Summary and Highlights of the Conference

John Womersley

Fermi National Accelerator Laboratory, Batavia, Illinois

http://www-d0.fnal.gov/~womersle/womersle.html

First of all . . .

- **I would like to thank**
  - **The scientific committee**
  - **The conference organizers**
  - **The University of Karlsruhe and the Institute for Experimental Nuclear Physics**
  - **All of the speakers**
  - **The conference secretariat**

  for making this an extremely well organized and uniformly high-quality meeting

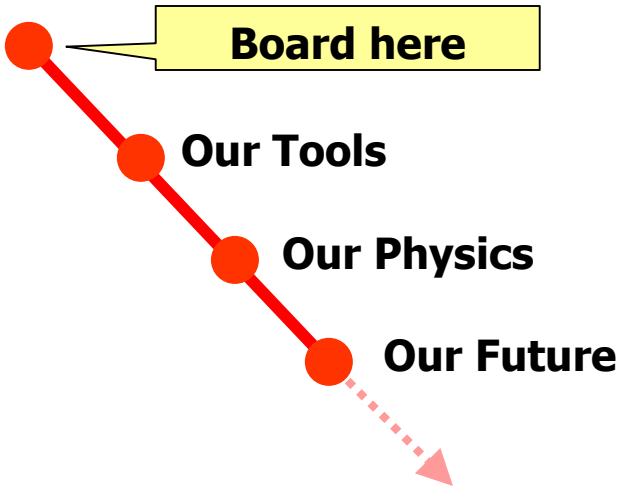
- **Thanks also to all those speakers who sent me material for this talk**
  - **Please don't be offended if I chose to paraphrase it rather than using verbatim**

Throughout this talk, speakers' names are shown like this: **Donald Duck**

Outline

- My task: summarize and highlight 27 hours of presentations in one hour
  - Requires that we travel at 0.9993c to achieve a sufficient time dilation
    - Things will be a bit of a blur!

- Route of this talk:



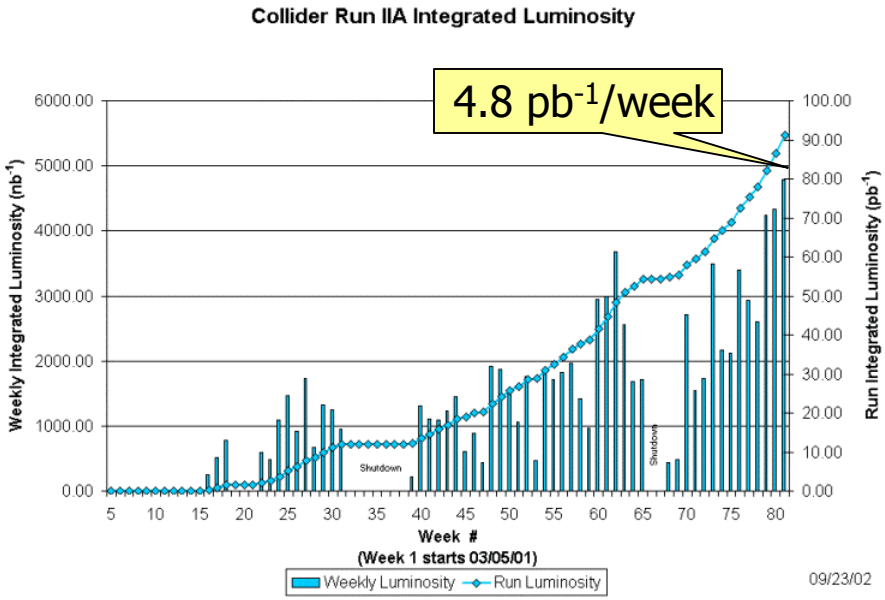
Our Tools

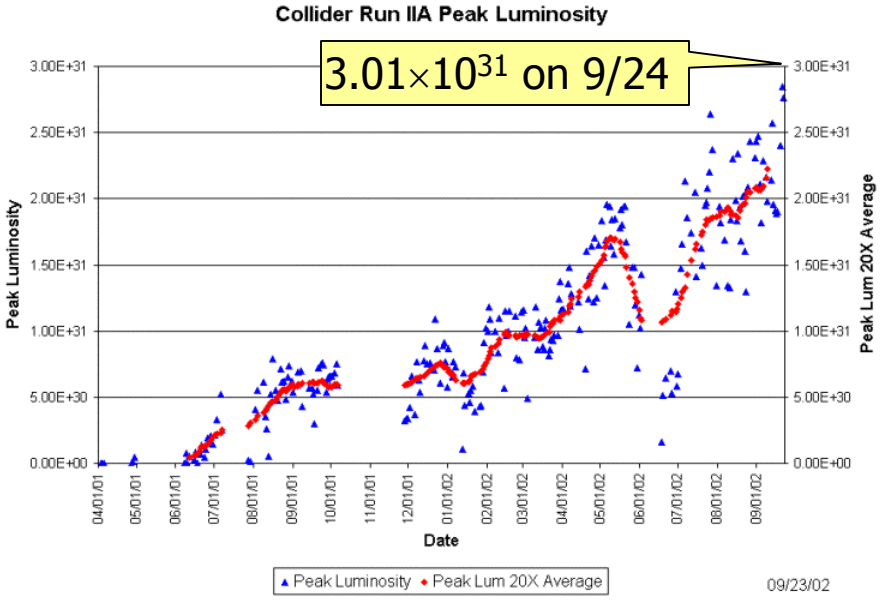
Accelerators, detectors, computing
Theoretical and simulation tools
Knowledge of the structure of the proton
Analysis techniques

Tevatron

Elvin Harms

- **Not out of the woods yet, but gratifying progress recently:**





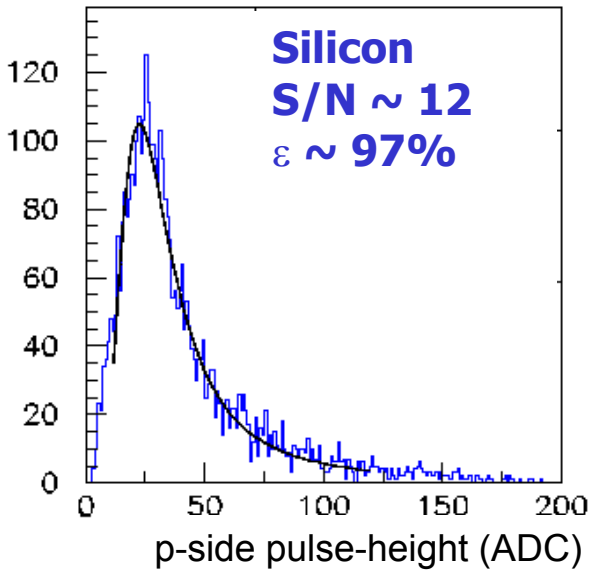
- **Now operating at least as well as Run I peak performance**
- **Injectors are providing the necessary beams for $L_0 = 6 \times 10^{31}$ cm^{-2}s^{-1}**
- **Much effort already spent to achieve current level of performance**
- **Tevatron major issues are**
  - **Injection aperture and lifetime, Beam-beam effects, and instabilities**
- **Identification and mitigation of luminosity impediments continues**

Status of DØ

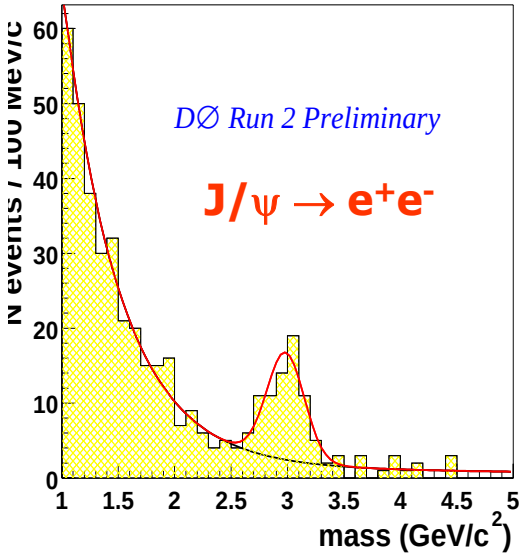
Volker Büscher

- **The detector is working well and recording physics data:**

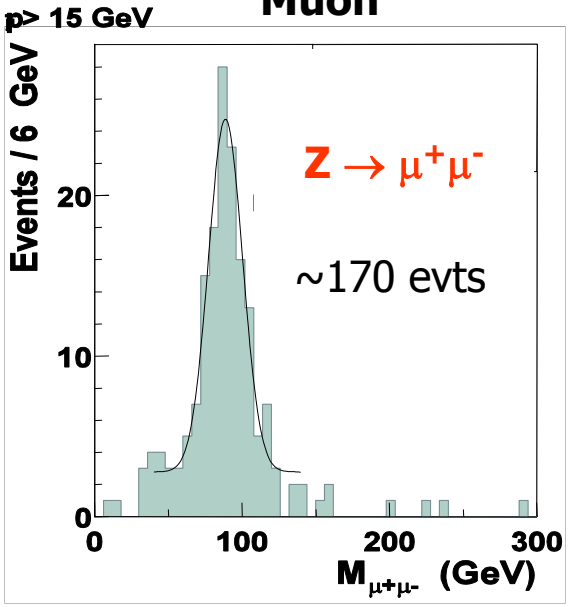
Tracking



Calorimeter



Muon



- **Currently emphasizing operational efficiency**
- **Improvements still in store**
  - **Trigger capabilities and L1 rate**
  - **Silicon vertex trigger under construction**

Status of CDF and Prospects for Run II

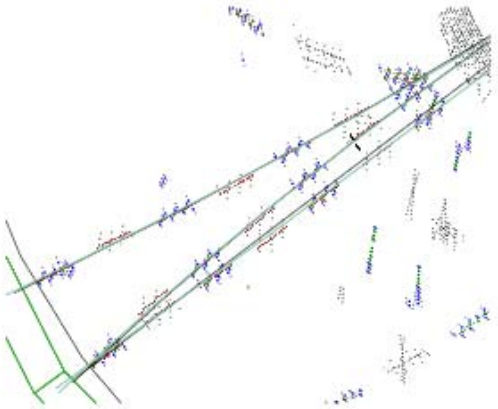
Frank Chlebana

Run II upgrades build on the experience from Run I

→ Improved acceptance
→ New trigger capabilities
→ Better detectors

Detector and Trigger are commissioned and working well, taking Physics Quality data since Jan 2002

