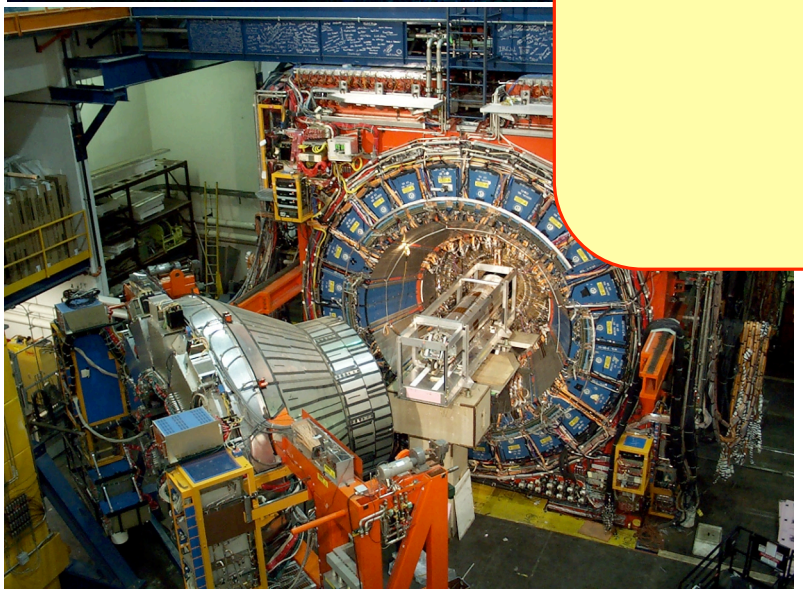
CDF UK



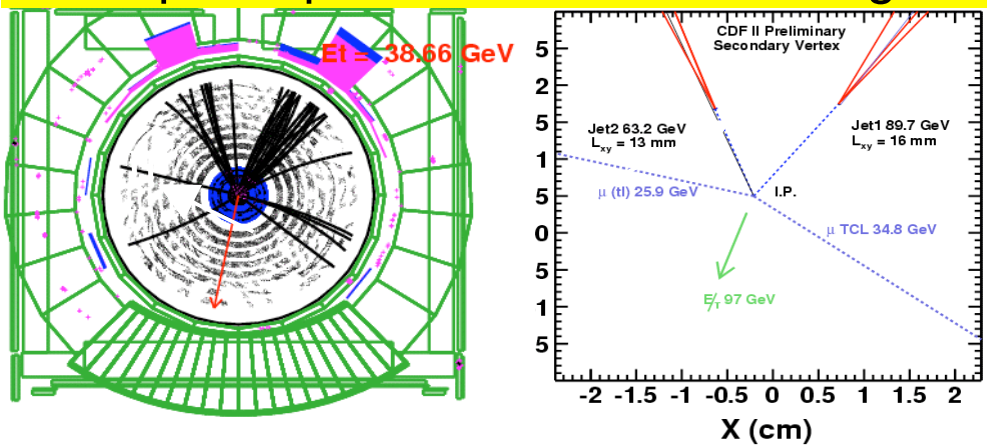
PPGP : April 20th 2004

David Waters

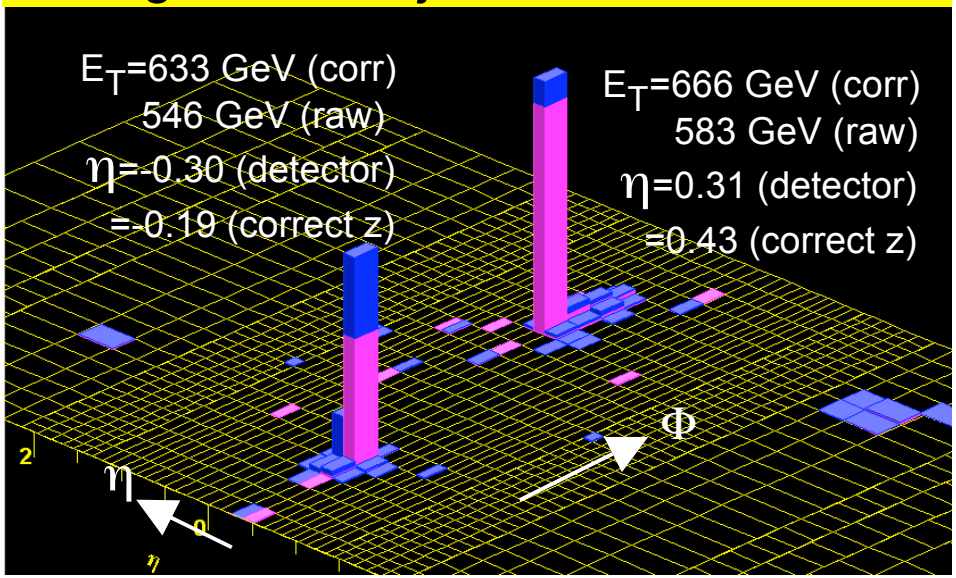
Glasgow
Liverpool
Oxford
UCL

CDF Experiment

Top di-lepton event with two b-tags



High mass di-jet event: 1364 GeV



New for Run 2

- **Tracking**
  - Intermediate silicon layers (ISL)
  - Silicon Vertex detector (SVX II)
  - Central Outer tracker (COT)
- Scintillating tile **forward calorimeter**
- Intermediate **muon** detectors
- **Time-Of-Flight** system
- Front-end **electronics**
- **Trigger** System (pipelined)
- **DAQ** system

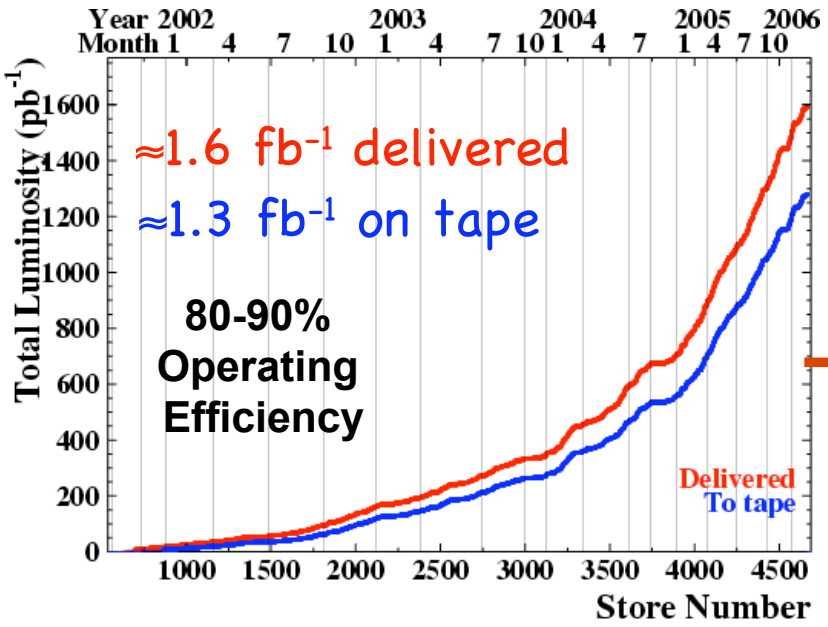
Final Upgrades Completed

- Central pre-shower detector; EM timing; various DAQ upgrades

Retained from Run 1

- Solenoidal magnet (1.4 T)
- Central Calorimeters
- Central Muon Detectors

Luminosity

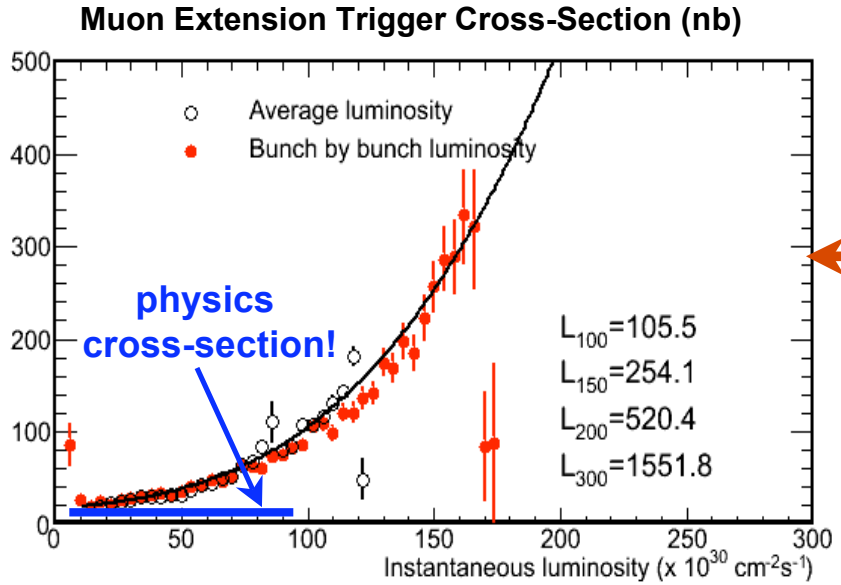


Large *Integrated* Luminosities

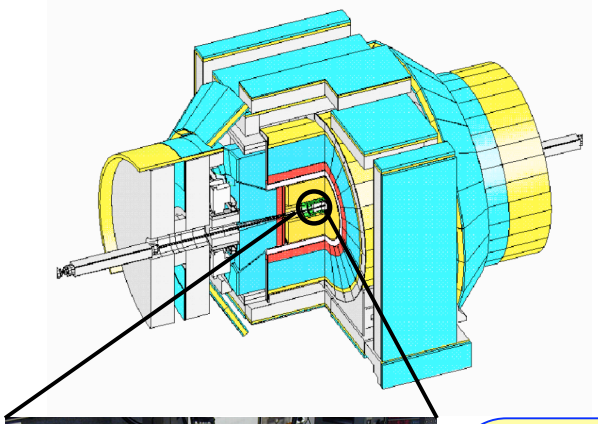
- Ageing of central drift chamber resolved & reversed.
- Silicon lifetime : projections indicate we will maintain excellent coverage, beam incidents aside.

Large *Instantaneous* Luminosities

- Record for hadron collider ~1.8E32 cm^{-2}s^{-1}
- At these luminosities we have ~ 5-6 overlapping min-bias events / bunch-crossing.
- Some trigger cross-sections are growing out of control.
- Trigger deadtime at high *L* has been the main challenge for the last year.
- Several upgrades are addressing this.



UK Responsibilities



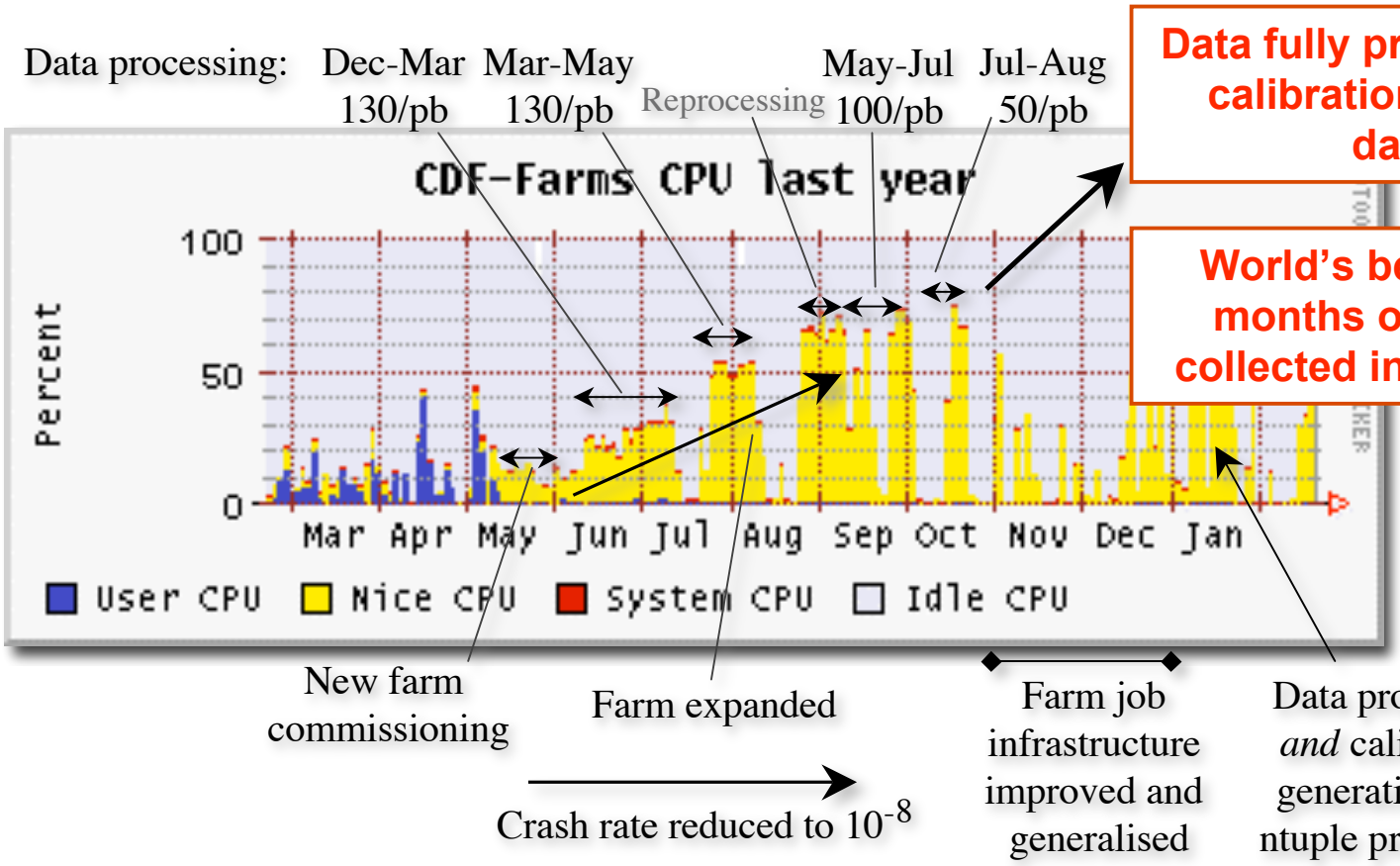
L00 :
Construction
Commissioning
Alignment
Monitoring

2.5 MHz → L1 Trigger
~20 kHz → L2 Trigger
~600 Hz → L3 Trigger
~90 Hz, ~20 MB/s → Offline Reconstruction
~1 PB/yr → Data Handling

Trigger Coordination
Level3 Trigger
Calibration Coordination
Calorimeter Reconstruction & Jet Corrections
Simulation
Data-handling & Grid Computing for CDF

All students and most post-docs serve as **A**ccelerator **C**ontrol **E**xperts - a real taste of a running experiment.

Data Handling @ CDF



Data fully processed with final calibrations 6 weeks after data-taking

World's best M_{TOP} within 4 months of the data being collected in the control room

- UK has provided data-handling convener and offline operations managers.
- Data processing to be performed onsite for the remainder of Run II.
- Monte Carlo production and analysis CPU mainly provided offsite.

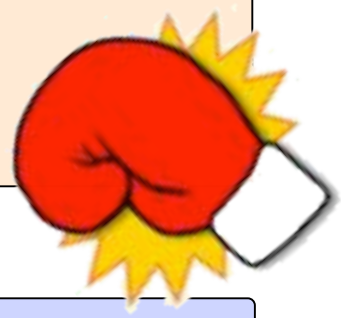
Our Roles in CDF

Physics

- 1 fb^{-1} Analysis Coordinator
- Exotic Physics Group Co-Convener
- Electroweak Physics Co-Convener (×2)
- Subgroup Conveners :
  - Jet Energy Scale & Resolution (×2)
  - W Mass & Width (×2)
  - W/Z Cross-Section
  - Dibosons
  - B Mixing & Lifetime
  - SUSY
  - Photon

Collaboration

- Member of "P5" Committee Taskforce
- DoE PP Data Grid Steering Committee
- Spokesperson Election Committee
- Spokesperson's Paper Reading Group
- Chairman, CDF Statistics Committee
- International Finance Committee
- Speaker's Committee



