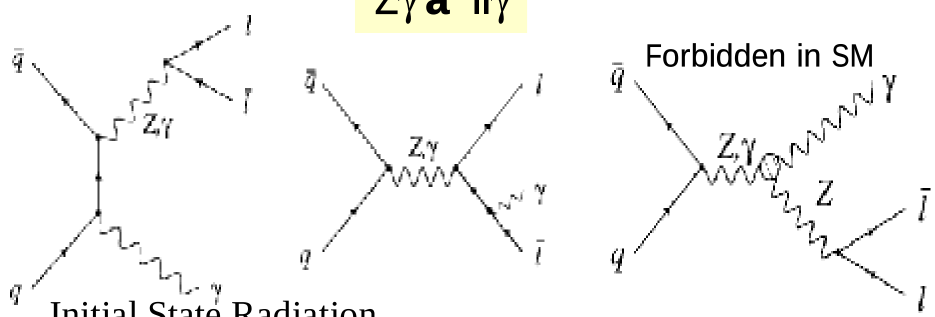
Diboson Production

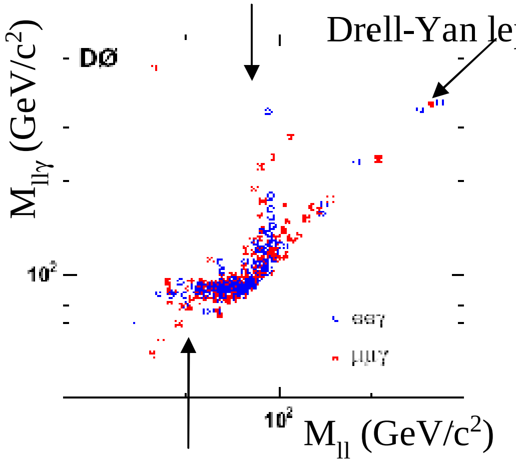
- WW, WZ, ZZ, Wγ, Zγ production test SM and tell us about boson self-coupling
- Background studies to many interesting searches, like H à WW

Zγ à llγ

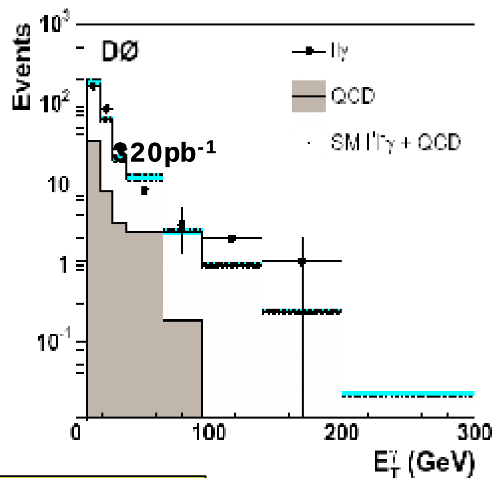


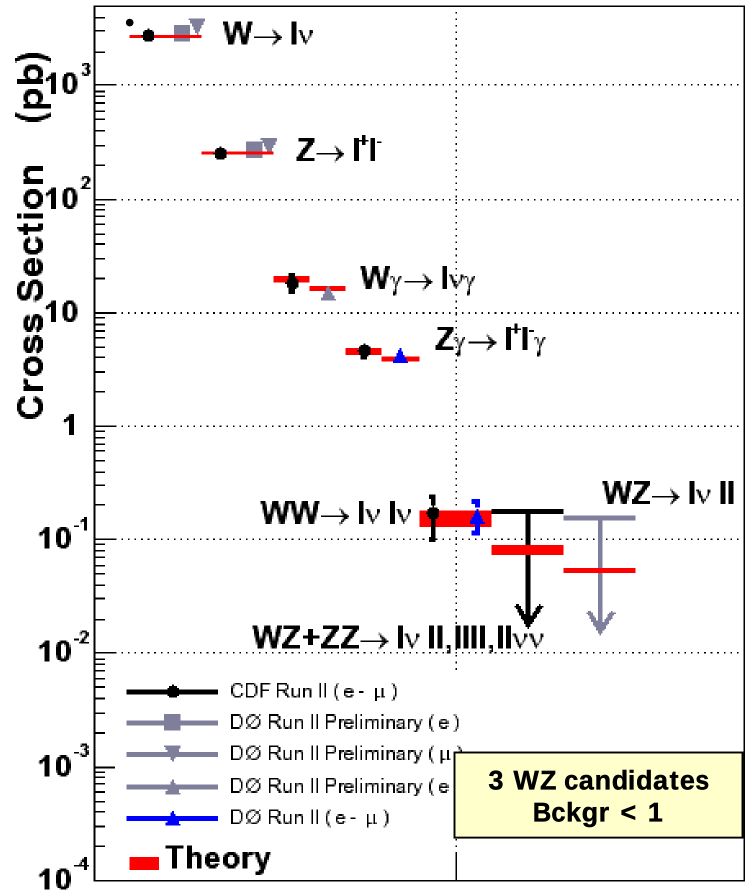
Initial State Radiation

Drell-Yan leptons



Final State Radiation





No SM ZZγ or Zγγ interaction!

Limits on Anomalous Couplings set (DØ preliminary) for ZZγ and Zγγ :