Currently running with ∼ 40/80/140 triggers at L1/L2/L3



The Extremely Fast Tracking trigger (XFT) able to select tracks with p_T as low as 1.5 GeV at *L1!*

Silicon Vertex Tracker (SVT) working well, selects events with displaced tracks at *L2!*

HERA

Carsten Niebuhr

- Accelerator substantially upgraded since the last physics run in 2000
  - Two new IR's
    - ~500m of "new accelerator" , 58 new magnets
  - Goals: increase luminosity by ~4
  - Deliver ~ $1fb^{-1}$ to experiments by 2006
  - Add spin rotators
    - longitudinally polarized $e^{\pm}$ beams

- Now commissioning: painful process
  - Serious background problems
    - Synchrotron radiation (must improve shielding)
    - Beam-gas interactions (need better vacuum)

- Detector upgrades
  - Luminosity counters, tracking, triggering

- Physics goals
  - Proton structure, QCD, searches

LHC

Gigi Rolandi

Challenges: complexity and scale

- **Detector challenges**
  - **Tracker: occupancy, radiation**
  - **Muon system: high momentum muons require huge detectors**
  - **Calorimeter: $H \rightarrow \gamma\gamma$ requires excellent EM resolution**
  - **Trigger, data processing**
  - **Management, logistical, assembly**

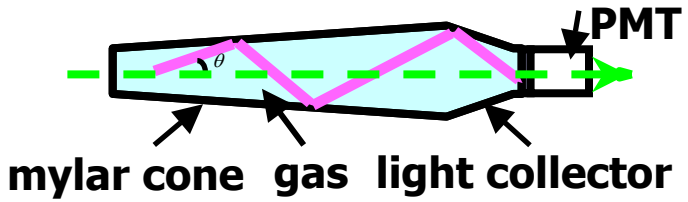
- **Accelerator**
  - **Scheduled start is 2007**
  - **Dipole production is the critical path; still early in the process**
    - **40 out of 2000 dipoles expected by end of 2002**

- **CERN financial situation . . .**

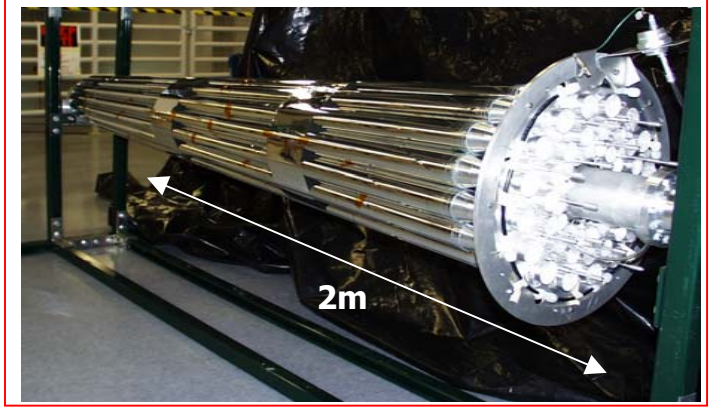
Luminosity

Sergei Klimenko

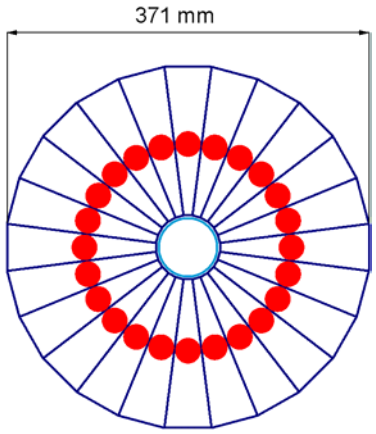
- Requires counting the rate of a reference process with known σ
  - Traditionally have used total inelastic cross section
    - Allows real time, instantaneous, bunch-by-bunch measurements

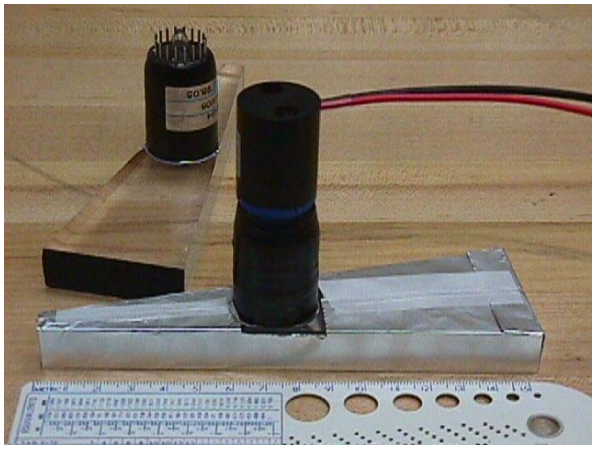


CDF Čerenkov counters



DØ Scintillator counters





  - Disadvantage:
    - What cross section to use? CDF ≠ DØ
    - What error?

$\delta\mathcal{L} \sim 3\text{-}5\%$

We will resolve this problem for Run II

Luminosity from W/Z

Michael Dittmar

Walter Giele

- Use W/Z production as reference process
  - Better known, calculable process
  - But acceptance needs to be modelled, and the calculated cross section depends on PDF's
    - Important to understand errors due to the latter
  - Feasibility demonstrated using DØ Run I data, but not used by the experiments (yet)

CDF and DØ will do this for real in Run II

$\delta\mathcal{L}$ ~ 3-5% $\rightarrow$ 1%?

Luminosity at LHC

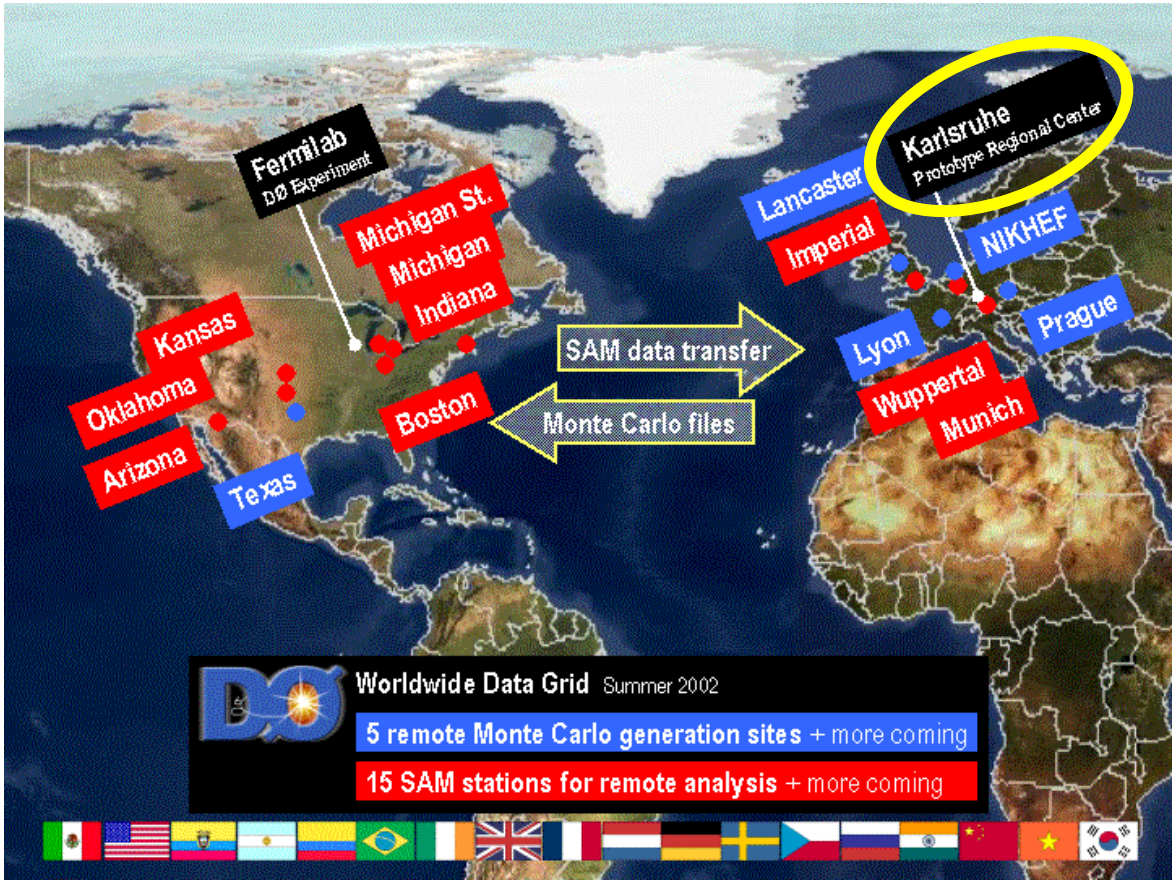
Michael Rijssenbeek

- ATLAS and CMS goals ~ 2%
- "Covering all the bases"
  - Dedicated small angle detectors (TOTEM for CMS, Roman pots in ATLAS)
    - special running at detuned β^* to measure reference processes
  - Forward detectors for real-time monitoring
  - Physics processes

Computing Infrastructure

Matthias Kasemann

- **"Something like" the GRID is becoming real:**
  - **SAM data access and distribution now being used by CDF and DØ**
  - **push towards offsite analysis of Run II data**



Event Generators

Stefan Gieseke

- **Matrix Elements and Parton Showers**
  - **Double counting problem**
  - **Correct PS by ME**
  - **Matching ME and PS—various efforts**
  - **Merging NLO ME with PS: MC@NLO (Frixione and Webber)**

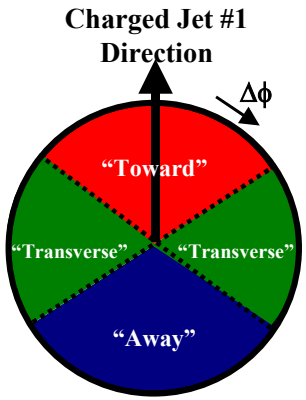
Dear Microsoft, this is not a hyperlink…