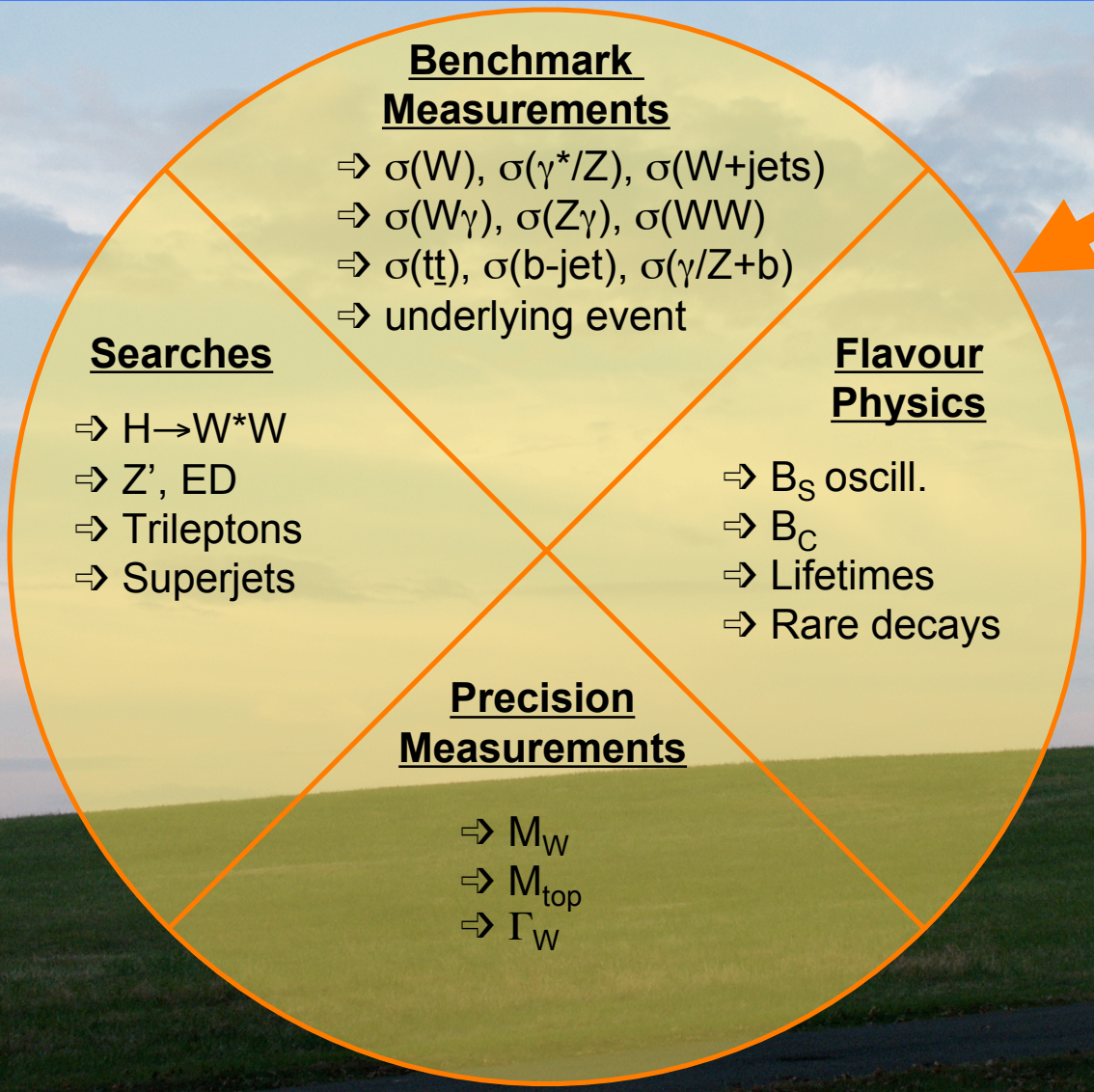
Training Students

- 8 PhD's awarded to UK students during the last 2 years

Operational

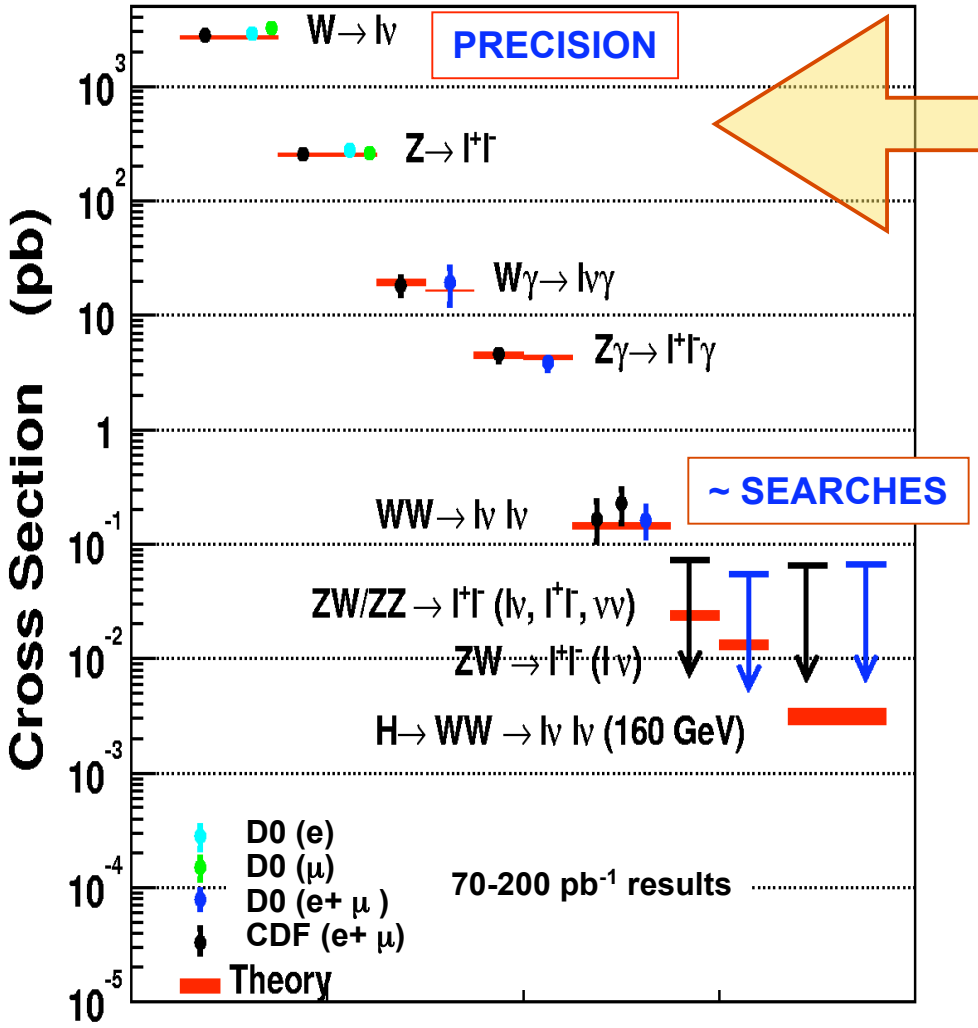
- Trigger Coordinator
- Level-3 Sub-Project Leader
- Database & Data-Handling Co-Leader
- Offline Operations Managers (×2)
- B Monte Carlo Coordinator

Physics @ CDF : Landscape To Date

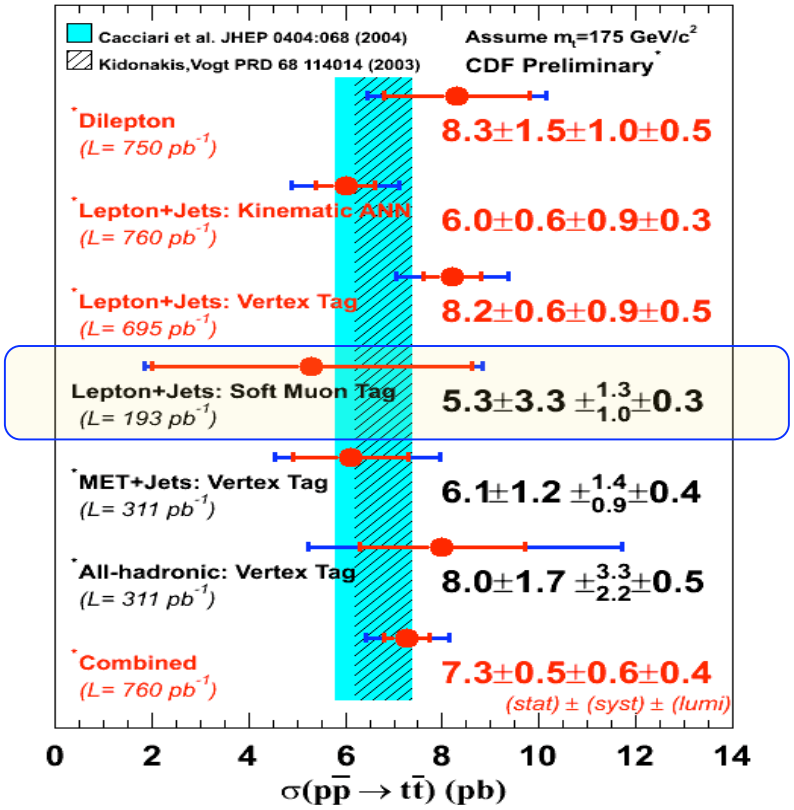


- UK physicists led or played key roles in all of these analyses.
- In addition UK physicists were architects of many of the building blocks:
  - ⇨Jet corrections
  - ⇨CAL reco code
  - ⇨MC tuning
  - ⇨… etc.

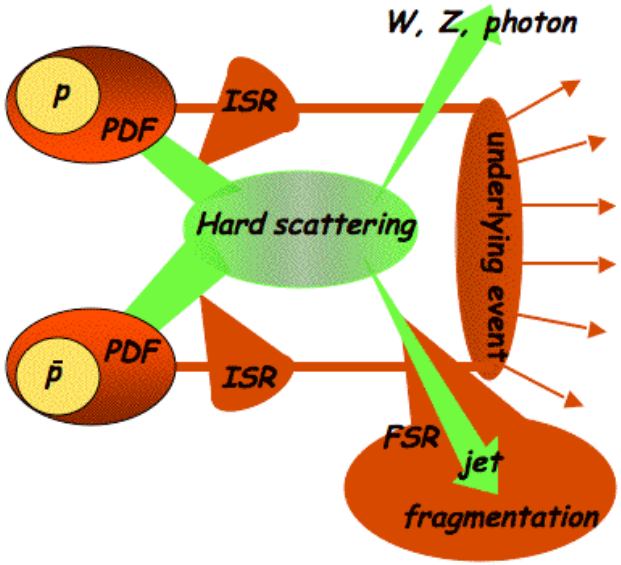
Benchmarks : Cross-Sections



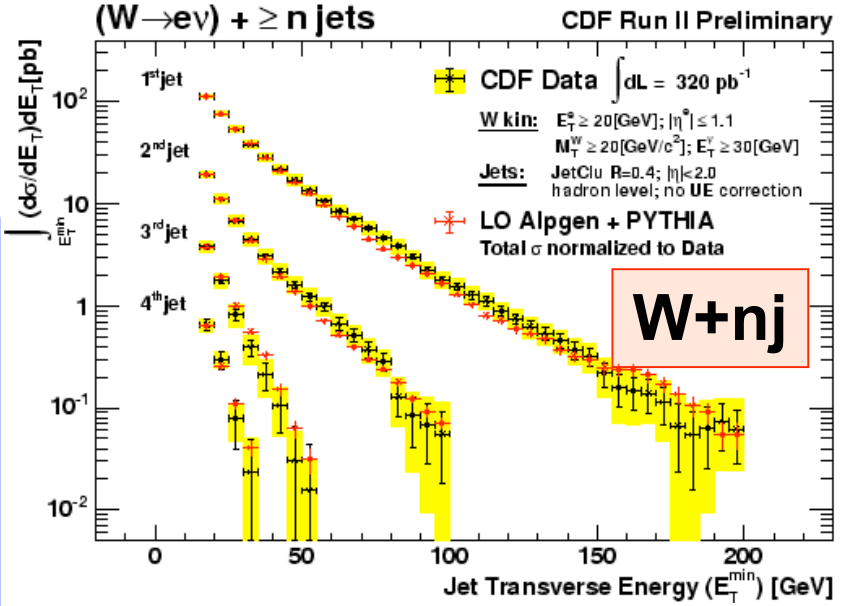
The gold standard that all subsequent analyses are being measured against.

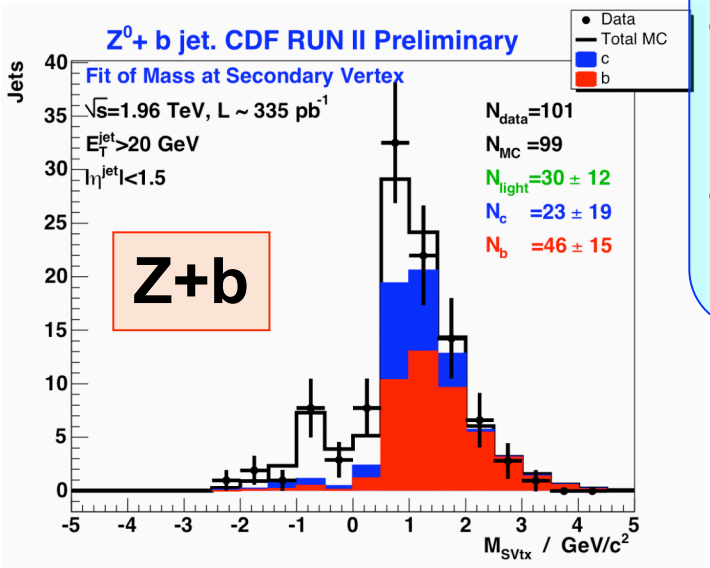


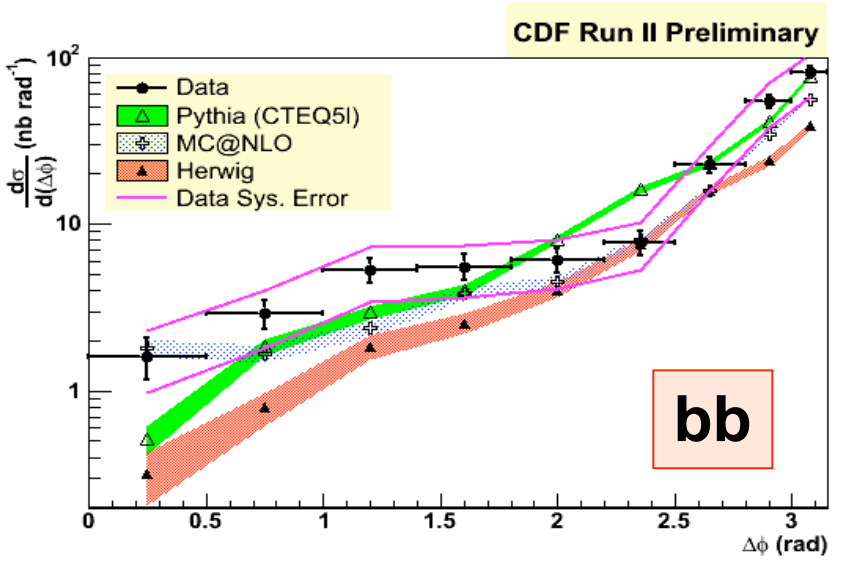
Benchmarks : QCD



- Test QCD cross-sections & event shapes.
- Backgrounds to top & new physics.
- Prepare tools for Higgs searches.
- MC tuning for LHC.

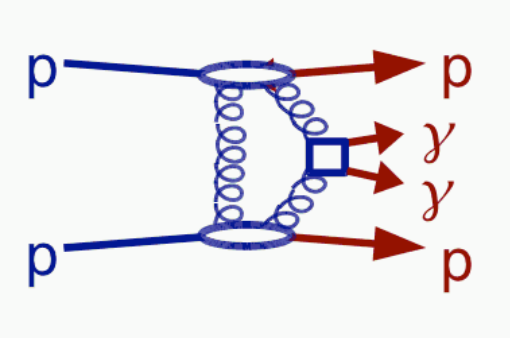


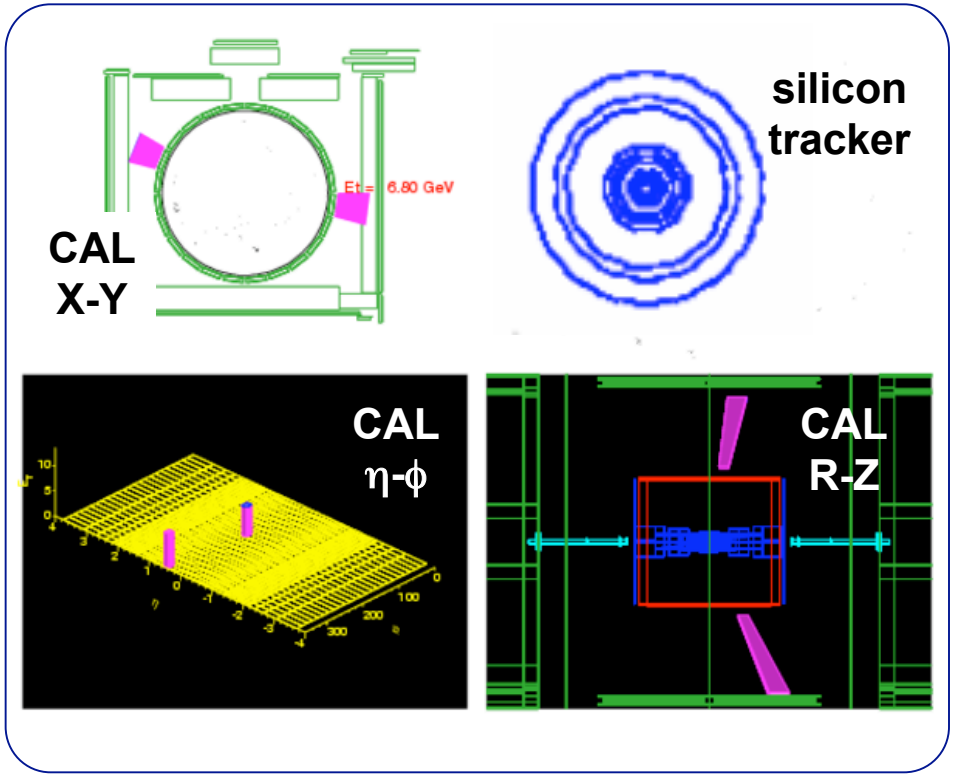




Diffractive Diphoton Cross-Secion

- Testing models for diffractive Higgs production at the LHC (FP420)
- Special trigger implemented.
- Demand exclusivity out to $|\eta|$ ~ 7 using forward detectors.





- 3 events observed against expected background of 0.0-0.2

$$\sigma_{p\bar{p}\to p\bar{p}\gamma\gamma} = 0.14^{+0.14}_{-0.04}\ (\text{stat})\ \pm 0.03\ (\text{syst})\quad \text{pb}$$

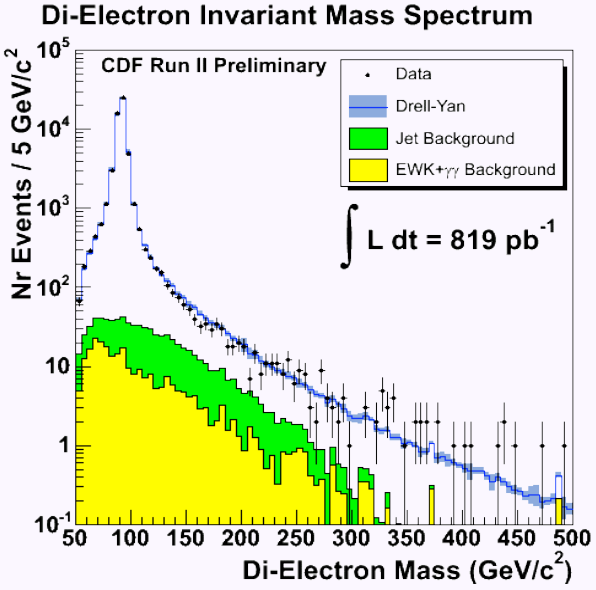
- Compare to theory :

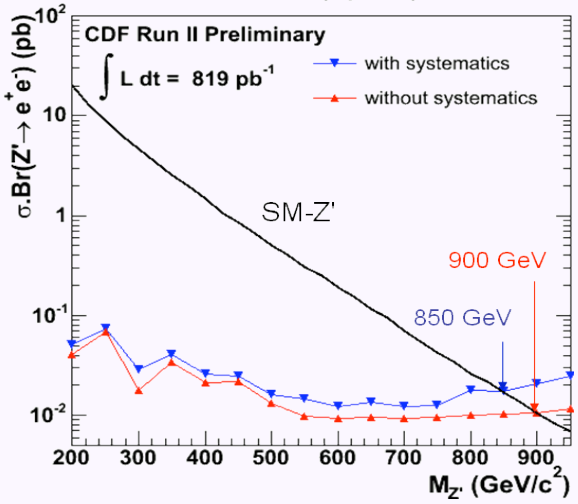
$$\sigma_{KMR} = 0.04 \times /\div (3-5)\quad \text{pb}$$

- Builds on search for exclusive χ_C search pioneered by UK.