$|h_{30}^{\gamma}| < 0.22$

$|h_{40}^{\gamma}| < 0.019$

$|h_{30}^{Z}| < 0.21$

$|h_{40}^{Z}| < 0.019$

Cross sections are in good agreement with SM

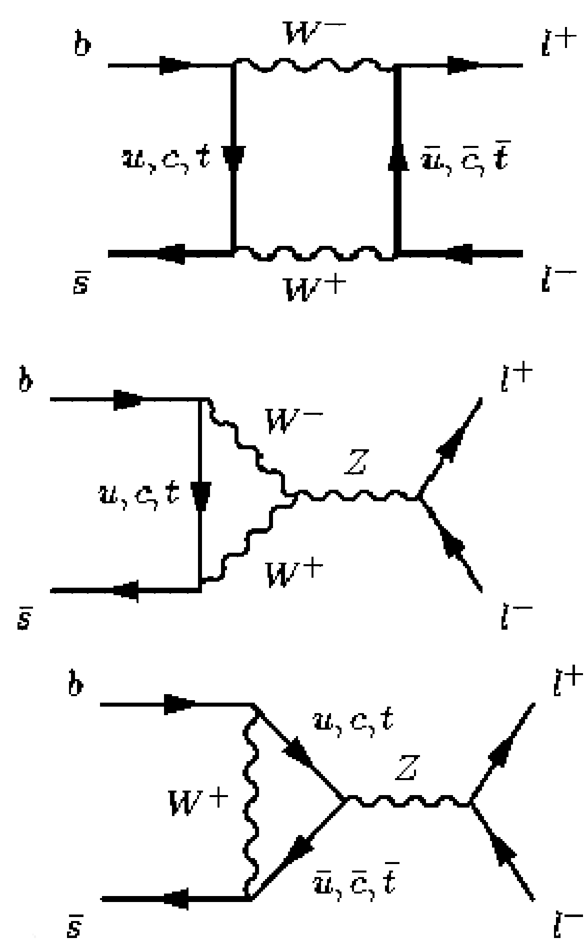
Search for B_s ® 2 μ Decay

- Only place in world to study B_s mesons - Tevatron
- The silicon microstrip tracker allows to realize a search for $B_s \to 2\mu$ rare decay. Since $\tau(B_s) = 1.46$ ps (400 μm) a search idea is to find secondary vertices in a region B_s mass
- Decay $B_s \to 2\mu$ strongly suppressed in SM. Contribution from all possible $B_s \to 2\,\mu$ SM diagrams give branch ratio $(3.5 \pm 1.0) \cdot 10^{-9}$
- We are looking for some evidence of possible Standard Model enhancements (MSSM, SUSY etc.) Br ($B_s \to 2\,\mu$) grows $\sim \tan^6\beta$ in MSSM. It increase the Br($B_s \to 2\,\mu$) up to $10^{-7} \div 10^{-6}$
- Main backgrounds from $b\bar{b}$-production
- There are existing 2 published upper limits now at 95% C.L.:

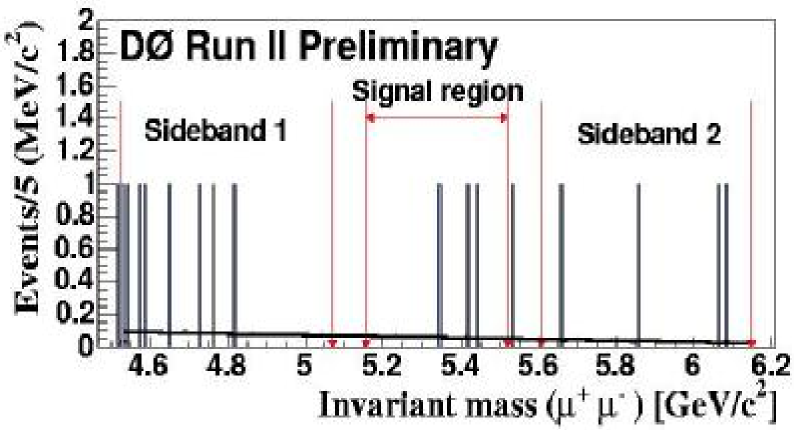
CDF (171 pb^{-1}): 7.5×10^{-7} PRL93(2004)032001

DØ (240 pb^{-1}): 5.0×10^{-7} PRL94(2005)071802

Tevatron perspectives for 1 fm^{-1} integral luminosity is : Br ($B_s \to 2\,\mu$)< $1.0 \cdot 10^{-7}$



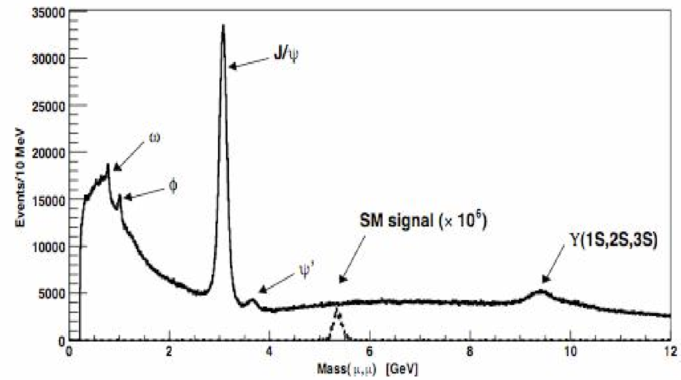
Search for B_s ® 2 μ Decay



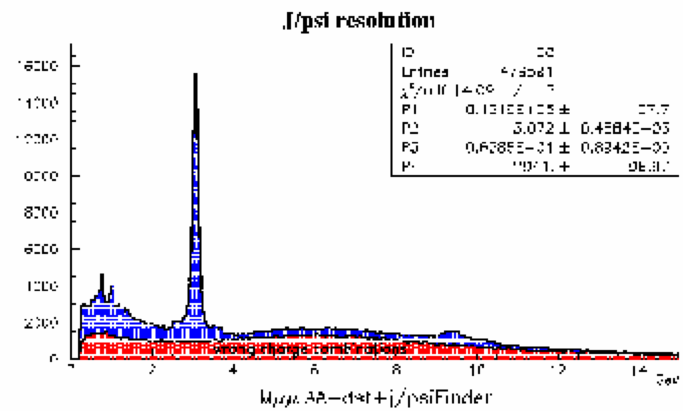
PRL result (240 pb^{-1}): observed 4, expected 3.7 ± 1.1

- This year updated result (300 pb^{-1}) : observe 4, expect 4.3 ± 1.2
- DØ last new preliminary result (300 pb^{-1}): Br ($B_s \to 2\mu$) < 3.7 •10^{-7} (95% C.L.)
- CDF last new preliminary result (360 pb^{-1}): Br ($B_s \to 2\mu$)< 2.0 •10^{-7} (95% C.L.)

There is some competition between CDF good momentum track resolution and good acceptance coverage by D0 Forward Muon System. But friendship won! CDF-D0 combined result (prelim.):Br ($B_s \to 2\mu$)<1.2 •10^{-7} (90% C.L.)



Experimental dimuon mass spectrum



The red color is a combinatoric background !

