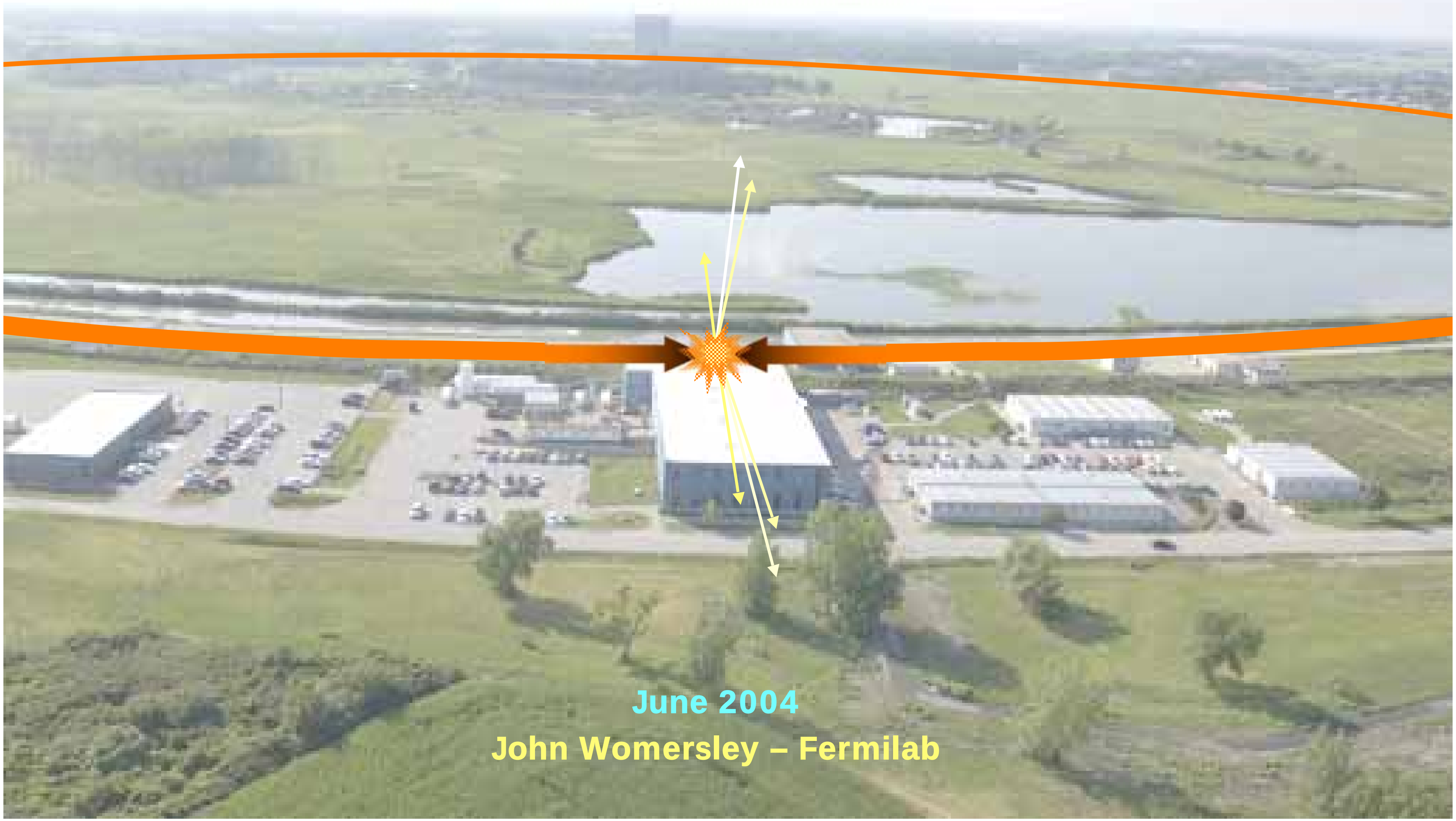
What's New at DZero



June 2004
John Womersley – Fermilab

DØ

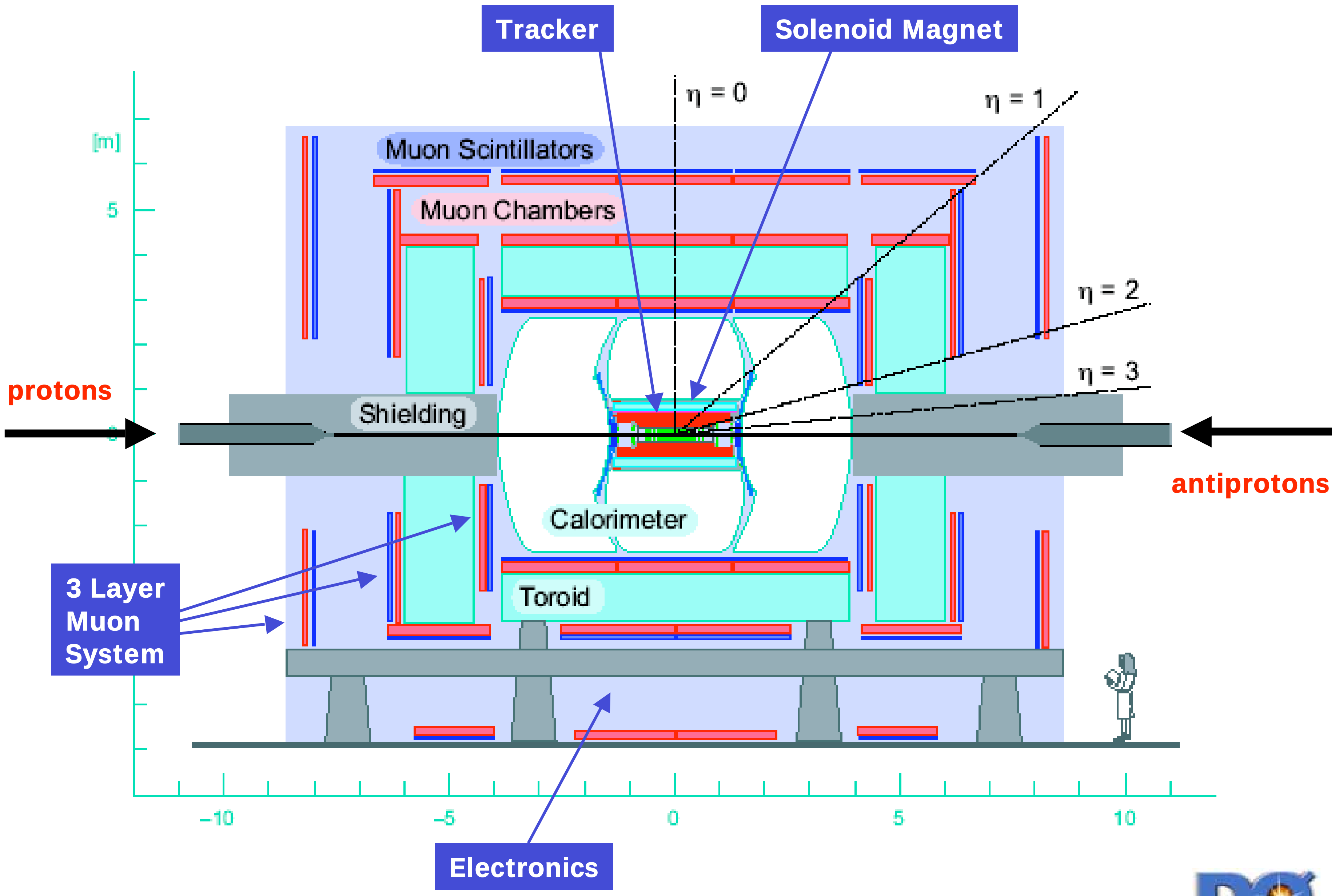
- **DØ is an international collaboration of ~ 650 physicists from 19 nations who have designed, built and operate a collider detector at the Tevatron**

Institutions: 37 US, 41 non-US

Collaborators:

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

~ 100 postdocs, 140 graduate students



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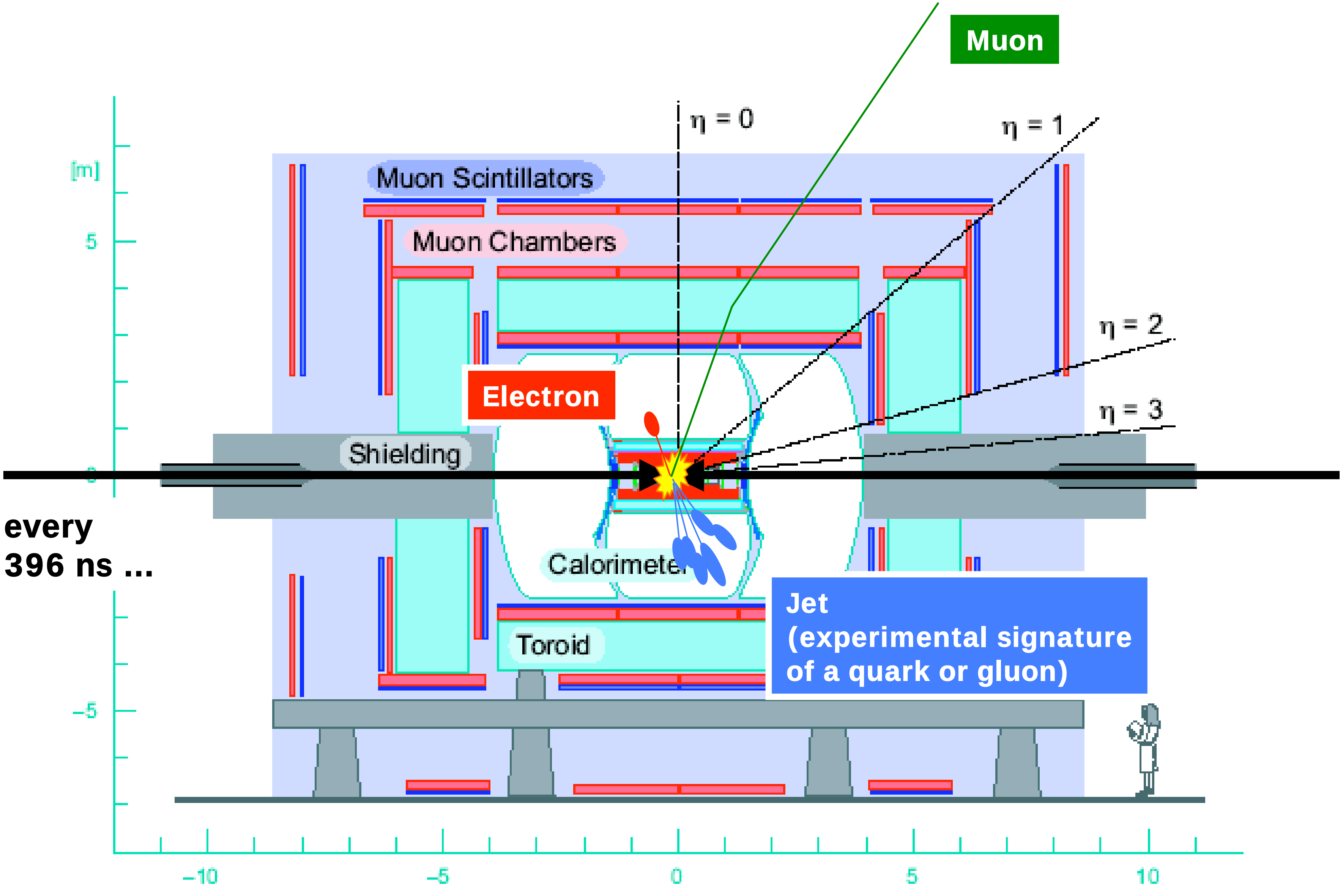
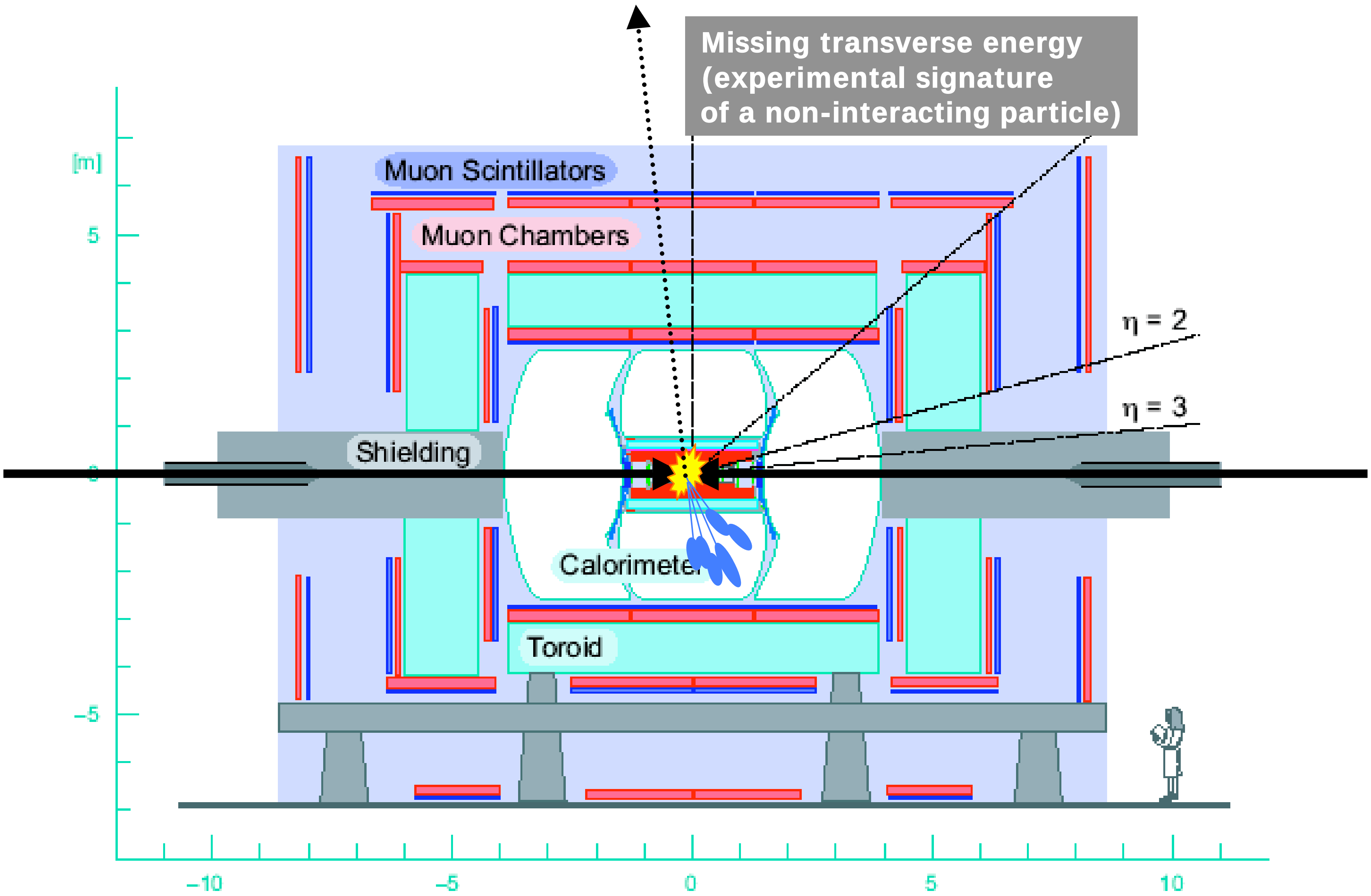
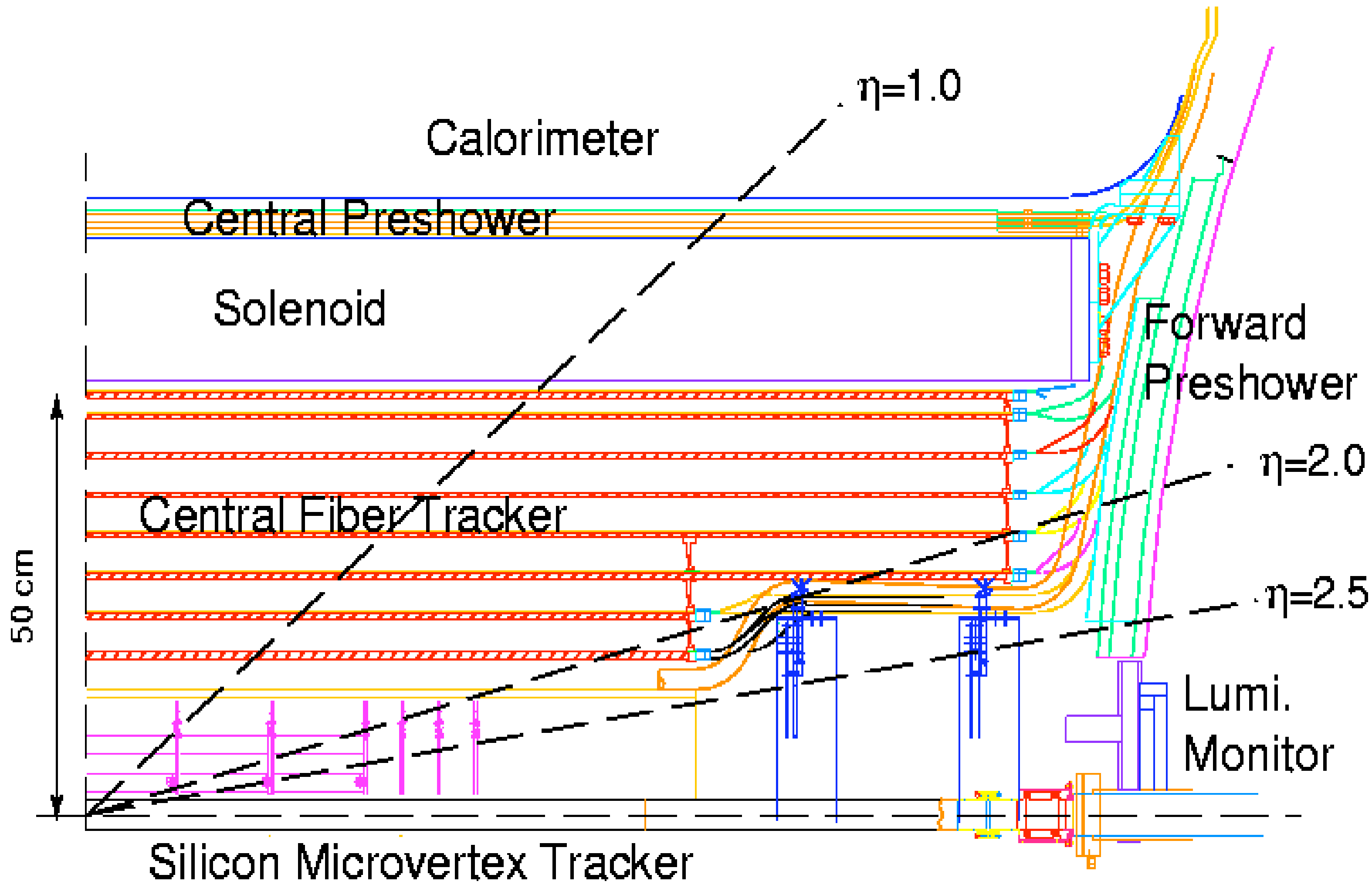


Muon
η = 0
η = 1
η = 2
η = 3
[m]
5
0
–5
Muon Scintillators
Muon Chambers
Electron
Shielding
Calorimeter
Toroid
Jet
(experimental signature
of a quark or gluon)
–10
–5
0
5
10
every
396 ns ...