Searches

Z'



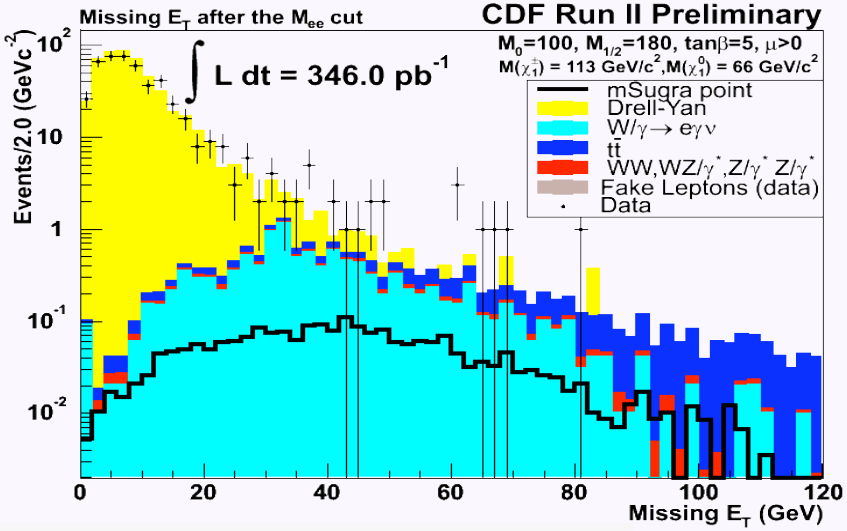


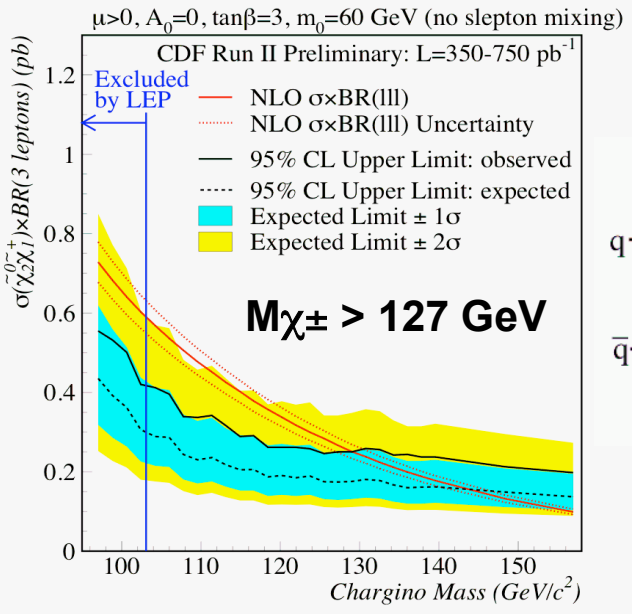
- ED
- GUT
- SUSY
- …
- A first target for LHC

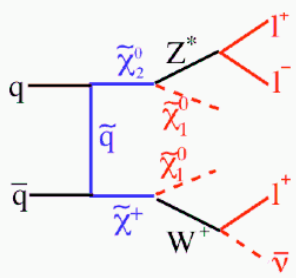
Trileptons

- SUSY

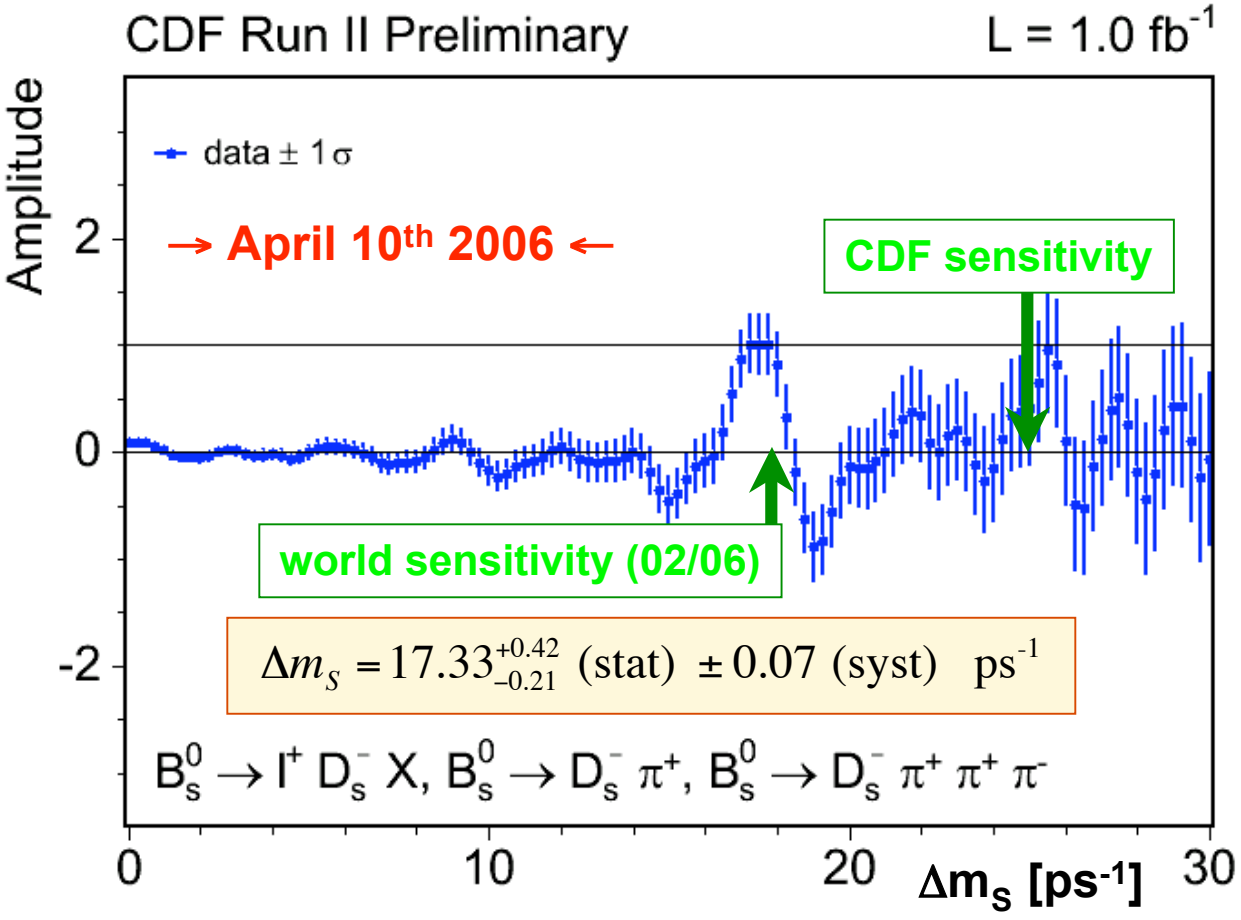
Search for $\chi_2^0\chi_1^\pm \rightarrow ee+l+X$



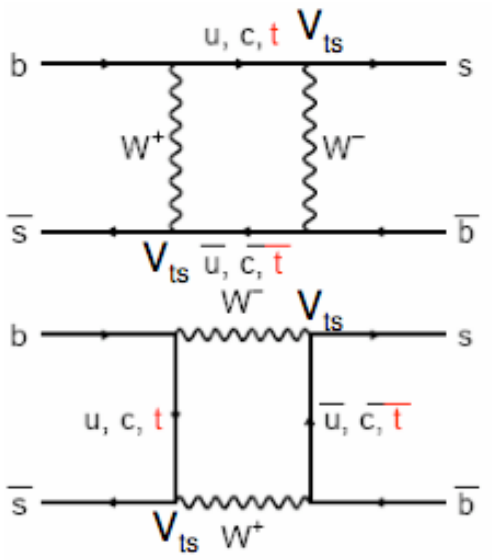




B_s Oscillations



P(fluctuation) = 0.5%

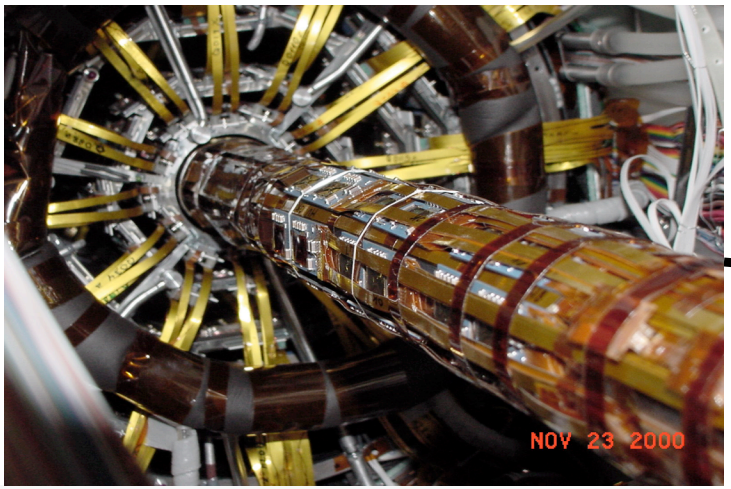


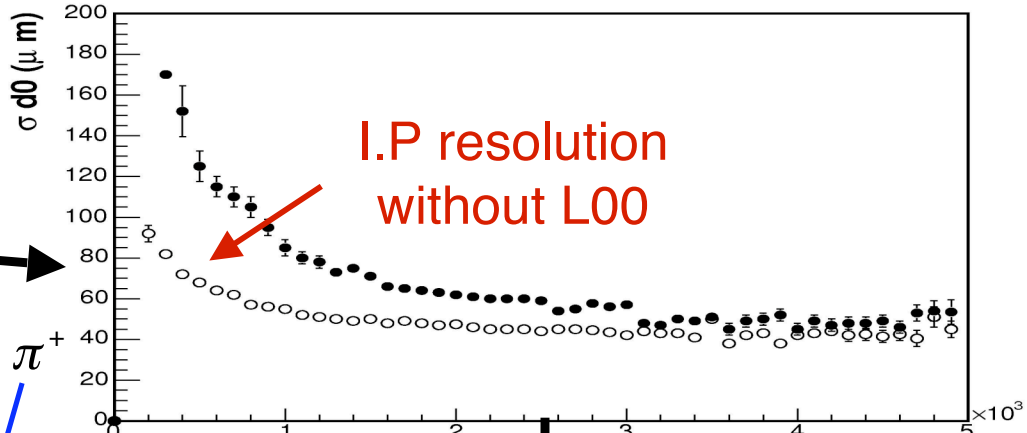
$$\Delta m_S \propto |V_{ts}|^2$$

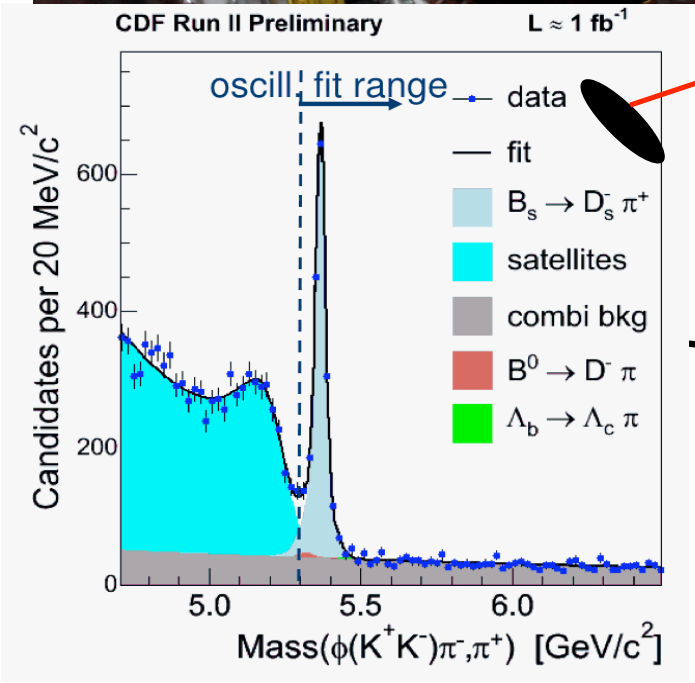
LATTICE → $\frac{|V_{td}|}{|V_{ts}|} = 0.208^{+0.008}_{-0.007}$ (stat. + syst.)

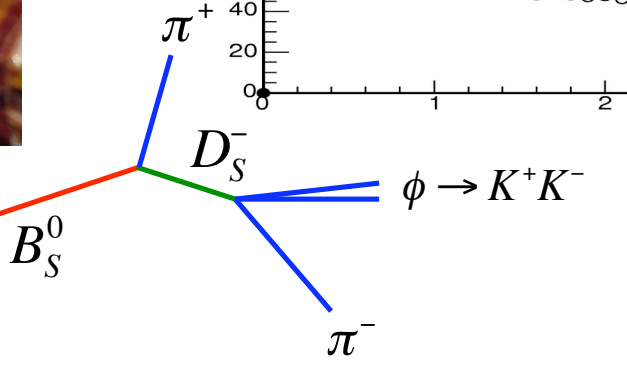
Δm_d →

B_S Oscillations : UK Contributions



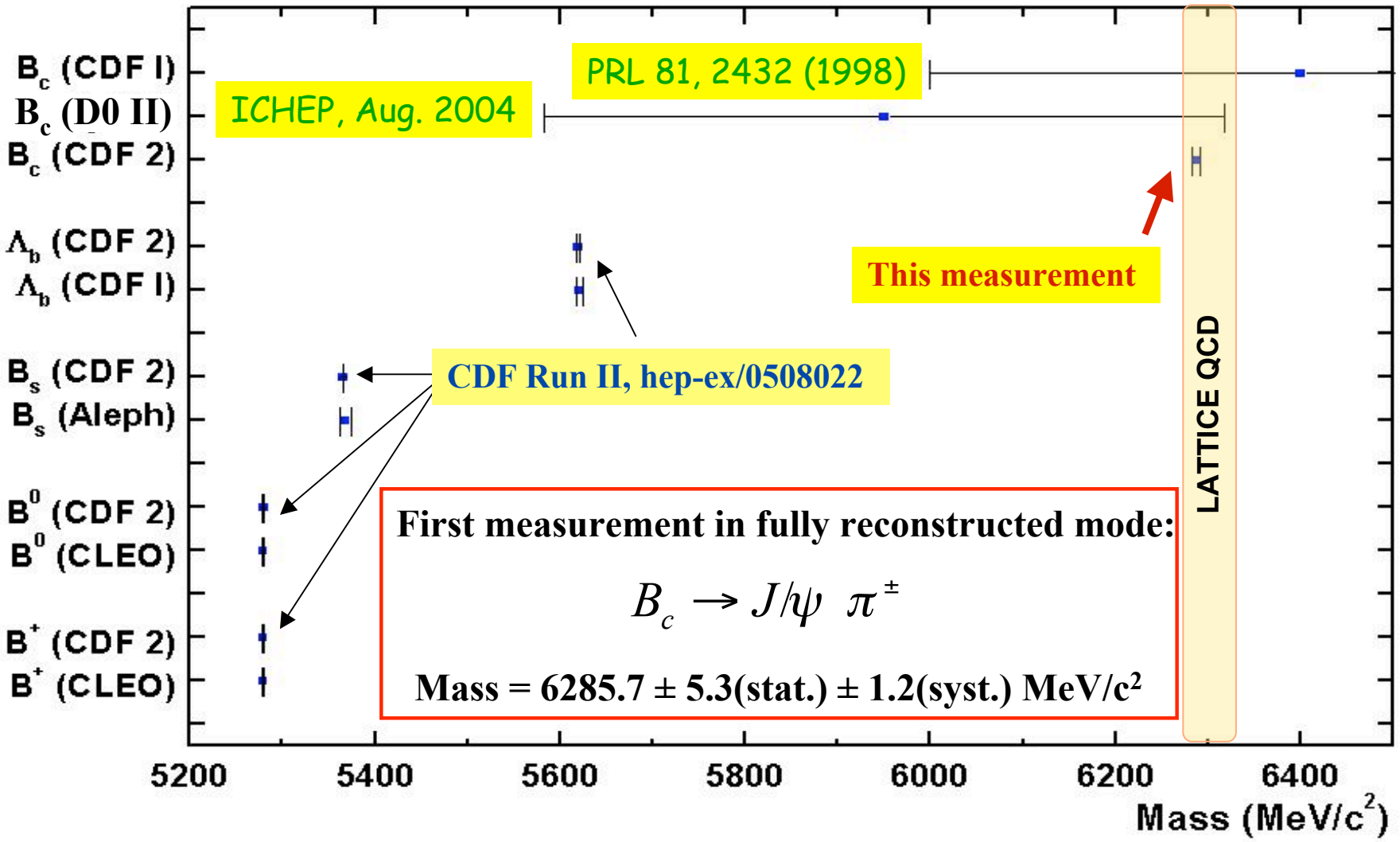






- **Layer-00** : improved impact parameter resolution **increases mixing sensitivity by ~35 %. Equivalent to collecting 80% more data.**
- Evaluation of physics backgrounds.
- B Mixing & Lifetimes Convener

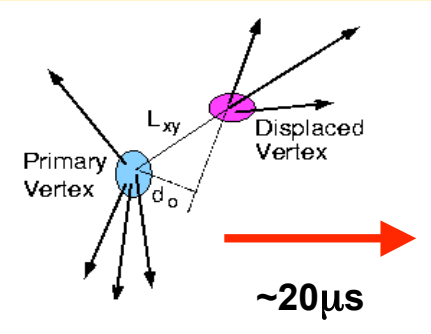
Mass Measurement in $B_c \rightarrow J/\psi\ \pi^{\pm}$

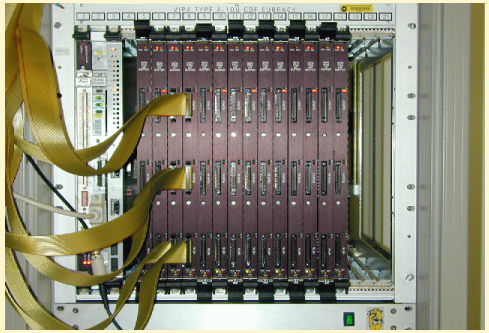


B Physics & CDF

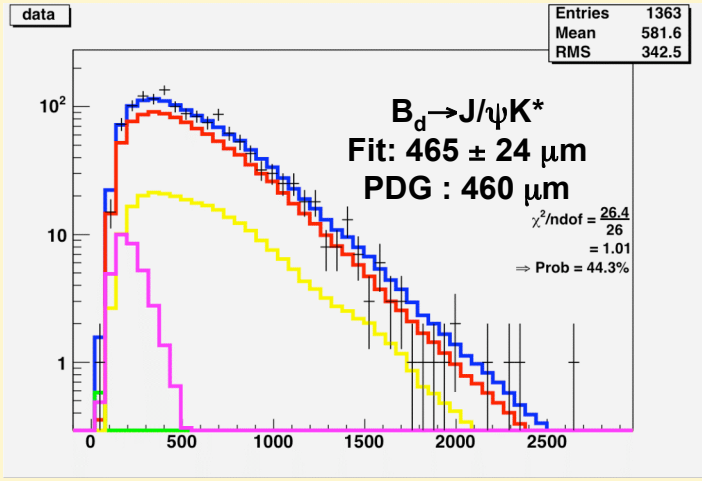
LIFETIMES

- Many measurements already by UK physicists in J/ψ decay modes, e.g. $\Lambda_b \rightarrow J/\psi\Lambda$
- Largest yields accumulated on CDF's **Displaced Track Trigger :**
  - **1 track + lepton : e.g.** $B_s^0 \rightarrow l\,\nu\,D_s^{\pm}$
  - **2 tracks : e.g.** $B_s^0 \rightarrow D_s^{(*)}\pi$





1 yr

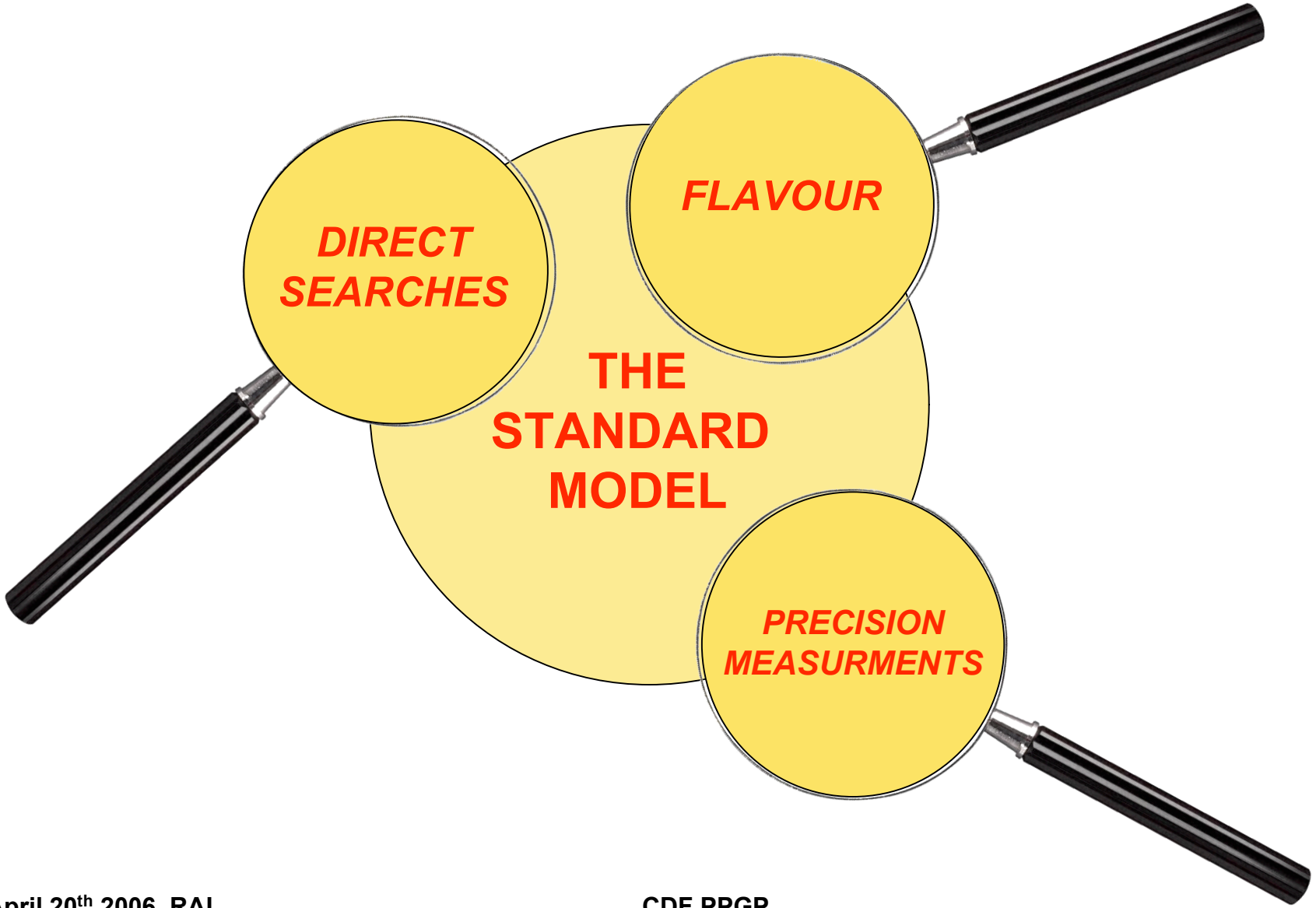


- UK physicists are pioneering new analysis methods for deconvolving trigger bias.
- UK physicists are developing new triggers, e.g. dedicated ϕ trigger (for $B_S \rightarrow \phi\phi$, etc.)