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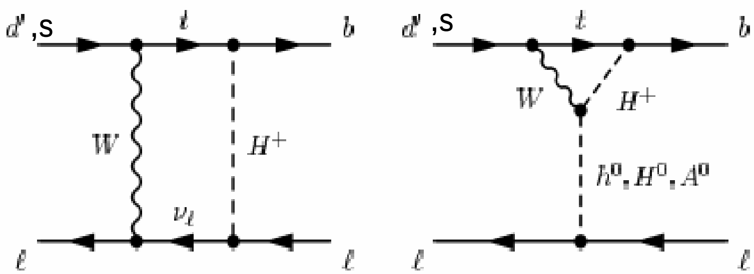
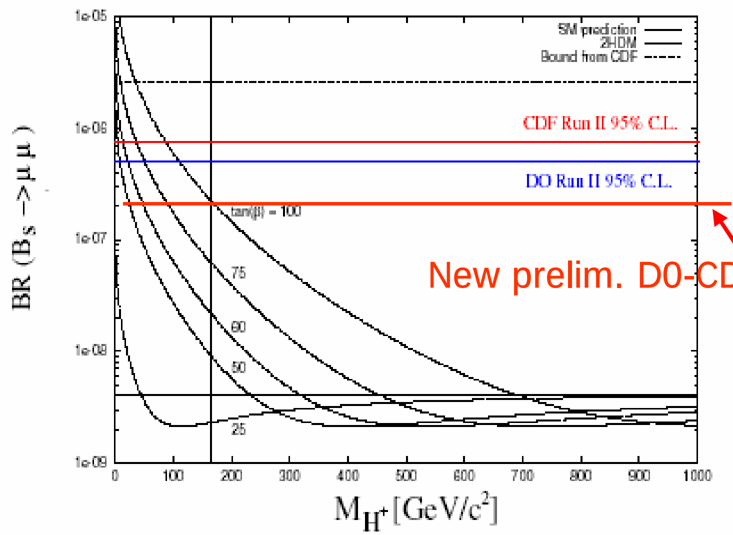
B_s ® 2 μ search predictions for MSSM, SO(10)

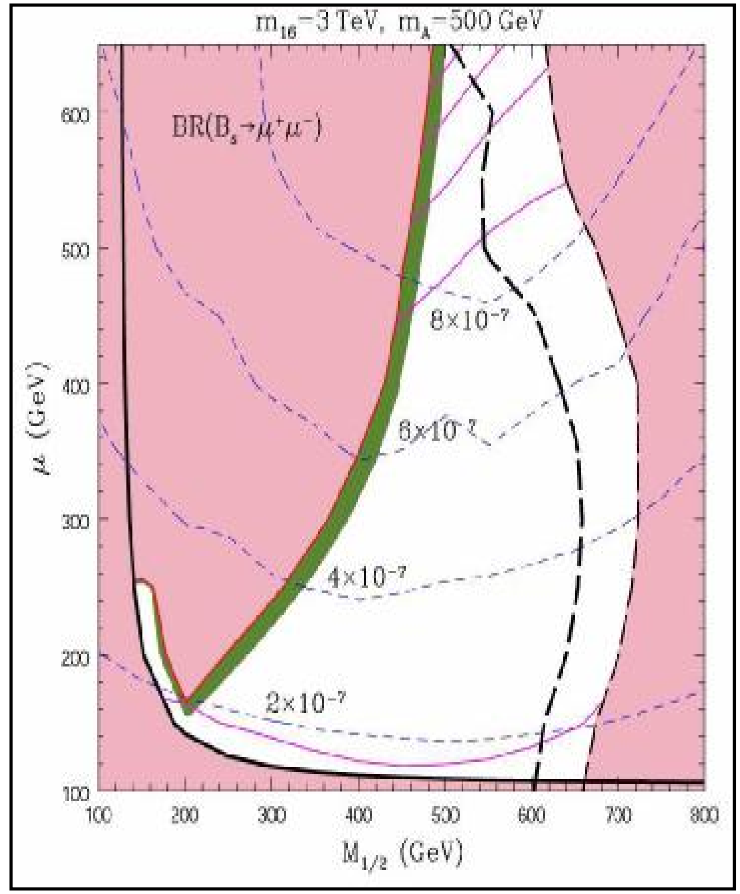
Two-Higgs Doublet models (MSSM): one charged $H^{\pm}$, two CP-even (h,H) and one CP-odd (A) neutral states. Higgs masses and couplings can be expressed in terms two parameters m_A and tan β





BR grows ~$\tan^6\beta$ in MSSM

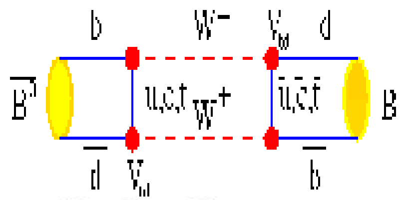
Example: SO(10) symmetry breaking model

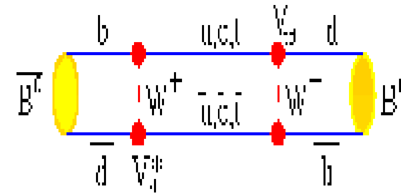


D0, CDF data provided very strong restriction to parameters SO(10) model !