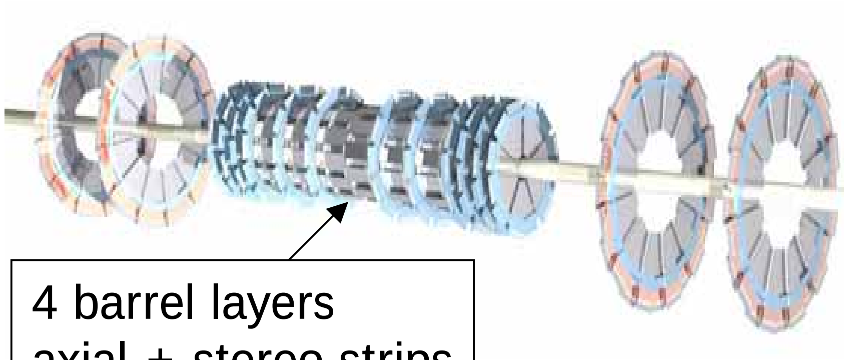


Missing transverse energy
(experimental signature
of a non-interacting particle)
[m]
5
0
−5
Muon Scintillators
Muon Chambers
Shielding
Calorimeter
Toroid
η = 2
η = 3
−10
−5
0
5
10

Inner Tracking

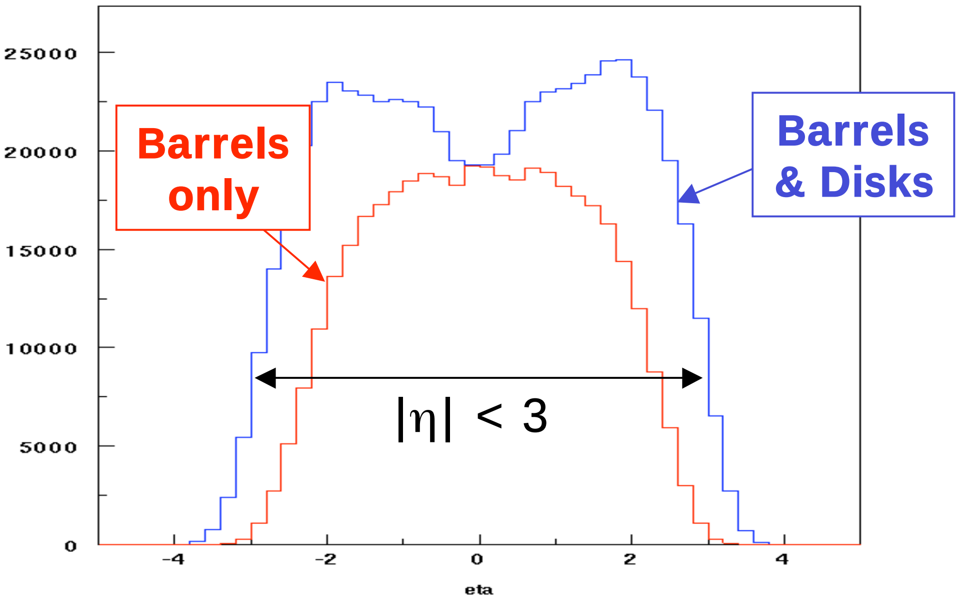


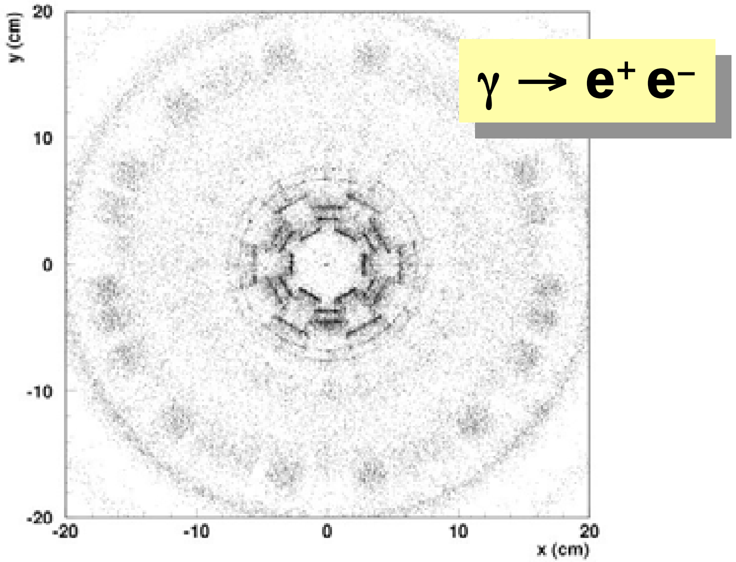
Silicon Microstrip Tracker Status



4 barrel layers
axial + stereo strips

1M channels, S/N > 10
Cluster Efficiency 97%





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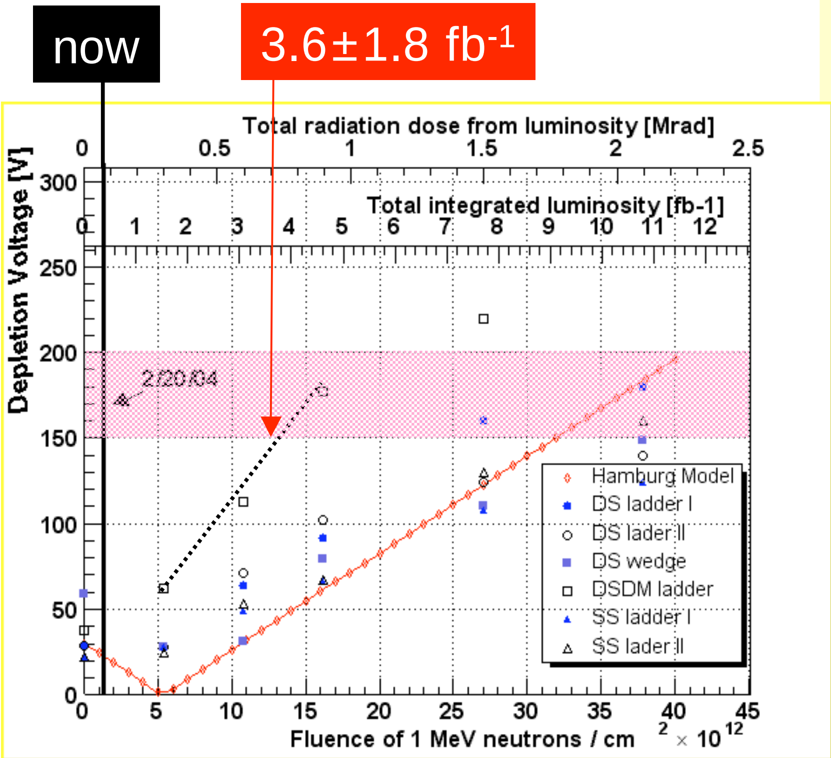
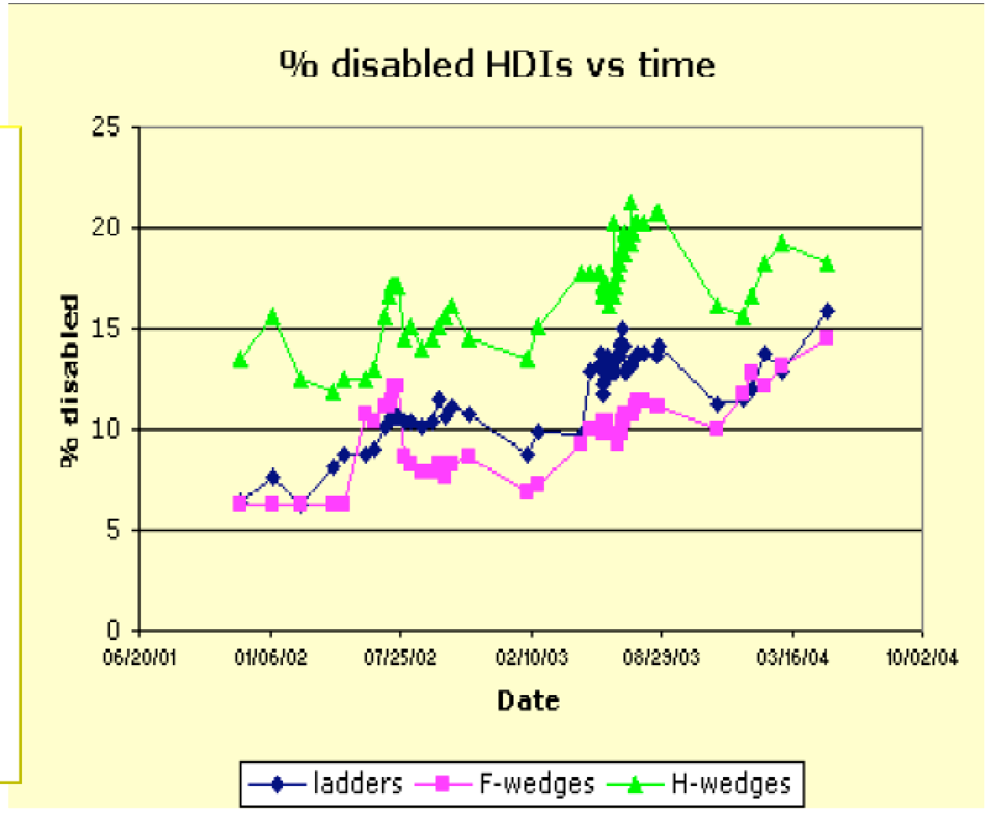
Silicon health



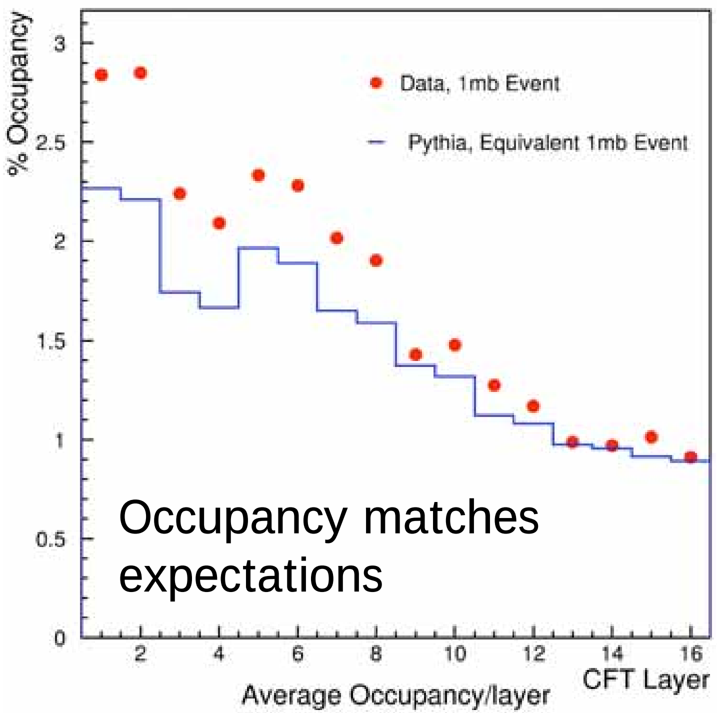


Radiation behavior as expected
Some concern over detector mortality

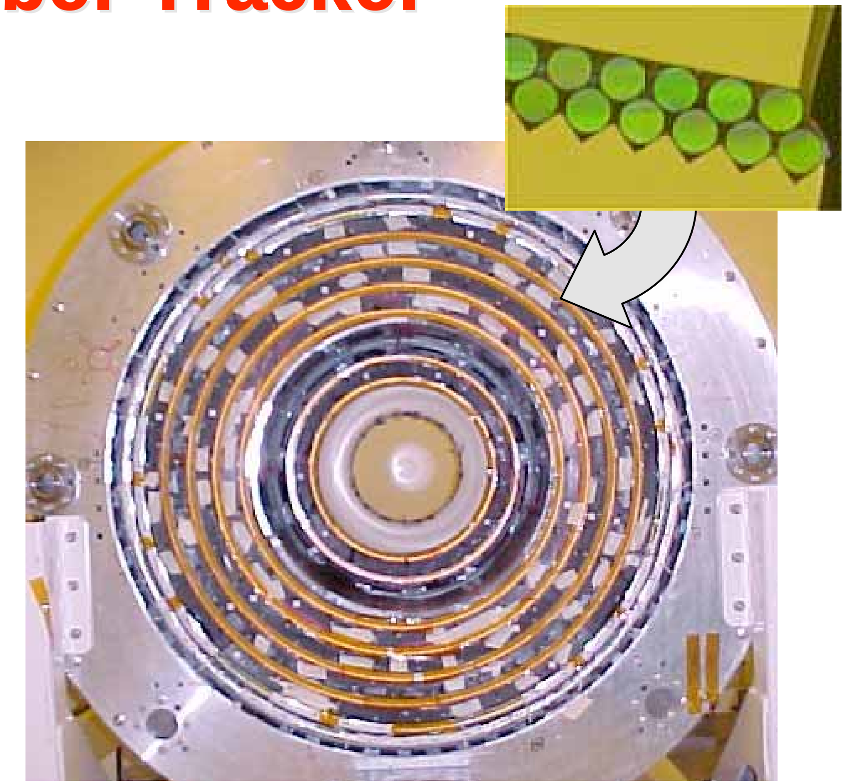
Scintillating Fiber Tracker

- **8 axial, 8 stereo layers**
- **VLPC readout**
- **Performing well**
  - **good light yield**
  - **layer ε > 98%**

    (including dead channels)

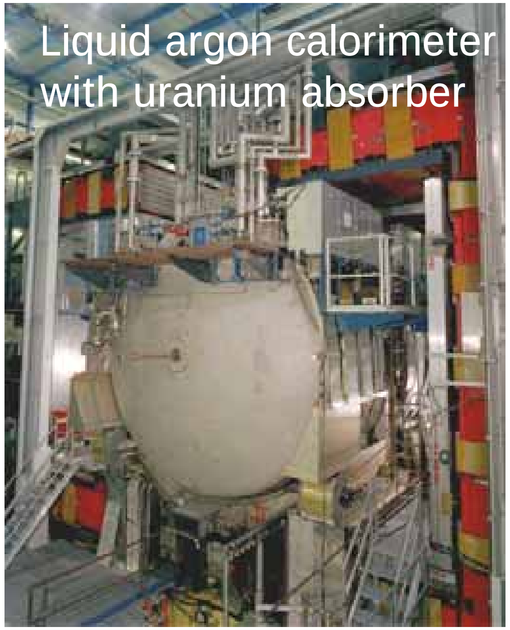


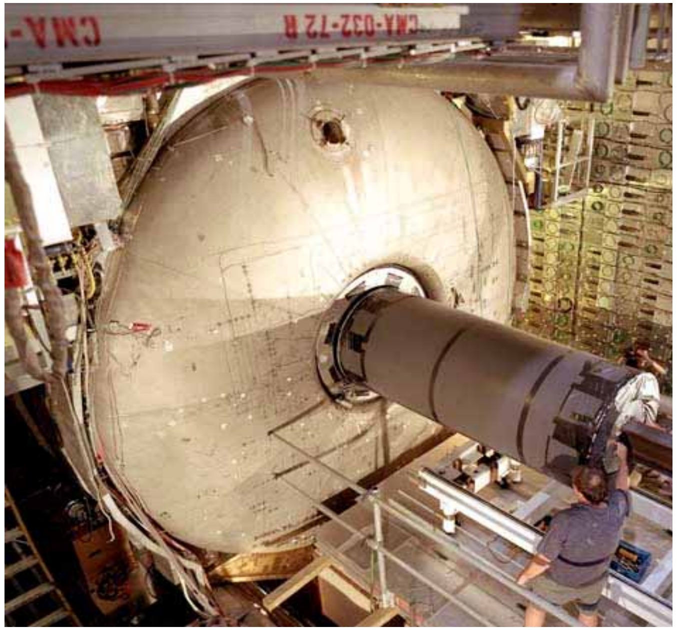
Occupancy matches expectations

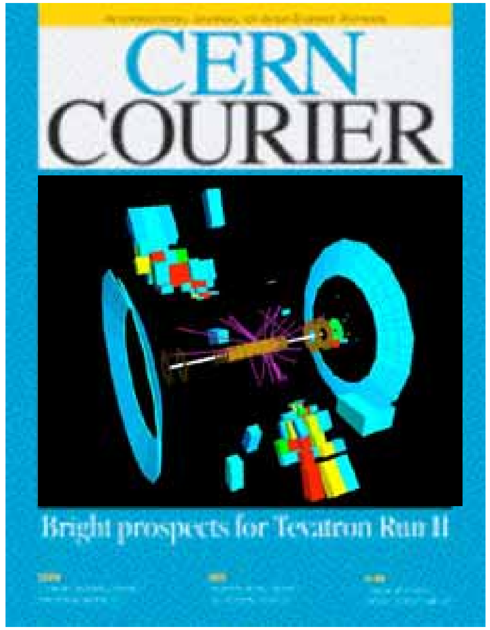


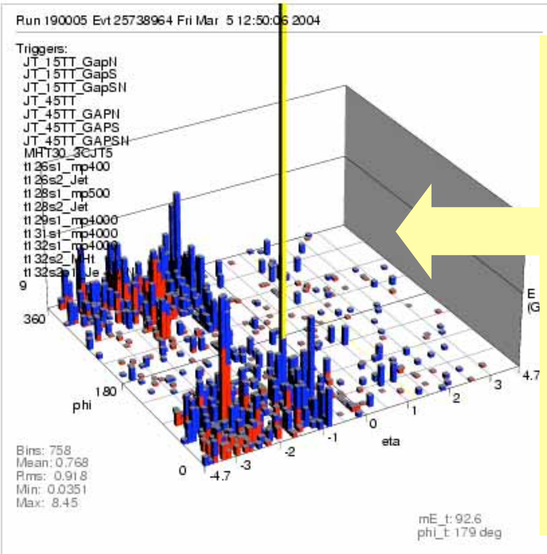
~ 1% of VLPC channels not functional after November 2003 shutdown
– a one-time event
– contamination in cryostat?

Calorimeter

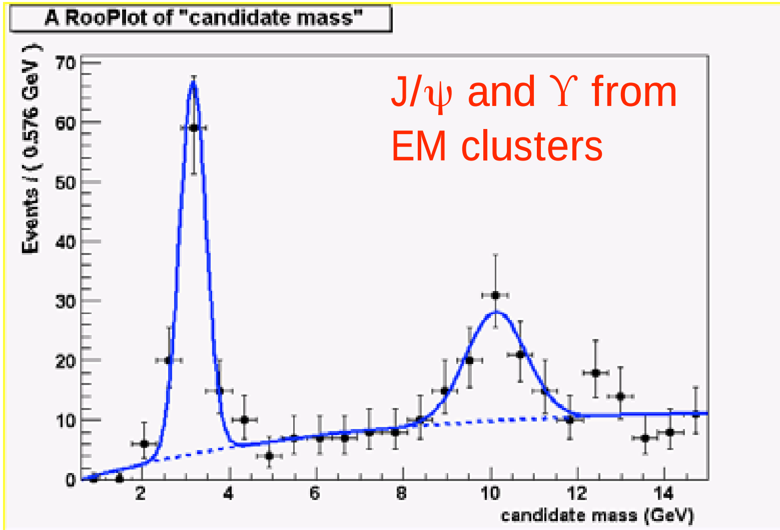








Intermittent problems with noise
– pickup from welding (2003)
– muon toroids
All OK now; still working to understand better



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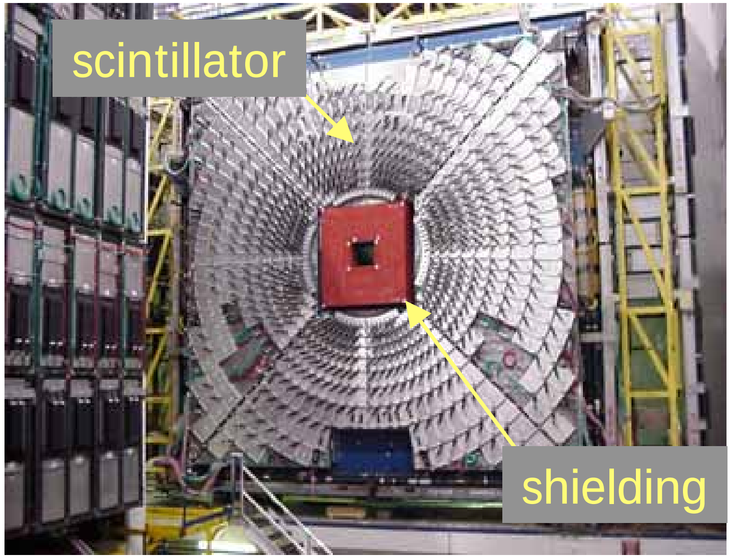
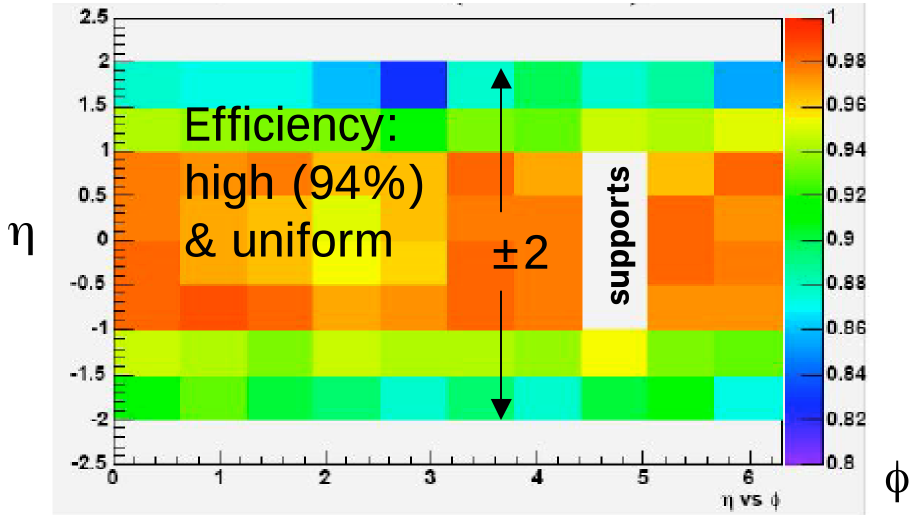
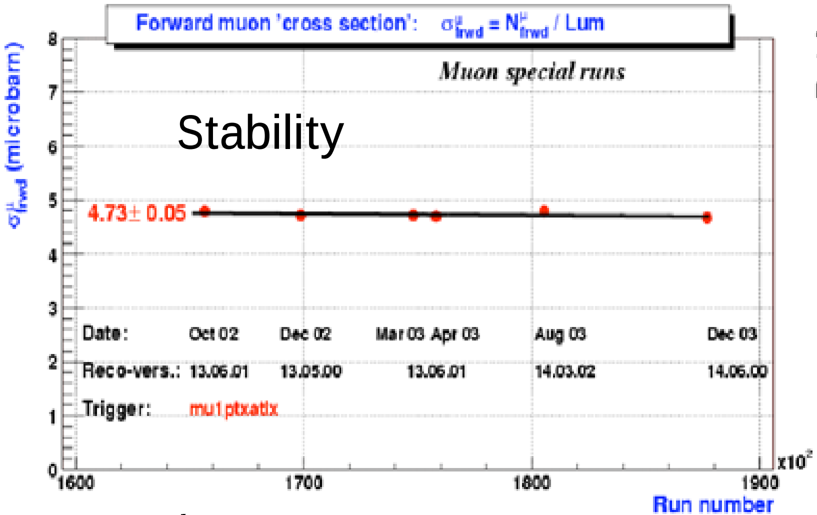
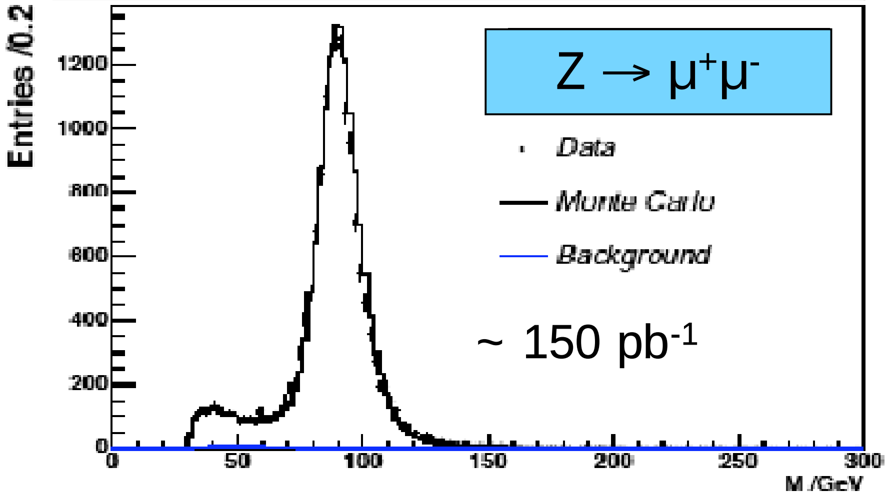
Muon System

- Three layers of scintillator planes for triggering, > 99% channels
- Three layers of drift tubes for muon track measurement, > 99% channels