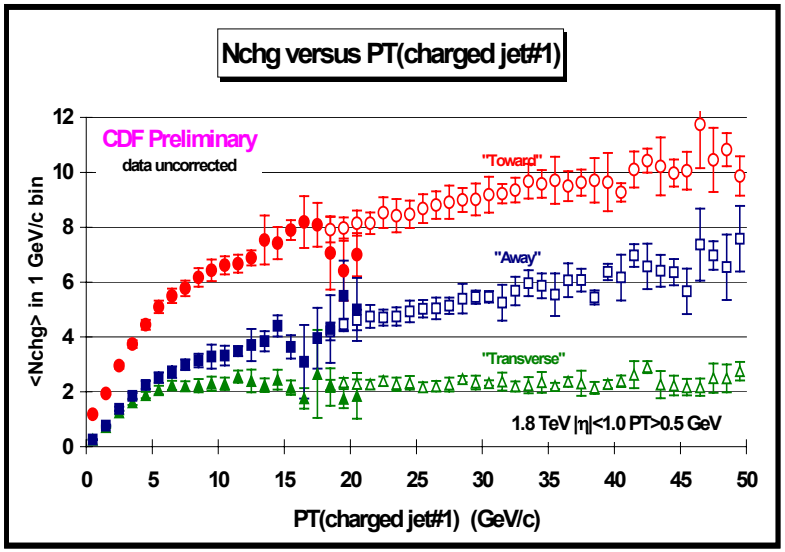
- **Herwig++ is coming**
  - **Uses common class library with Pythia7**
    - **(but not common physics functions)**
  - **Very tentative schedule**
    - **End 2002: beta version for LEP-I events with Fortran functionality**
    - **2003: first release, with improved shower, decays**
    - **2004: version for LHC**

Underlying event

- **We should strive to improve the modelling of the underlying event in hadronic collisions**
  - **Important uncertainty on jet energy scale**
  - **Data from CDF:**

Mario Martinez





- **Should include multiple parton scattering -- just a hard underlying event**
  - **what fraction of the Wbb cross section is W + bb from different parton-parton processes?**

Proton Structure

Henning Schnurbusch

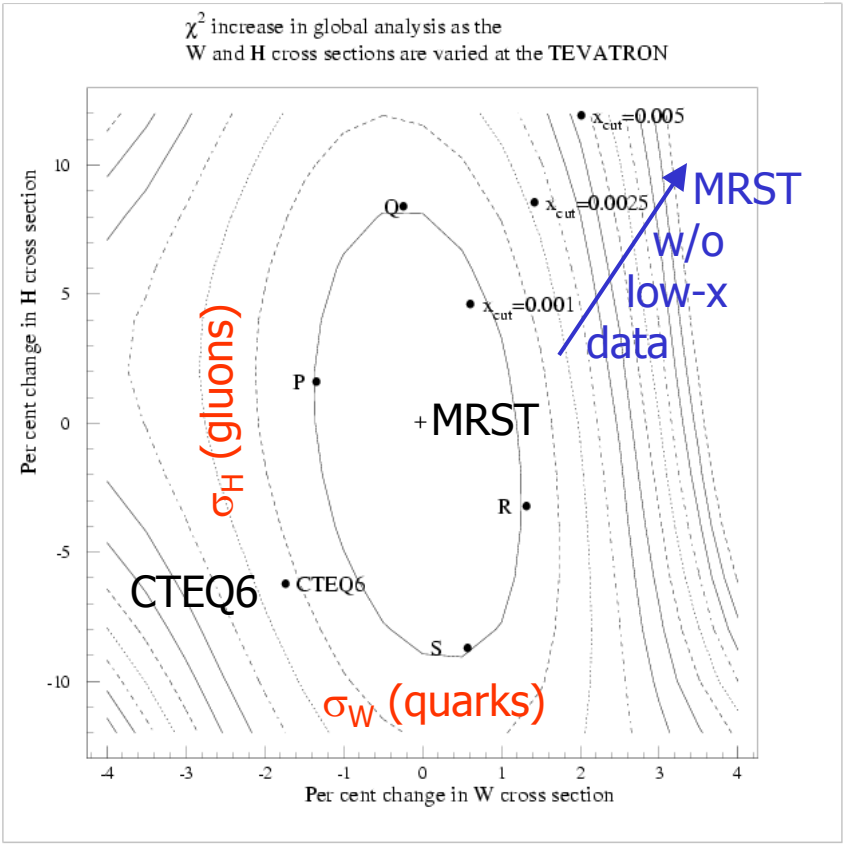
- Our current knowledge of parton distributions is dominated by DIS at HERA:
  - Few % precision on structure functions
  - Cover 6 orders of magnitude in x and Q^2
  - γ, Z, and $W^{\pm}$ exchange
- With HERA upgrade, will exploit higher luminosity, polarization, more e^- data

- Note:
  Now using Tevatron jet data to constrain gluons (CTEQ6/MRST2001)

Fits to Parton Distributions

Robert Thorne

- Can fit all the data with NLO theory + reasonably consistent PDF's
  - $\chi^2 \sim 1.1$ per DOF
- Much recent effort to understand uncertainties on these distributions
  - Variety of approaches
    - How to handle systematic errors
  - Uncertainties 1-5 % except in odd regions (g, d at high x)
- Find uncertainties from changing assumptions, α_S, cuts, etc. is significant (» exp. errors)
  - Points to inadequacy of theoretical predictions?
    - Higher order terms
    - Low x/high x resummation
    - Low Q^2/higher twist



"Do not believe any one group's errors!"

Back to using many PDF's to cover the range of uncertainty?

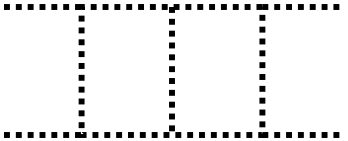
Towards NNLO QCD predictions

Nigel Glover

Thomas Gehrmann

- NNLO is required for theoretical predictions to challenge high statistics results from LEP, HERA, Tevatron, (LHC…)

- The bottleneck has been the calculation of the two-loop box graphs:
  - Critical component for NNLO jet cross sections



- Technical breakthroughs, great progress in last two years: many $2 \to 2$ processes with up to one off-shell leg are now calculated at two-loops
  - Must combine with tree level $2 \to 4$, one loop $2 \to 3$ and self interference of the one loop $2 \to 2$ to obtain physical cross sections
    - Still some way off, but lots of ideas, lots of people working

Expect the first NNLO parton level Monte Carlos in the next couple of years, including $\bar{p}p \to$ jet + X

- Also: LO parton-level simulations for up to 8 partons in the final state now available (e.g. QCD backgrounds to ttH)

Vector boson + jets production

Walter Giele

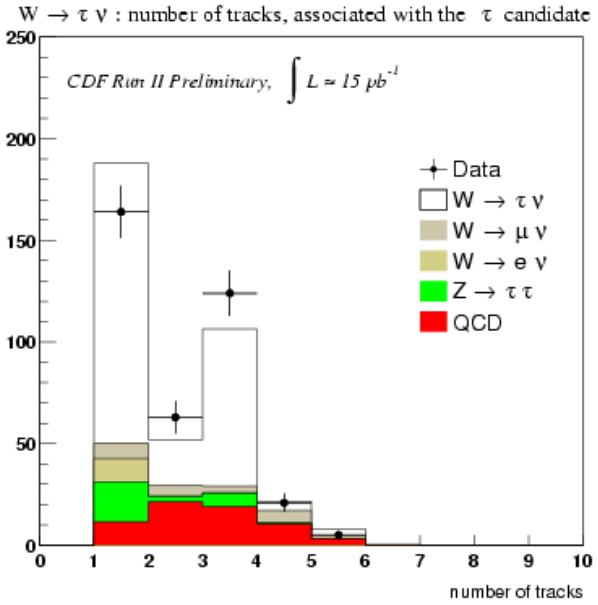
Background to top, Higgs, SUSY . . .
Laboratory for QCD studies with "unbiased jets"

- **Theoretical calculations**
  - **LO: W/Z + any number of jets, 2002 (alpgen + others)**
  - **NLO: W/Z + 2 jets at NLO, 2002 (mcfm)**
    - **real need for an n> 2 jets NLO parton level generator!**
  - **NNLO: W/Z + 1 jet parton level generator, 200x?**
- **Phenomenology**
  - **Cross sections reasonably stable at NLO**
    - **Good agreement between data and NLO theory for 0, 1jets**
      - And between data and LO for up to 4 jets w/ scale tuning
  - **Vector boson p_T**
    - **Non perturbative parameters at low p_T**
    - **Extract from data, assuming same ($\times m_W/m_Z$) for W and Z**

Tau triggers and analysis

John Smith

- τ's important for large tan β SUSY.
- CDF τ triggers installed.
- τ data coming in now.
- CDF first results $W \rightarrow \tau\nu$.



- Backwards differentiation provides a useful programing tool for optimization programs: alignment, tracking, Kalman filter, multivariate χ^2, Artificial Neural Nets.

Our Physics

I will mainly try to highlight Run II or other new results

Goals of Hadron Collider Physics

- Scott Willenbrock outlined five ways for hadron colliders to confront the SM
  - 1. Precision electroweak
  - 2. CKM
  - 3. Top quark
    - test its properties
  - 4. Higgs
    - As many processes and decays as possible
  - 5. QCD

- To which I will add
  - 6. Directly search for new phenomena not part of the SM

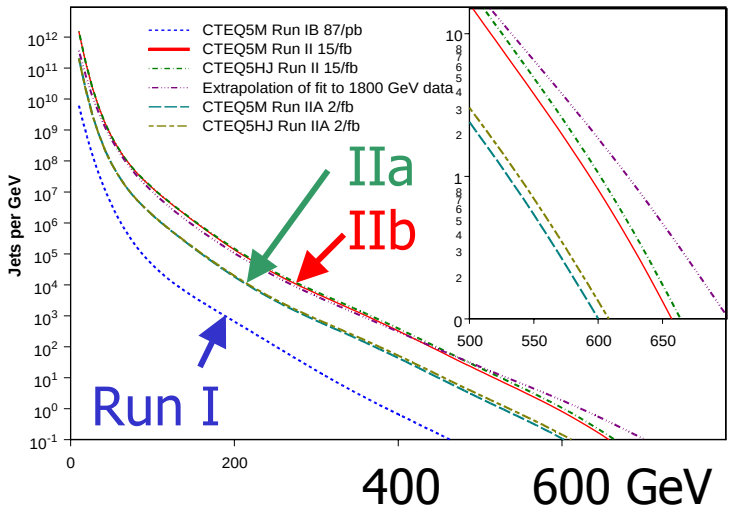
QCD

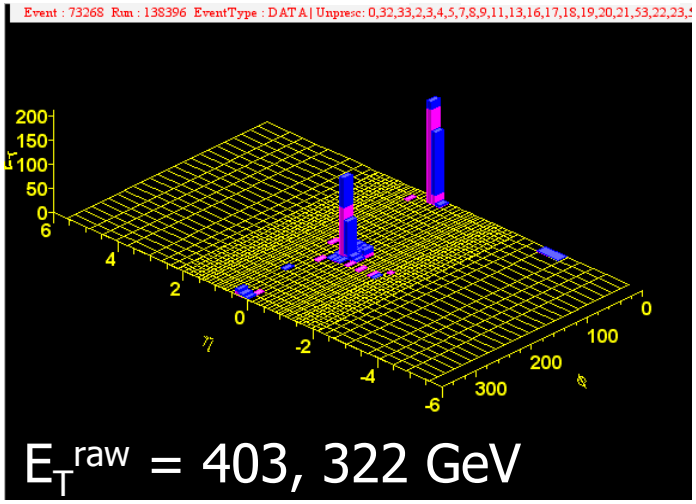
resolve some oustanding puzzles
understand the backgrounds to new physics