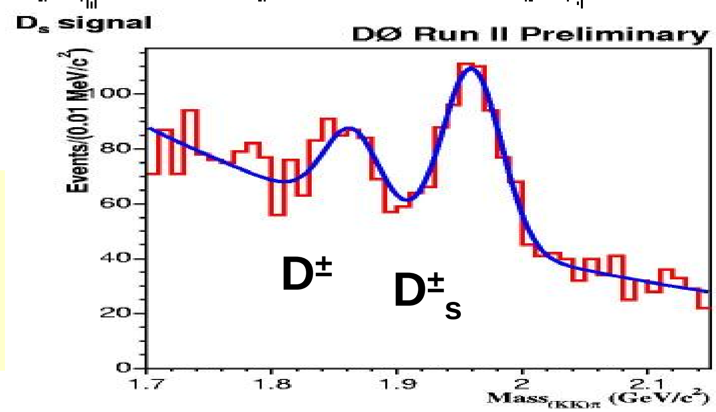
B_s Mixing

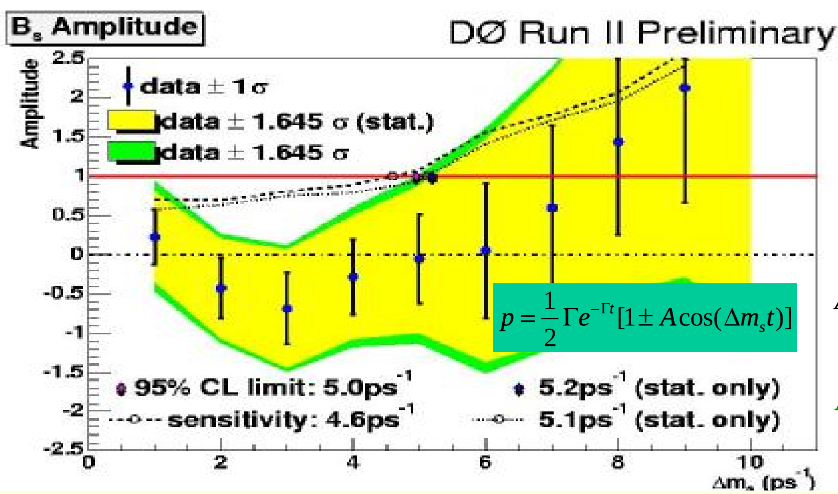
- B_s Mixing – transition of neutral mesons between particle and antiparticle
- In SM B-mixing is explained by box diagrams
- Δm_s, Δm_d provide constrains V_{td} and V_{ts} elements of CKM matrix. New physics means new particles in the box. Ratio $\Delta m_s/\Delta m_d$ is free from many theoretical uncertainties ($\Delta m_d = 0.456 \pm 0.034 \pm 0.025$ ps^{-1}, DØ RunII)





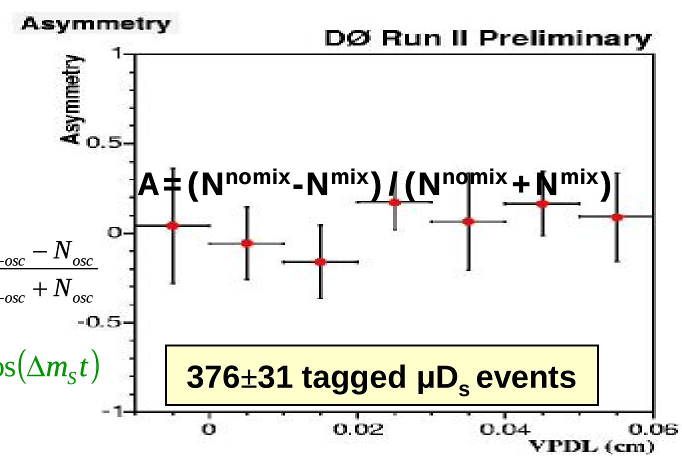
- semileptonic data sample B_s à μD_s used (muon triggering helps)
- Decay mode D_s à $\Phi\pi$, Φ à K^+K^- were studied
- 13,300 candidates in 460 pb^{-1}
- Charge of muons provides Final State Tag





$$Asymmetry = \frac{N_{non-osc} - N_{osc}}{N_{non-osc} + N_{osc}}$$

$$Asymmetry \propto \cos(\Delta m_s t)$$



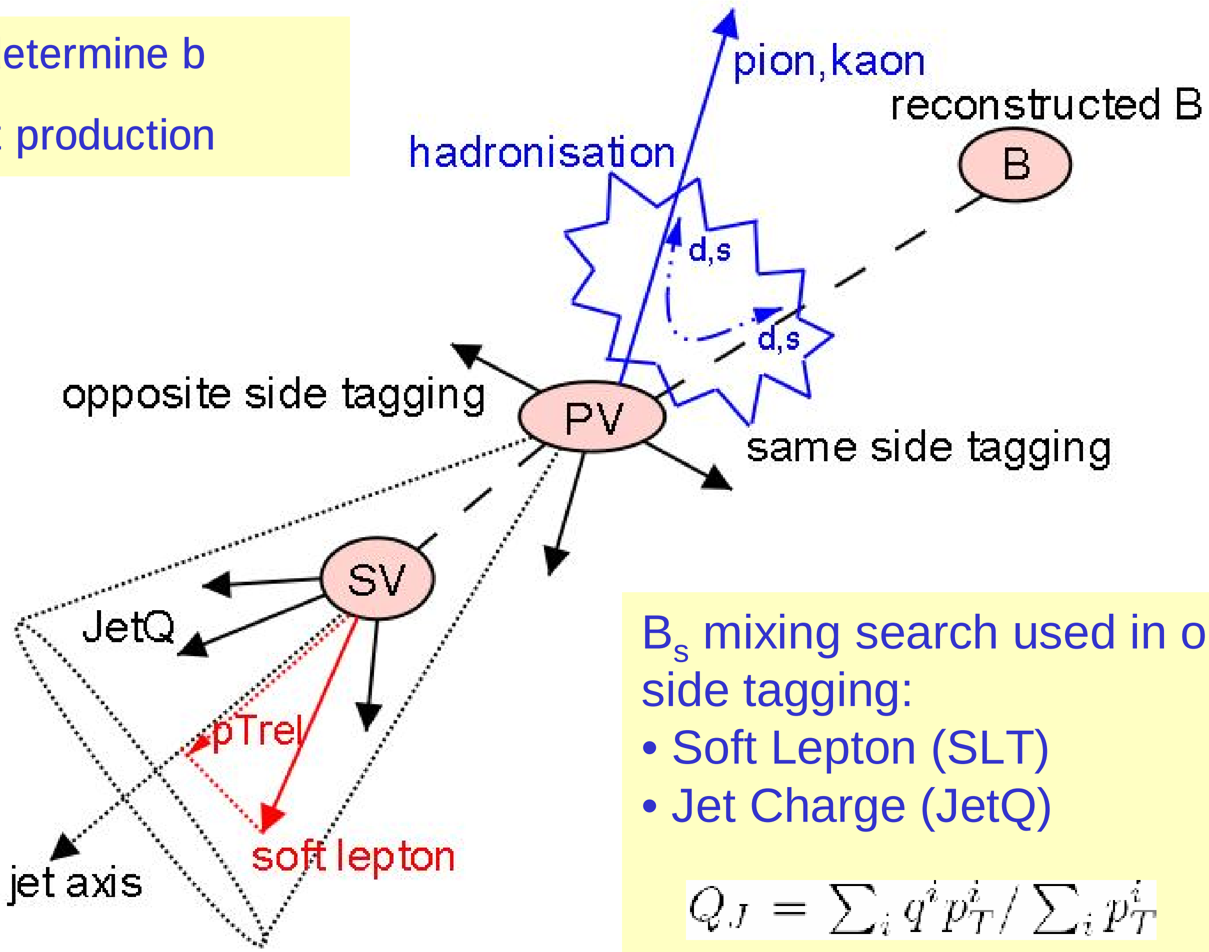
95% C.L. limit: $\Delta m_s > 5.0$ ps^{-1} , statistically limited

With next DØ upgrades, $\Delta m_s > 20$ ps^{-1} at 1 fb^{-1}

No evidence of oscillations yet !