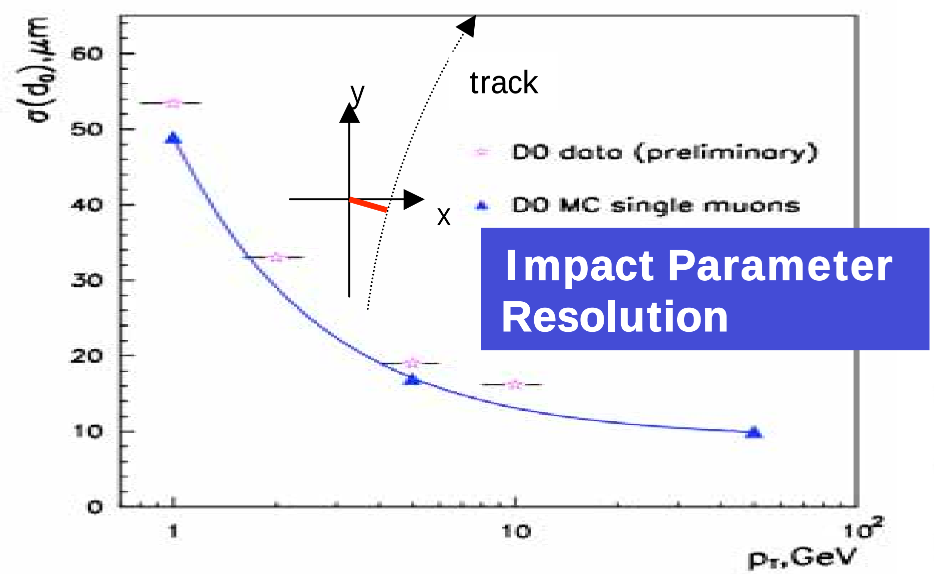


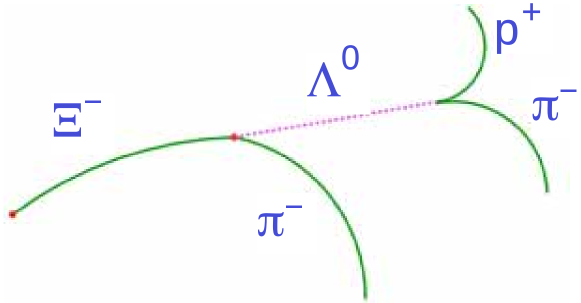


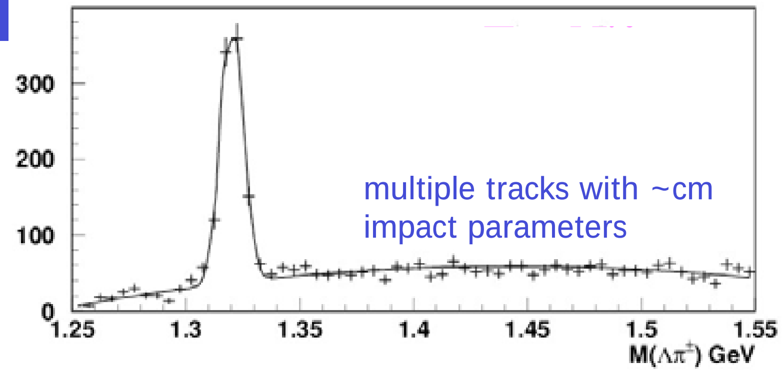




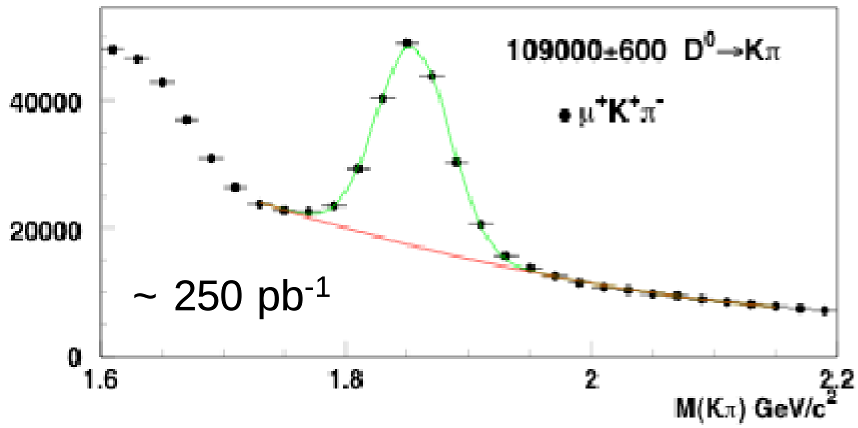
Tracking Performance

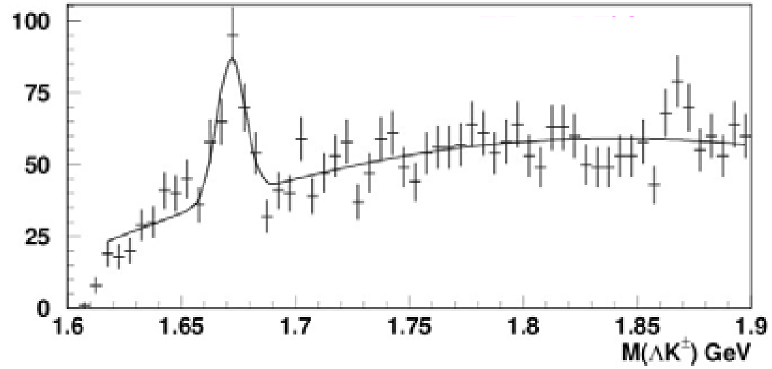






$B \to \mu\bar{\nu}D^0 X$

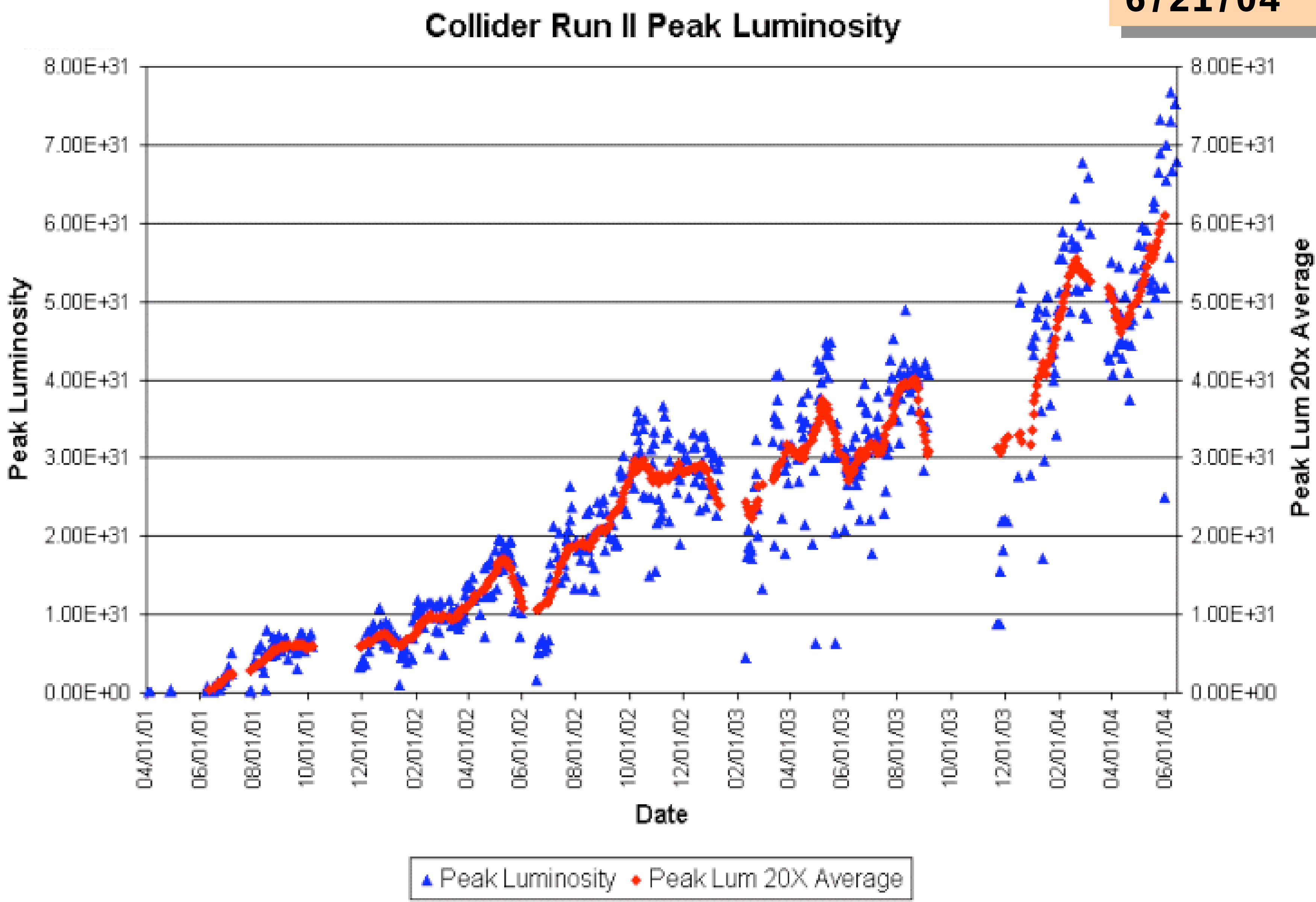




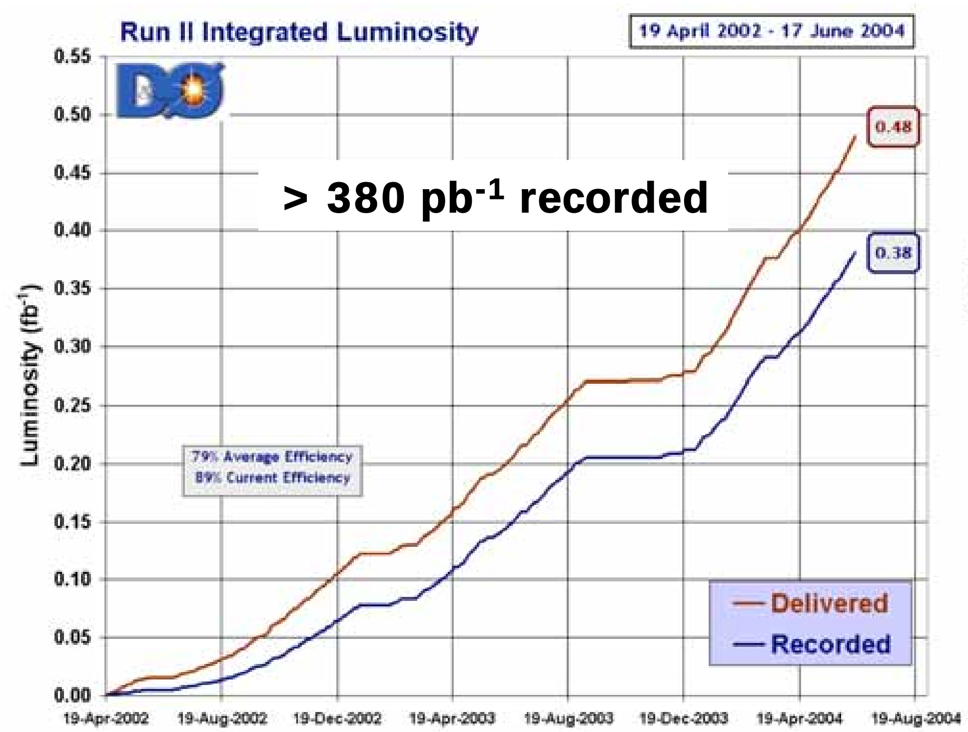
Opens new and exciting physics possibilities for DØ

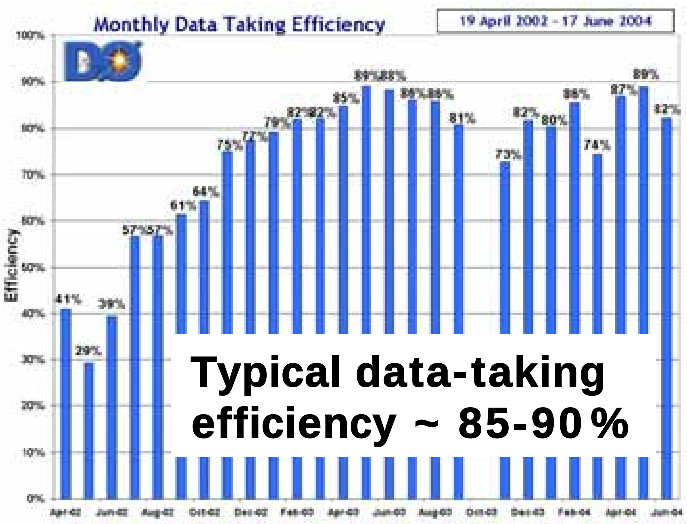
Tevatron Performance

New record
8.3×10^{31}
6/21/04



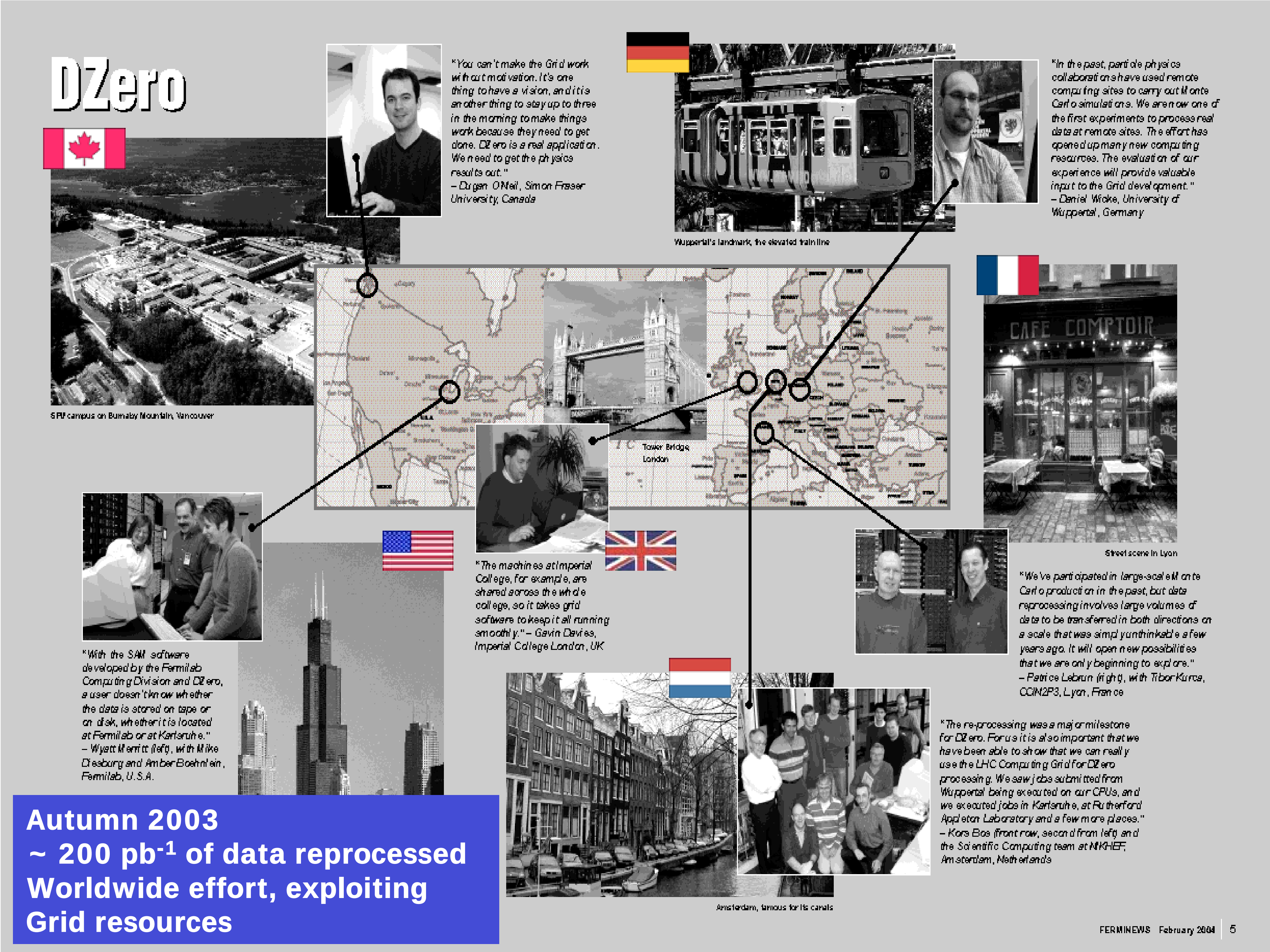
Operations





Typical "good" day 2 pb^{-1}
Typical "good" week 10 pb^{-1}
All of 1992-3 in a week

- Data are being reconstructed on the Fermilab computing farm within a few days
- Up to ~ 250 pb^{-1} being used in current physics analyses
- DØ computing systems served up 0.25PB of data, 8 billion events for analysis just in the last couple of months


DZero

"You can't make the Grid work without motivation. It's one thing to have a vision, and it is another thing to stay up to three in the morning to make things work because they need to get done. DZero is a real application. We need to get the physics results out."
– Dugan O'Neil, Simon Fraser University, Canada

SFU campus on Burnaby Mountain, Vancouver

Wuppertal's landmark, the elevated train line

"In the past, particle physics collaborations have used remote computing sites to carry out Monte Carlo simulations. We are now one of the first experiments to process real data at remote sites. The effort has opened up many new computing resources. The evaluation of our experience will provide valuable input to the Grid development."
– Daniel Wicke, University of Wuppertal, Germany

Tower Bridge, London

Street scene in Lyon

"With the SAM software developed by the Fermilab Computing Division and DZero, a user doesn't know whether the data is stored on tape or on disk, whether it is located at Fermilab or at Karlsruhe."
– Wyatt Merritt (left), with Mike Diesburg and Amber Boehnlein, Fermilab, U.S.A.

"The machines at Imperial College, for example, are shared across the whole college, so it takes grid software to keep it all running smoothly." – Gavin Davies, Imperial College London, UK

"We've participated in large-scale Monte Carlo production in the past, but data reprocessing involves large volumes of data to be transferred in both directions on a scale that was simply unthinkable a few years ago. It will open new possibilities that we are only beginning to explore."
– Patrice Lebrun (right), with Tibor Kurca, CCIN2P3, Lyon, France

"The re-processing was a major milestone for DZero. For us it is also important that we have been able to show that we can really use the LHC Computing Grid for DZero processing. We saw jobs submitted from Wuppertal being executed on our CPUs, and we executed jobs in Karlsruhe, at Rutherford Appleton Laboratory and a few more places."
– Kors Bos (front row, second from left) and the Scientific Computing team at NIKHEF, Amsterdam, Netherlands

Amsterdam, famous for its canals

Autumn 2003
~ 200 pb^{-1} of data reprocessed
Worldwide effort, exploiting Grid resources

Our Physics Goals

- Confront the Standard Model through
  - 1. The strong interaction
  - 2. The CKM matrix
  - 3. Precision electroweak tests
  - 4. The top quark
  - 5. The Higgs boson

- And directly search for new phenomena not part of the SM

<u>Current status</u>

- Reprocessed 200pb^{-1} of data last fall – greatly improved tracking
- > 40 analyses in underway/review, many presented at Winter/Spring conferences
- Expect tens of publications this year
  - First two papers submitted
    - H^{++} search – hep-ex/0404015
    - X(3872) – hep-ex/0405005

... more in review

QCD

We need to:

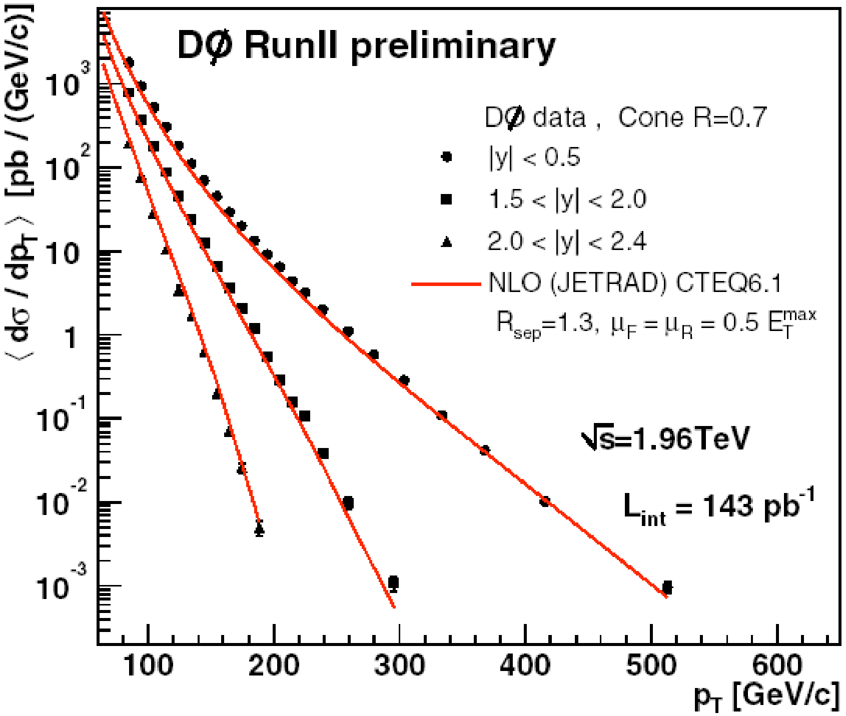
Use well-understood processes to measure proton structure