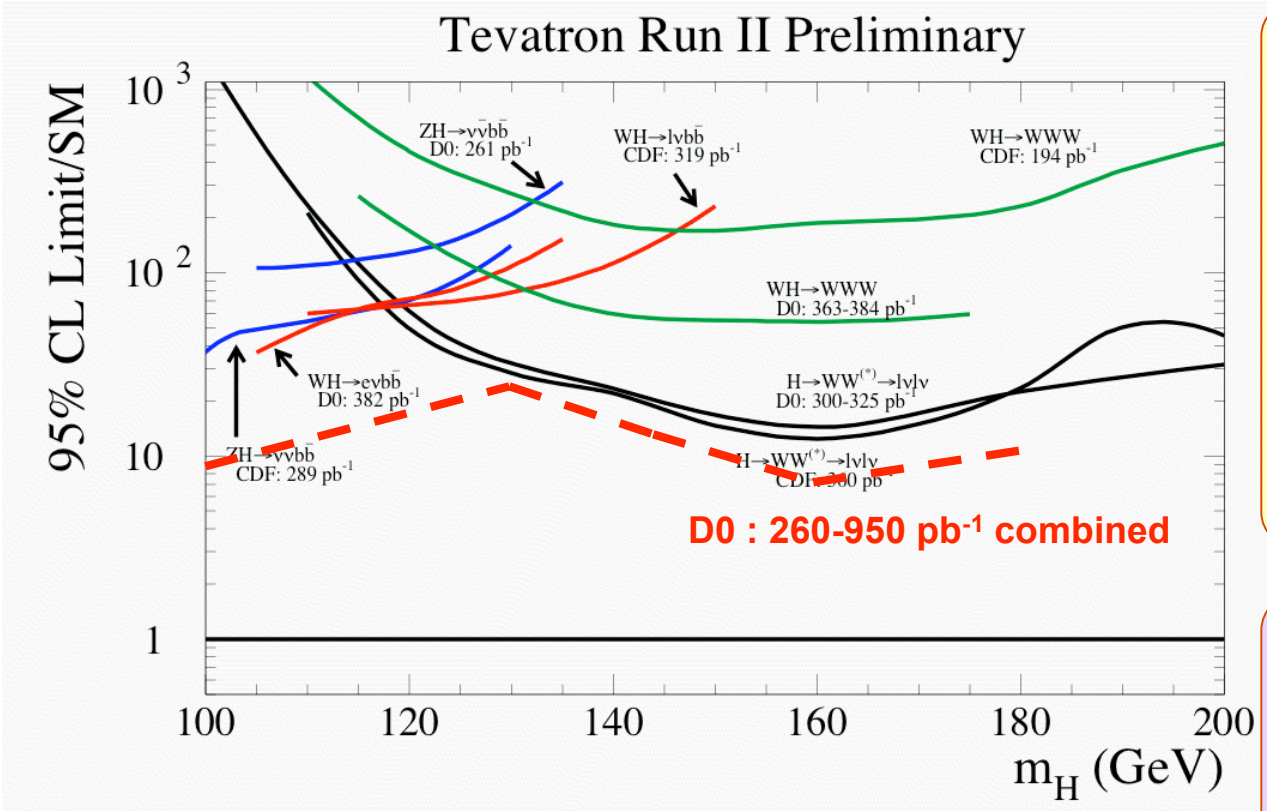
RARE DECAYS

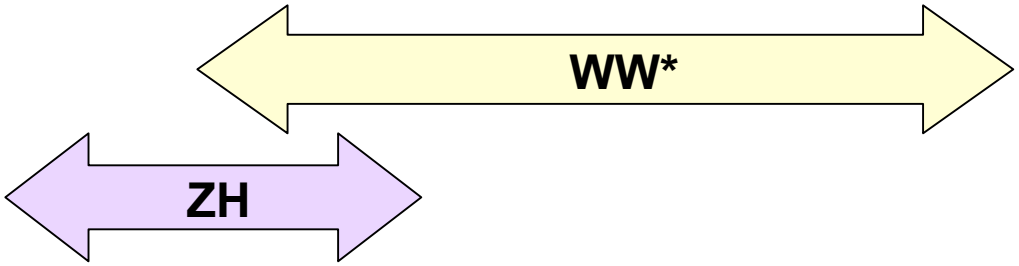
- $B_{s,d} \rightarrow \mu^+\mu^-$: very stringent limits on new physics.
- Searches for $B_S \rightarrow \mu^+\mu^-\phi$, $\Lambda_b \rightarrow \mu^+\mu^-\Lambda$ underway
- $X_b \rightarrow \Upsilon(1S)\pi^+\pi^-$ [sister of X(3872)→ J/ψ $\pi^+\pi^-$]

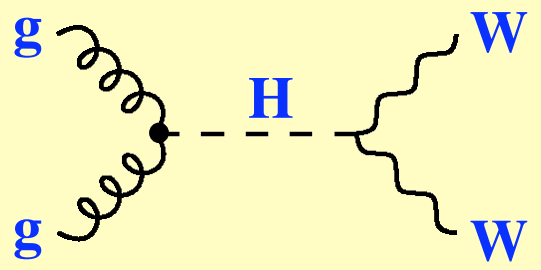
CDF UK Plans


DIRECT SEARCHES
FLAVOUR
THE STANDARD MODEL
PRECISION MEASURMENTS

Future : Higgs Search

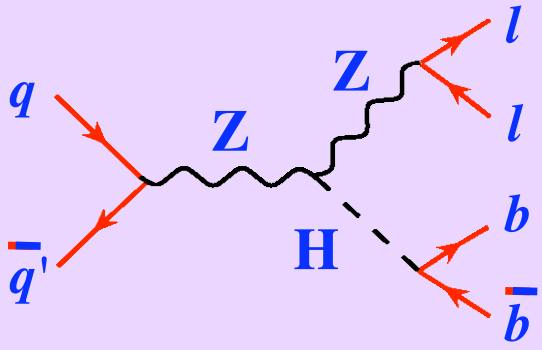






- UK measurement of $p\bar{p}\rightarrow WW$ @ CDF in Run II
- New ideas to increase sensitivity

- UK measurement of Z+b.
- UK leading improvements in dijet mass resolution.



Future : Higgs Search

- What improvements have to made for the Tevatron to say something incisive about the SM Higgs with a few fb^{-1} ?

	Luminosity equivalent=$(S/\sqrt{B})^2$		
Improvement	WH->lvbb	ZH->vvbb	ZH->llbb
mass resolution	1.7	1.7	1.7
Continuous b-tag (NN)	1.5	1.5	1.5
Forward b-tag	1.1	1.1	1.1
Forward leptons	1.3	1.0	1.6
Track-only leptons	1.4	1.0	1.6
NN selection	1.75	1.75	1.0
WH signal in ZH	1.0	2.7	1.0
Product of above	8.9	13.3	7.2
CDF+DØ combination	2.0	2.0	2.0
All combined	17.8	26.6	14.4

Example of work being undertaken by UK physicists.

17% → 12% : proven
12% → 10% : in progress

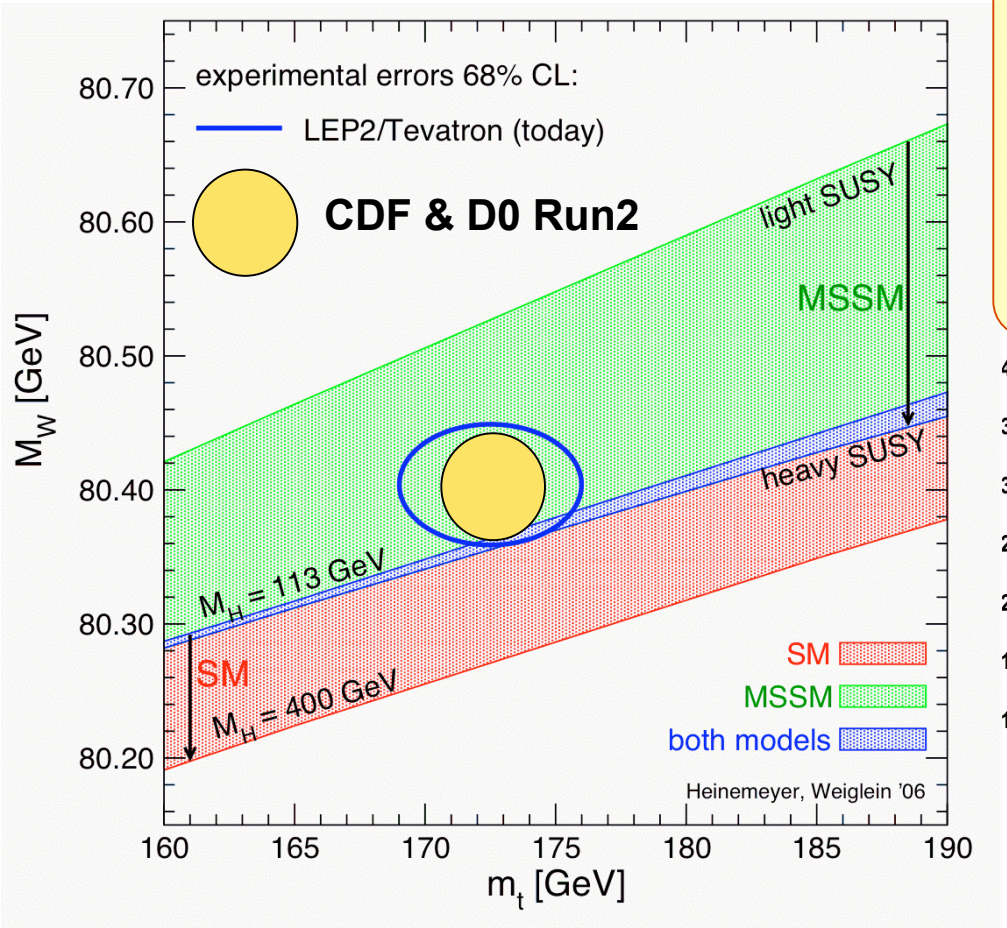
Half of these improvement factors will be in place for Summer '06 results

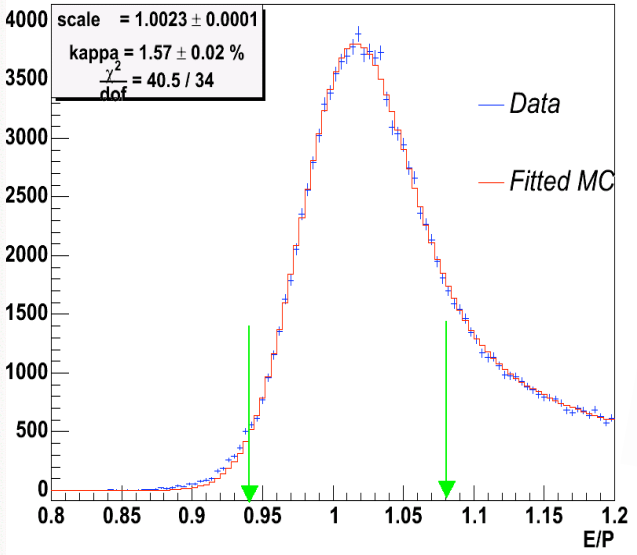
- 95% exclusion of 115 GeV Higgs with 2.5 fb^{-1} (median experiment, no Higgs!)

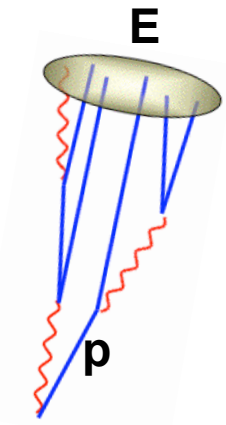
Future : W Mass

New CDF M_{TOP} combination :
172.4 ± 2.6 GeV (750 pb^{-1})
[TDR : 3 GeV for 2 fb^{-1}]

- Constraining power on **M_H :**
  $\Delta(M_{TOP})\approx 1.5$ GeV : $\Delta(M_W)\approx 10$ MeV
  O(1%) on M_{TOP} : (0.01%) on M_W
- Requires exquisite understanding of energy & momentum scales, non-linearities and energy loss mechanism.
- Skill set is concentrated in UK :
  - 3 past & current EWK conveners
  - Involved in first Run II M_W measurement.
  - Is performing Run II Γ_W measurement.







Future : B Physics

B_S Oscillations & Lifetime :

- Turn the B_S oscillations measurement into a >5-σ determination with $\delta^{EXP} << \delta^{THE}$ ($|V_{td}|/|V_{ts}|$)
  - Addition of more data
  - Inclusion of additional modes
  - Improvements to vertex resolution (L00 hit efficiency)
- Put the **B_S** under the microscope :
  - Lifetimes in different channels
  - $\Delta\Gamma/\Gamma$ using different decay modes
  - Searches for significant CP violation (BSM)

Rare Decays :

$B^+ \to \mu^+\mu^- K^+$

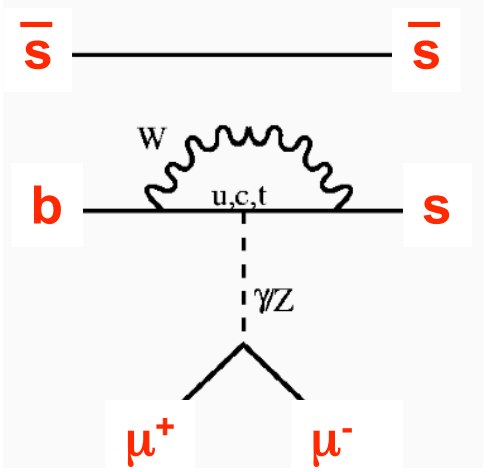
$B^0 \to \mu^+\mu^- K^*$

$B_S \to \mu^+\mu^- \phi$

$\Lambda_b \to \mu^+\mu^- \Lambda$

e.g. FCNC processes can be enhanced by new physics.

- $BR(B_S \to \mu^+\mu^-\phi) = 16.1 \times 10^{-7}$ in SM.
- First 3σ evidence with 1 fb^{-1} ?



Conclusions

- The Tevatron collider & CDF are performing at or beyond expectations.
- UK physicists have played a crucial role in many of the benchmark measurements upon which we are now building.
- We have developed a focused plan for the remainder of Run II, building on unique strengths of the Tevatron and commensurate with our skills & manpower levels :
  - ⇨ Searches for the Higgs Boson

    Light SM & BSM Higgs discovery a real possibility with large integrated luminosities
  - ⇨ B_S Physics & Rare Decay Searches

    Proven & unique strength of the Tevatron
  - ⇨ Precision W Mass & Width Measurements

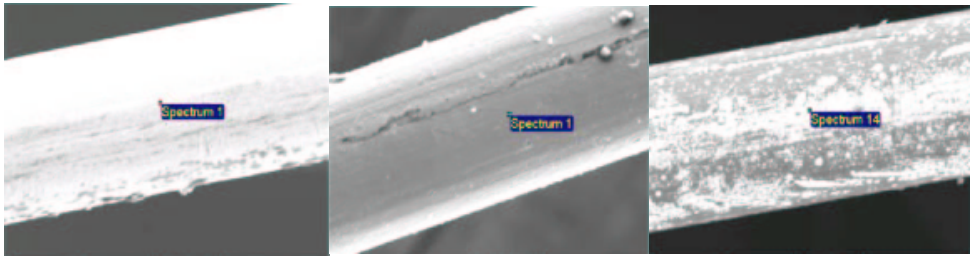
    Key measurements well into the LHC era
- Continues to be a great training ground for a generation of pre-LHC students & post-docs.
- Groups are planning a managed transition to the LHC, but remaining responsive to any surprises at the Tevatron.

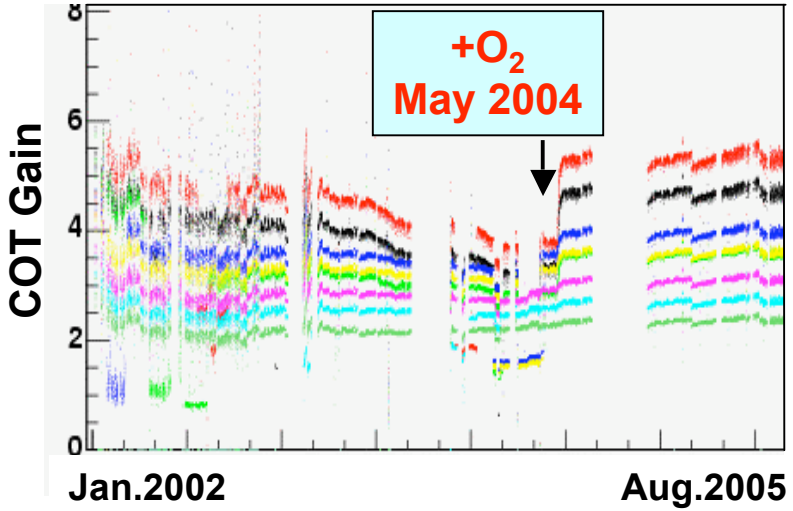
BACKUP

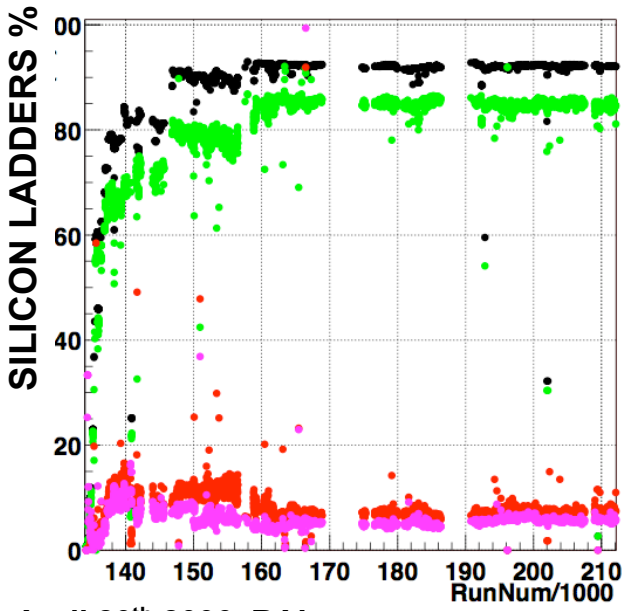
CDF Status

- **C**entral **O**uter **T**racker aging. A whiff of oxygen (air into the gas) did the trick.

NEW WIRE | AGED WIRE | REVERSE AGED







92% operating

86% good data

- **Silicon Tracker** :
  - Stable operations
  - Most early failure modes (e.g. wire bond resonances) no longer a serious issue.
  - Coverage still adequate for both offline tracking & secondary vertex triggering.
  - Beam incidents remain the biggest threat. Mitigating action already taken.
  - Disasters aside, excellent prospects for silicon coverage to remain very high for remainder of Run II.