Flavour Tagging at B_s Mixing Studies

- Need to determine b flavour at production



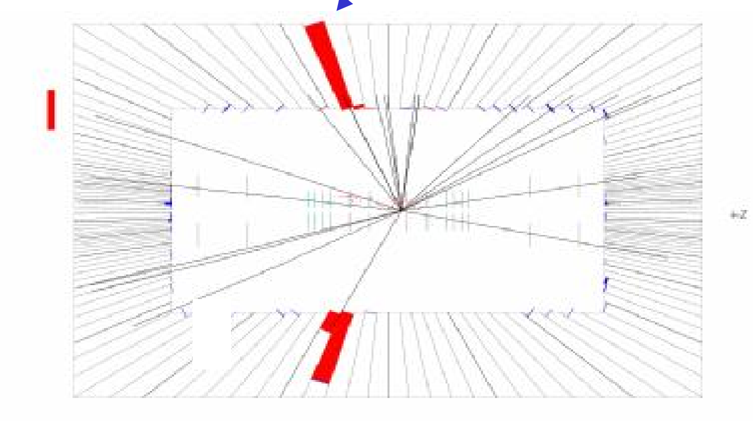
B_s mixing search used in opposite side tagging:

- Soft Lepton (SLT)
- Jet Charge (JetQ)

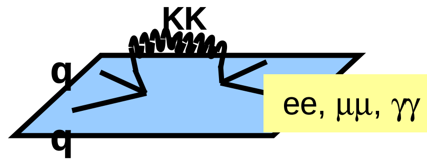
$$Q_J = \sum_i q^i p_T^i / \sum_i p_T^i$$

Search for Extra Dimensions

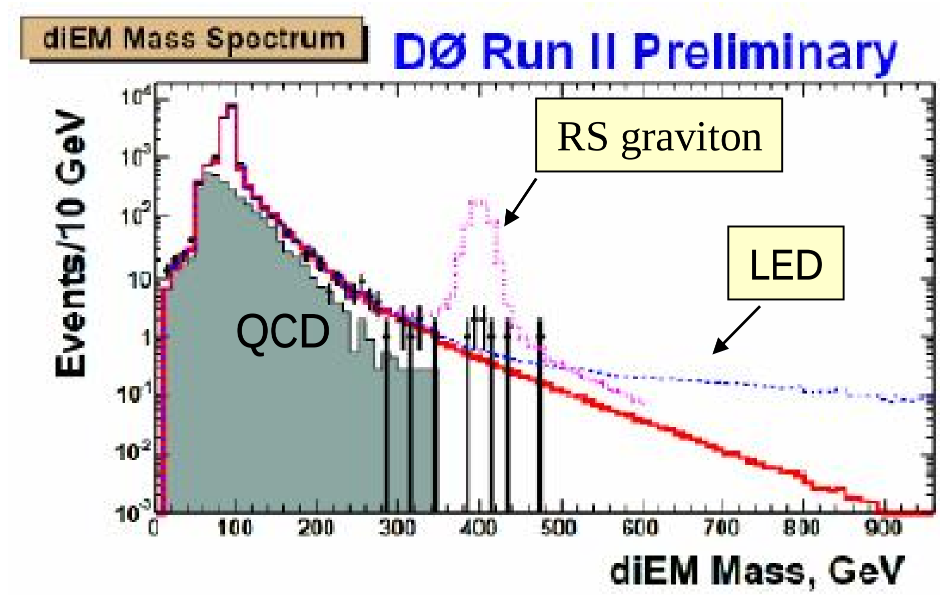
High-mass electron pair event
Mass=475 GeV



There is out of the our World physics…



$M^2_{PL} \sim M_S^{n+2} R^n$



Expect: a virtual exchange of graviton in Kaluza-Klein modes or a real graviton emission

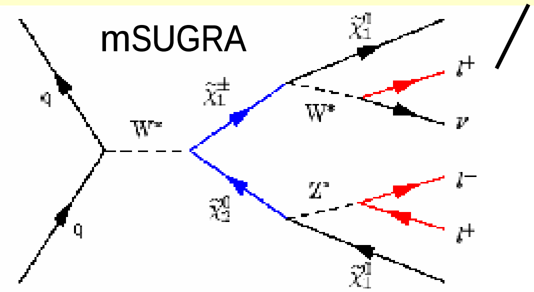
- Signal would be an excess of ee, μμ or γγ events at large mass due to virtual graviton exchange
- Latest DØ limit from $\bar{p}p \to ee, \mu\mu$ and $\gamma\gamma$ events is M_S(GRW) > 1.43 TeV (200 pb^{-1}, 95% C.L.)

This result most stringent limit to date on Large Extra Dimensions

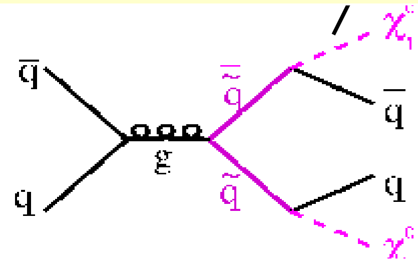
Search for SUSY

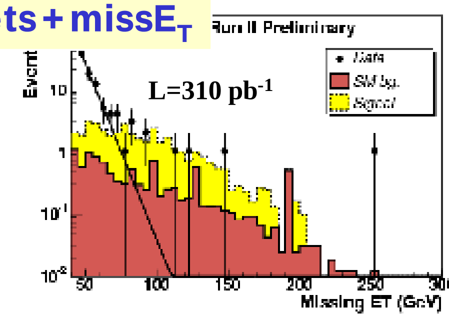
- SUSY solves "Hierarchy Problem", provides Grand Unification on scale less than 10^{16} GeV
- SUSY particles are good Dark Matter Candidates