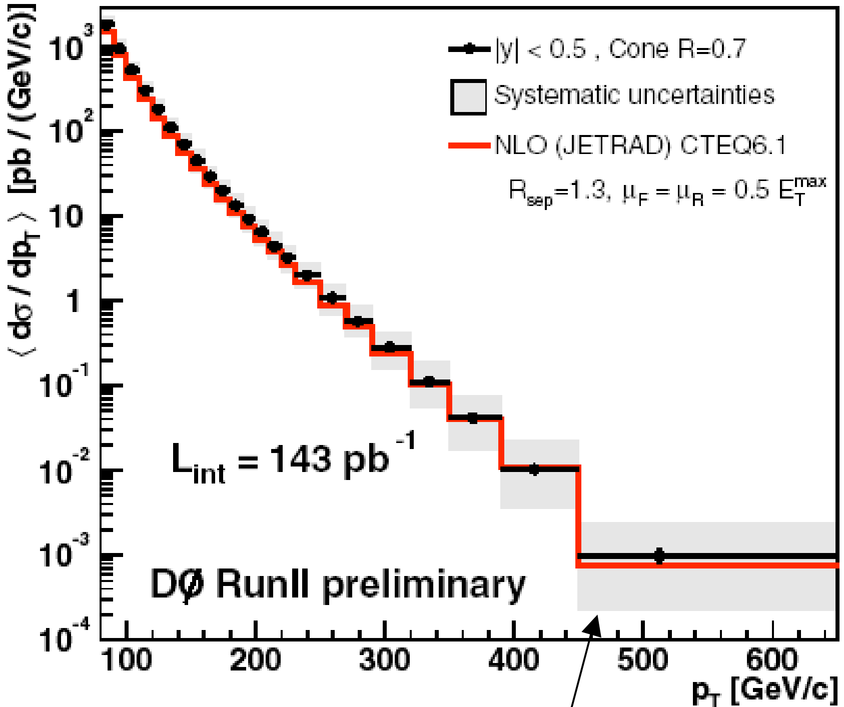
Resolve some outstanding puzzles

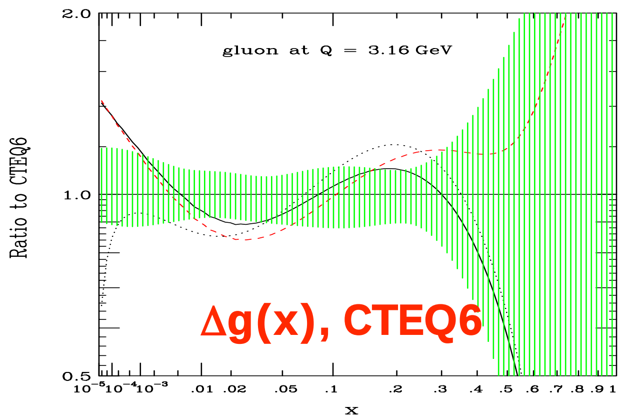
e.g. heavy flavour production, hard diffraction

Understand the backgrounds to new physics

Jet cross sections







High p_T jets constrain the gluon content of the proton

Still working hard to reduce the dominant systematic uncertainty: the jet energy scale

- **derived from p_T balance in photon + jet events**

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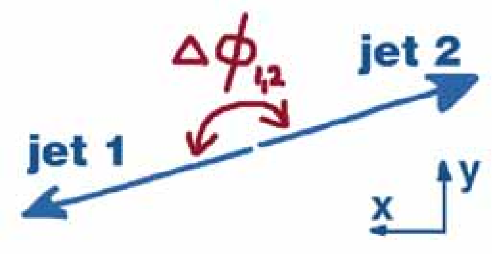
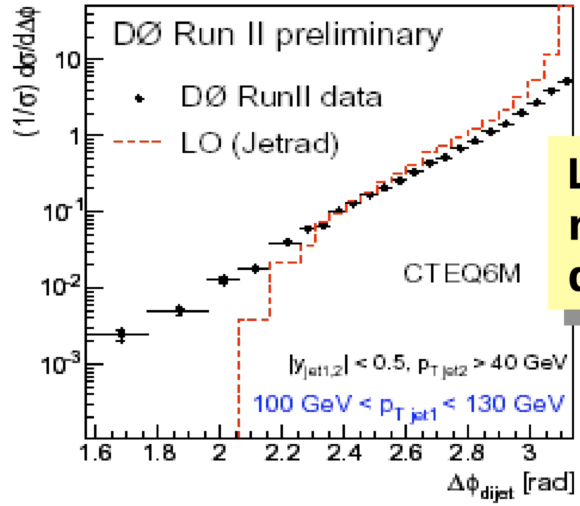
Dijet angular distributions

- Compare with LO QCD and with parton shower Monte Carlo generators

Leading Order QCD

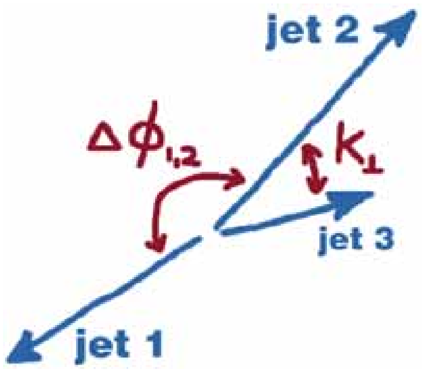


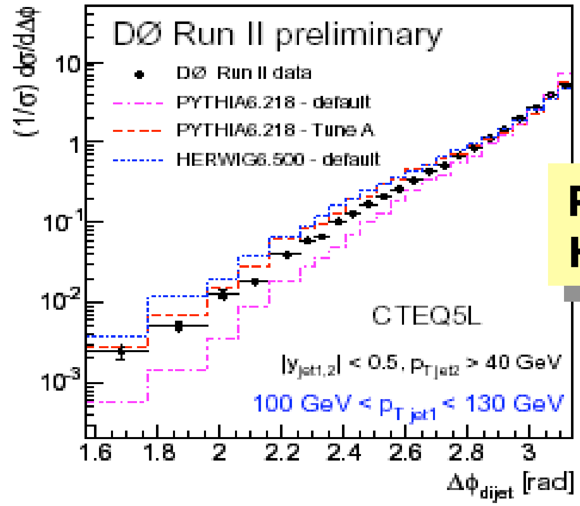
Jets are predominantly back-to-back



LO QCD not a good description

Higher order QCD or showering MC

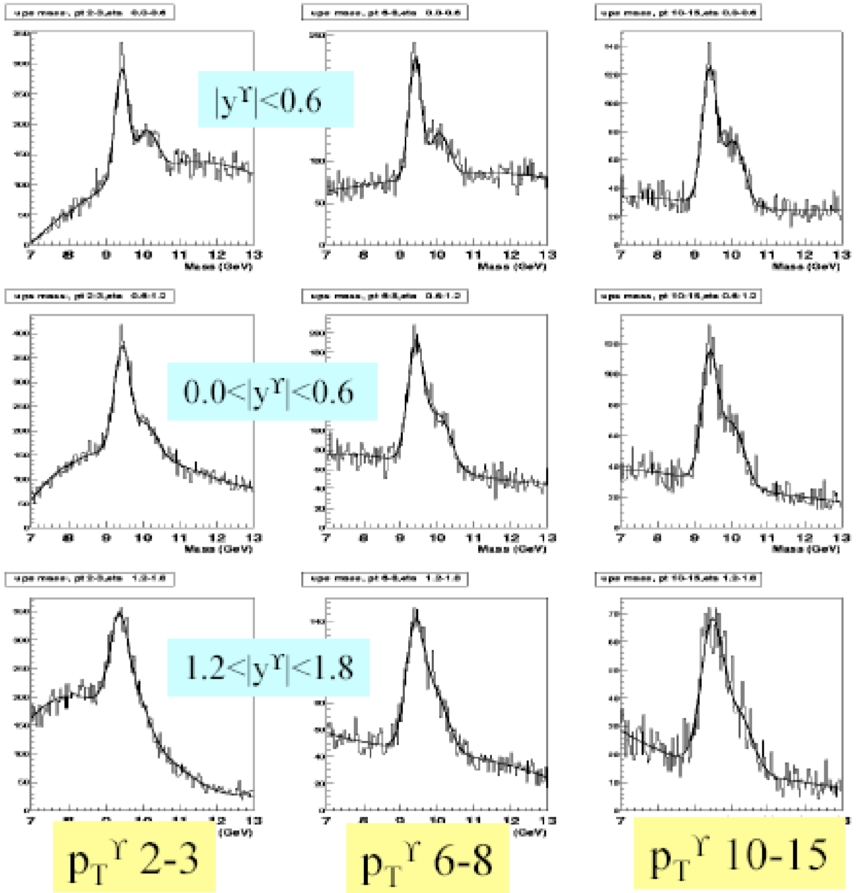




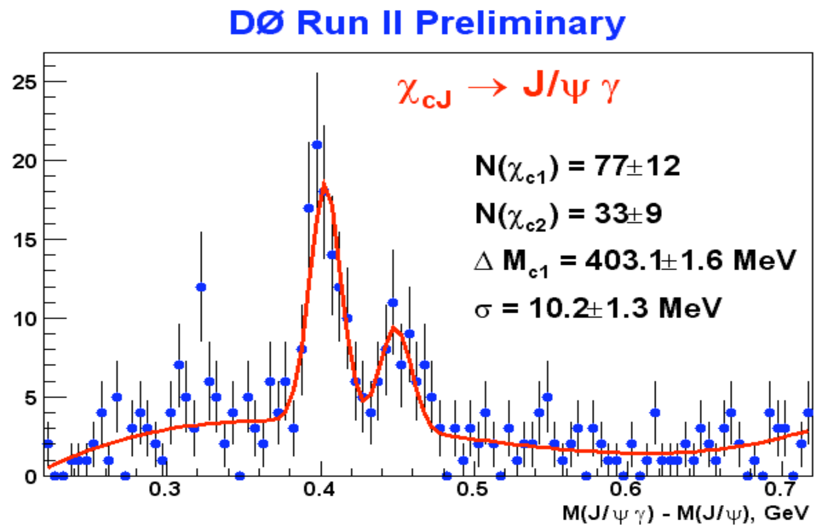
PYTHIA & HERWIG

Heavy flavour production

Upsilon → μ⁺μ⁻



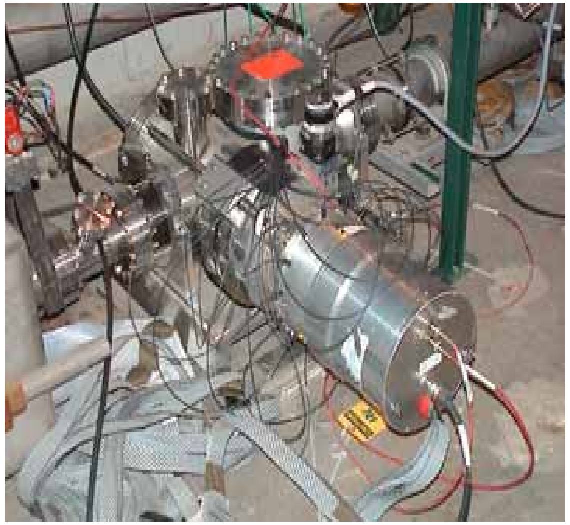
Charmonium



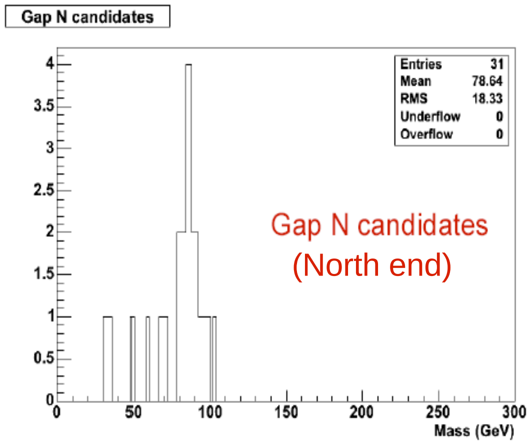
~ 160 pb^{-1}

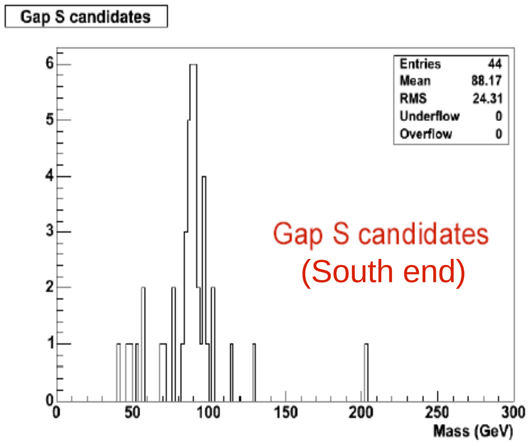
Hard diffraction

- How can we produce a high mass state like a W or Z and yet leave one of the beam particles intact?
- New instrumentation for Run II:
  - FPD (Roman pots at z = ± 23, 33, 57, 59m)
  - veto counters to cover $2.5 < |\eta| < 6$



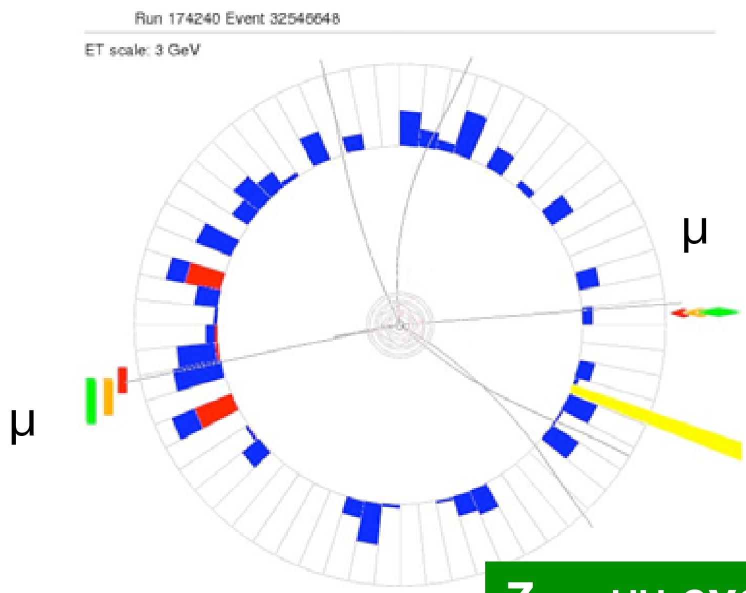
- Diffractive Z analysis now underway using both rapidity gaps and FPD
  - Relate rapidity gaps to diffractive (anti-)protons seen in Roman Pots
  - Measure the "gap survival probability"



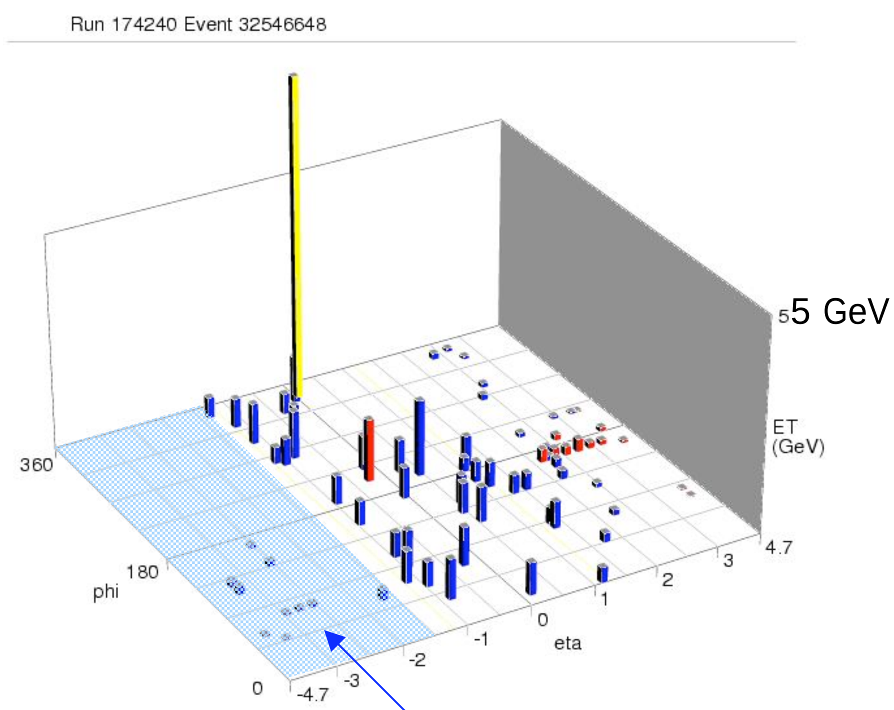


Z (→ μμ) produced with a rapidity gap at one end of detector

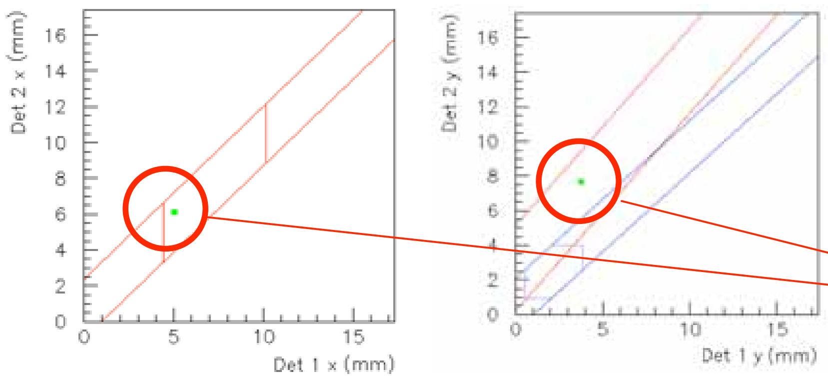
Diffractive Z Candidate



Z → μμ event



...with rapidity gap



... and coincident hits in the FPD detector

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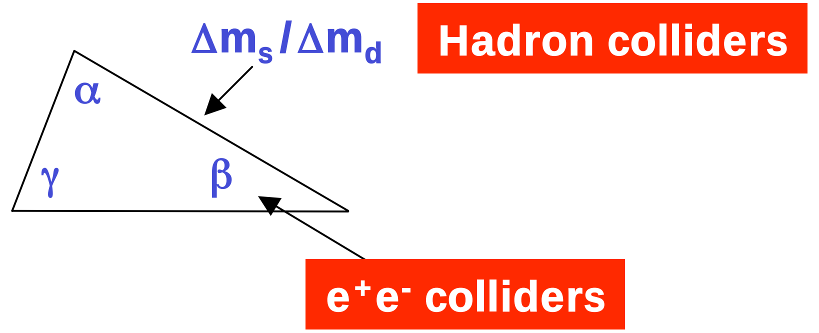
B physics and the quark mixing matrix

If quark mixing is described by a unitary 3_3 matrix, we can parametrize the phases and magnitudes by a triangle.

Hadron colliders confront this "unitarity triangle" in ways that complement measurements at the e^+e^- B-factories e.g. through the B^0_S system . . .



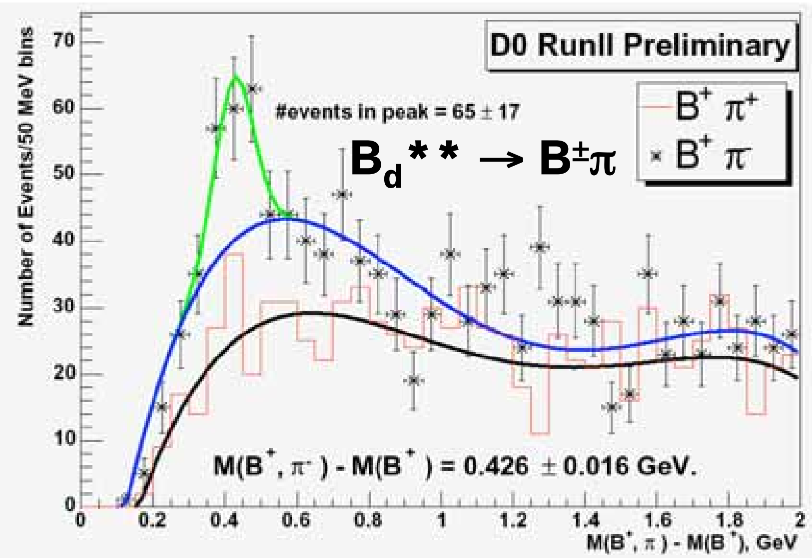
B^0_S mixing is a good way to see indirect effects of new physics not detectable at B-factories

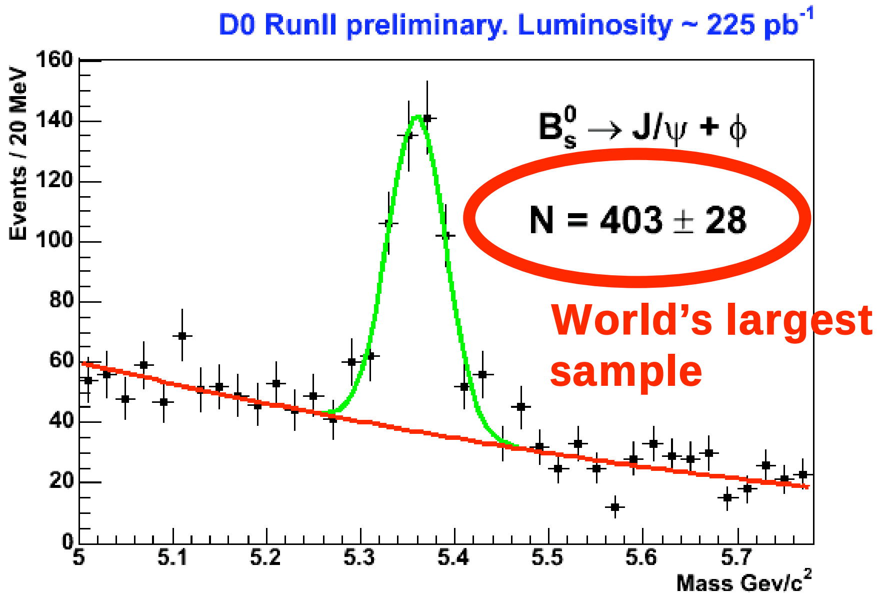
e.g. Δm_s, B_s asymmetries, $B \rightarrow \phi K_S$ asymmetries…

Putting the tools in place

DØ does not exploit purely hadronic triggers, but benefits from large muon acceptance, forward tracking coverage, and (in future) the ability to make use of $J/\psi \rightarrow e^+e^-$