People

Glasgow: P.Bussey, R.StDenis, Burgon-Lyon, S.D'Auria, A.Robson, S.Thompson

Farrington, Unverhau, Nicolas, Davies

Liverpool: B.Heinemann, T. Berry, M.Houlden, G.Manca, R.McNulty, A.Mehta, R.Oldeman, T.Shears, S.Farrington, B.King

Gajjar, Griffiths, Hayward, S-M Wynne, N.Austin

Oxford: F.Azfar, L.Cerrito, J.Goldstein, C.Hays, B.T.Huffman, L.Lyons, P.Renton, J.Rademacker, J.Sjolin, O.Stelzer-Chilton, S.Stonjek

Robson, Pounder, Harper, Malde, Linacre

UCL: M.Lancaster, D.Waters, I.Bizjak, E.Nurse, V.Bartsch, L.Cerrito, A.Wyatt

Beecher, Cooper, Malik, McGivern, Vine

XXX = not included in 10/2006-09/2010 FTE contributions

YYY = students completing/continuing in last 2 years

PhD's Awarded In Last 2 Years

[1] M. Turner; **Measurement of the Mass of the Λ_b Baryon**; University of Liverpool; (2004).

[2] H. Hayward; **Measurement of $Z\gamma$ Production in p anti-p Collisions at $\sqrt{s}$=1.96 TeV**; University of Liverpool; (2005).

[3] A. Gajjar; **Measurement of the b anti-b cross section in p anti-p Collisions at $\sqrt{s}$=1.96 TeV**; University of Liverpool; (2005).

[4] S. Farrington; **A measurement of the B_s lifetime at CDF run II**; University of Glasgow; (2004).

[5] T. Unverhau; **A measurement of the lifetime of the Λ_b baryon with the CDF Detector at Tevatron run II**; University of Glasgow; (2004).

[6] L.Y.Nicolas; **Radiation environment simulations at the Tevatron, studies of the beam profile and measurement of the B_c meson mass**; University of Glasgow; (2005).

[7] A. Robson; **A Measurement of Z Boson Production and Rapidity Distribution in p-pbar Collisions at $\sqrt{s}$ = 1.96TeV**; Univesity of Oxford; (2005).

[8] D. McGivern; **A Measurement of the W+W- production cross section in proton anti-proton collisions at $\sqrt{s}$ =1.96 TeV in the DiLepton channel and limits on anomalous WWZ/gamma couplings**; UCL; (2005).

Resource Management

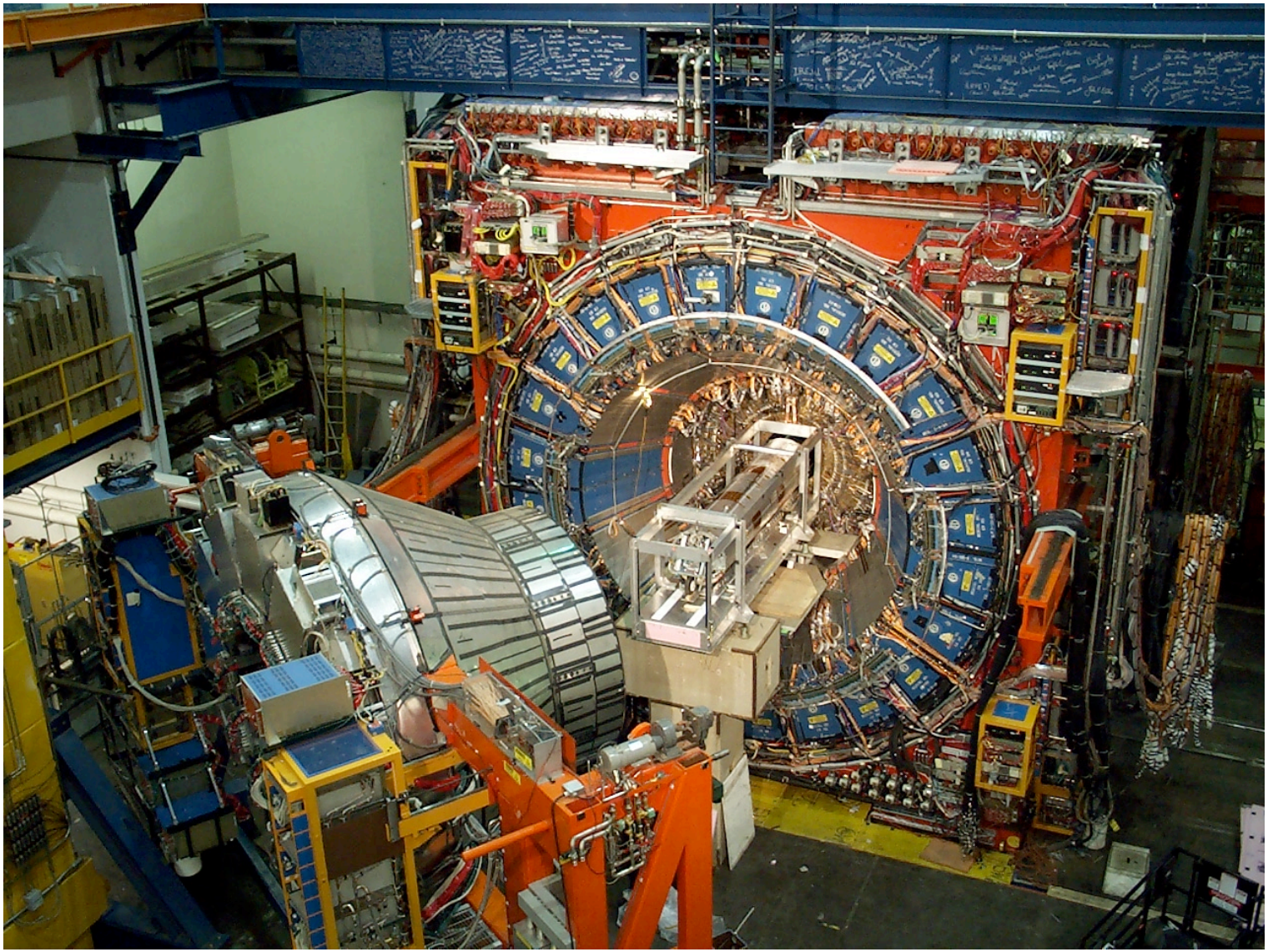
	2002/3	2003/4	2004/5	2005/6	Request
Common Fund	0	0	63	103	100
M&O	7	8	6	7	5
Travel	150	154	152	192	190
Cumulative Spend	157	319	540	842	
Cumulative Allocation	158	328	598	877	

Common Fund low : good value physics return

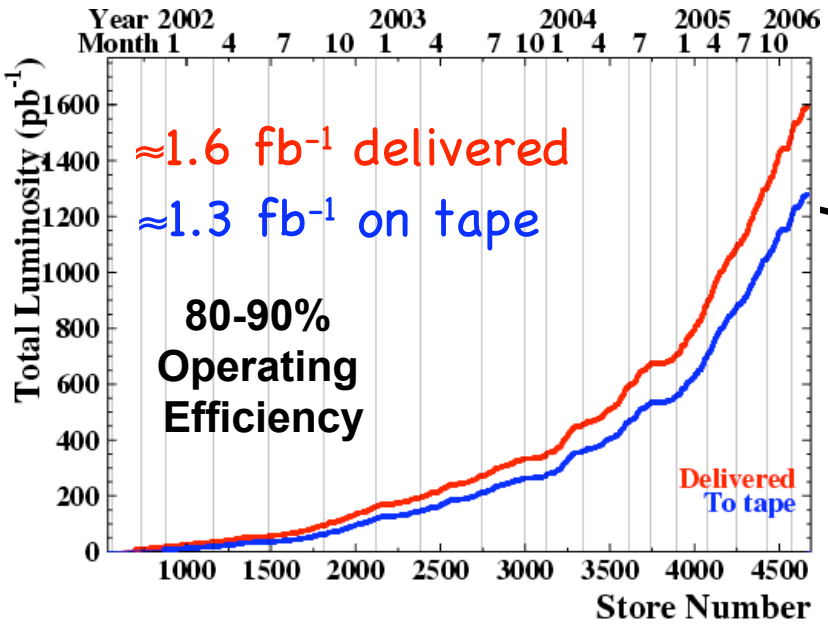
Budget spend very close (-4%) to allocation.

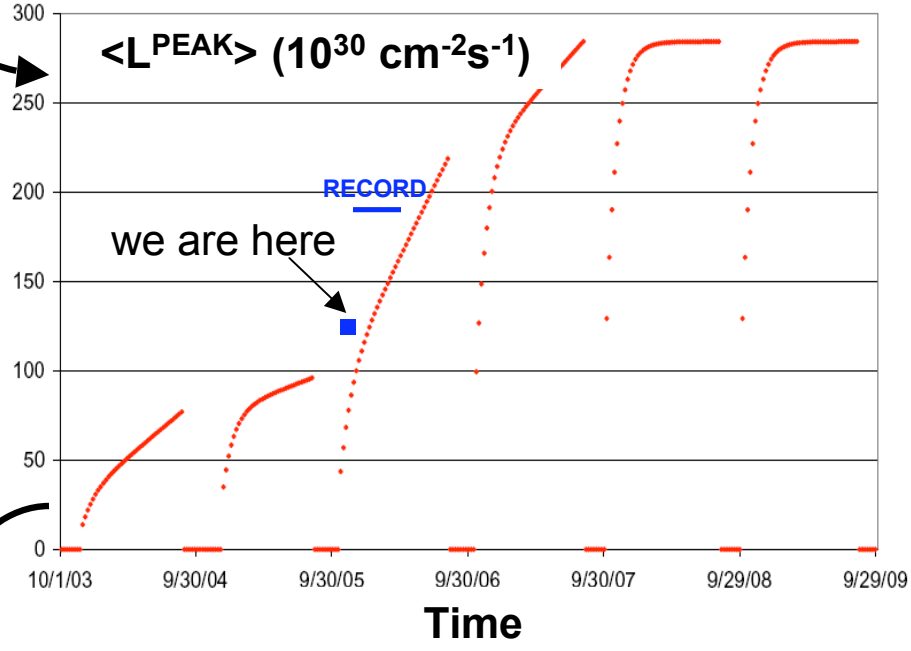
Request is for funding at the same level & scaled by FTE which falls in 2008/9

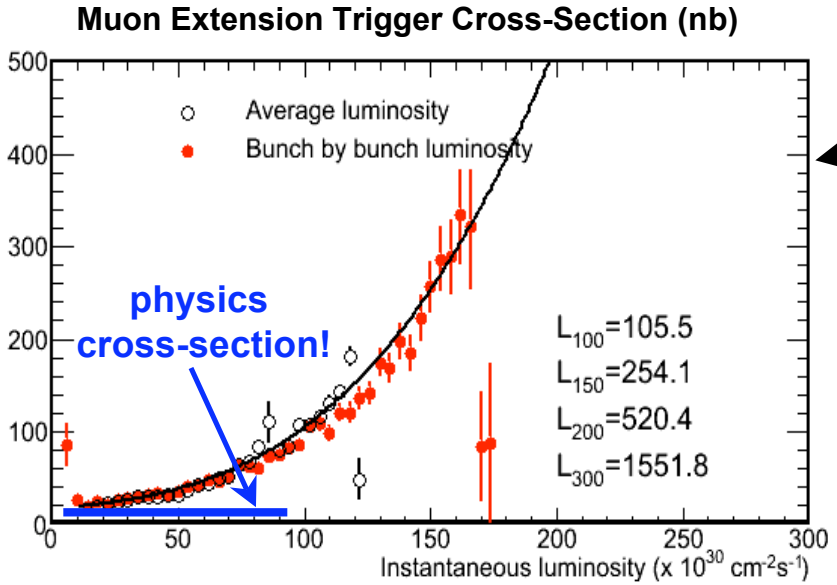
CDF Experiment



Luminosity

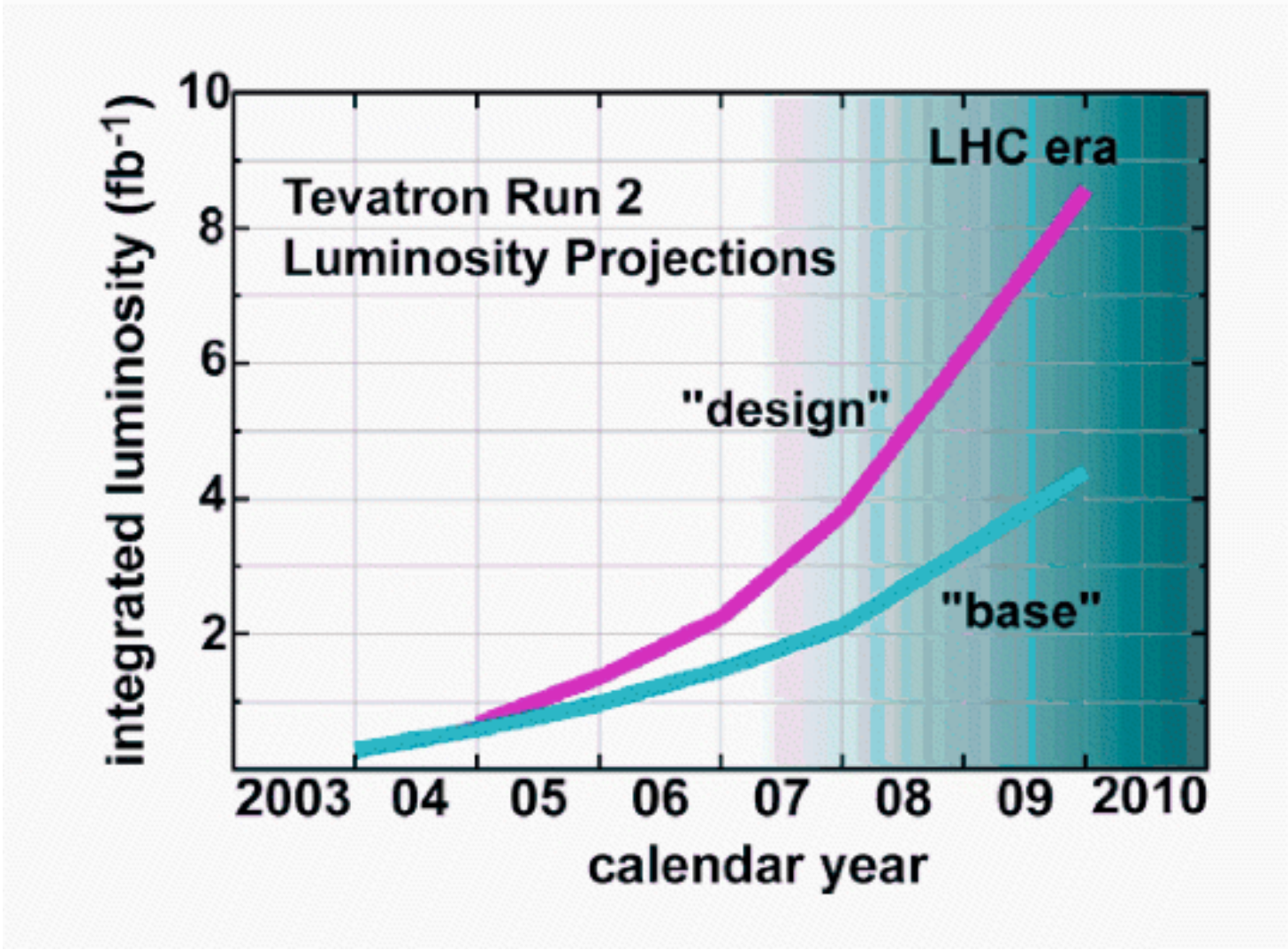






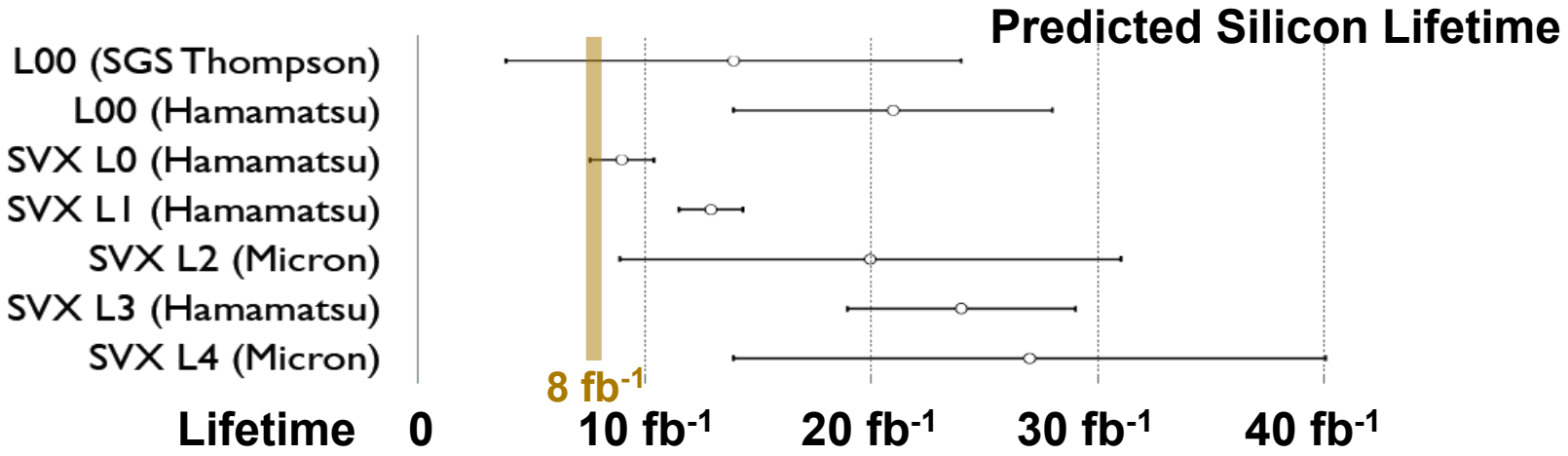
- At highest instantaneous luminosities we have ~ 5-6 overlapping min-bias events.
- Some trigger cross-sections are growing out of control.
- Trigger deadtime at high *L* has been the main challenge for the last year.
- Several upgrades are addressing this.

Run 2 Luminosity Projection



Silicon Lifetime

- Radiation damage
  - > 90% of total radiation is due to collisions: NIM A514, 188-193 (2003)
  - Bias voltage scans as luminosity accumulates
    - Study collected charge (hits on tracks) and mean noise
    - Measurements agree with predictions up to 1 fb^{-1}.

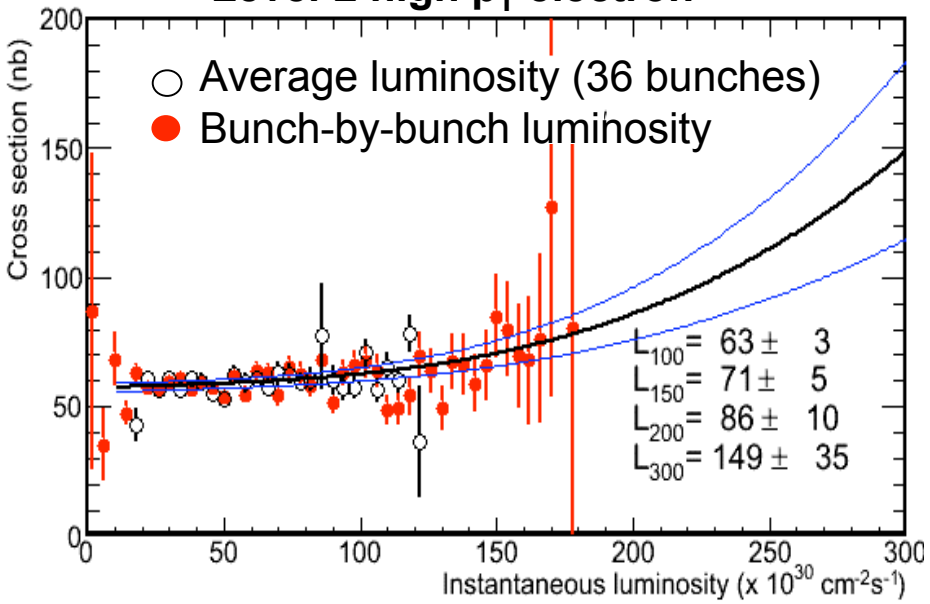


- Efforts to increase the Silicon lifetime
  - Lowered Silicon operating temp. gradually from -6°C to -10°C.
  - Thermally isolated SVX from COT inert regions such that the silicon can be kept cold during COT work.