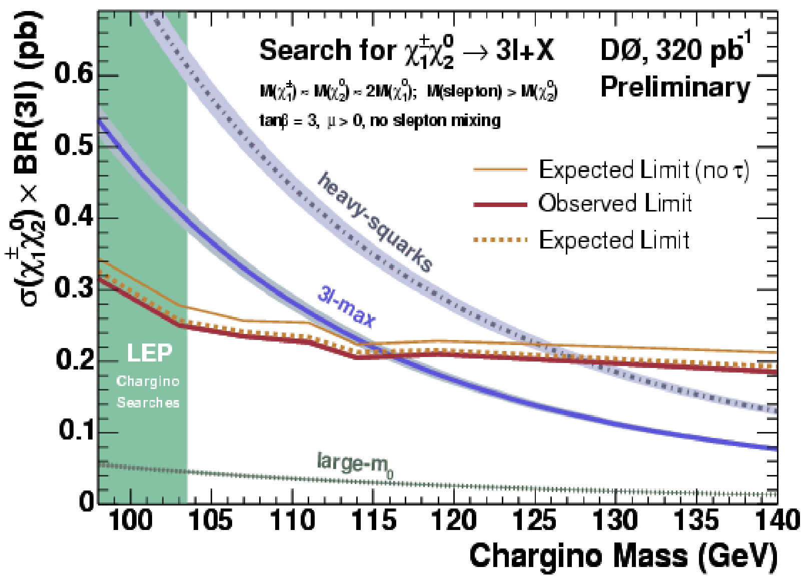
Chargino/Neutralino production in 3l+E_T

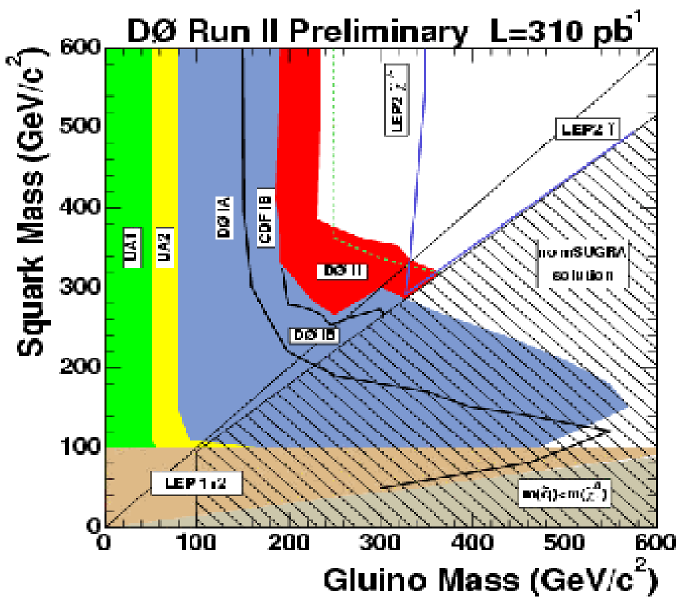


Squarks and Gluinos in jets+missE_T









RunII DØ result improved Run I limits of 1.6 pb in 3-lepton search and extends LEP mSUGRA reach

Standard Model Higgs Search

• The mass of the Higgs boson is not predicted in Standard Model

• Precision measurements constrain:

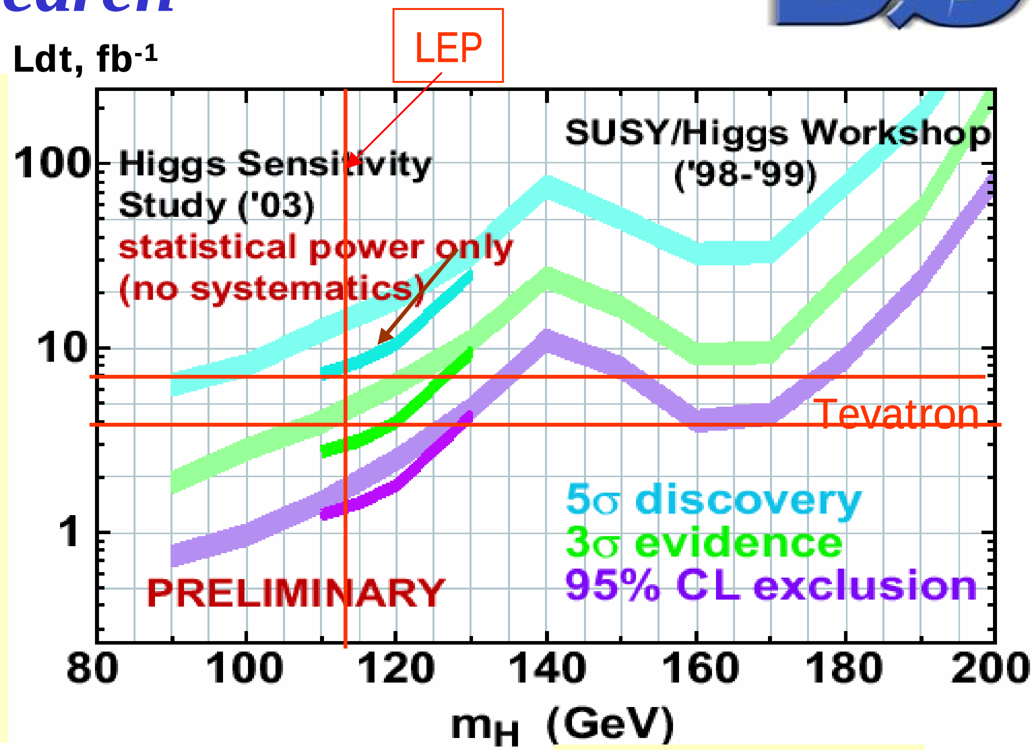
114 GeV < m_H < 260 GeV

§ Low mass region 120 ÷ 130 GeV is available to search for Higgs on Fermilab Tevatron

§ For high Higgs mass region only low limit for Higgs mass can be estimated

§ In 2003 the Higgs sensitivity analysis was updated for the low Higgs mass region:

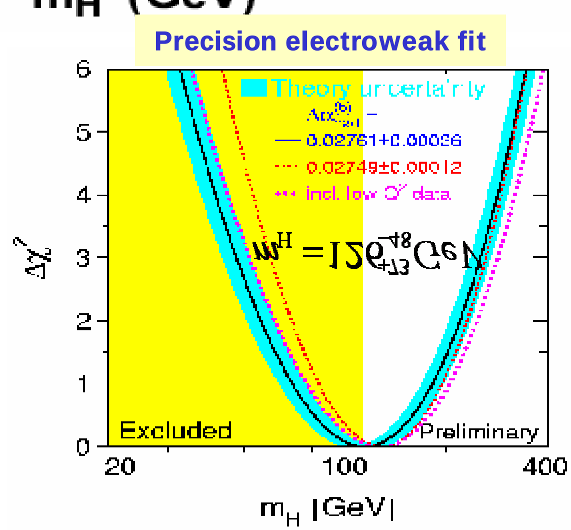
- W(Z)H à lν(νν,ll)bb were included
- Run II data and full detector simulation was used
- optimization of analysis has been done