- **J/ψ, ϕ, K … B reconstruction**

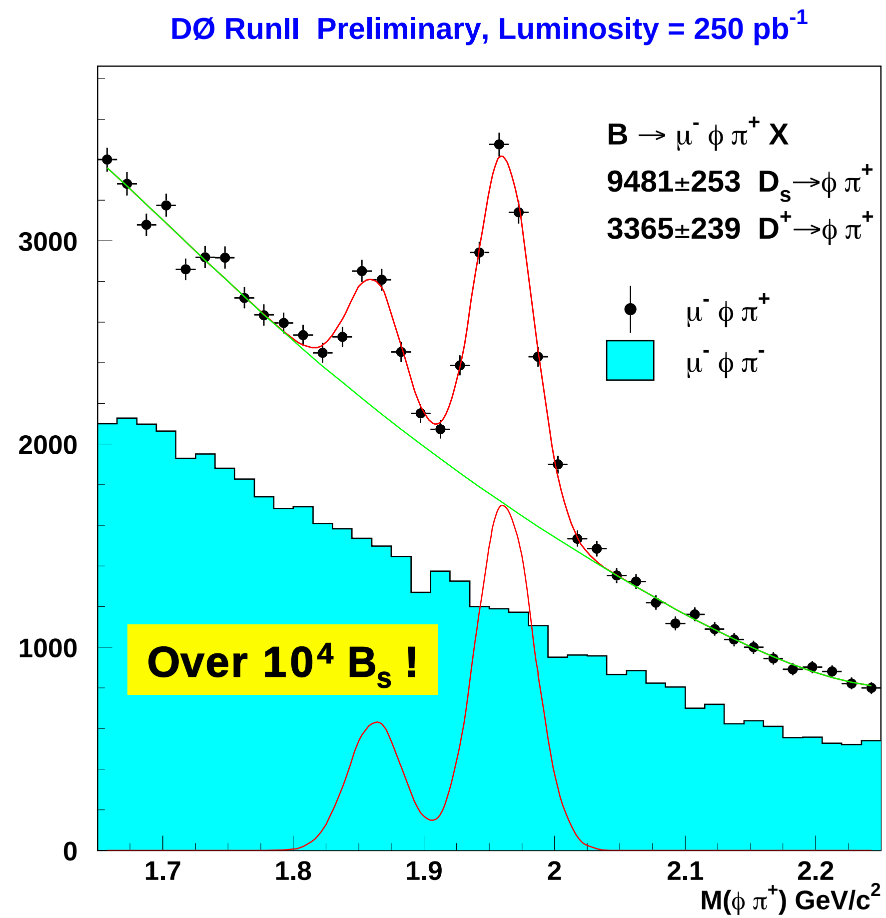




- **Displaced vertex reconstruction (B lifetimes)**
- **Flavour tagging – example from $B \rightarrow D^*\mu\nu$**
  - **Opposite side μ: efficiency = 4.8±0.2 %, Dilution = 46.0±4.2 %**
  - **Also jet charge and same-side pion tags**

Towards a B_s Mixing Measurement

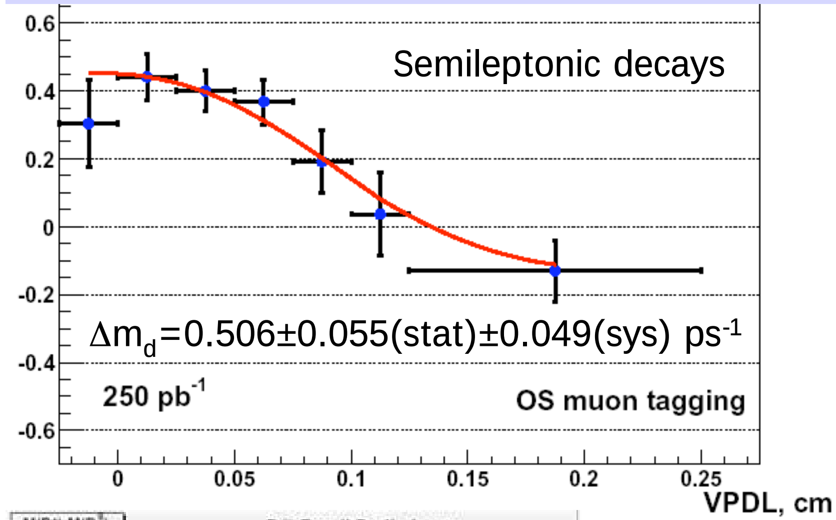
- $B_S \to \mu + X$

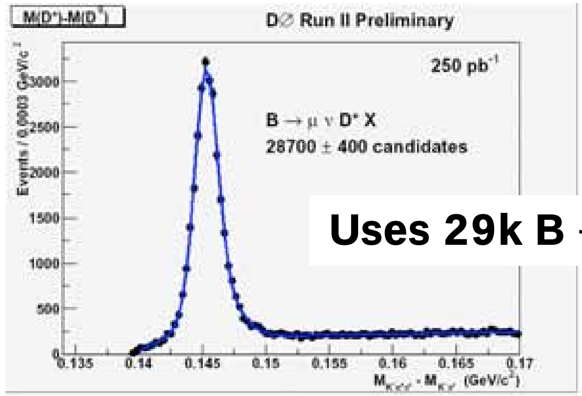


Over 10^4 B_s !

- B_d oscillations

$A = (N_{non\text{-}osc} - N_{osc}) / (N_{non\text{-}osc} + N_{osc})$

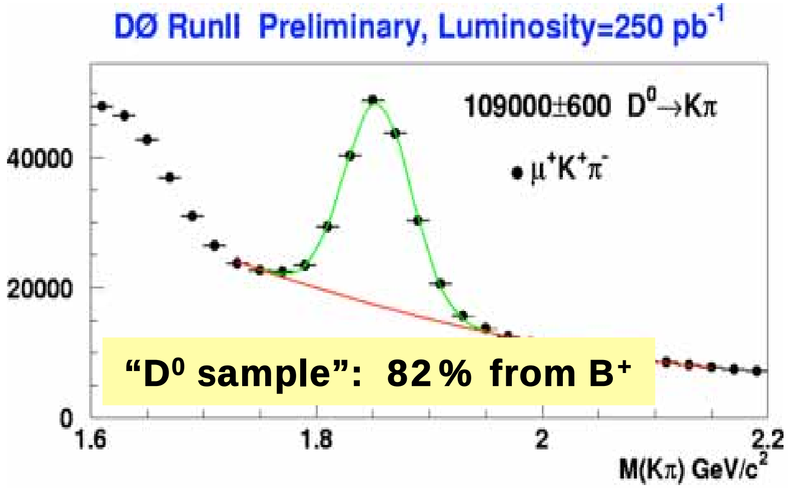


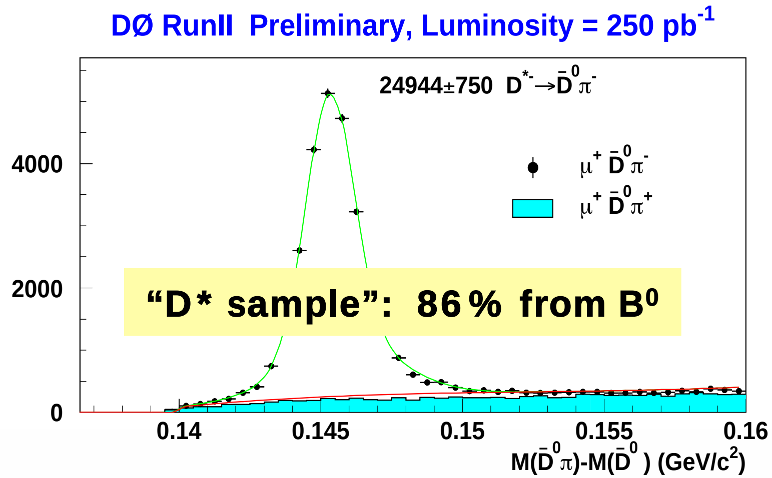


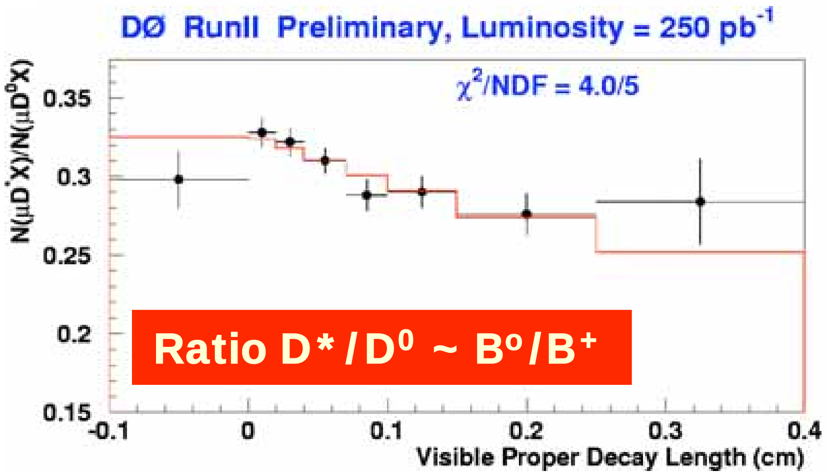
Uses 29k $B \to D^*\mu\nu + X$

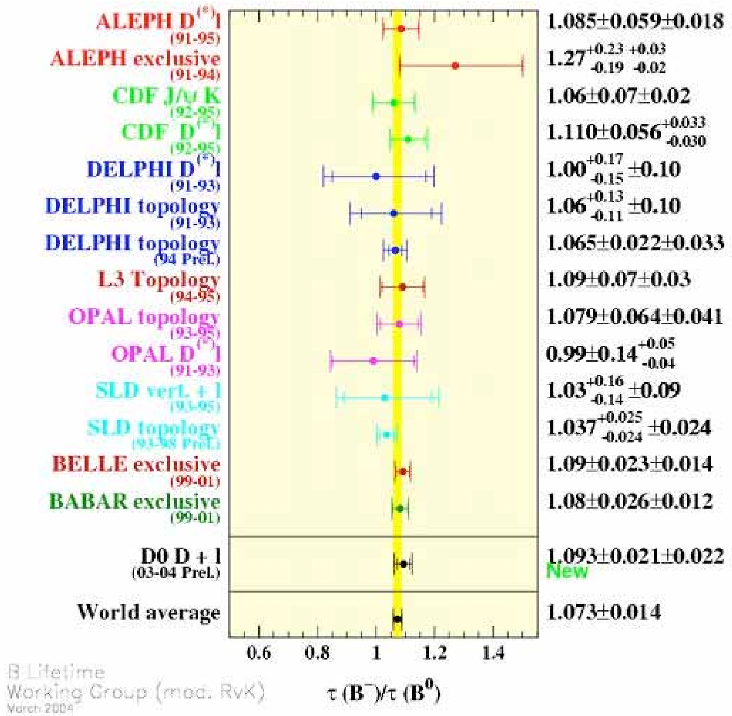
B_s mixing: aiming for results late this summer

B^+ / B^0 lifetime ratio: a new technique







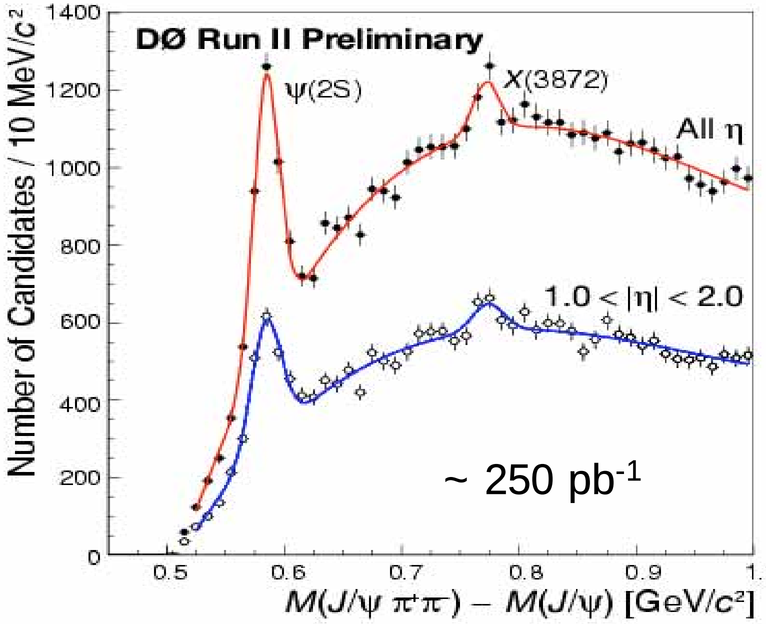


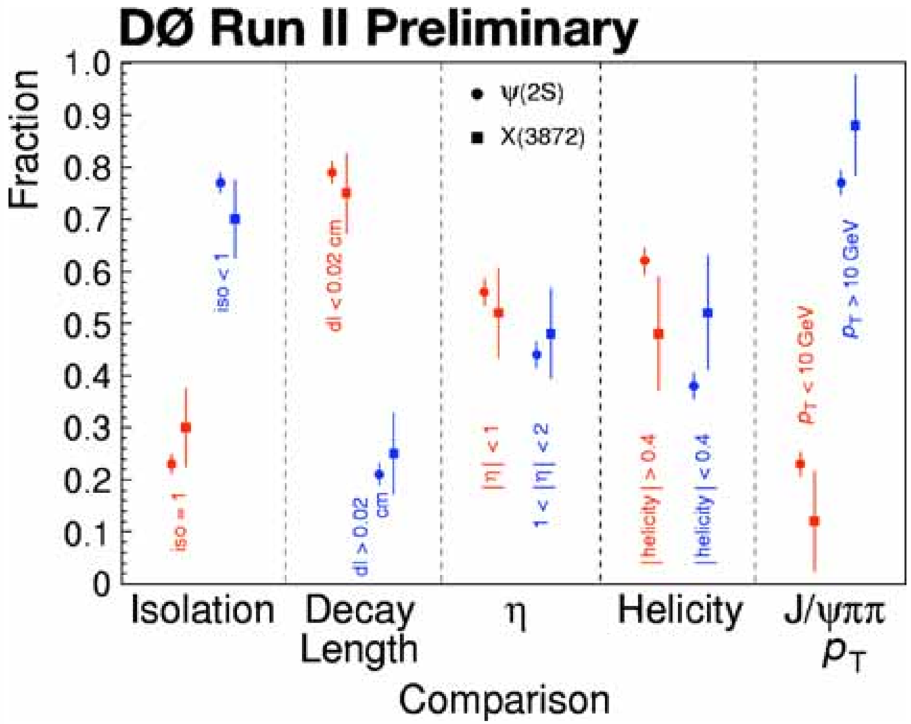
One of the best measurements to date

Lifetime ratio τ^+ / τ^0 =
1.093 ± 0.021 (stat) ± 0.022 (sys)

X(3872) → J/ψ π⁺π⁻

Belle, CDF ...





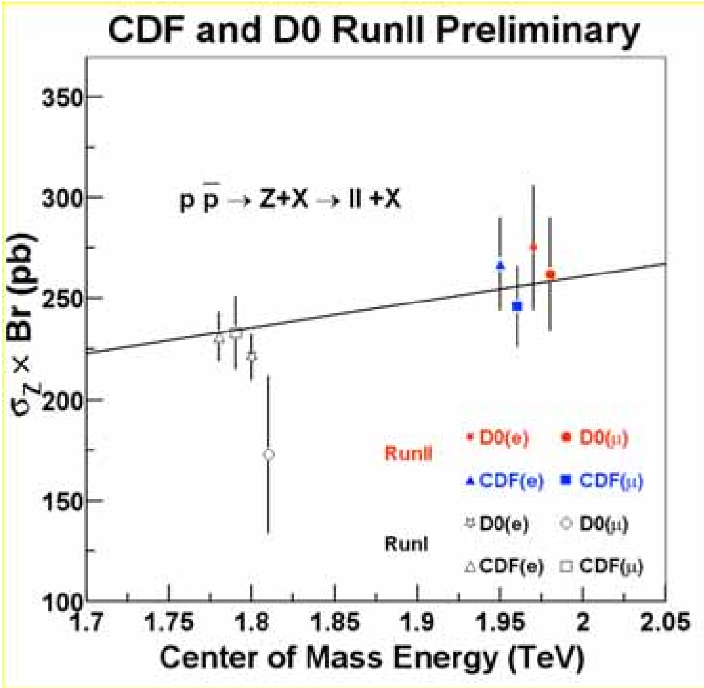
- **X(3872) seems to behave similarly to ψ(2S)**
- **Can we detect its production mechanism (prompt vs. B-decays)?**
  - **Analysis in progress…**

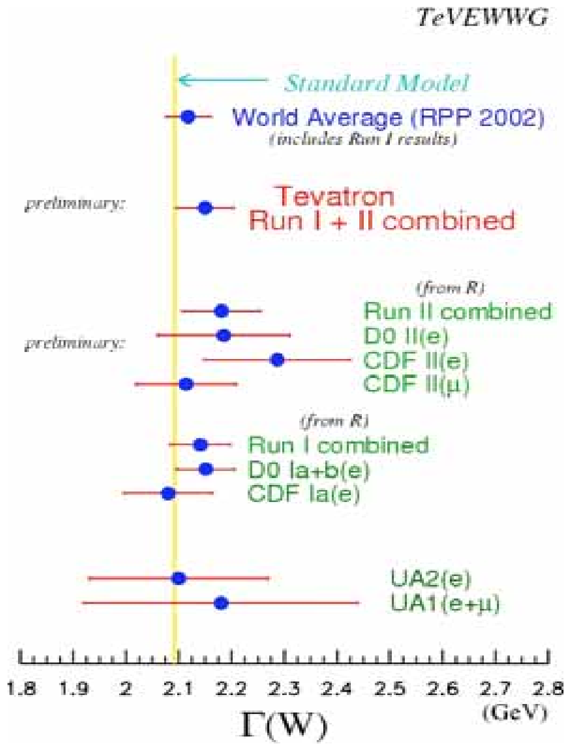
Electroweak Physics

Indirectly constrain new physics through precision measurements of electroweak parameters, especially m_W

Also measure forward-backward asymmetry in Z production, multiboson production, boson + jets, ...

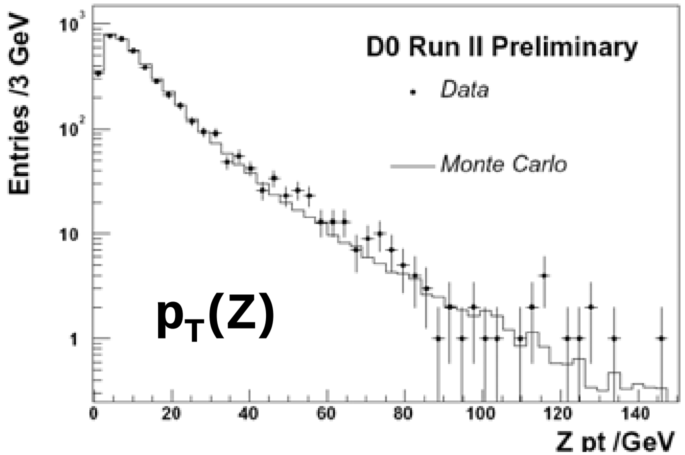
W and Z production

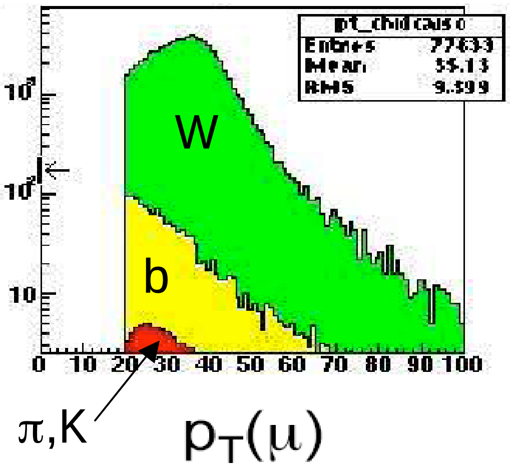




Indirect W width

First result from new Tevatron EWWG

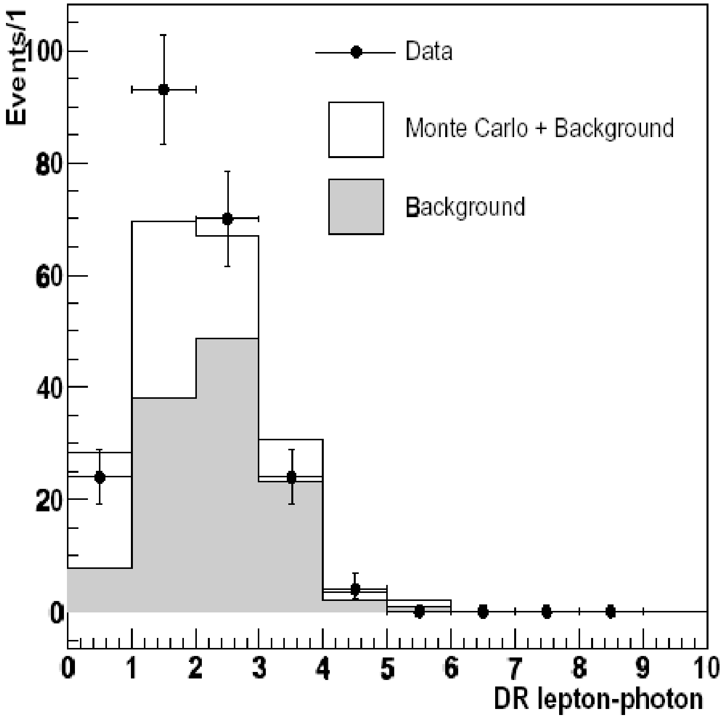




W → μν

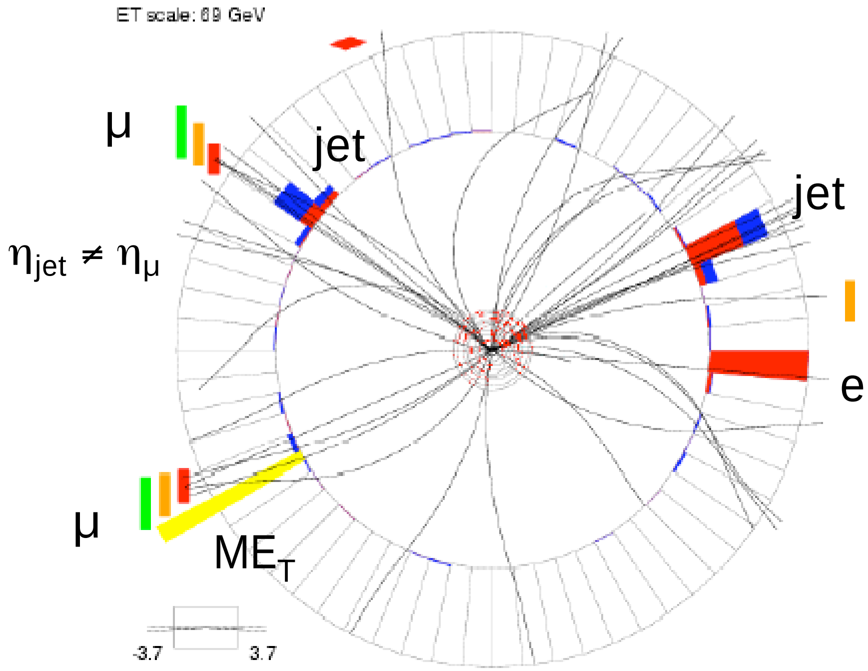
Working on a detailed understanding of backgrounds; Prelude to m_W