Jet Production at CDF

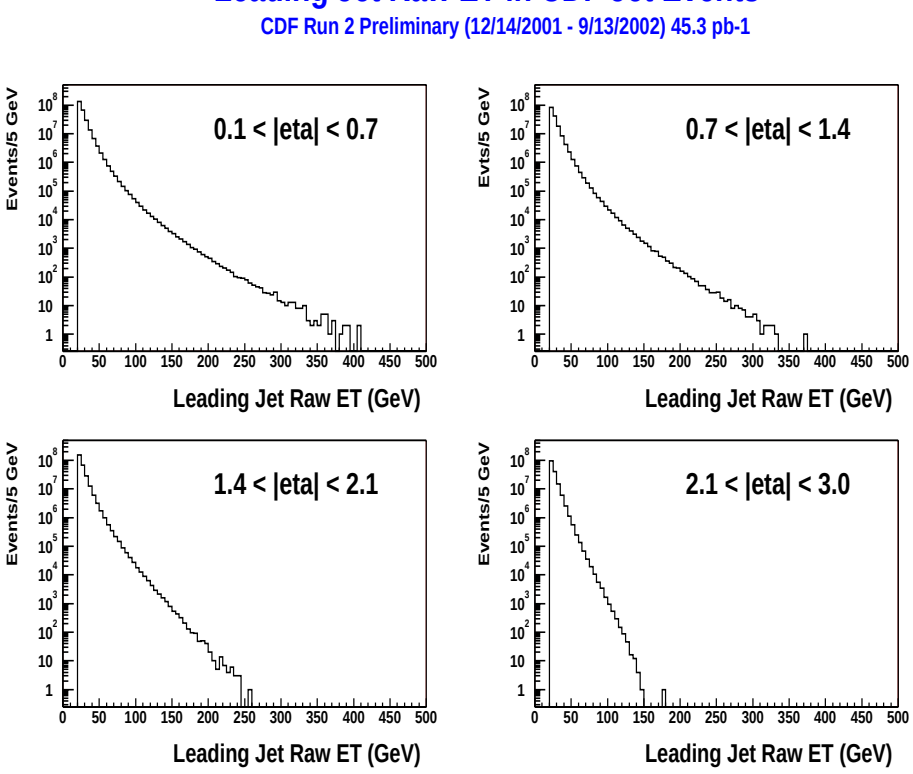
Mario Martinez

Expected central jet yield





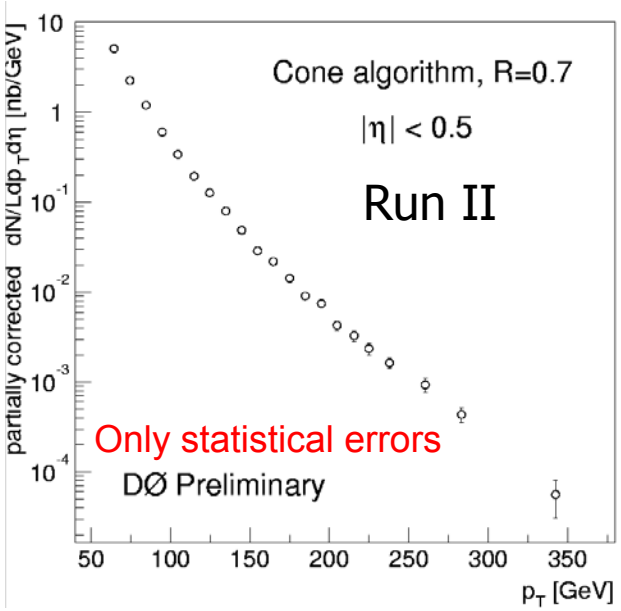
Run II jets in central and forward regions



Jet production at DØ

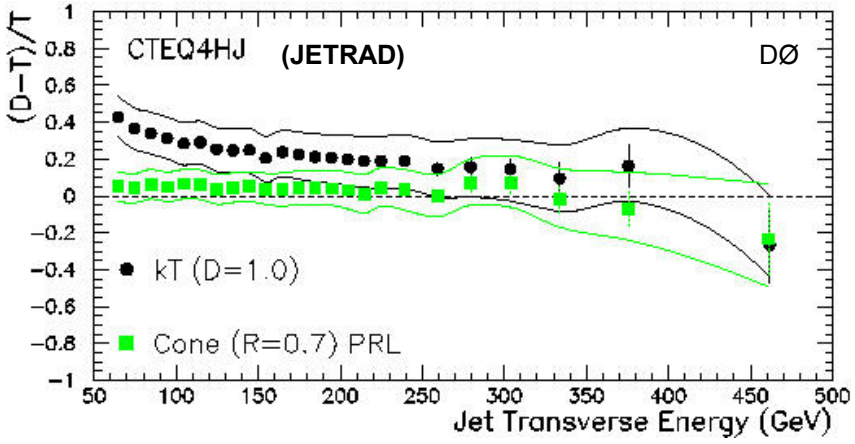
Elizabeth Gallas

Inclusive Run II jet p_T spectrum

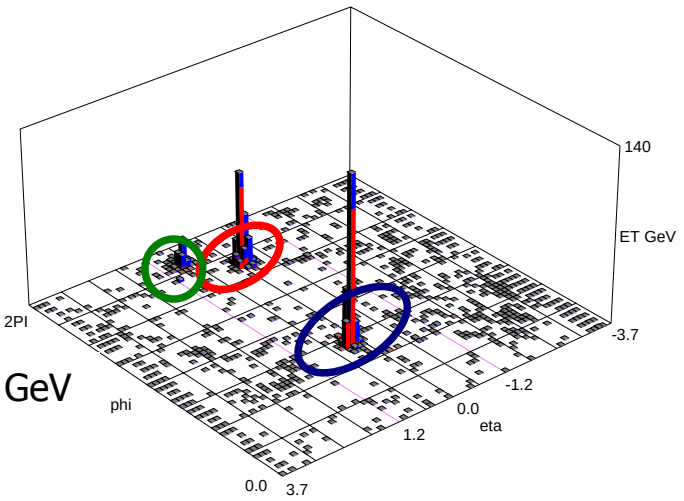


Another issue provoking discussion: choice of Jet Algorithm for Run II and why $k_T \neq$ cone

Sergei Chekanov



- **Central jets, ~ 1.9± 0.2 pb^{-1} at √s = 1.96 TeV**
- **Not yet fully corrected**
  - **Preliminary correction for jet energy scale (but no unsmearing or resolution effects)**
  - **30-50% systematic error in cross-section**
  - – **No trigger selection efficiency corrections**



Highest E_T Run II 3-jet event E_T : 310, 240, 110 GeV, E_t^{miss} : 8 GeV

Jet physics at HERA

Oscar Gonzalez

Jet studies at HERA allow very precise tests of QCD predictions.

Studies performed in two regimes: photo-production and deep inelastic scattering.

- Tests of perturbative QCD

Big effort to reduce the experimental uncertainties.

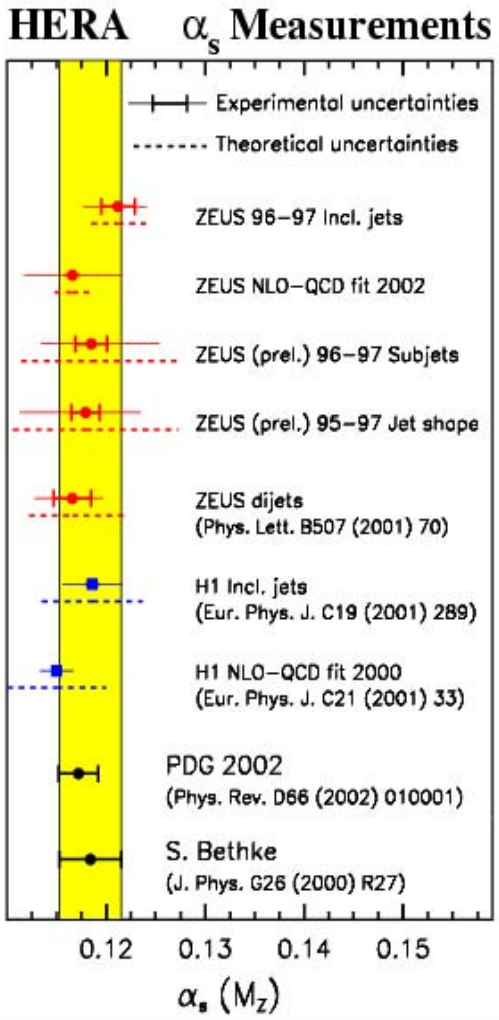
The uncertainties of the theoretical predictions are limiting the precision of the results in many analyses.

Higher orders or resummed calculations are needed.

- Tests of the photon PDFs

At present, the precision in the predictions is not enough to constrain the partonic content of the photon.

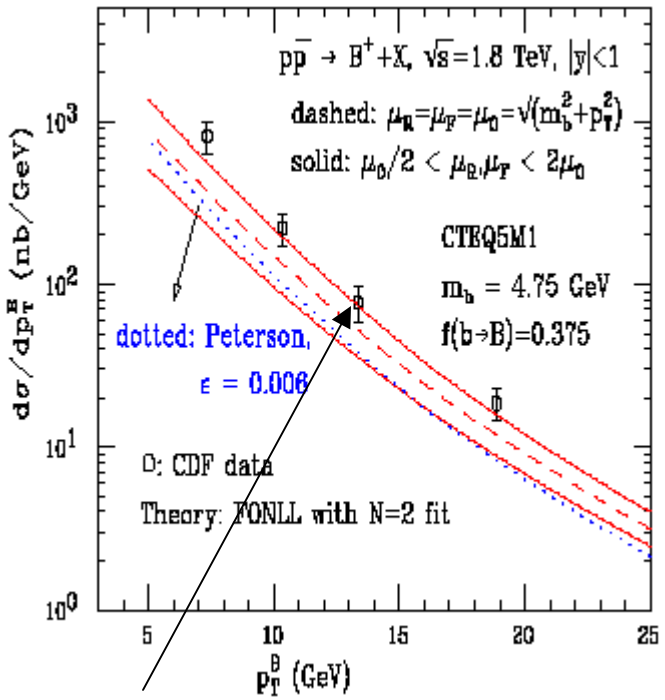
- Precise determinations of α_s in DIS.