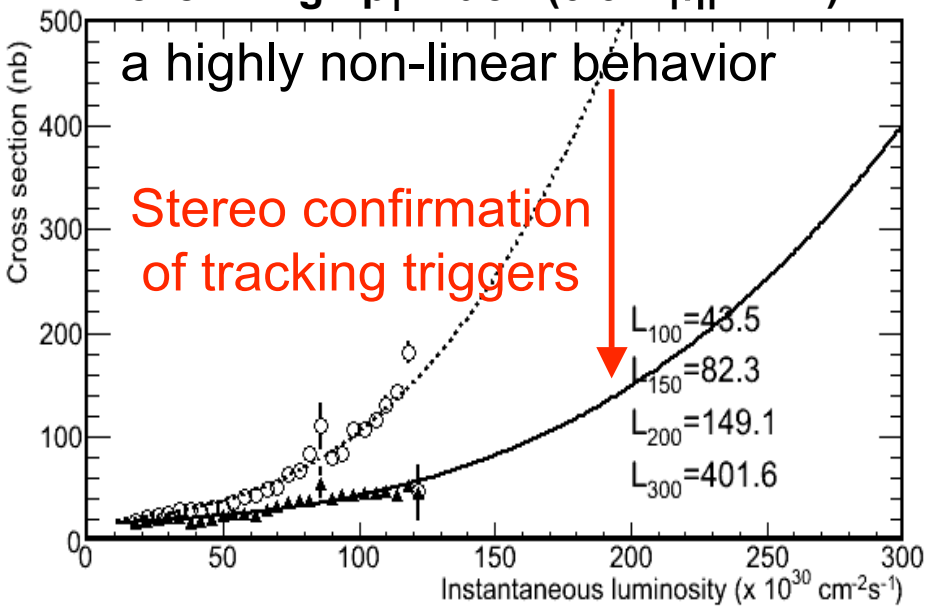
Trigger Rates

- Triggers are sensitive to multiple interactions.
- Measure cross section vs # of primary interaction vertices.
- Calculate cross sec vs lum. using Poisson distribution of # of primary vertices.
- Good agreement with bunch-by-bunch data.

Level-2 high p_T electron



Level-2 high p_T muon (0.6 < |η| < 1.1)

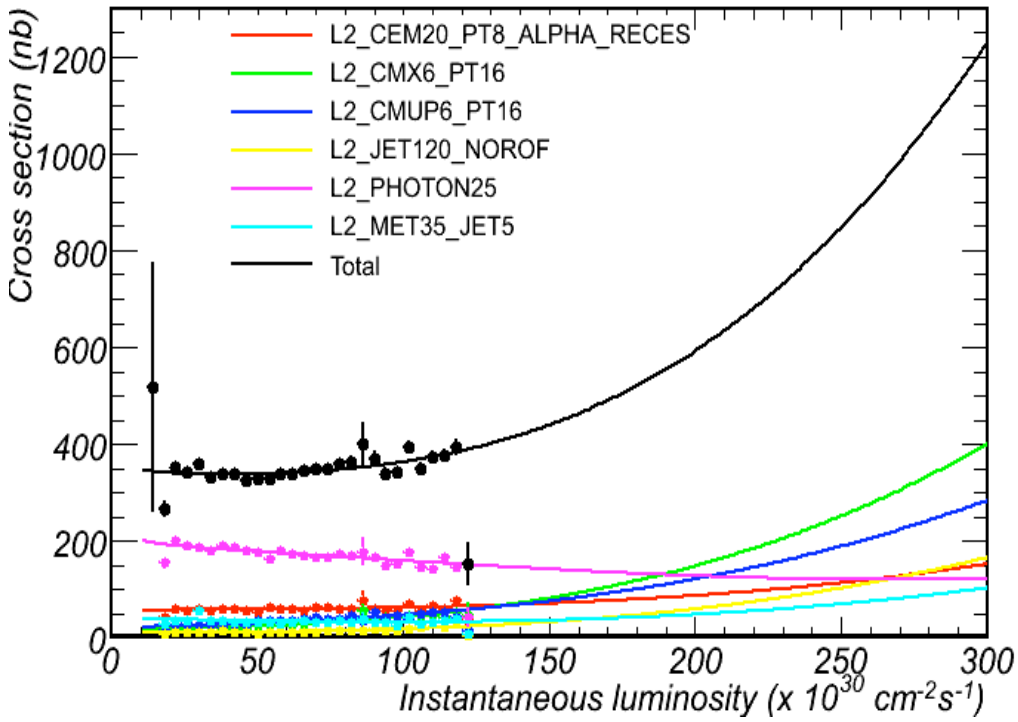


trigger rate = cross section x $\mathcal{L}$

At 3 x 10^{32} $cm^{-2}s^{-1}$
~3% of Level-2 bandwidth

~50% of Level-2 bandwidth.
Reduce to ~10 % with XFT upgrade

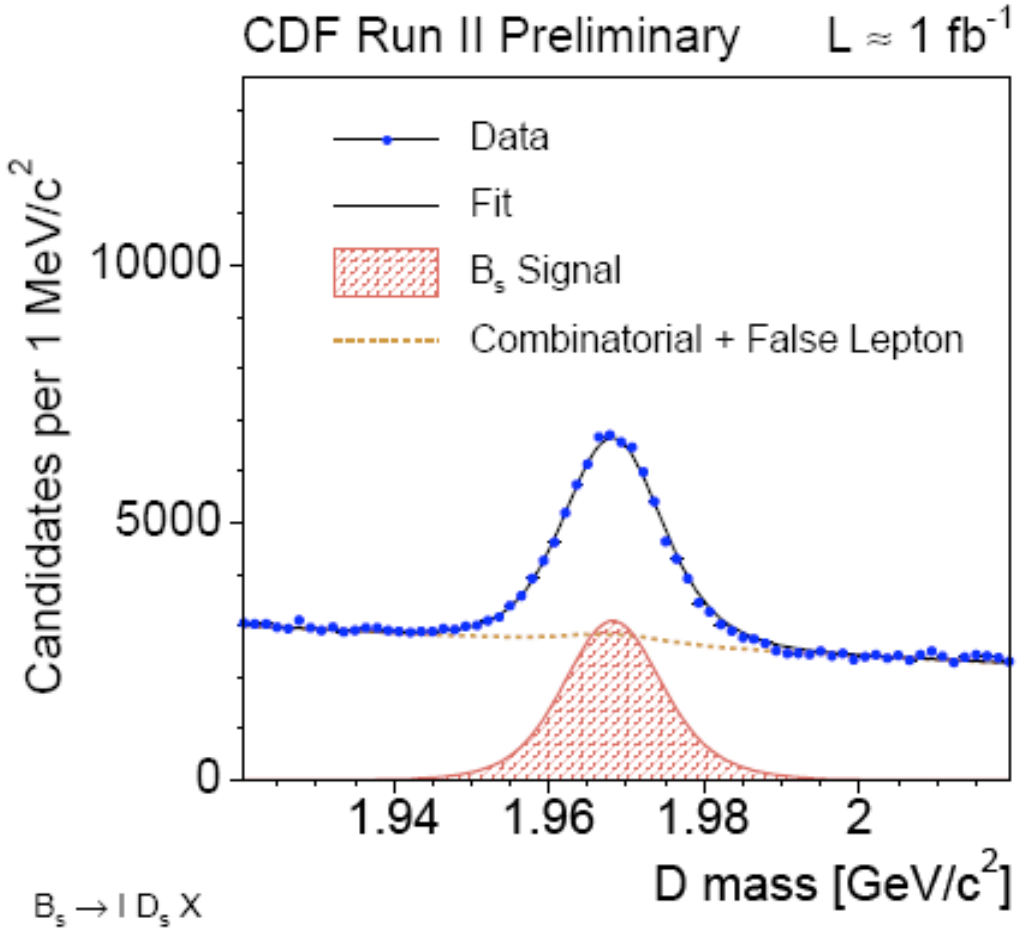
Cross sections of high p_T triggers (high p_T e,μ,γ,jet,$\not{E}_T$) with Level-1 upgrade
Covers W, Z, Top, WH, ZH, H→WW, SUSY (partial), LED, Z'



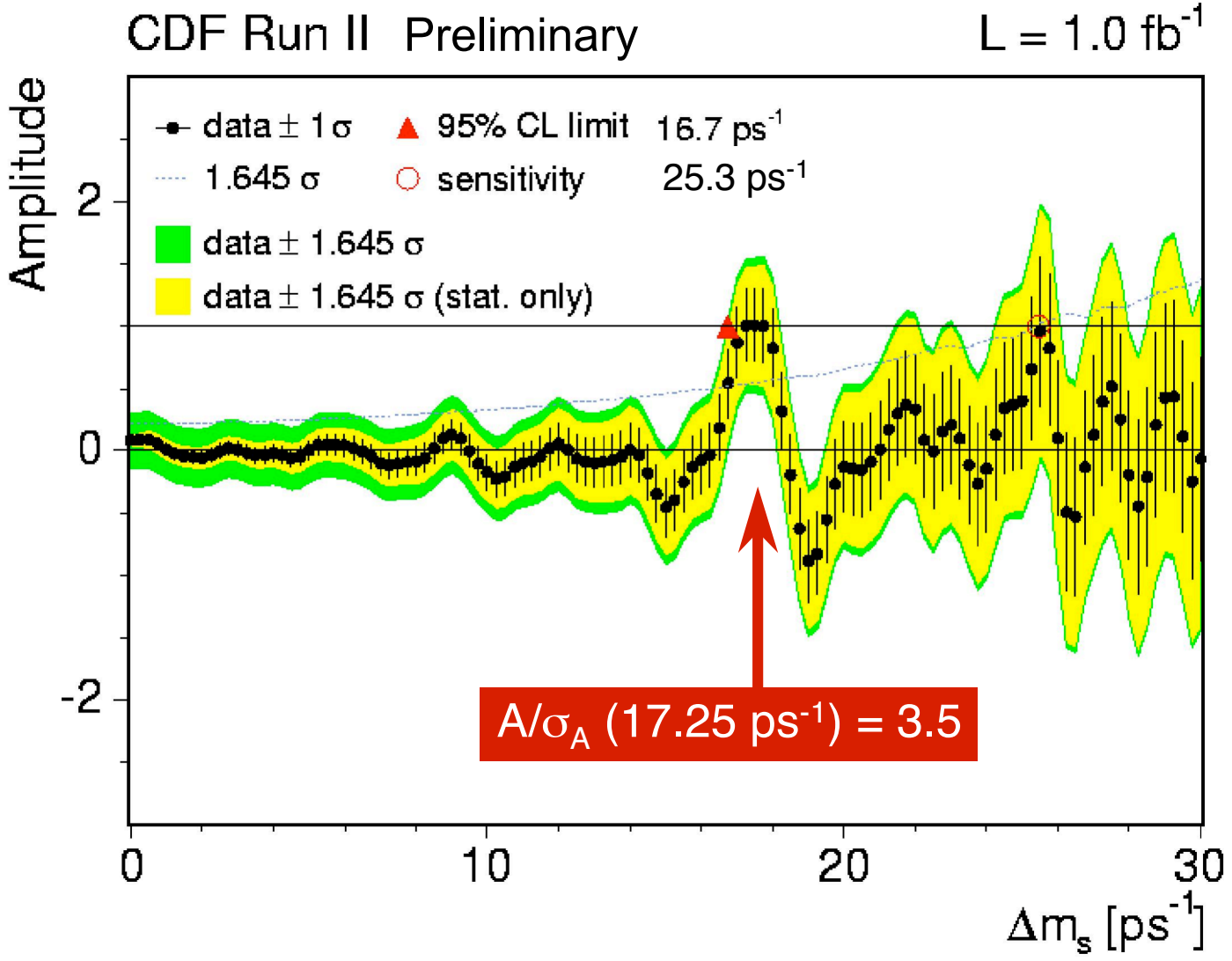
~1/3 of Level-2 bandwidth at $3x10^{32}$ $cm^{-2}s^{-1}$: studying further improvements

Studied triggers for "full" high p_T physics program: ~2/3 of bandwidth.
Goal : make this for 50% of bandwidth

B_S Oscillations



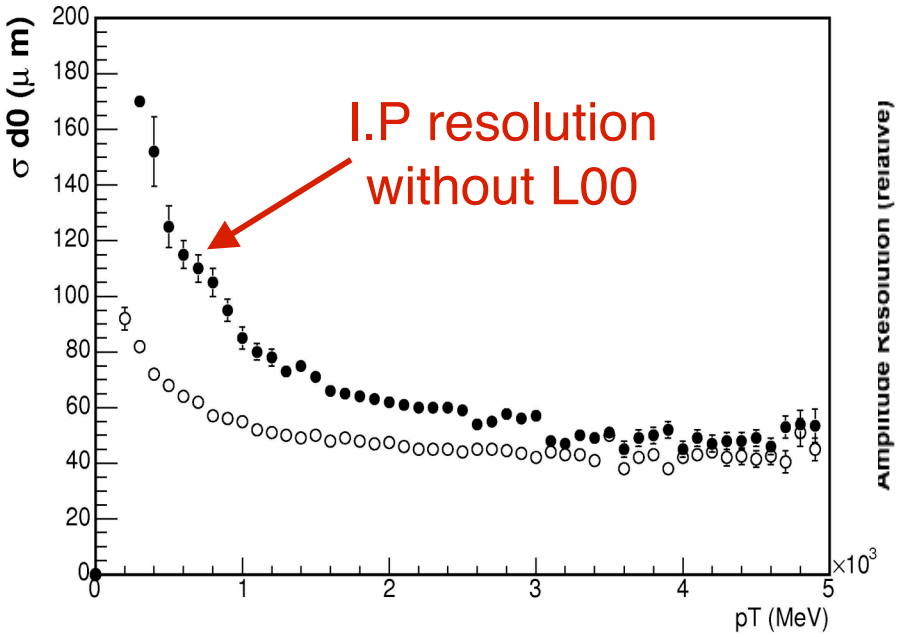
B_S Oscillations

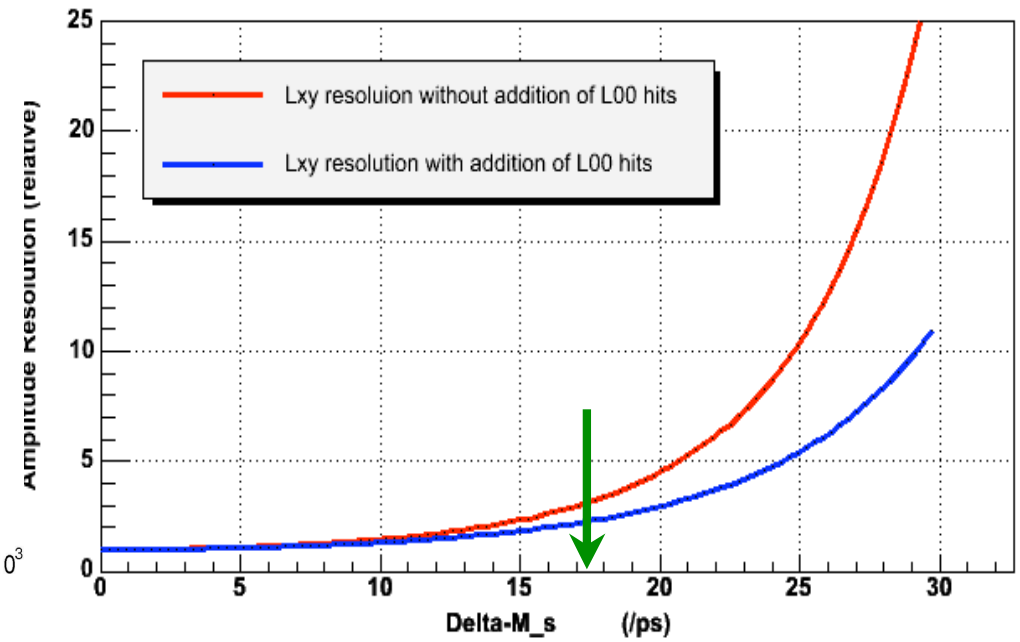


B_S Oscillations

- L00 improves track impact parameter resolution.
- Average improvement to L_{XY} resolution is 15%.
- Given the measured value of Δm_S, this corresponds to a ~35% increase in amplitude resolution :

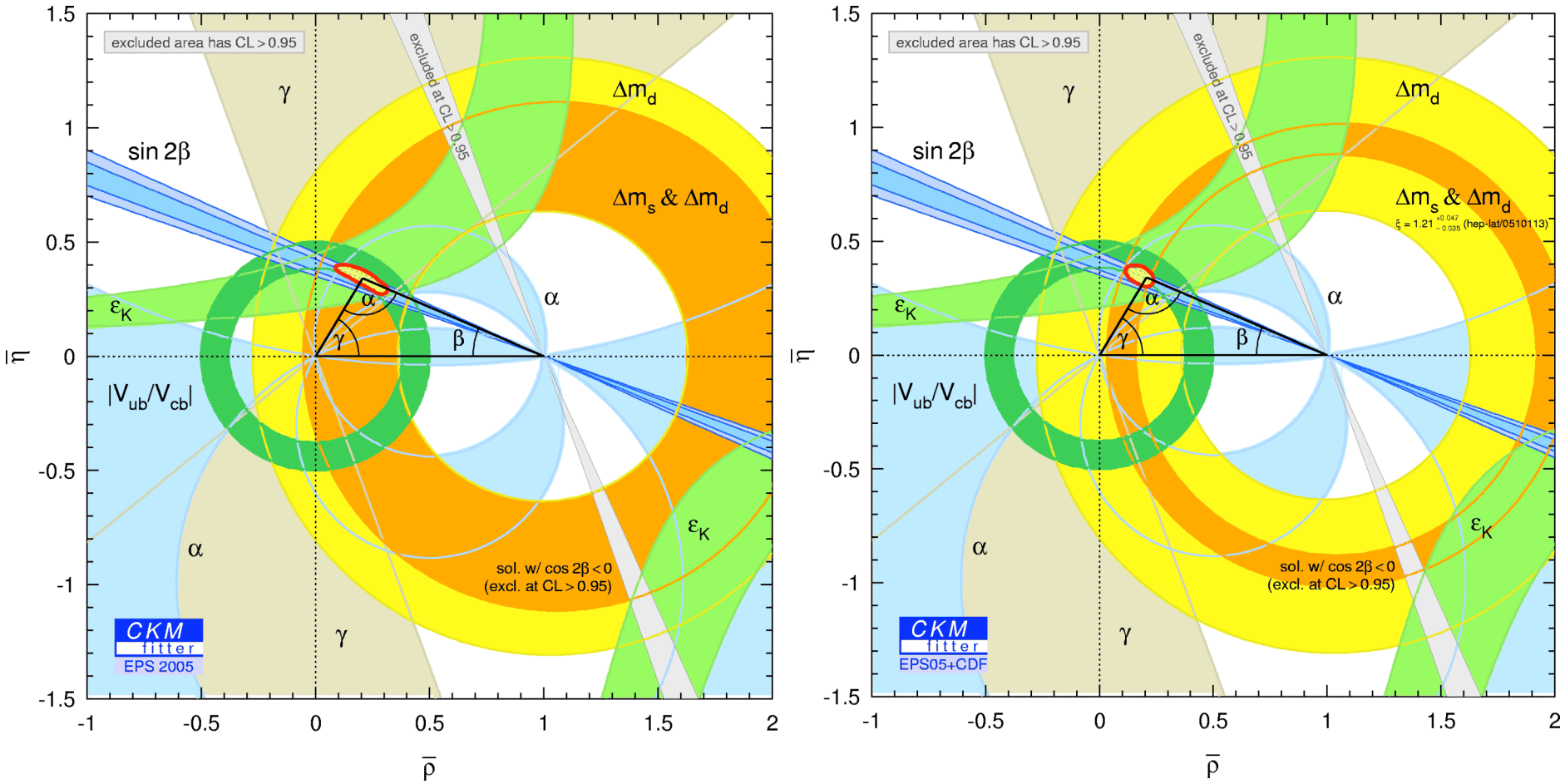
$$\frac{1}{\sigma} = \sqrt{\frac{S\varepsilon D^2}{2}} e^{-\frac{(\Delta m_S \sigma_t)^2}{2}} \sqrt{\frac{S}{S+B}}$$