Multiboson production



Wγ

- Separation between photon and charged lepton in Wγ candidate events



WZ

- 2 candidates in eμμ and 1 in μμμ
  - Rate roughly consistent with SM

The Top Quark

The Tevatron Collider is the world's only source of top quarks

Top couples strongly to the Higgs field:
offers a window on fermion mass generation

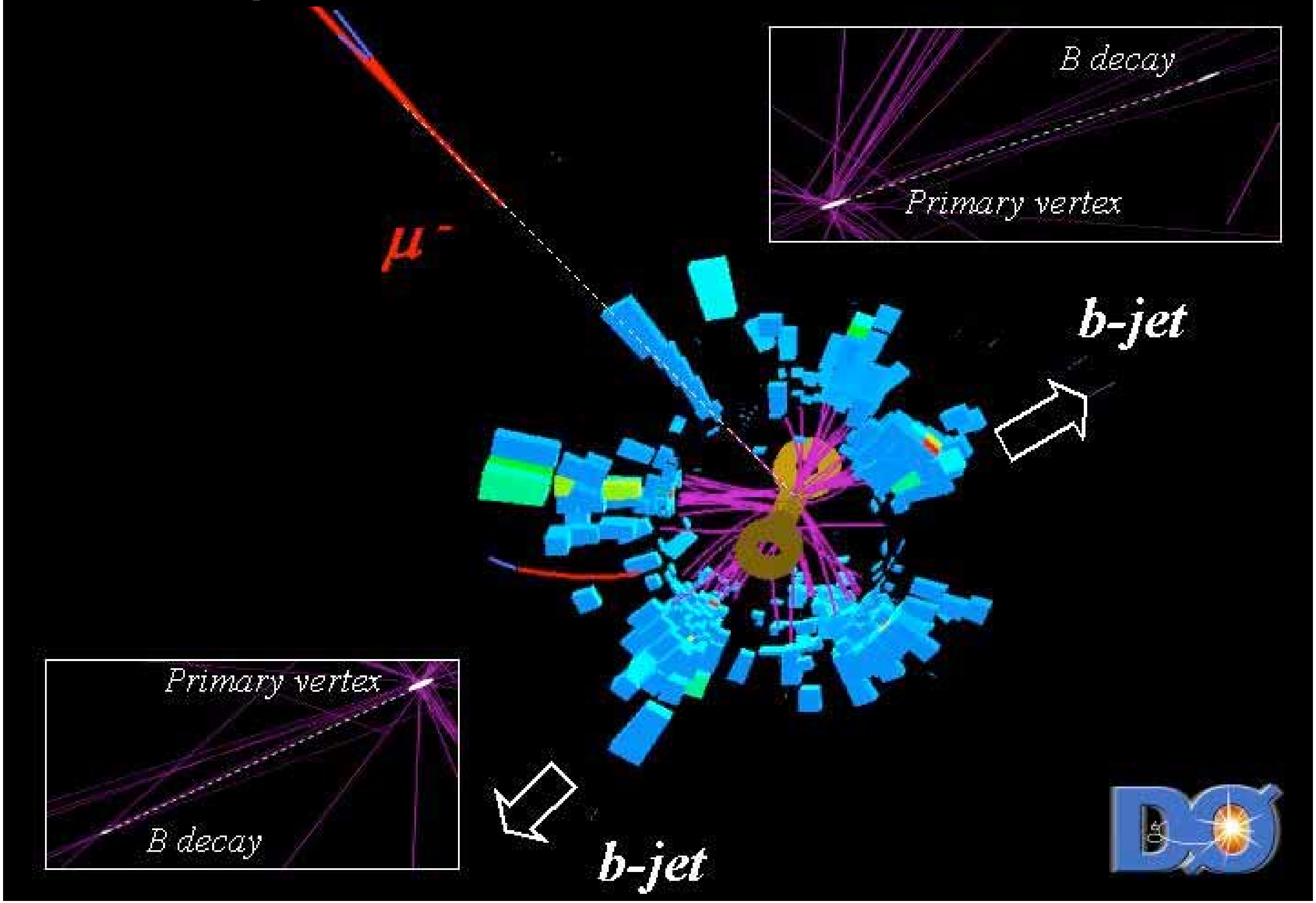
We need to:

Measure its properties with greatly increased statistics

- the top mass constrains the Higgs sector

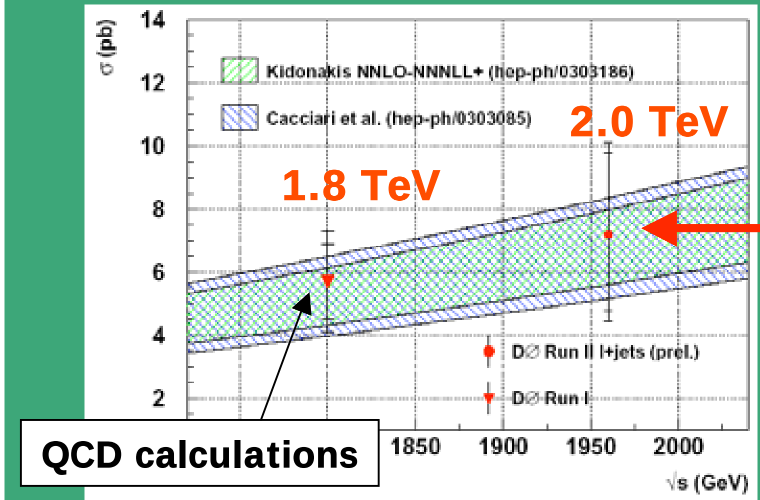
- search for surprises, anomalies?

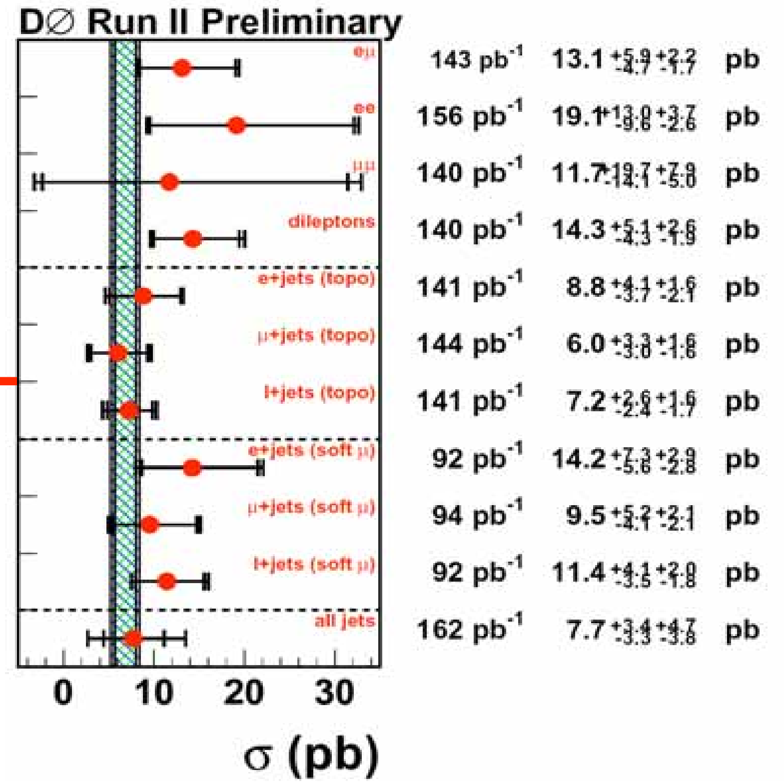
Run II top candidate

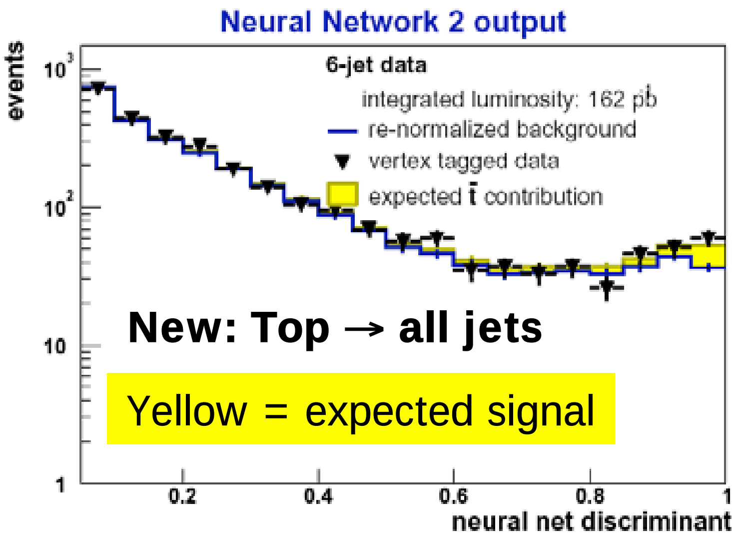


Top Production

Is the cross section what is expected from QCD?



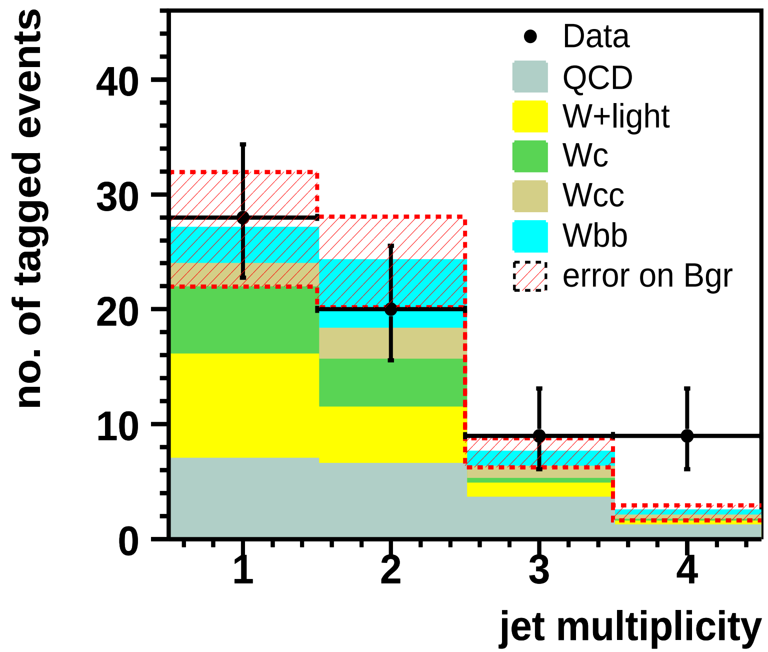


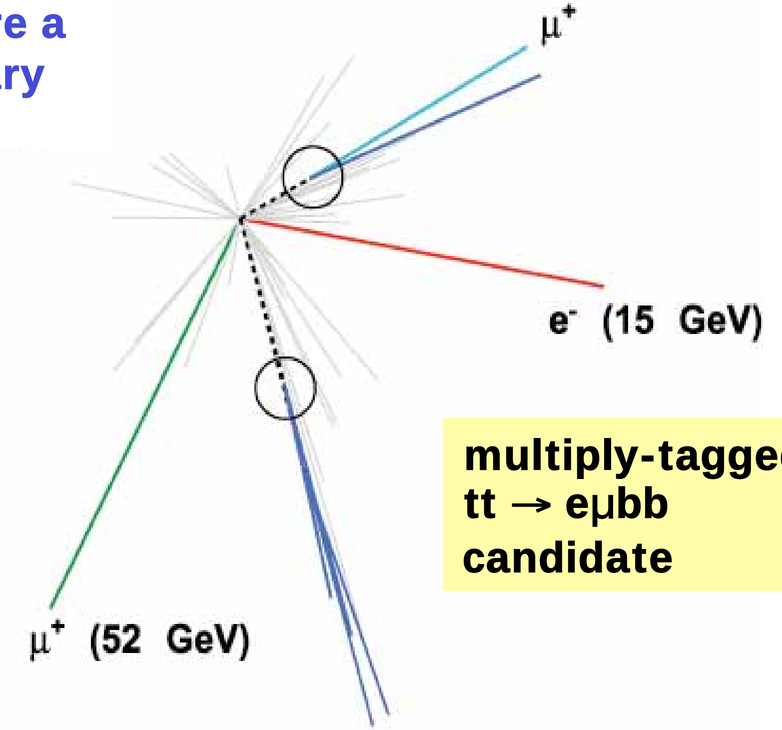


New limits on single top production coming soon

Top cross section with b-tagging

- **Relax topological selection and require a jet with impact parameter or secondary vertex tag**





multiply-tagged tt → eμbb candidate

Impact Parameter tag:

$$\sigma_{t\bar{t}} = 7.4^{+4.4}_{-3.6}(stat)^{+2.1}_{-1.8}(syst) \pm 0.7(lumi)pb$$

Secondary Vertex tag:

$$\sigma_{t\bar{t}} = 10.8^{+4.9}_{-4.0}(stat)^{+2.1}_{-2.0}(syst) \pm 1.1(lumi)\,pb$$

Tagging Efficiency ~ 50%
Mistag rate
(light quark jets) ~ 1-1.5%

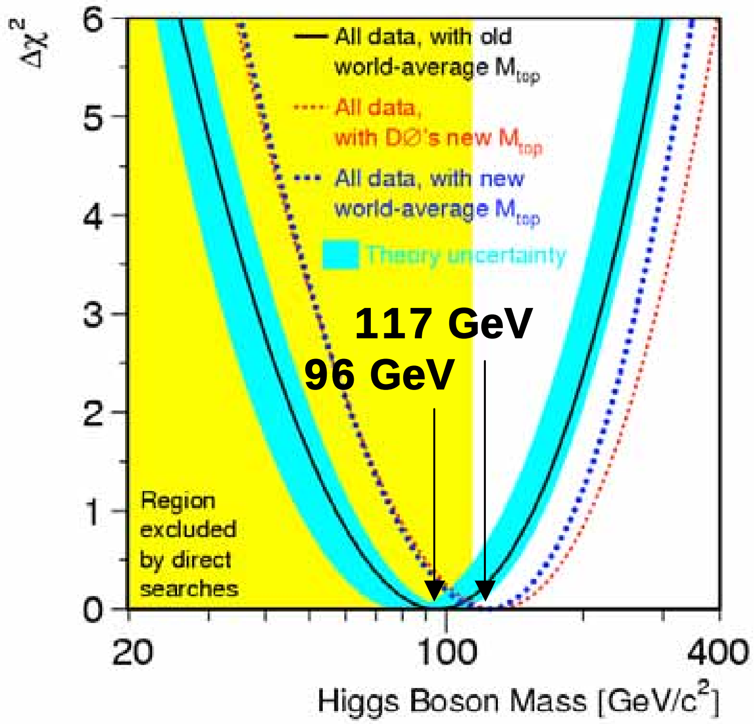
Top mass

- **New DØ Run I lepton+ jets mass measurement:**
  - **m_{top} = 179.0 ± 5.1 GeV (DØ combined)**
  - **m_{top} = 178.0 ± 4.3 GeV (2004 World Ave)**

Method inspired by Kondo (1988), Dalitz and Goldstein

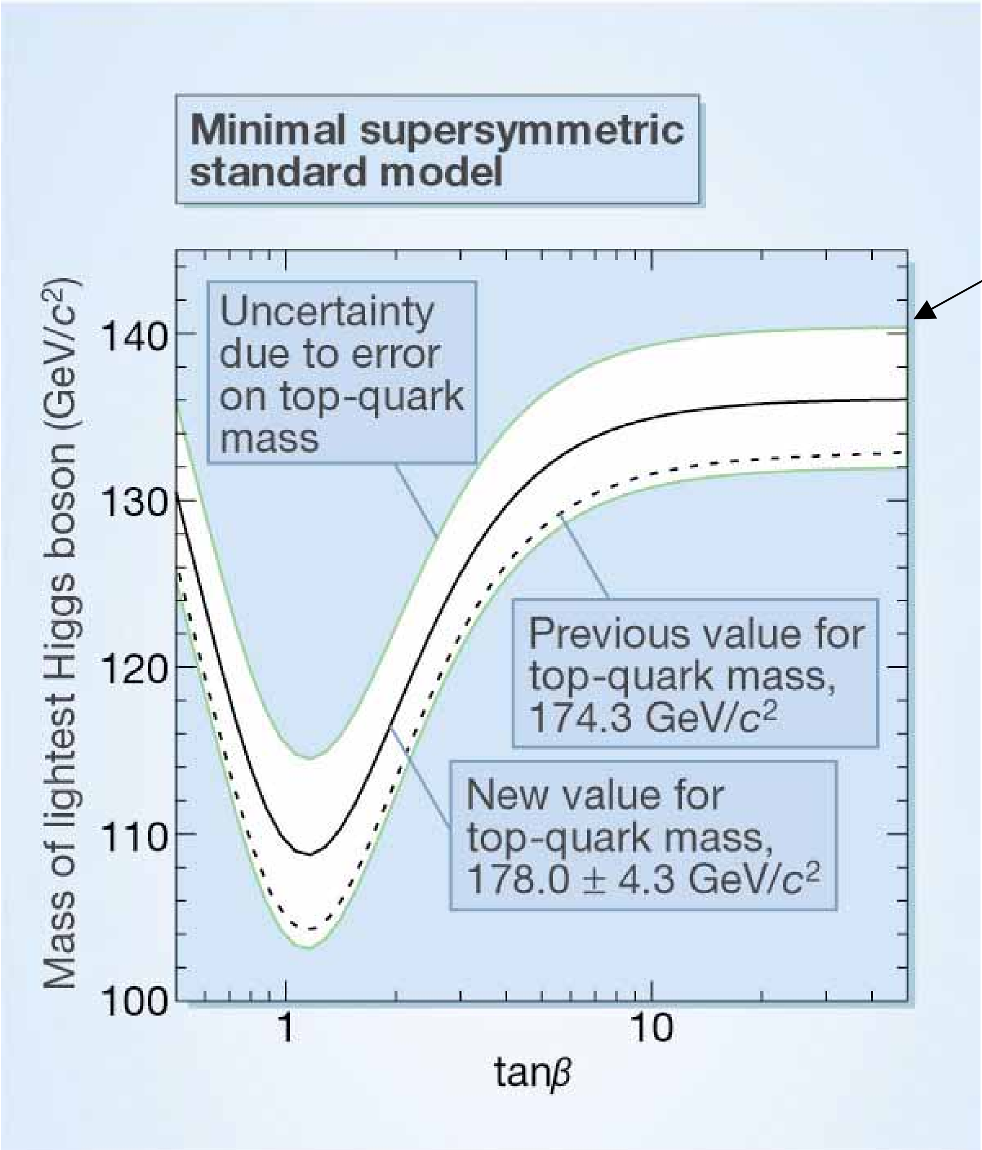
Precise m_{top} is important! *example…*

Top mass	2003 World Ave	2004 World Ave
Higgs mass best fit	**96 GeV + 60 – 38**	**117 GeV + 67 – 45**
95% CL upper limit	**219 GeV**	**251 GeV**



Nature 429 (2004) p638

Top mass



New top mass also raises the upper limit on lightest supersymmetric Higgs mass

- From G. Weiglein

CDF have reported a new Run II top mass, using a similar analysis technique:

$m_{top} = 177.0\ ^{+4.5}_{-5.0} \pm 6.2$ GeV
(CDF preliminary 2004)

DØ Run II mass analysis is in progress, using three complenary techniques
Expect results for ICHEP

The Higgs Sector

Discover (or exclude) scalar particles related to EWSB
Constrain their properties

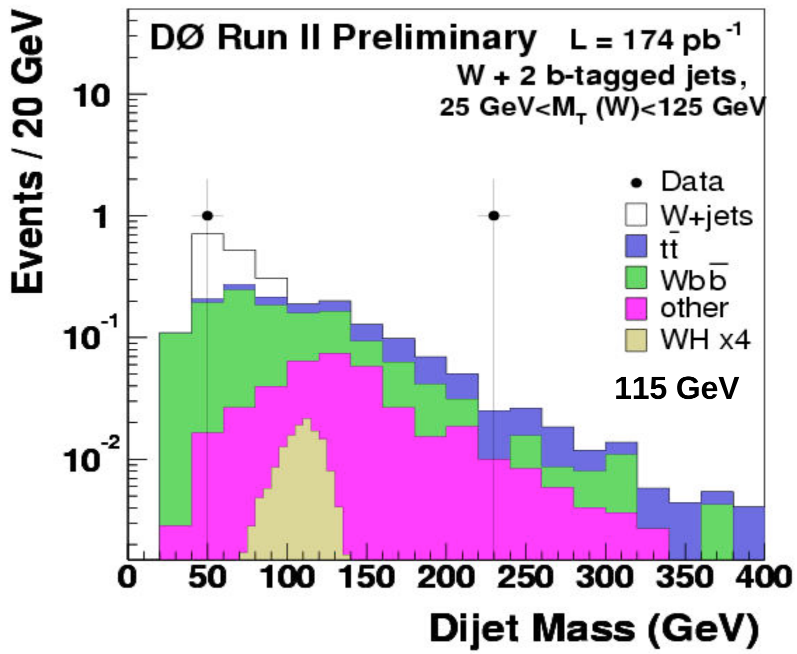
The latest Tevatron luminosity plan makes it hard to cover the whole SM Higgs mass range, but we will do what we can — and the lowest masses (115 GeV!) are the most interesting

Higgs searches

- With our current dataset, we don't expect to see a standard model Higgs signal
  - looking for nonstandard variants
  - developing our tools, our understanding, and ability to model backgrounds
    - e.g. W/Z +bb