Sensitivity in the mass region above LEP limit starts at ~2 fb^{-1}

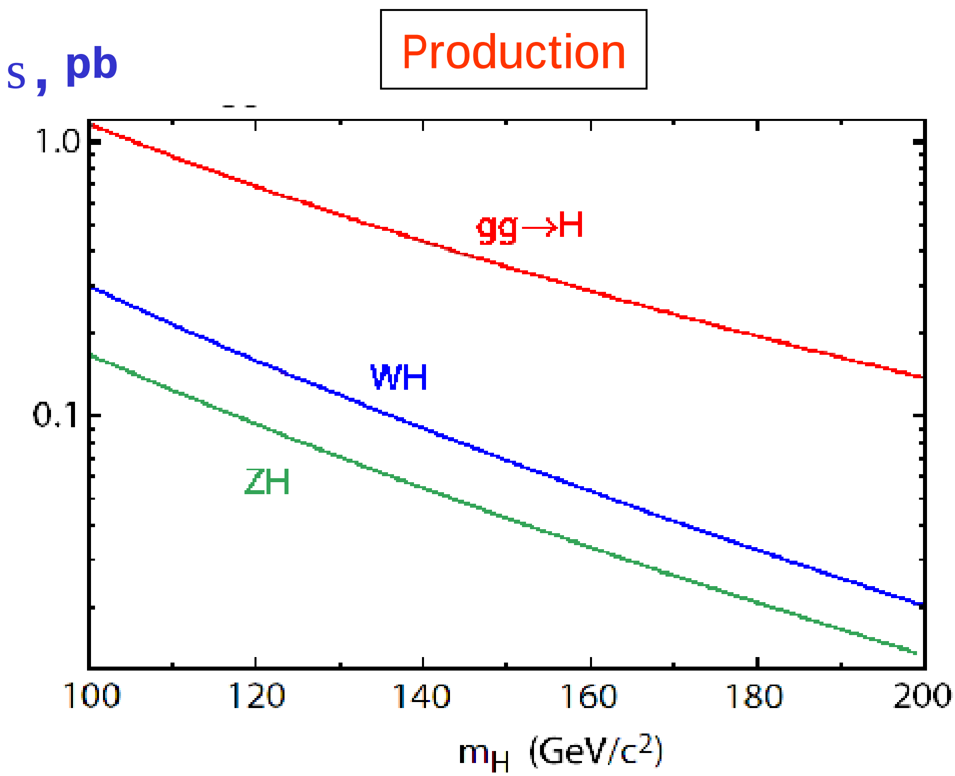
• Next efforts:

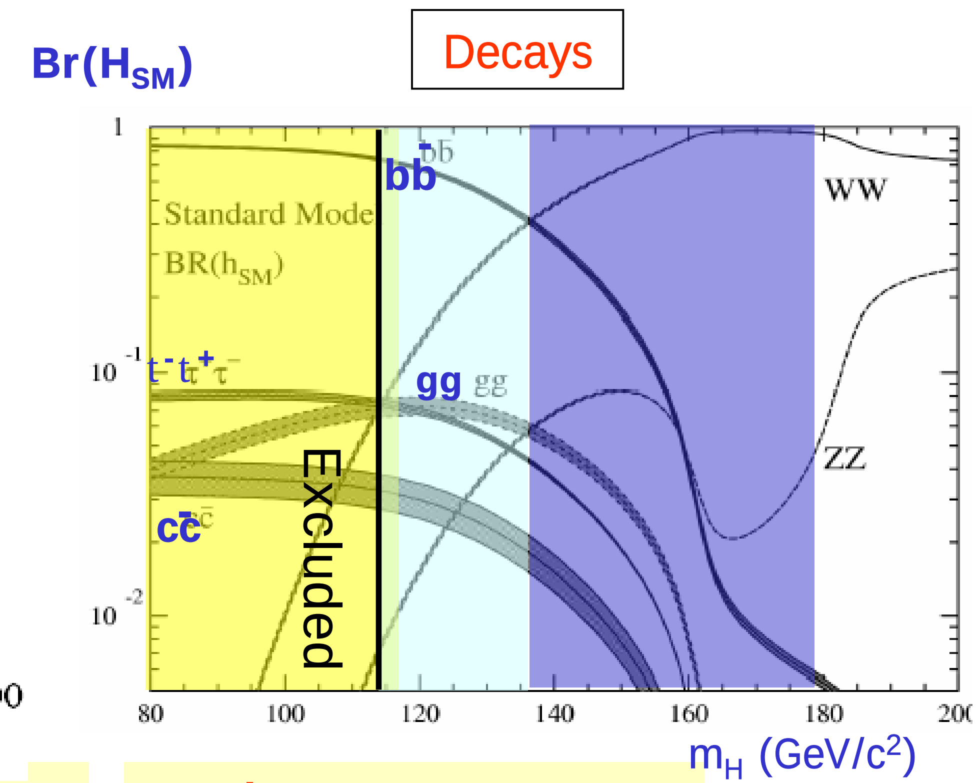
- optimizing analysis techniques
- understanding detectors better
- searching for non-SM Higgs with higher production cross sections