Heavy flavour production at CDF

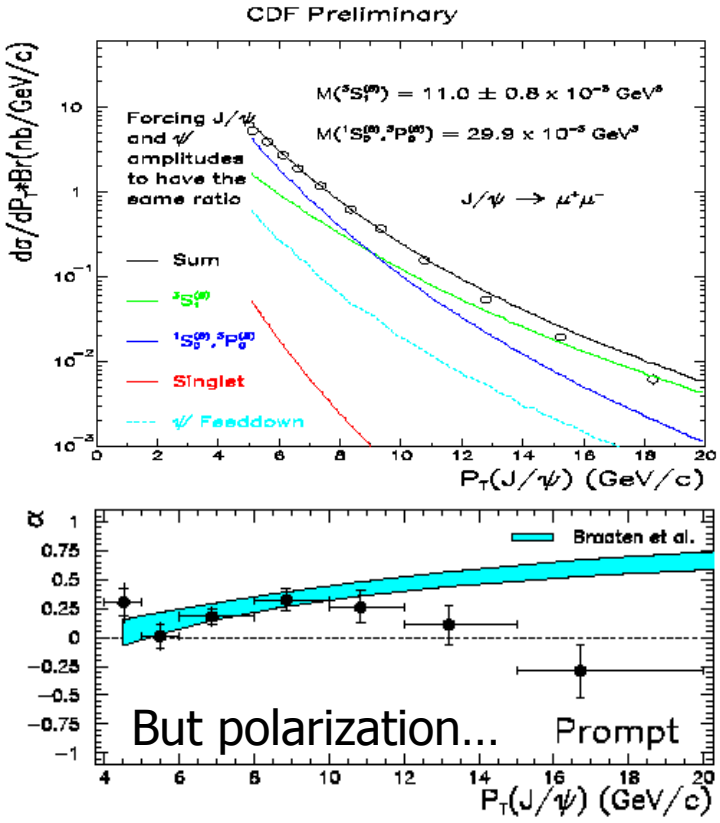
Mary Bishai

- **Lots of unanswered questions from Run I**
  - **B production cross section**

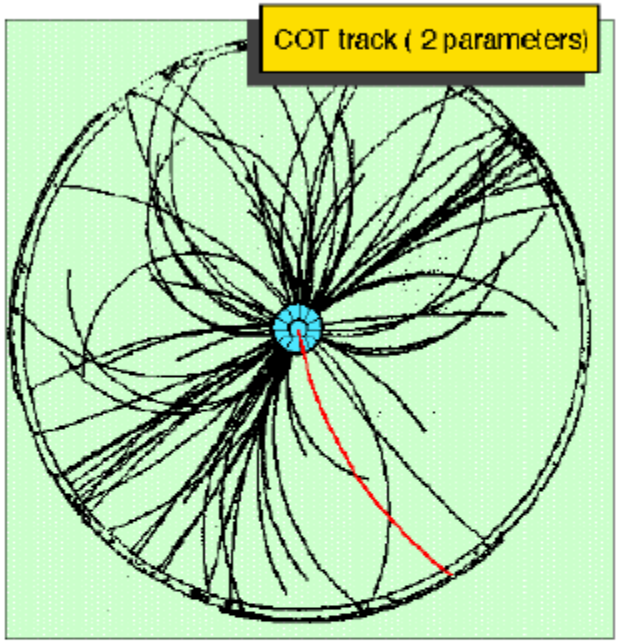


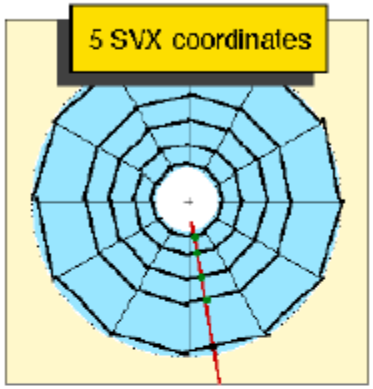
Can be made to fit with resummation plus retuned fragmentation