WH → Wbb search

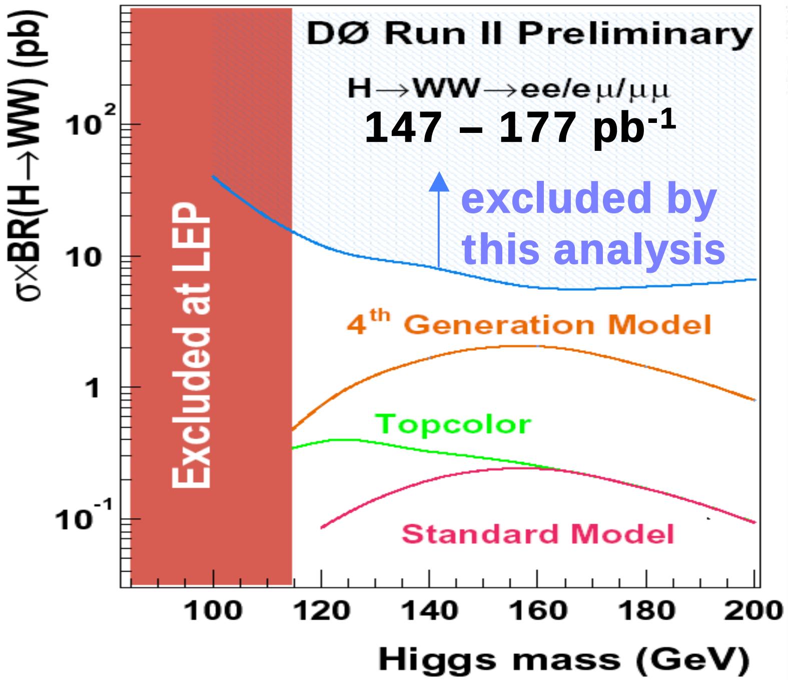
$\sigma(WH)B(H \rightarrow bb) < 12.4$ pb
(m_H = 115 GeV/c^2)



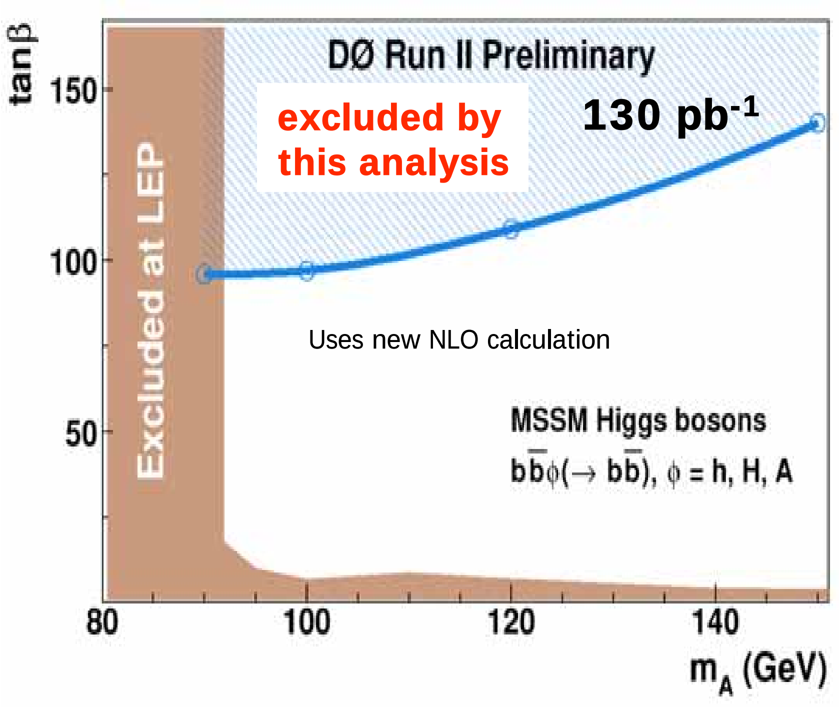
Will start to be sensitive to SM Higgs with 2 fb^{-1} or so

Non-standard and SUSY Higgs

H → WW search



SUSY (A/H/h)bb search



Also fermiophobic Higgs, doubly charged Higgs ...

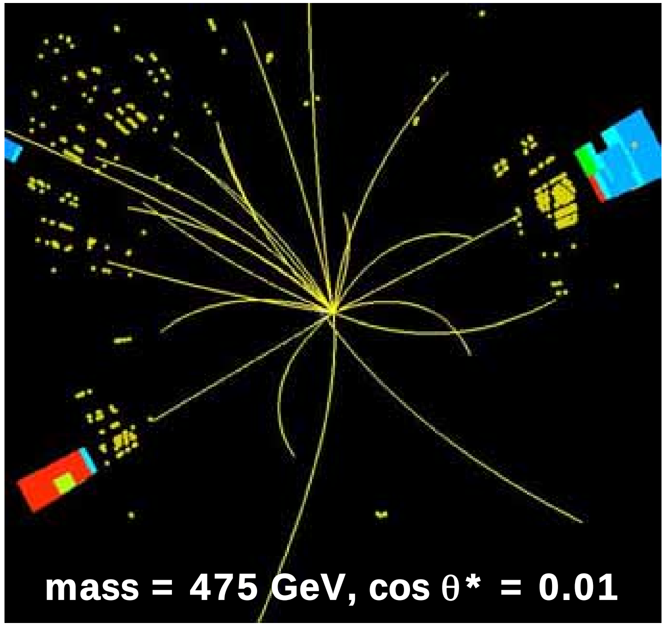
Searches

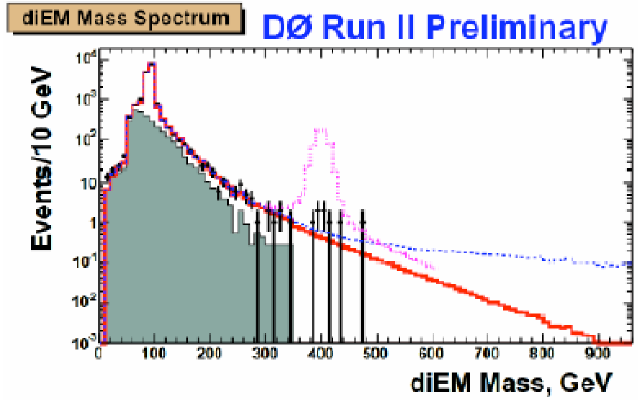
Find evidence for phenomena outside the SM
Improve constraints on such theories

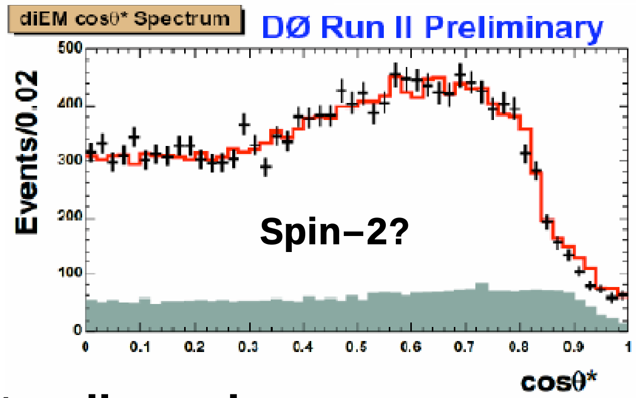
Searching for Extra Dimensions

- Signal would be an excess of ee, μμ, γγ events at large mass and large angle, due to virtual graviton exchange

High-mass electron pair event







Latest DØ limits from $p\bar{p} \rightarrow$ ee, μμ, γγ

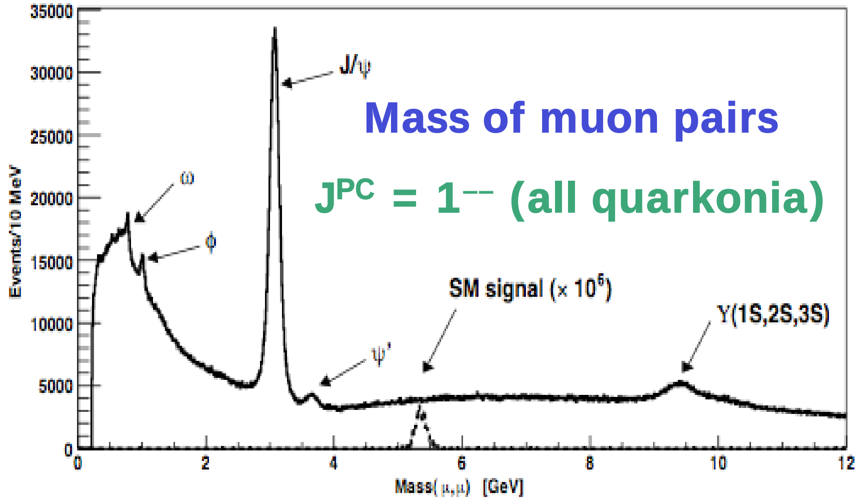
M_S(GRW) > 1.43 TeV (~ 200 pb^{-1}, 95% CL)

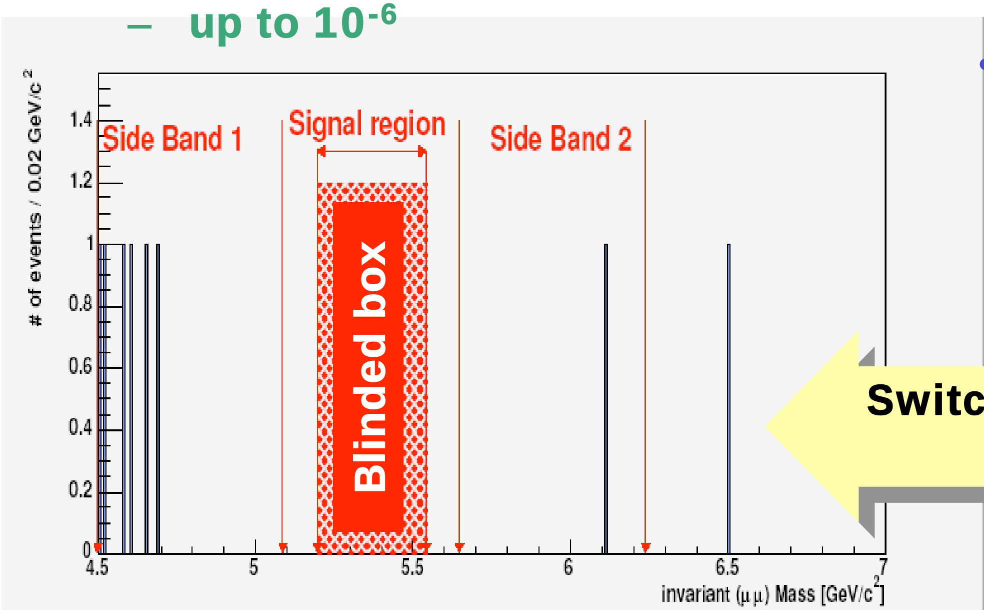
most sensitive search to date for large extra dimensions

Same dataset places limits on TeV-scale extra dimensions, Z' …

Indirect searches for new particles

- Measure the rate of the rare decay $B_s \to \mu^+\mu^-$
- In the Standard Model, cancellations lead to a very small branching ratio
  - SM BR= 3.7×10^{-9}
- New particles (e.g. SUSY) contribute additional Feynman diagrams, increase BR
  - up to 10^{-6}





- 2003 result ($100 pb^{-1}$ of data)
  - Observed 3 events
  - Expect 3.4 ± 0.8 bkg.
  - BR ($B_s \to \mu^+\mu^-$) < 1.6×10^{-6} (90% CL)

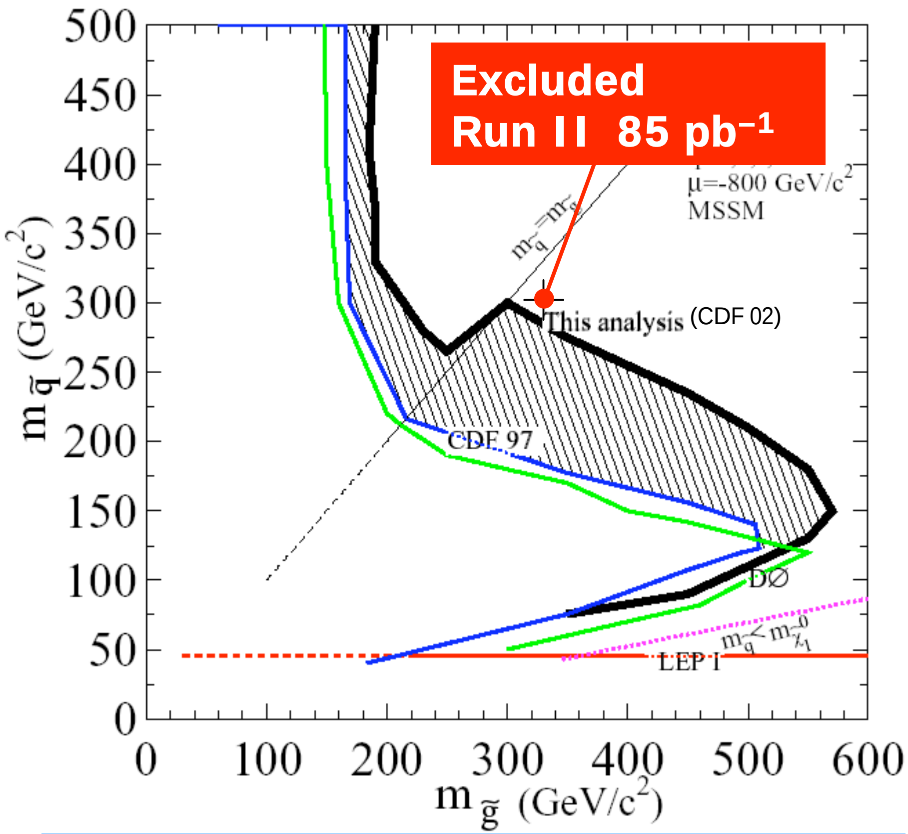
Switched to a blind analysis for summer 2004

Still optimizing cuts; don't want to be biased

Direct supersymmetry searches

At any hadron collider, the most copiously produced super-partners are squarks and gluinos, because they are colored particles

→ Jets + missing E_T signature



New DØ Run II analysis:

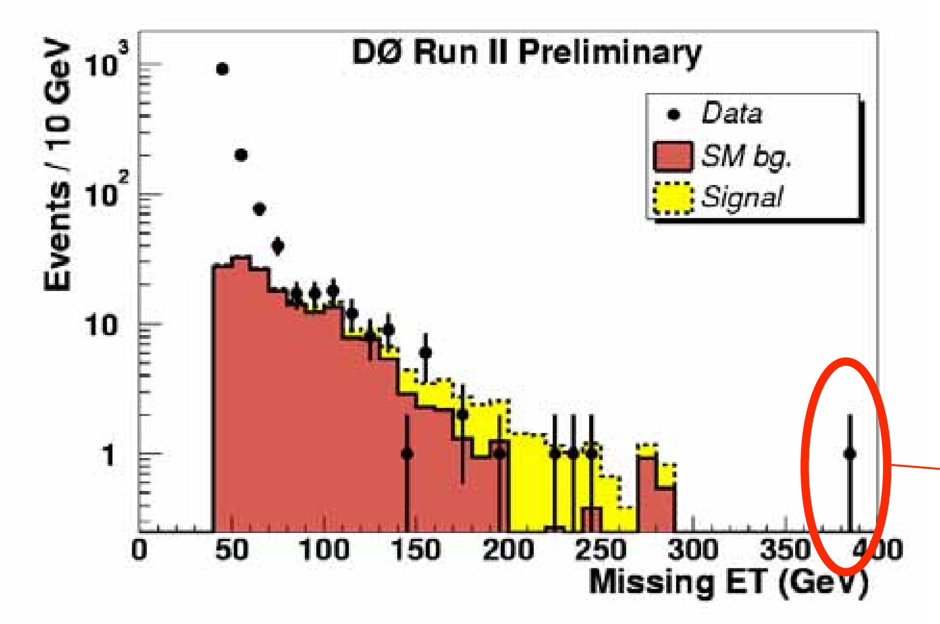
$m_{\tilde{g}}$ **> 333 GeV** for M_0 =25 GeV
cf. 310 GeV in Run I (CDF 2002)

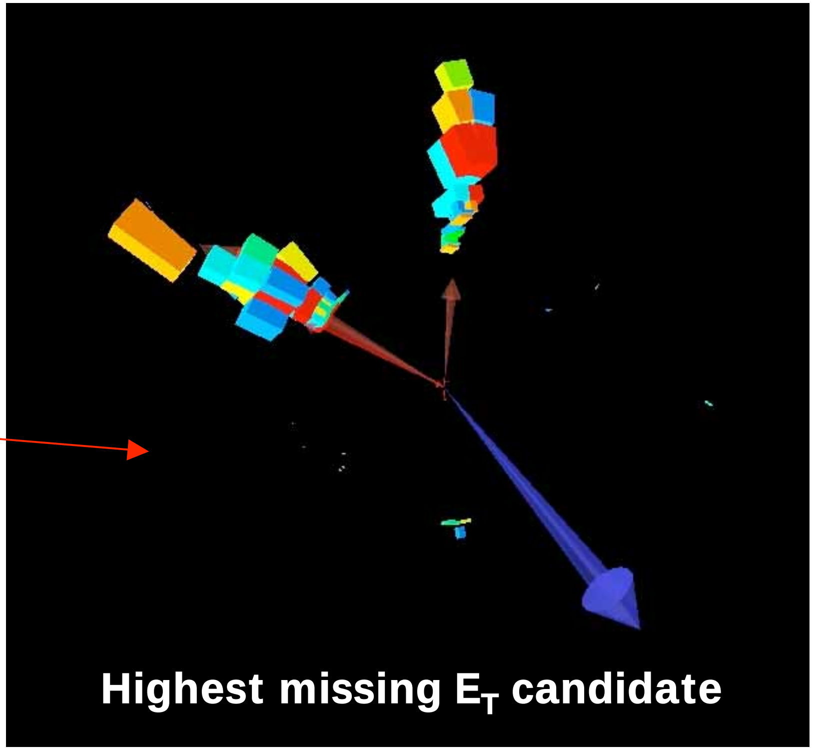
We have entered unexplored territory in terms of sensitivity to new physics

Also …

- Gauge mediated SUSY (photons+ missing E_T)
- Stop searches
- R-parity violating searches …

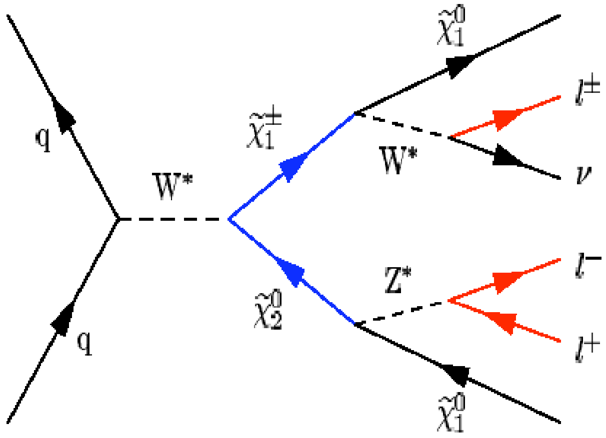
Squark candidate?

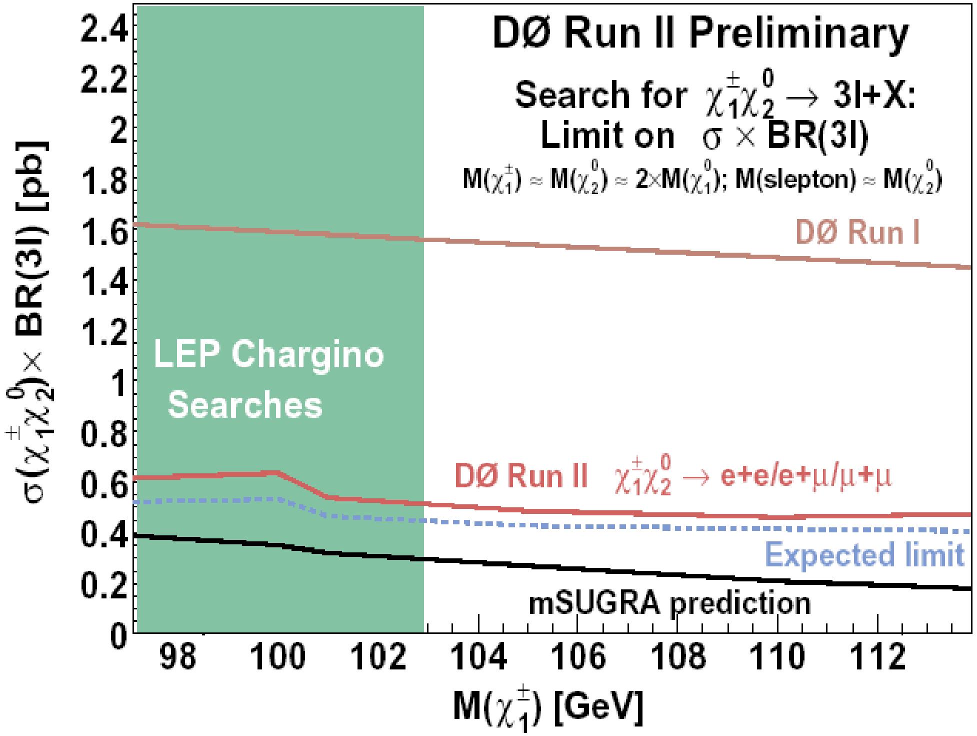




Chargino / neutralino searches

Electroweak production
Charginos + neutralinos
→ dilepton and trilepton signatures