Yury Shcheglov, PNPI,
February 2006, Repino

SM Higgs Production and Decays



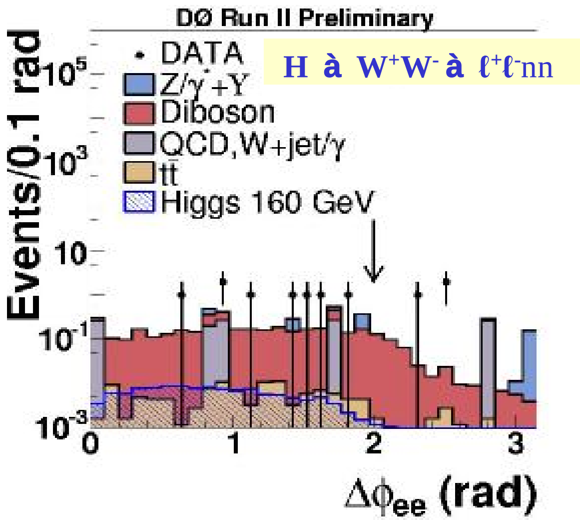


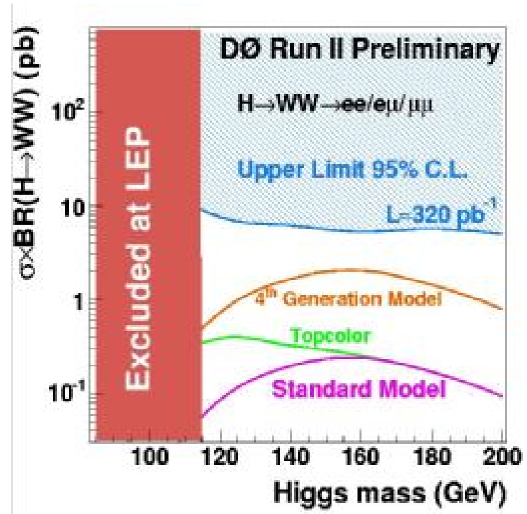
Production cross section
à in the 1.0-0.1 pb range for gg à H
à in the 0.2-0.02 pb range for associated Z,W

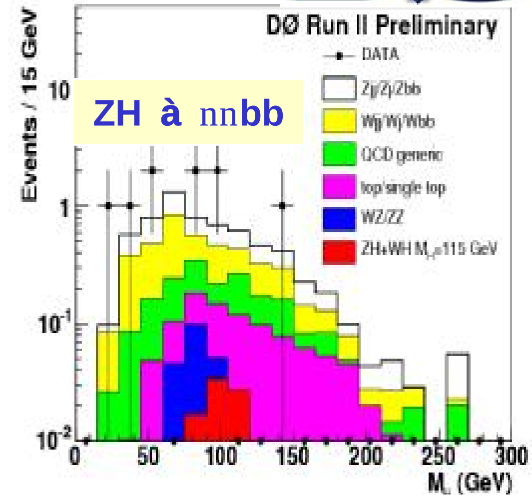
Dominant Decays
à bbar for M_H < 135 GeV
à WW^* for M_H > 135 GeV

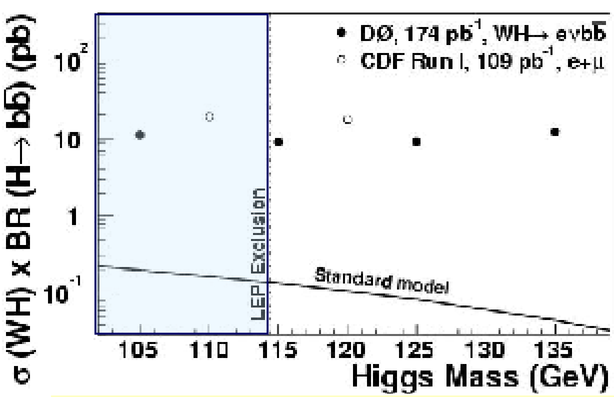
Search strategy:
M_H <135 GeV - associated production WH and ZH with H à bb decay, Backgrounds: top, Wbb, Zbb... M_H >135 GeV gg à H production with decay to WW^* Backgrounds: electroweak WW production...

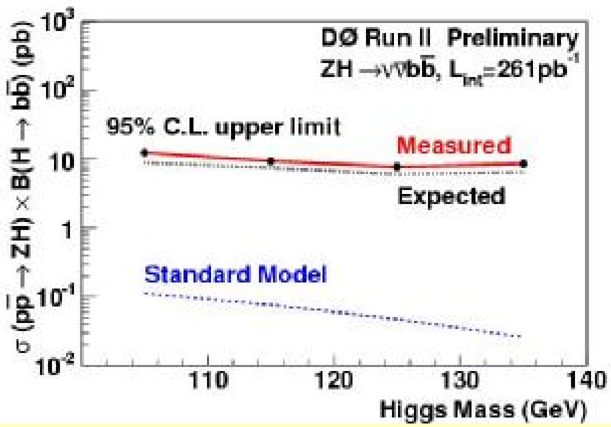
SM Higgs Search results

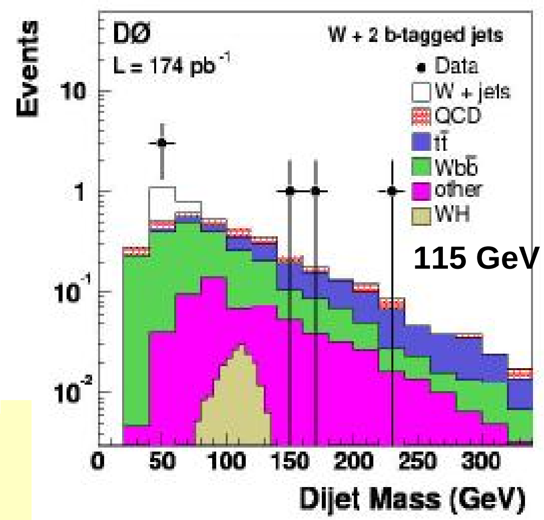












- Standard model Higgs searches on DØ : **H à W$^+$W$^-$** for m_H >135 GeV
- Associated production with W,Z bosons: W(Z)H for m_H > 115 GeV.There are no enhancements under Standard Model background was found
- All results (WH)174pb^{-1},(ZH)261pb^{-1},(WW)320 pb^{-1}: < 10 pb at 95%CL
- Light Higgs observed sensitivity is close to expected

Conclusion

- **The DØ detector is working well with high data taking efficiency**
- **20 publications over last year**
- **Now bigger than 100 approved physics analyses. Most will be published**
- **We are waiting: new Top quark mass, single Top quark discovery, B_s – mixing discovery, significant improvement of $B_s \rightarrow 2\mu$ upper limit and many improvements of search for SUSY particles, new QCD results in the high pT region (calibration of calorimeter done !)**
- ***Next D0 upgrades:***
  - **new silicon tracker Layer 0 will be installed: further improvement in b-tagging**
  - **proposal for dedicated 50Hz data taking rate for B physics**
- **Operation of Tevatron and DØ-CDF data taking will continue to 2009 year**
- **Fermilab Tevatron efforts are very important before the LHC started**

Visit please,

http://www-d0.fnal.gov/Run2Physics/WWW/results.htm to see all DØ physics results