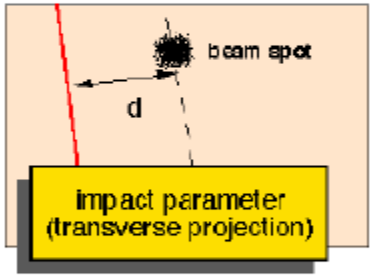
  - **Charmonium cross section**

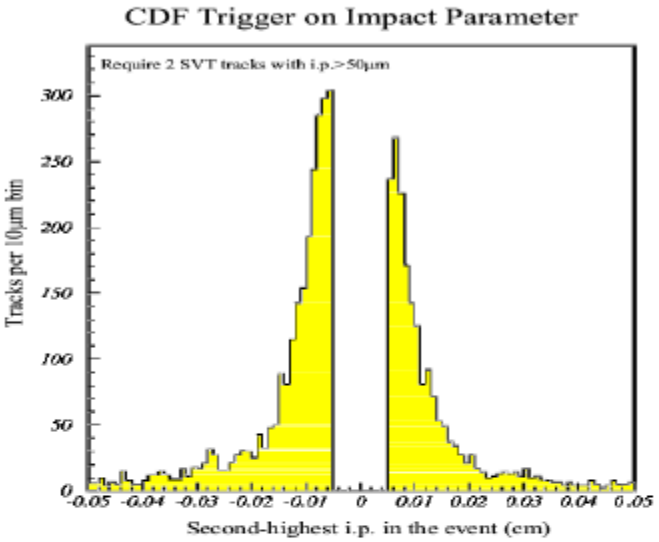


Run II Secondary Vertex Trigger

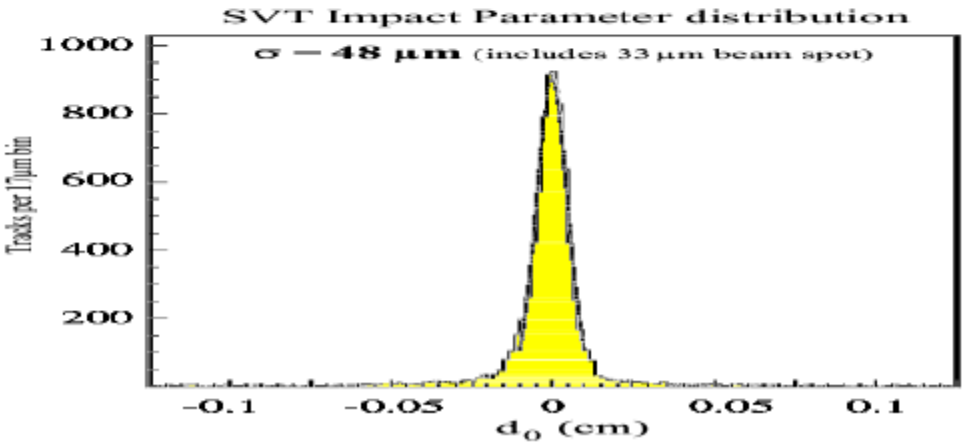


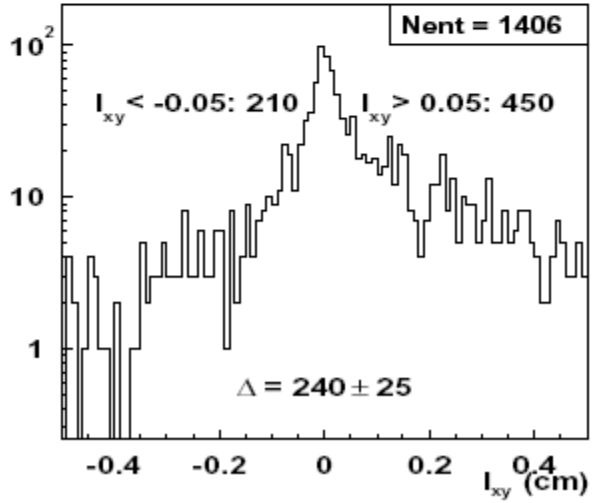






$150\,\mu m \leq d_0 \leq 1mm \quad 2^\circ \leq \Delta\phi \leq 90^\circ$



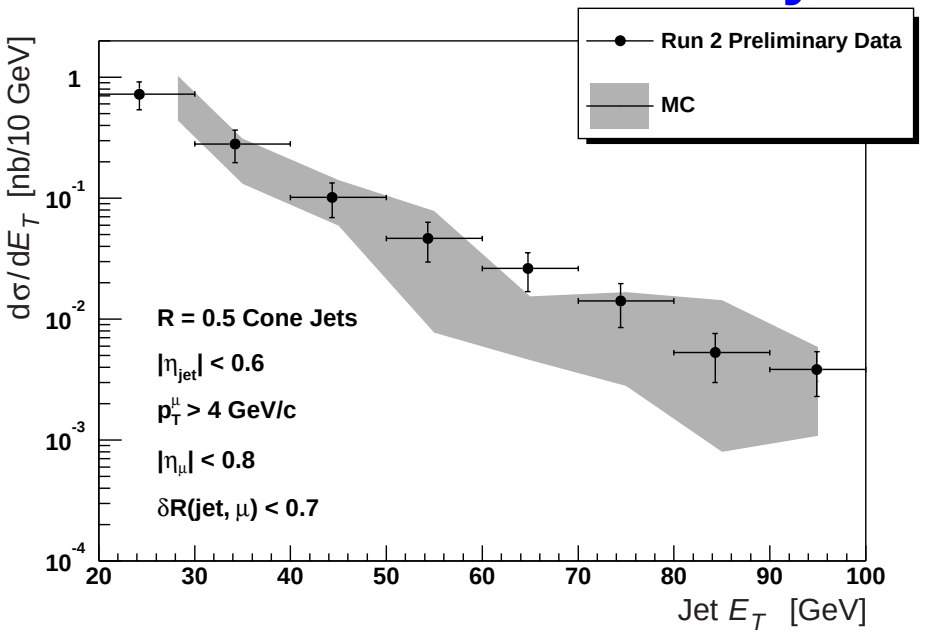


Daniela Bauer

J/ψ cross section

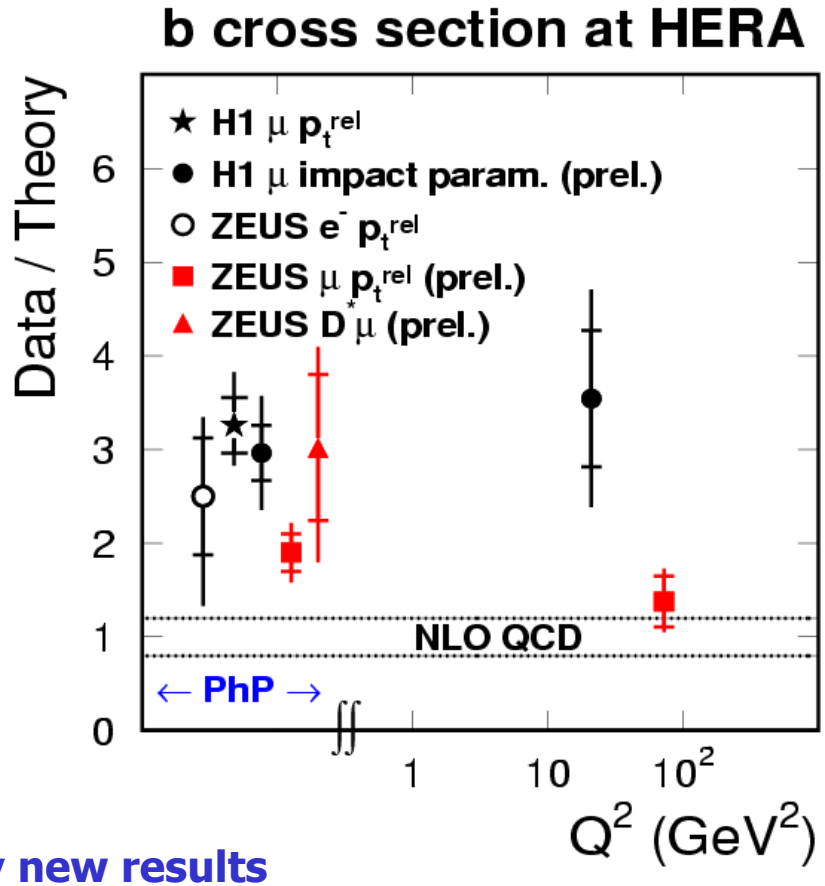
→ polarization
(test production mechanism)

DØ Run 2 Preliminary



Heavy quark production at HERA

Andreas Meyer



- 2002: many new results
- Almost all lie significantly above NLO theory, though ZEUS DIS at large Q^2 is OK

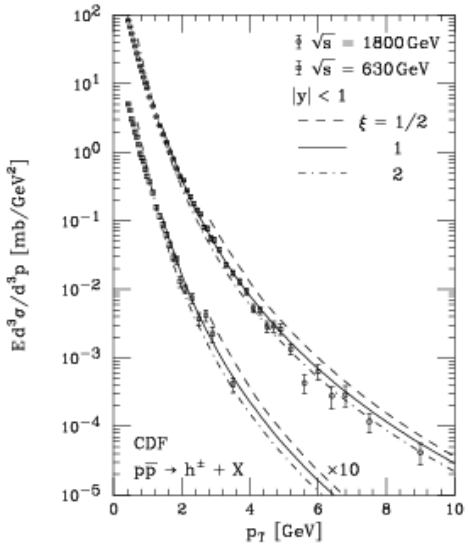
Charmonium

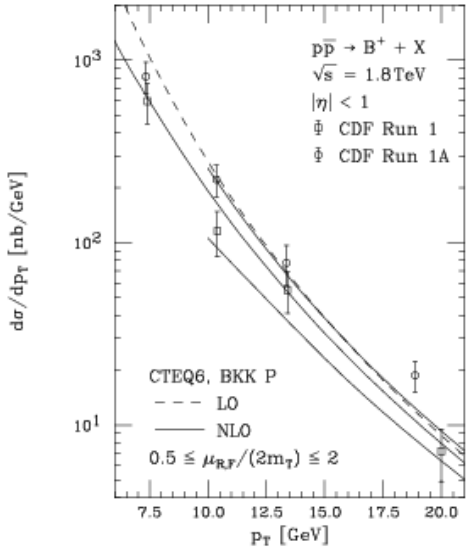
- No hard evidence for (or against) colour octet contribution to J/ψ

- **B-production excess may be due to incomplete treatment of heavy quark fragmentation**
  - **Depends on how extracted and parameterized**
  - **Suggestion that updated Tevatron measurements needed**

Thomas Gehrmann

Bernd Kniehl





- **NLO appears insufficient**
  - **need for NNLO calculation of both charmonium and b-production**

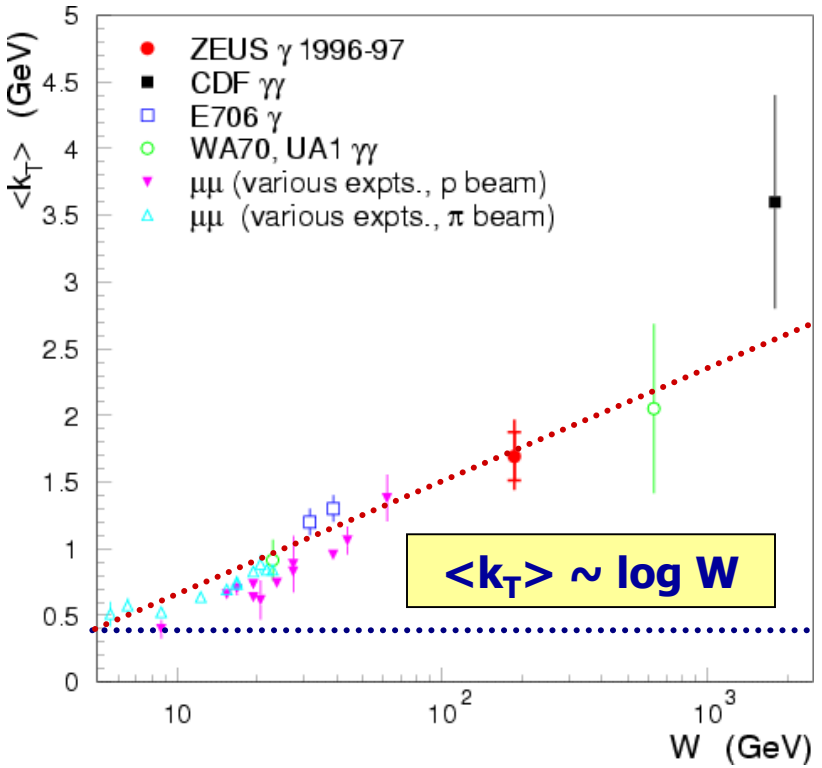
- **Suggestion to test charmonium production mechanism using V + charmonium (V=γ/W/Z, charmonium=J/ψ or χ_c)**

Cesar Palisok

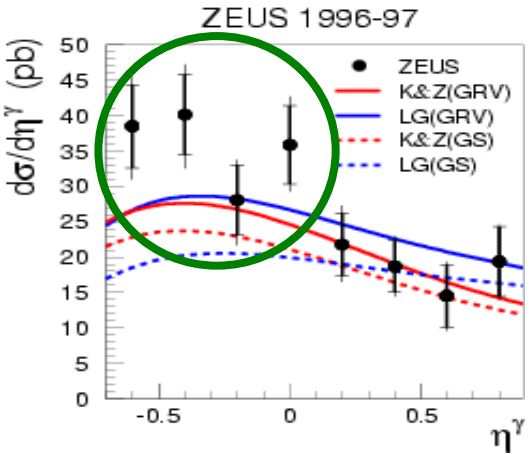
Direct Photons

Sung-Won Lee

- Photon results from Hadron collisions are quite consistent with NLO QCD at high p_T
- But CDF/DØ/E706 data indicate possible excess over NLO QCD in the low p_T region.
- One explanation proposed is that the partons have a significantly higher k_T (due to initial state soft gluon radiation)
- Can model with Gaussian smearing, but resummation offers hope for a more predictive calculation
- Fragmentation contribution from LEP data



ZEUS results may indicate need to review the present modelling of the partonic structure of the photon.

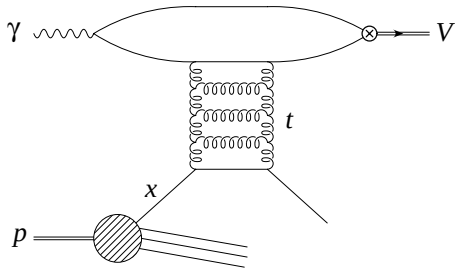


QCD at the 1 GeV scale

- **Low-x DIS at HERA** — **Olaf Behnke**
  - DGLAP evolution of F_2 works down to about 2 GeV^2
    - LO DGLAP + resolved photon describes the data well
  - Below 2 GeV^2, a variety of models: Regge, color dipoles . . .
  - No sign in the data of BFKL or saturation effects in F_2
- **Comparison of BFKL to ZEUS data on high-t vector meson production**
  - LO BFKL works remarkably well
  - Two-gluon exchange fails

Jeff Forshaw

← first time I have seen data that prefer BFKL



- **Fermilab E735**
  - particle production at $p_T \sim 1$ GeV in $\bar{p}p$ collisions at 1.8 TeV
  - parton rescattering included
  - source region size and pion density calculated

Laszlo Gutay

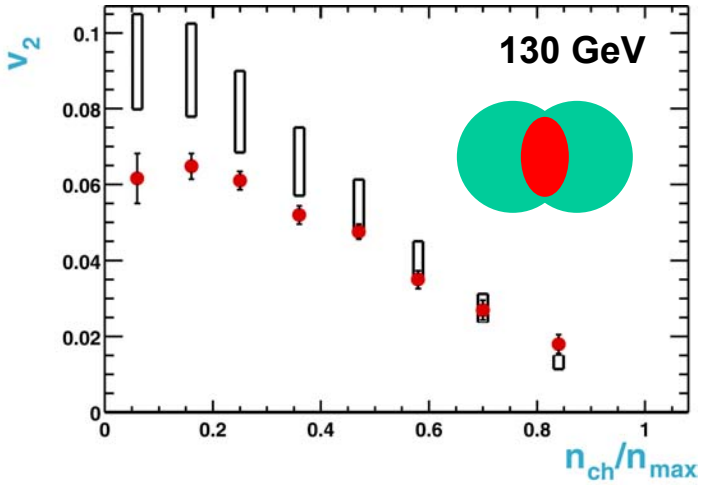
    - Energy density = 1.1 GeV/fm^3 too many degrees of freedom for a pion gas … onset of q/g deconfinement?