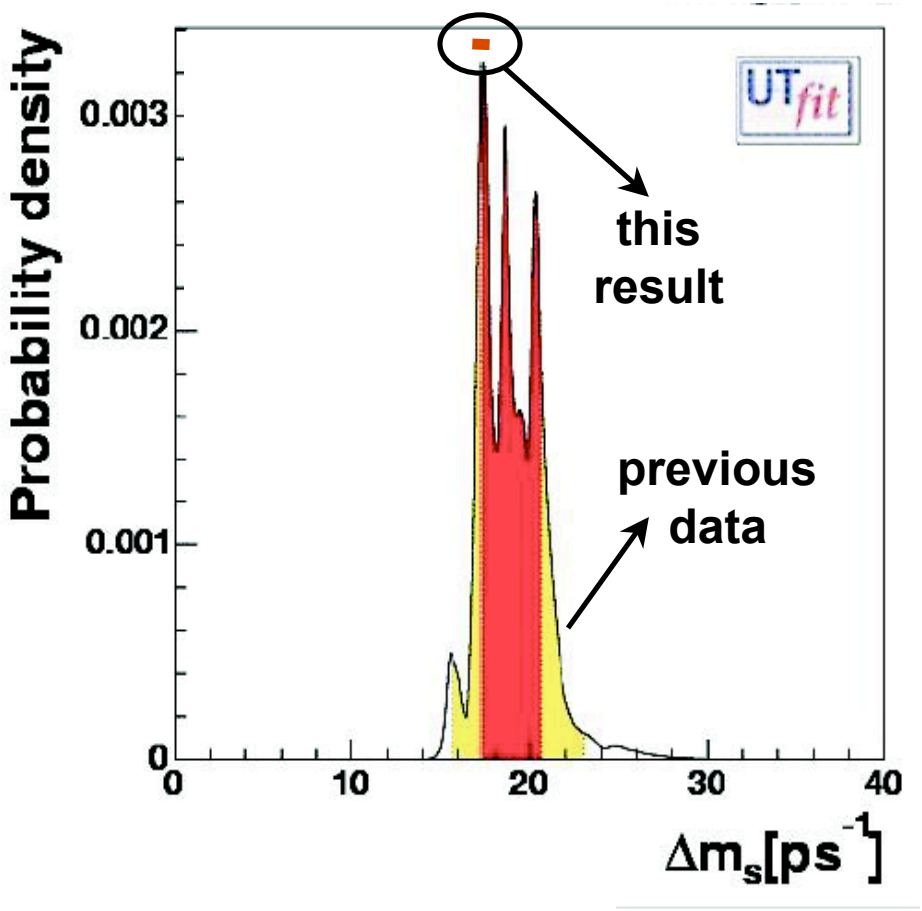


B_s Oscillations

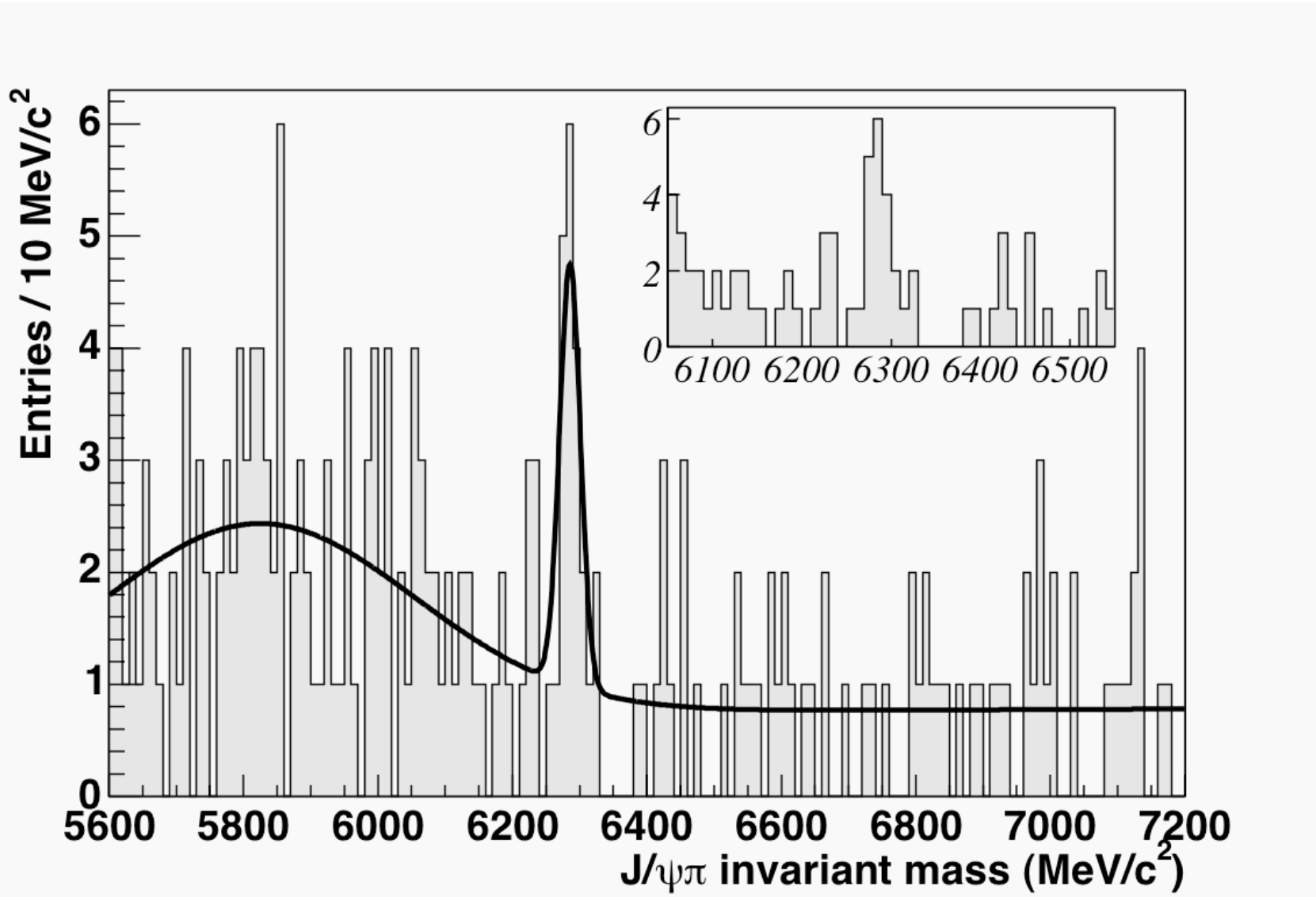
CDF measurement & New Lattice Calculation of ξ



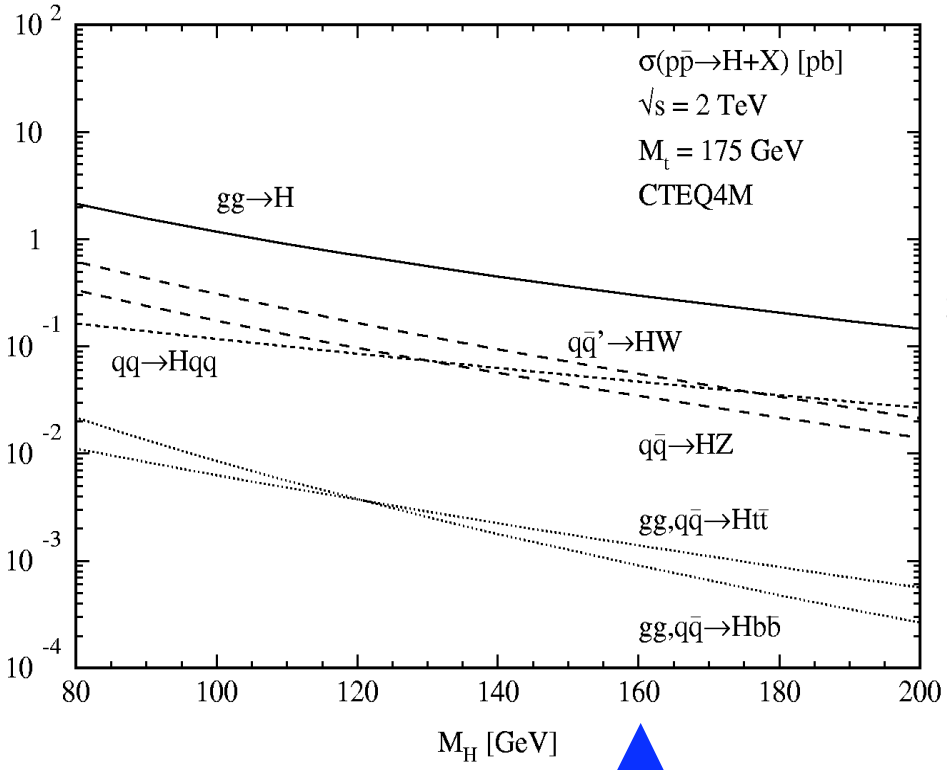
B_S Oscillations



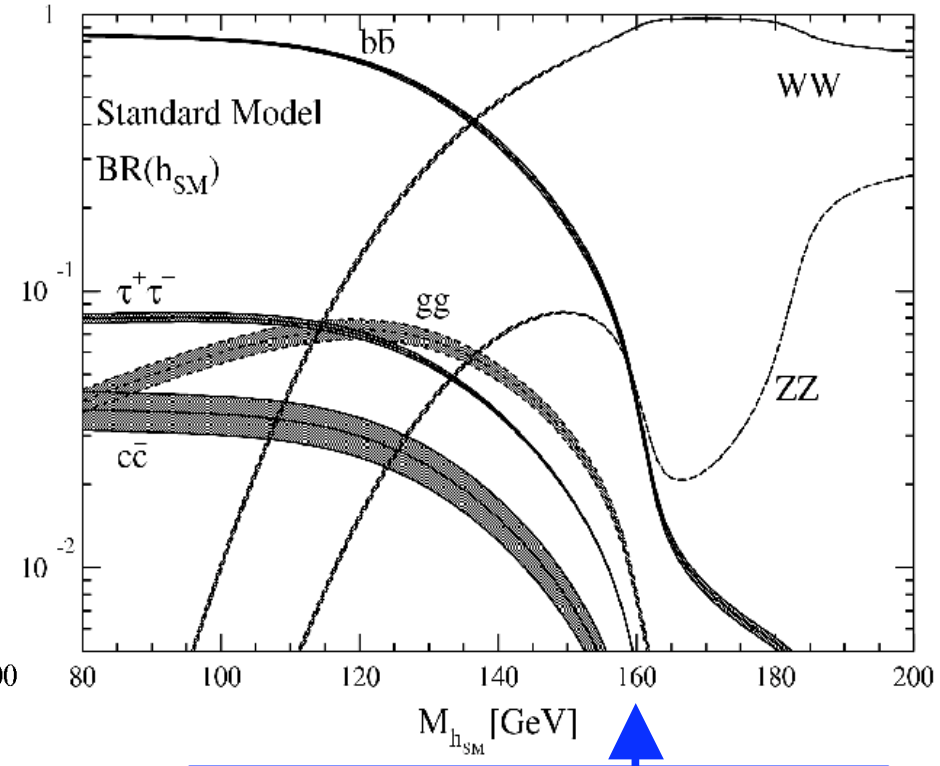
B_C : Mass Fit


Entries / 10 MeV/c^2
0
1
2
3
4
5
6
5600
5800
6000
6200
6400
6600
6800
7000
7200
J/ψπ invariant mass (MeV/c^2)
0
2
4
6
6100
6200
6300
6400
6500