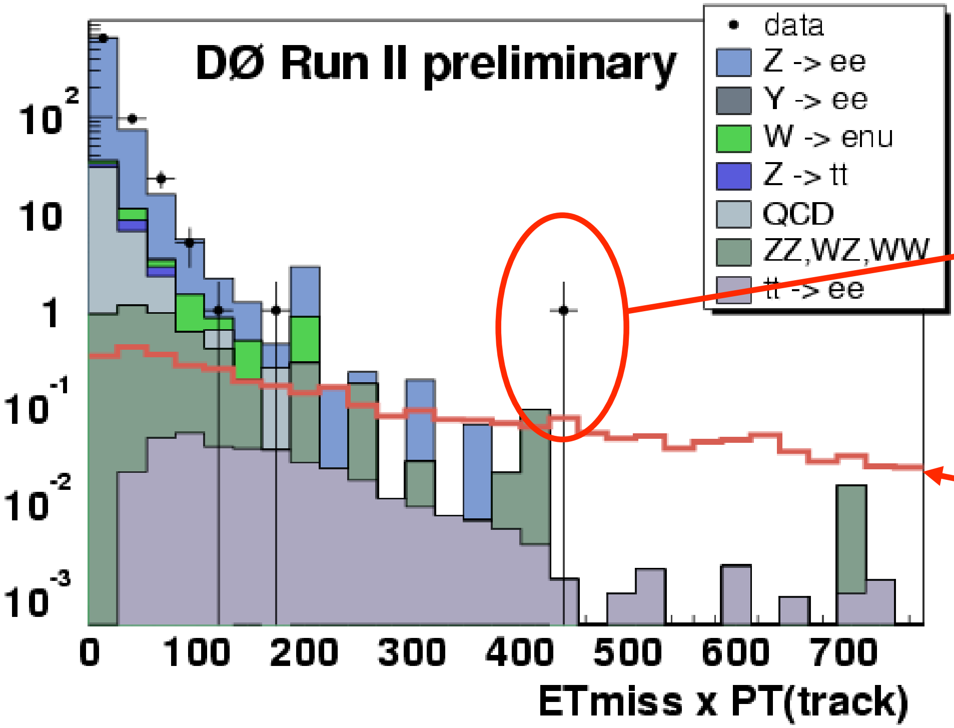




- **Major improvement in sensitivity over Run I**

Things are starting to be fun

- With 250 pb^{-1} in Run II, it is no longer crazy to imagine that new physics may be present in our data at the few event level



1 trilepton candidate event
Expected background fairly small
Expected SUSY signal 1-2 events

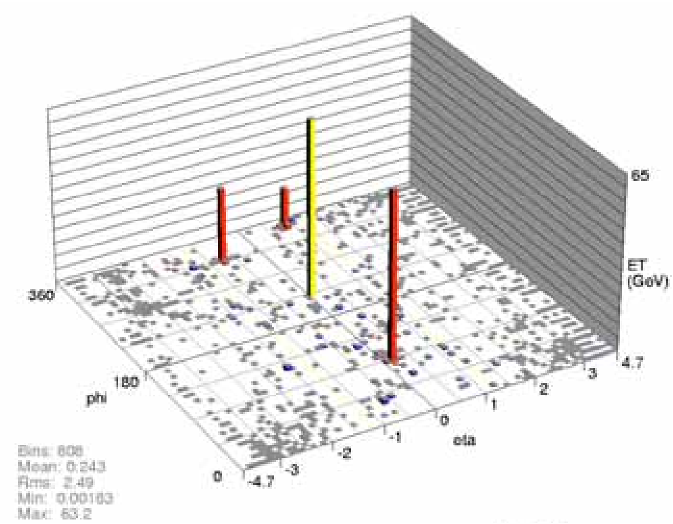
One of our mSUGRA reference points

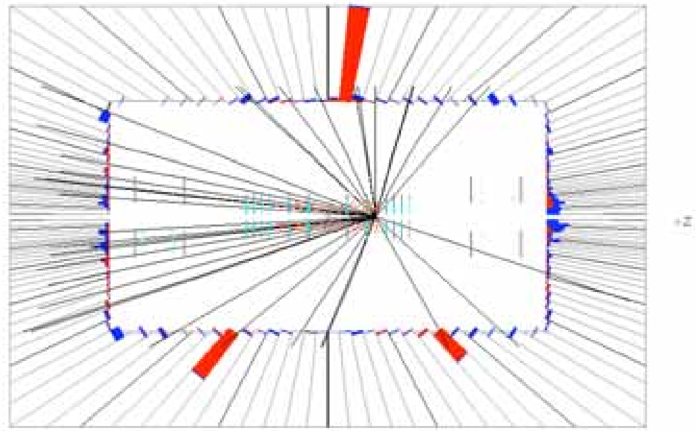
$m_0=76$ $m_{1/2}=170$ $A_0=0$ $\tan\beta=3$ $\mu > 0$
$m(\chi^0_1\ \chi^0_2\ \chi^\pm) = 59,\ 106,\ 101$ GeV

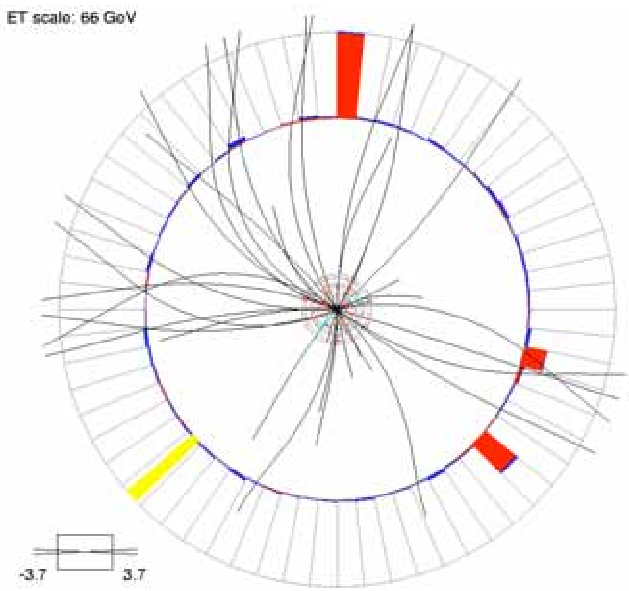
... also find 1 like-sign muon event
Expected background fairly small

John Womersley

... and more fun





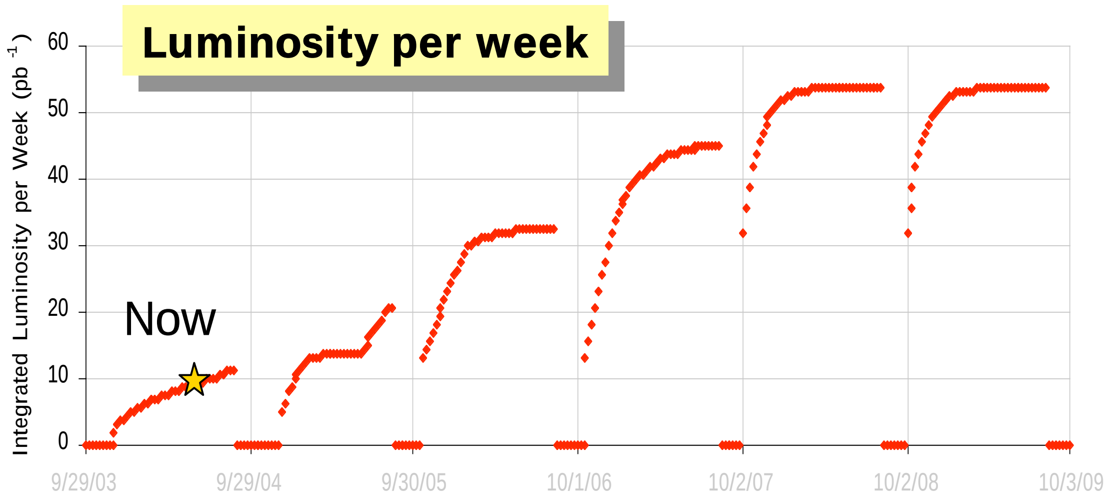


- Search for gauge mediated SUSY found this intriguing $e\gamma\gamma + ME_T$ event
  - Transverse mass of e and ME_T = 68 GeV
    - Consistent with a W
- What is the expected rate of $W\gamma\gamma$ production?

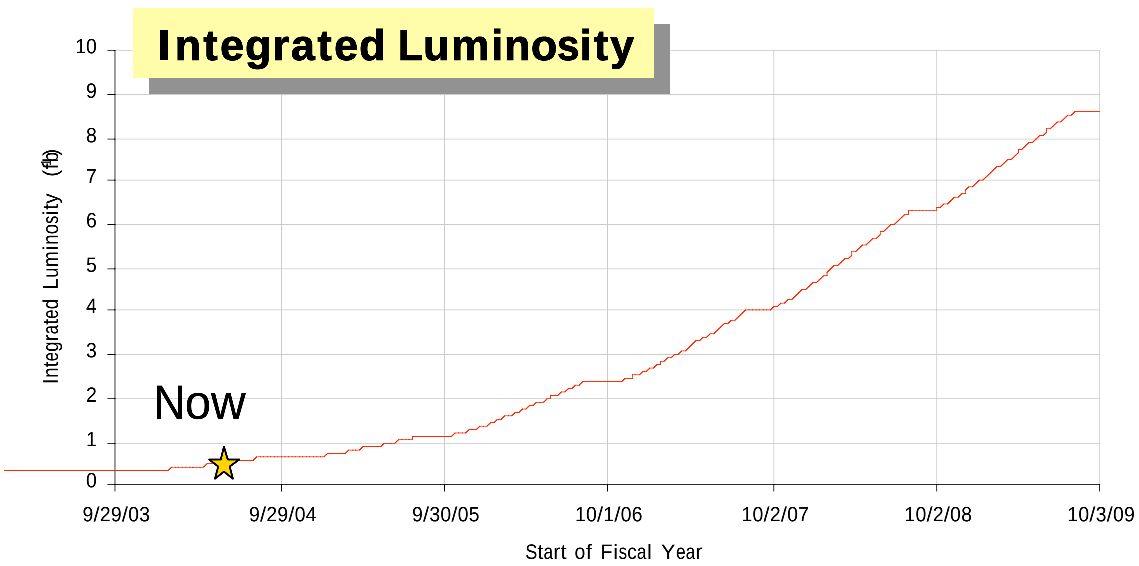
Recall CDF Run I $ee\gamma\gamma + ME_T$ event

Prospects, plans

Tevatron Prospects



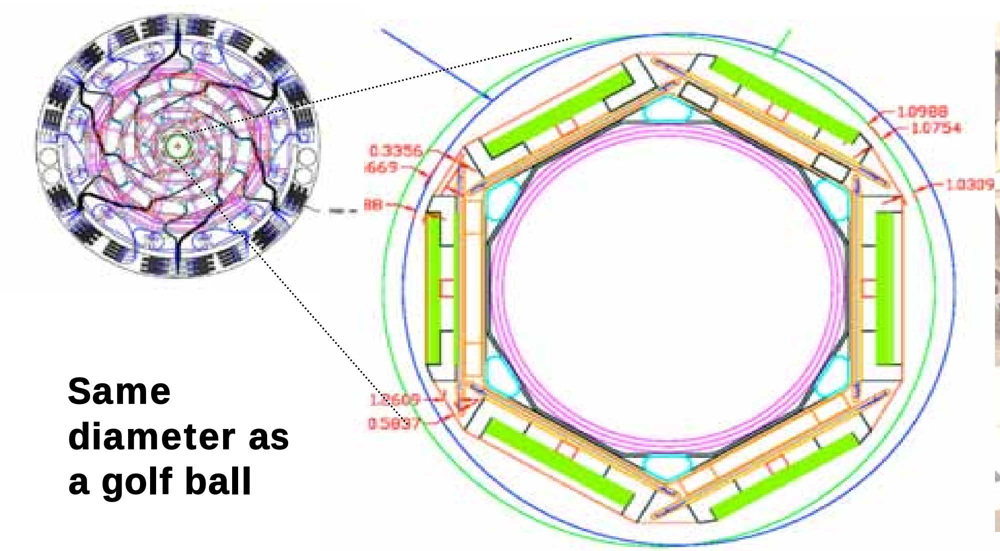
Major improvement will come from increasing the antiproton current: Recycler Ring, with electron cooling
(install summer 2004)



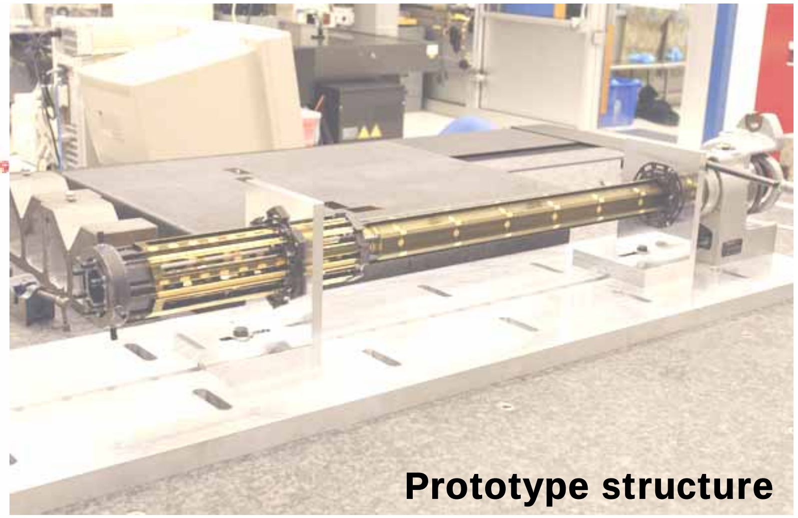
Accumulated Luminosity		
Fiscal Year	Design (fb^{-1})	Base (fb^{-1})
FY03	0.3	0.3
FY04	0.6	0.6
FY05	1.1	0.9
FY06	2.4	1.4
FY07	4.0	2.0
FY08	6.3	3.1
FY09	8.6	4.0

Detector Upgrades

- In light of the financial and luminosity situation, the Fermilab director decided not to proceed with a full silicon detector upgrade
- In order to mitigate concerns over radiation damage and pattern recognition in DØ, we are constructing a new Silicon Layer 0
  - Fits inside the existing detector
  - Adds an additional radiation-hard tracking layer



Same diameter as a golf ball



Prototype structure

- Also upgrades to Calorimeter and Track triggers

On track for installation of both silicon and trigger in Summer 2005

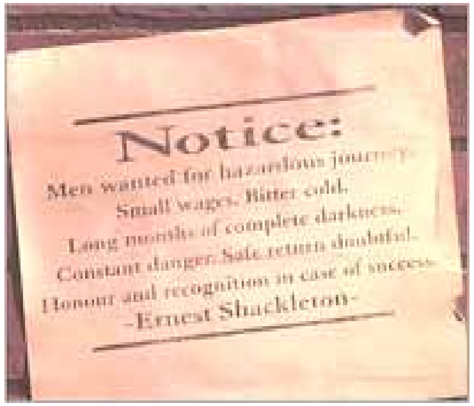
Conclusions

- The Run II physics program is unmatched in breadth and importance
- This physics program is based on the detailed understanding of Standard Model particles and forces that we have obtained over the last few decades
- Based on that understanding we can contribute to some very big questions about the universe

  For example
  - What is the cosmic dark matter? (Supersymmetry?)
  - Is the universe filled with energy? (Higgs?)
  - What is the structure of spacetime? (Extra dimensions?)

  The Tevatron is in the only facility in operation that can do this

- **The DØ detector is working well and the collaboration is enthusiastic**
- **We have entered unexplored territory — who knows what we will find!**



QUANTUM UNIVERSE

THE REVOLUTION IN 21ST CENTURY PARTICLE PHYSICS

DOE / NSF

HIGH ENERGY PHYSICS ADVISORY PANEL

QUANTUM UNIVERSE COMMITTEE

From the charge

Ray Orbach and Michael Turner, October 2003

- Recent scientific discoveries at the energy frontier and in the far reaches of the universe have redefined the scientific landscape for cosmology, astrophysics and high energy physics, and revealed new and compelling mysteries.

- We are writing to ask the High Energy Physics Advisory Panel (HEPAP) to take the lead in producing a report which will illuminate the issues, and provide the funding and science policy agencies with a clear picture of the connected, complementary experimental approaches to the truly exciting scientific questions of this century.

- This report is the opportunity to describe why this is the most exciting time in particle physics in over a half a century, if not much longer.

The Quantum Universe Committee

- Andreas Albrecht (UC Davis)
- Sam Aronson (BNL)
- Jon Bagger (Johns Hopkins)
- Keith Baker (Hampton)
- Neil Calder (SLAC)
- Persis Drell (SLAC)
- Evalyn Gates (Chicago)
- Fred Gilman (CMU)
- Judy Jackson (FNAL)
- Steve Kahn (SLAC)
- Rocky Kolb (FNAL)
- Joe Lykken (FNAL)
- Hitoshi Murayama (Berkeley)
- Hamish Robertson (Washington)
- Jim Siegrist (LBNL)
- Simon Swordy (Chicago)
- John Womersley (FNAL)

Committee very active:

Weekly telephone meetings since mid-October
Trip to Washington in November
Face-to-face meeting at SLAC in January
Numerous drafts
Report discussed and presented to HEPAP April 2004

Input from our “customers”

- November meeting in Washington with representatives of the funding agencies, OMB and OSTP
- What we heard:
  - Lead with the science!
  - We see a large array of tools that are seemingly unconnected.
    - “Why can’t we discover the Higgs with Icecube?”
  - Articulate the questions that are driving the field
    - give a roadmap:
    - how will we answer these questions
    - what is the toolkit?
  - Show how scientific questions map onto experimental space
    - How are the different tools connected?
- We took this input very seriously in crafting the report
- Document is “layered”
  - Repetition of ideas with increasing technical detail
  - Executive Summary is a stand-alone document

Physics Questions

We came up with nine physics questions

<u>Einstein's Dream of Unified Forces</u>

1. **Are there undiscovered principles of nature: new symmetries, new physical laws?**
   ... supersymmetry ...

2. **How can we solve the mystery of dark energy?**
   ... and how is it related to the Higgs field?

3. **Are there extra dimensions of space?**

4. **Do all the forces become one?**
   ... grand unification...

The Particle World

5. **Why are there so many kinds of particles?**
   Why are there three families, why do their masses and mixings exhibit the patterns and variations that we see?

6. **What is dark matter? How can we make it in the laboratory?**

7. **What are neutrinos telling us?**

The Birth of the Universe

8. **How did the universe come to be?**
   inflation, phase transitions ...

9. **What happened to the antimatter?**

... we then talk about the tools needed to answer these questions

- **map the questions on to a list of experiments and facilities**

Primary US Physics Program of Major Facilities

	Tevatron	LHC	Linear Collider	NuMI / MINOS	ν Superbeams	BaBar	BTeV	JDEM	RHIC	Proton Decay
Undiscovered Principles? 1	X	X	X			X	X			
Dark Energy? 2		X	X					X		
Extra Dimensions? 3		X	X							
Unified Forces? 4			X							X
Why So Many Particles? 5	X					X	X			
Dark Matter? 6			X					X		
Neutrinos? 7				X	X					
Origin of Universe? 8		X							X	
Antimatter? 9					X	X	X			

Primary US Physics Program of Selected Smaller Facilities

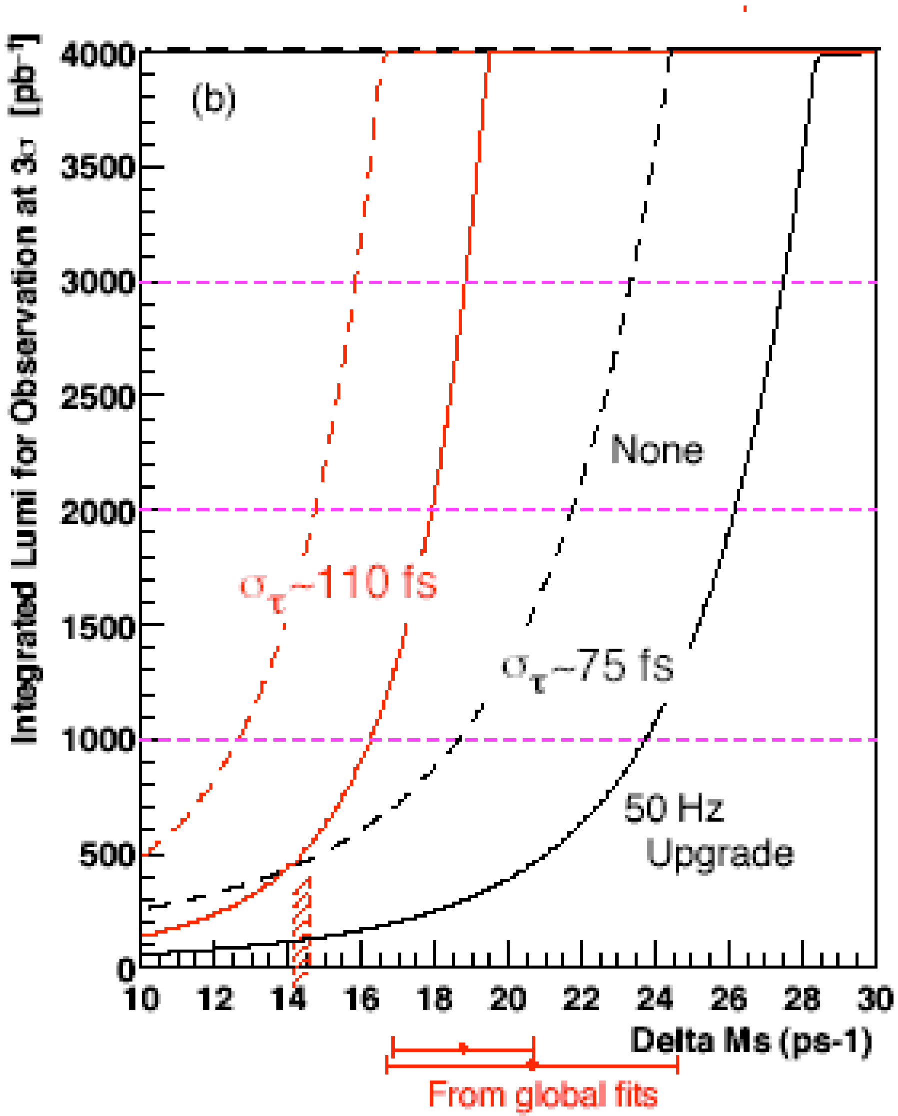
	Mini-BooNE	MECO	Reactor ν Experiments	CLEO-c	KOP10	Neutrinoless Dbl Beta Decay	SDSS	LSST	Undrgrnd Dark Matter Expts	WMAP	CMB Polarization	Lattice Computational Facilities	Precision Gravity
Undiscovered Principles? 1		X											
Dark Energy? 2								X		X			
Extra Dimensions? 3													X
Unified Forces? 4						X							
Why So Many Particles? 5		X		X								X	
Dark Matter? 6							X	X	X	X			
Neutrinos? 7	X		X			X							
Origin of Universe? 8										X	X	X	
Antimatter? 9					X								

Summary

- The report was requested by the US agencies and so it focuses on the US experimental program
  - but the science questions are of course universal

- We hope you find the report, and the ideas it contains, useful when you try to explain what we in high energy physics are doing, and why

- Your feedback is most welcome!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3500
3000
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None
σ_τ~110 fs
σ_τ~75 fs
50 Hz
Upgrade
10
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Delta Ms (ps-1)
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