Recent Results from STAR

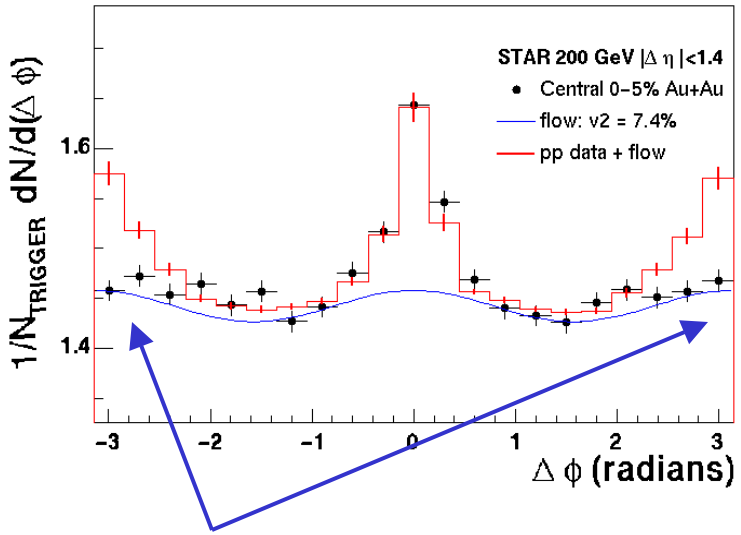
130/200 GeVA Au-Au collisions

Markus Oldenburg

- Large anisotropic flow, consistent with hydrodynamical picture
- Saturation of v_2 (elliptic flow) at high p_T

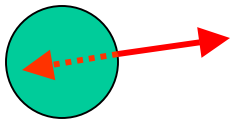


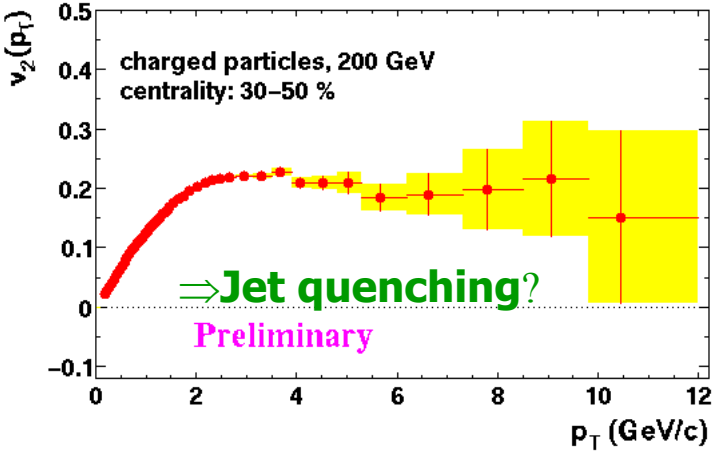
$$C_2(Au+Au) = C_2(p+p) + A*(1+2v_2^2\cos(2\Delta\phi))$$



- Suppression of back-to-back jets

⇒ Surface emission?





Diffraction

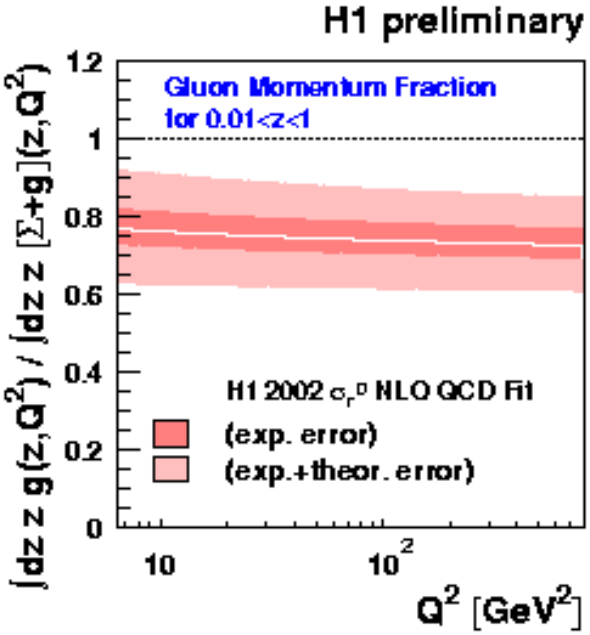
Jeff Forshaw

Aharon Levy

Dino Goulianos

- **Four presentations**
  - **Seemed simultaneously too much and too little?**
  - **Maybe it's just me, but I found it hard to grasp a very coherent picture**

- **Even though factorization (apparent partonic structure of a pomeron) is not guaranteed to work at pp, Pomeron parton densities from HERA tend to work well at the Tevatron in conjunction with a 10% gap survival factor**
  - **The parton distribution is ~ 80% gluon**



Just a thought:

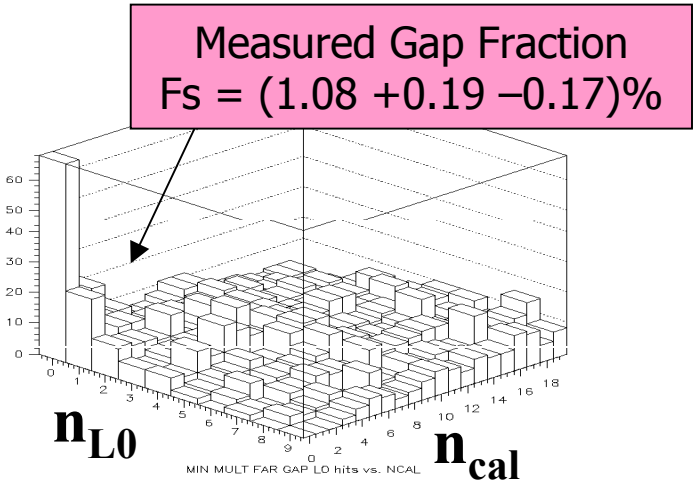
- Can we relate somehow
  - **Production of J/ψ where a single gluon becomes a color-singlet**

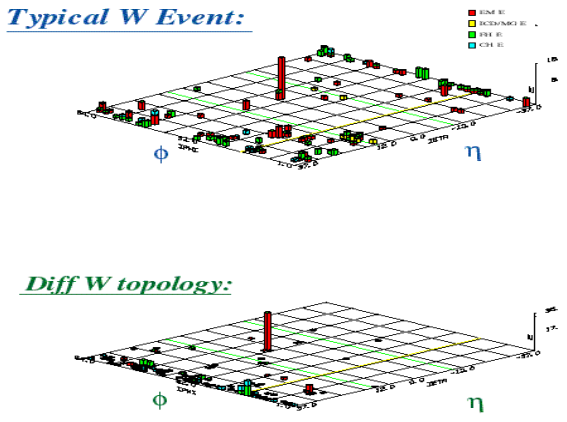
  and
  - **Hard diffraction where a color singlet behaves like a single gluon**

Diffractive W production

Silvia Tendindo-Repond

- DØ showed diffractive W signal (CDF have reported similar signal earlier)





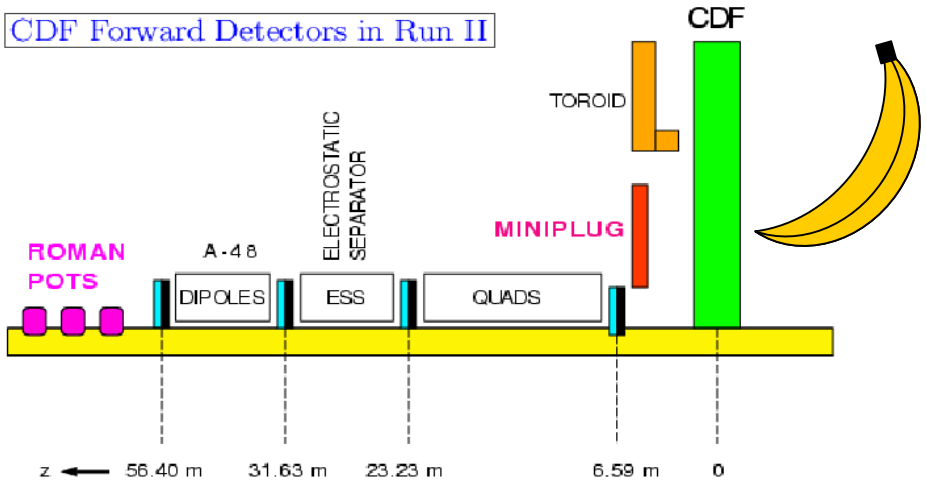
- If a rapidity gap really implies diffraction, how can it be that we can kick a parton out of a proton with $Q^2 = m_W^2$ and not destroy the proton in the process?
  - And do this 10% of the time? *(1% rate, 10% survival probability)*
  - What does this tell us about the colour content of the proton?
- How do we relate gaps to the "normal" underlying event?
  - Is a rapidity gap an underlying event as particle/energy flow $\rightarrow$ 0?
  - Or one possible colour configuration? (or is that the same thing?)

Run II

Both CDF and DØ are improving their diffractive instrumentation for Run II

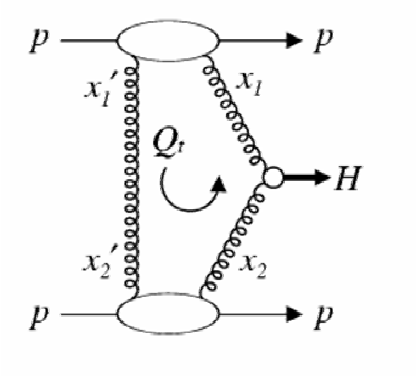
CDF: calorimeters and shower counters to cover $3.5 < \eta < 7.5$

DØ: Roman pots in $\pm$ z direction



A modest list of projects

- **Measure the gap survival probability**
- **Relate rapidity gaps to diffractive (anti-)protons seen in Roman Pots**
- **Measure $\bar{p}p \rightarrow \bar{p}$ (gap) jj (gap) p**
  - **Will provide a sanity check on Higgs production at the LHC**



Khoze, Martin & Ryskin predict S/B > 1 for m_H = 115 GeV includes gap survival factor 1/50

BUT other authors say it's impossible (e.g. Schlein)

Published cross section estimates cover 3 orders of magnitude

CKM Physics

Confront the unitarity triangle through (e.g.) B^0_S mixing . . .