Higgs XS & BR

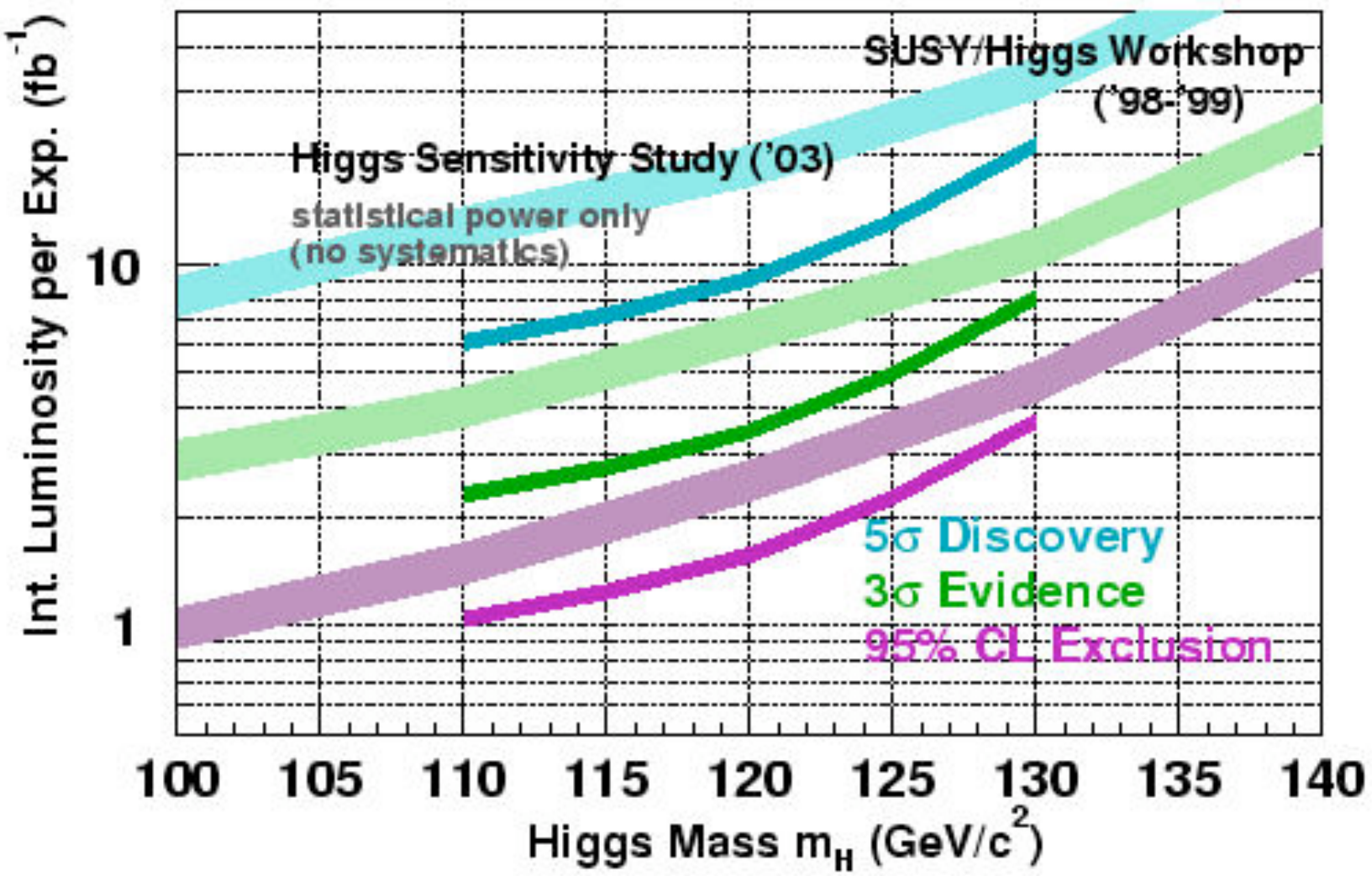


σ(gg→H) ~ 0.3 pb @ 160 GeV



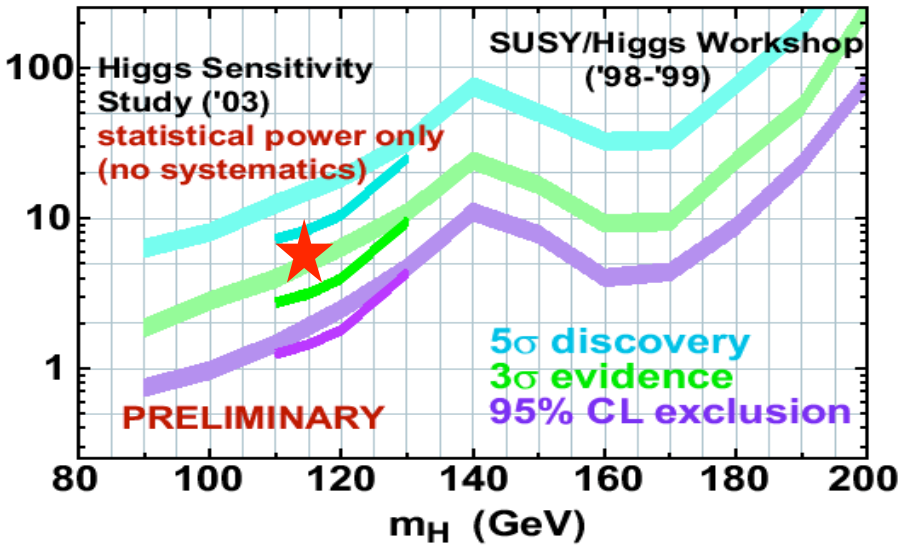
BR(H→WW) ~ 90% @ 160 GeV

Higgs Sensitivity

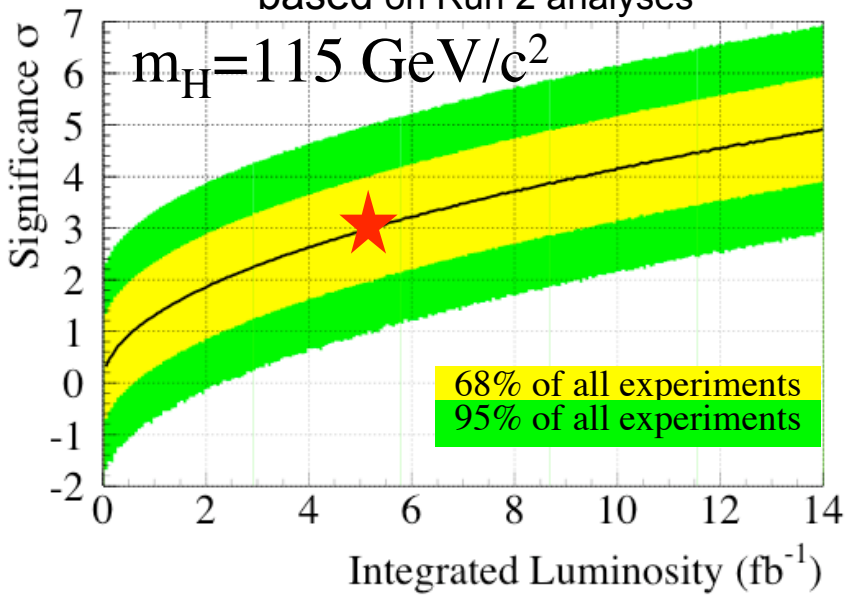


Higgs Projections

based on pre-Run 2 analyses



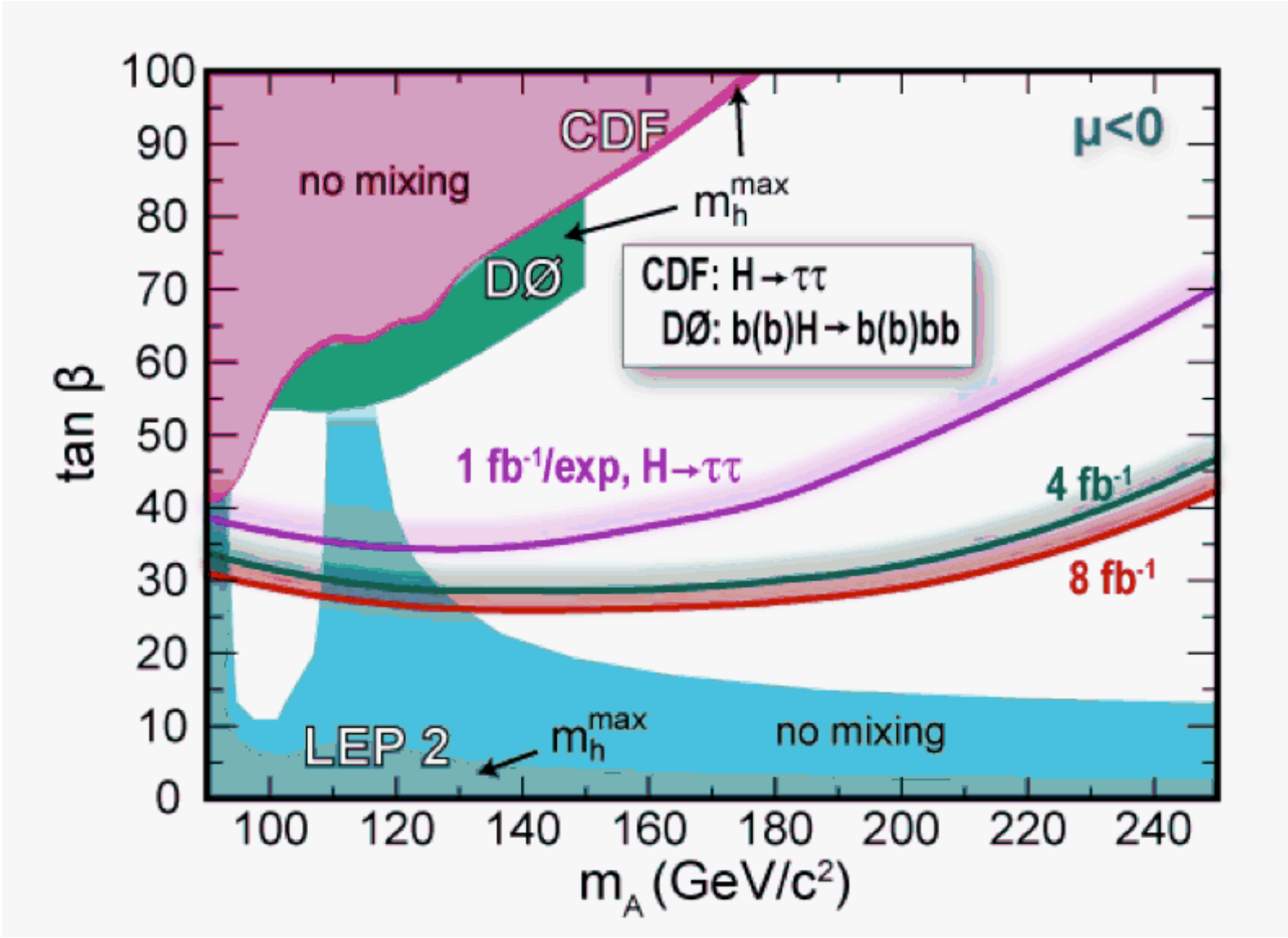
based on Run 2 analyses



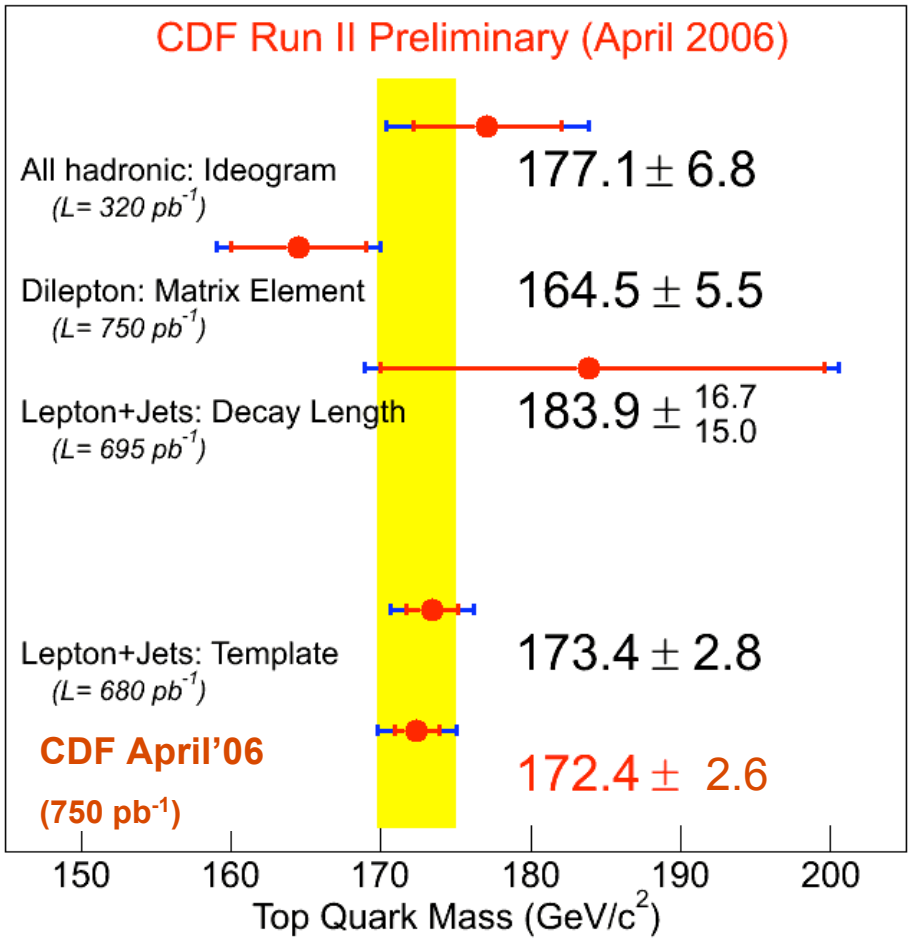
- Confirmed previous studies with run 2 data experience
  - Syst. uncertainties increase required luminosity by 40%
- 95% C.L. exclusion:
  - $\int$ Ldt =2-2.5 fb^{-1}: probe LEP excess at m_H=115 GeV/c^2
  - $\int$ Ldt =4.0 fb^{-1}: up to m_H=130 GeV/c^2
  - $\int$ Ldt =8.0 fb^{-1}: up to m_H=135 GeV/c^2

  } Severely constrains MSSM
- 3s evidence: ★
  - $\int$ Ldt ≈5.0 fb^{-1}: for m_H=115 GeV/c^2

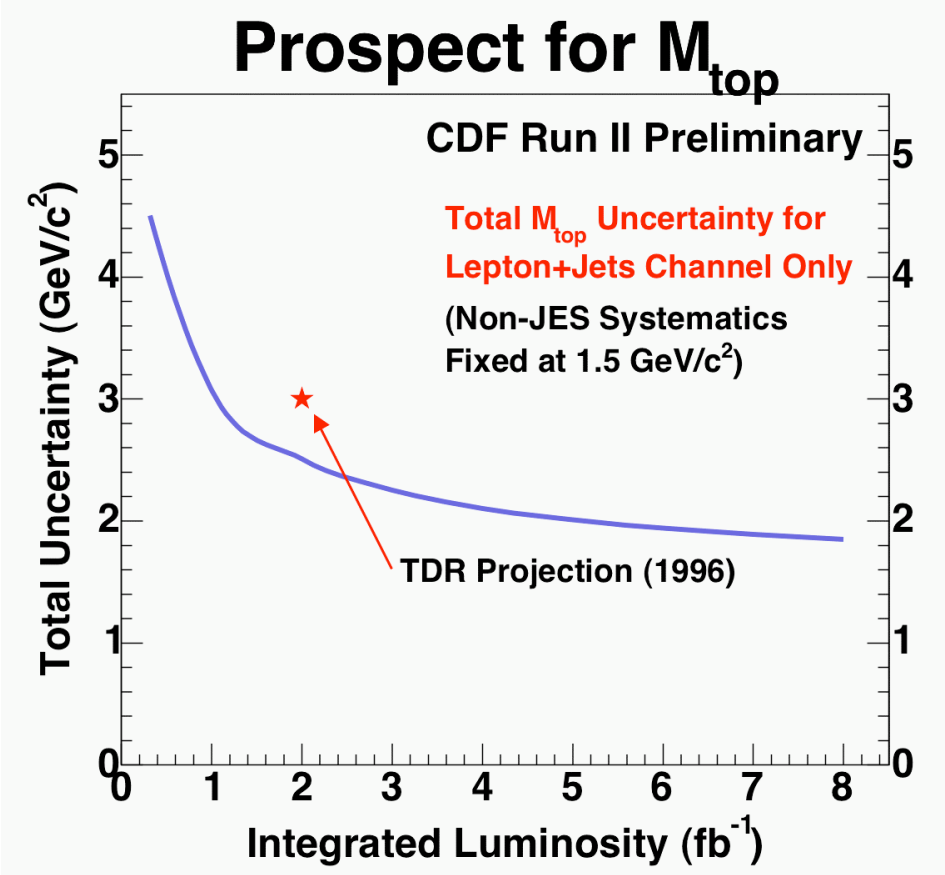
MSSM Higgs

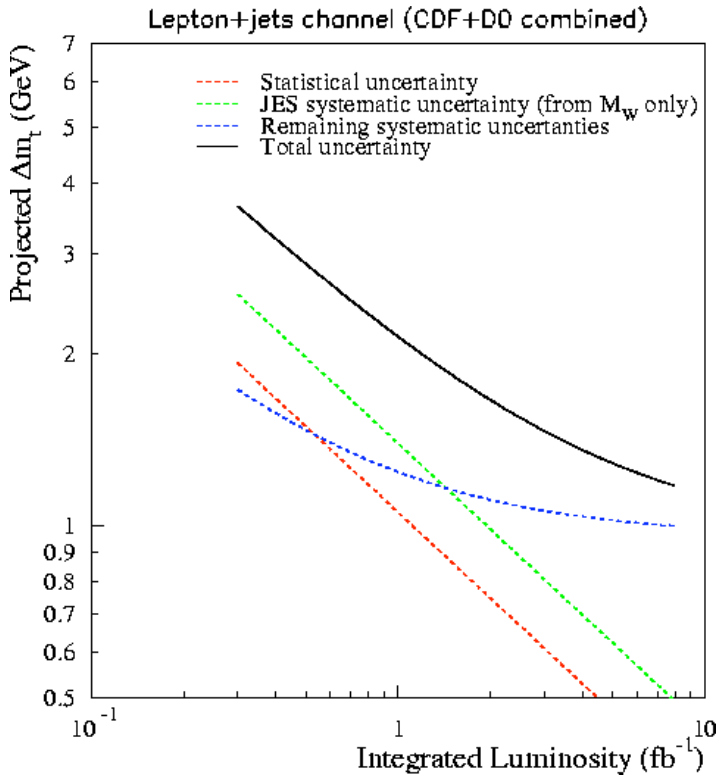

CDF
no mixing
DØ
m_h^{max}
μ<0
CDF: H→ττ
DØ: b(b)H→b(b)bb
1 fb⁻¹/exp, H→ττ
4 fb⁻¹
8 fb⁻¹
LEP 2
m_h^{max}
no mixing
tan β
m_A (GeV/c²)
100
90
80
70
60
50
40
30
20
10
0
100
120
140
160
180
200
220
240

Top Mass Combination

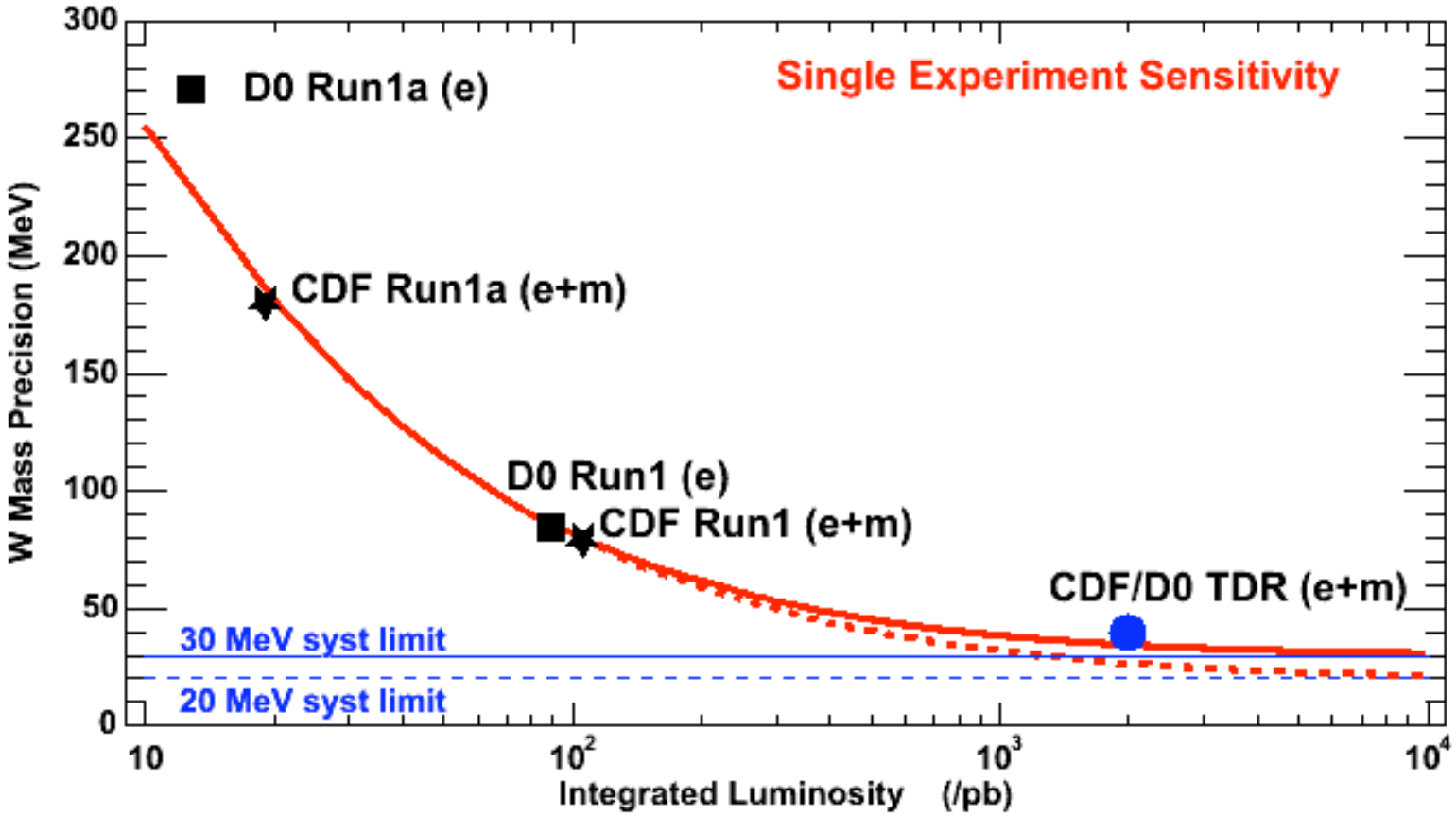


Top Mass Projection

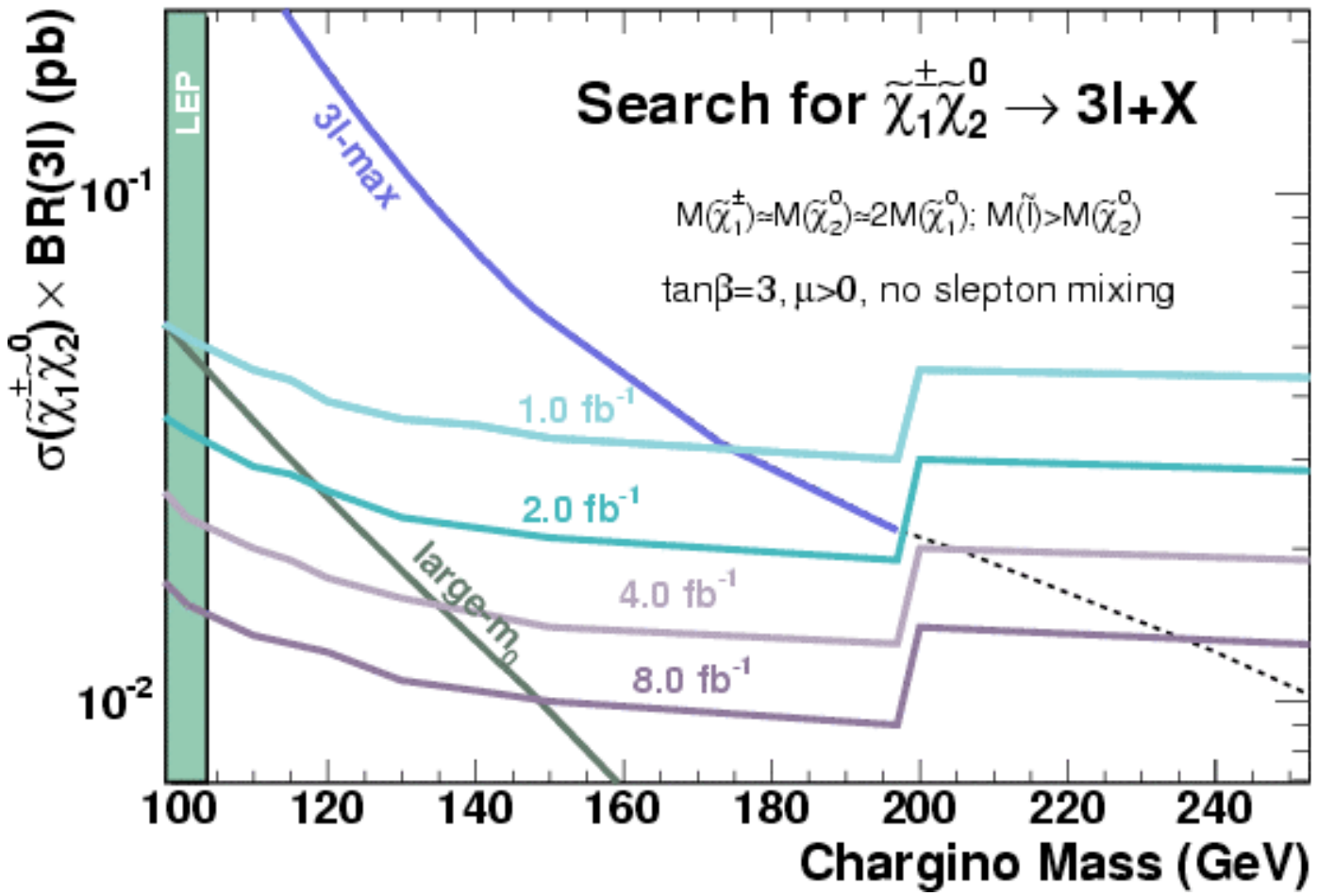




W Mass Projection



Chargino Mass Projection



Rare Decay Projections