B-physics at Hadron Colliders

Robert Fleischer

- CP violation established in the B system through $B_d \to J/\psi\, K_S$
  - $\sin\phi_d = 0.734 \pm 0.054$
    - Either $\phi_d = 47°$ (2β in SM) or $133°$ (new physics)
- BaBar and BELLE can do much more with their data e.g.
  - Is $B \to \pi K$ consistent with SM $\gamma < 90°$?
  - Same mixing asymmetry in $B_d \to J/\psi\, K_S$ and $B_d \to \phi\, K_S$?
  - $B_d \to \pi\,\pi$ will be an important piece of the puzzle
- Hadron colliders (Tevatron and LHC) will in addition, provide access to the B_S system ("the El Dorado")
  - Mixing parameters Δm, $\Delta\Gamma$
  - Sizeable CP violation in $B_S \to J/\psi\, \phi$?
  - $B_S \to KK$ complements $B_d \to \pi\,\pi$; $\to$ extract γ
  - $B_S \to D_S K$: extract $\phi_S + \gamma \to \gamma$

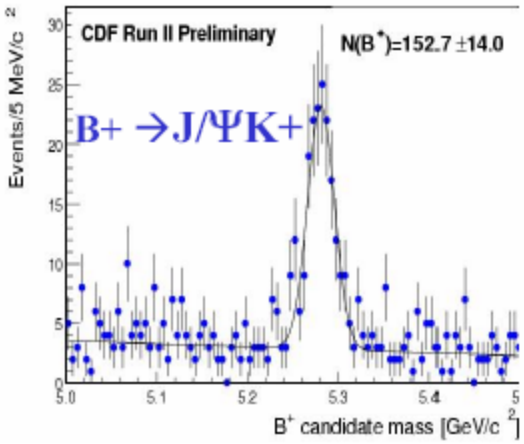
Marcel Merk

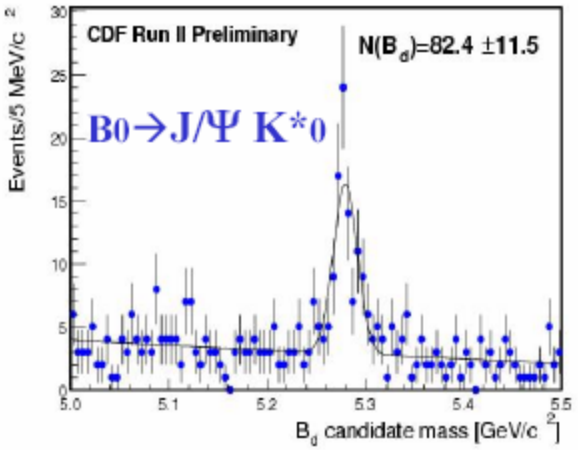
    - Fully exploit all of these in the LHC era
- Many other interesting topics e.g.
  - Rare decays e.g. $B \to K^* \mu^+ \mu^-$, $B_{s,d} \to \mu^+ \mu^-$
  - Relation of CP in B-system to $K \to \pi\nu\nu$

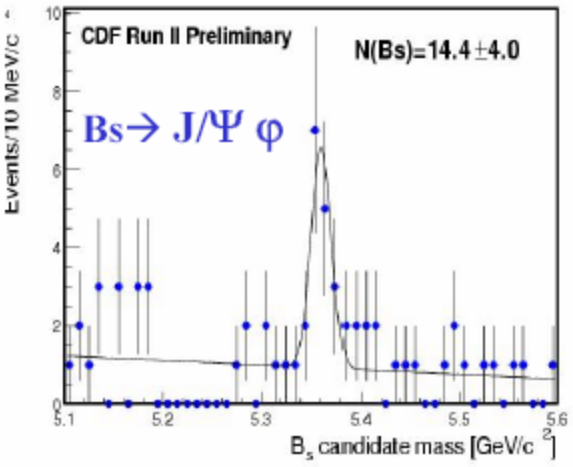
B-physics at CDF in Run II

Sandro de Cecco

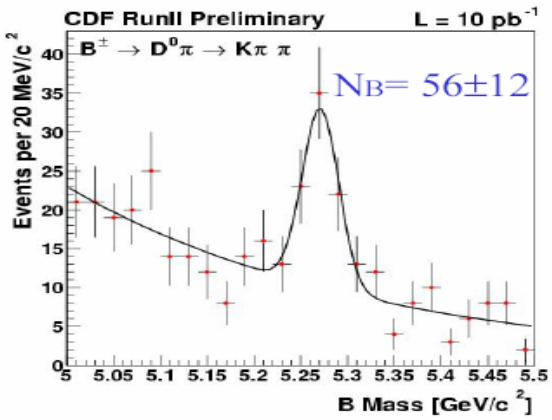
- **Build on Run I experience + new capabilities (SVT, TOF)**
  - **Leptonic signals**

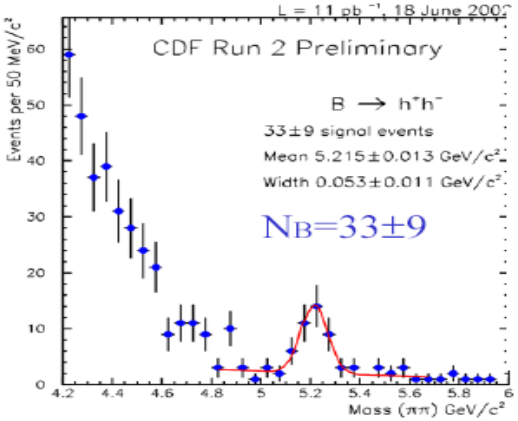






  - **First purely hadronic signals (using SVT)**





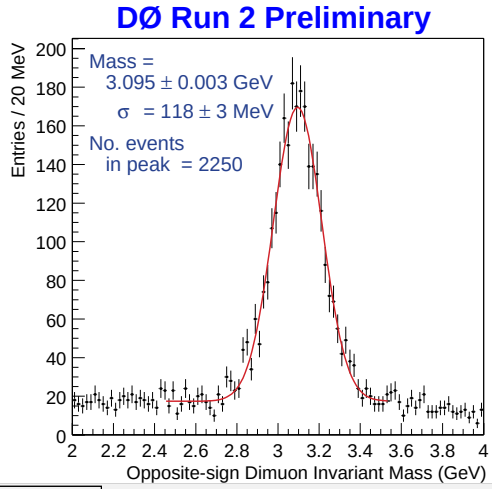
Hugely impressive results; impossible for me to do justice to them here!

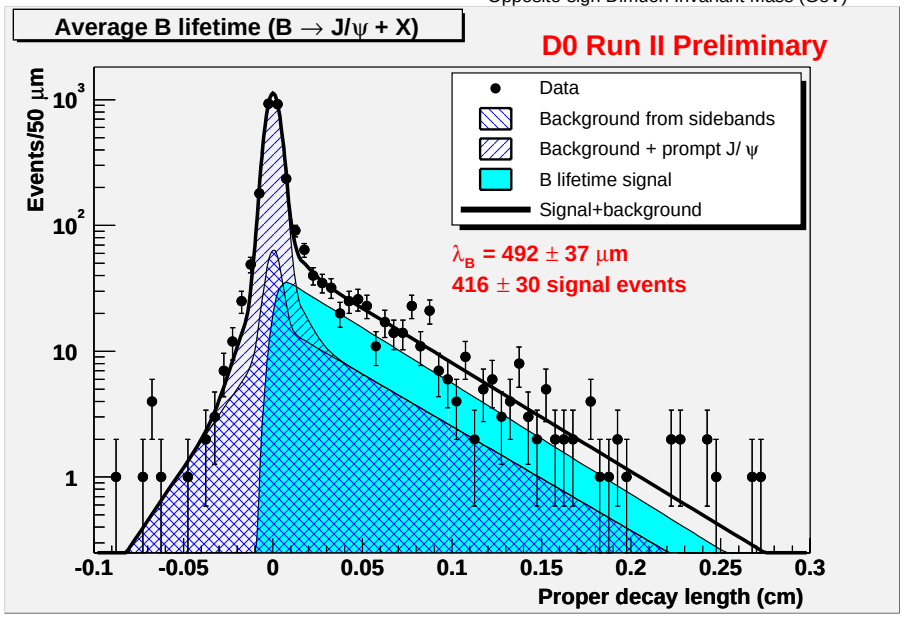
B Physics at DØ in Run II

Wendy Taylor

Putting the tools in place

$J/\psi \rightarrow \mu^+\mu^-$

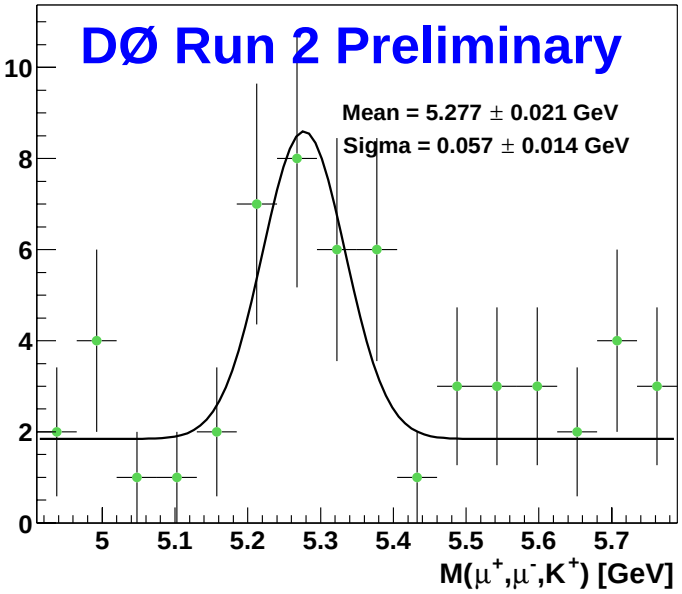




$\tau(B) = 492 \pm 37\ \mu m$

DØ's First B mesons

$B^{+(-)} \rightarrow J/\Psi\ K^{+(-)}$



DØ does not exploit purely hadronic triggers, but benefits from large muon acceptance, forward tracking coverage, and can use $J/\psi \rightarrow e^+e^-$

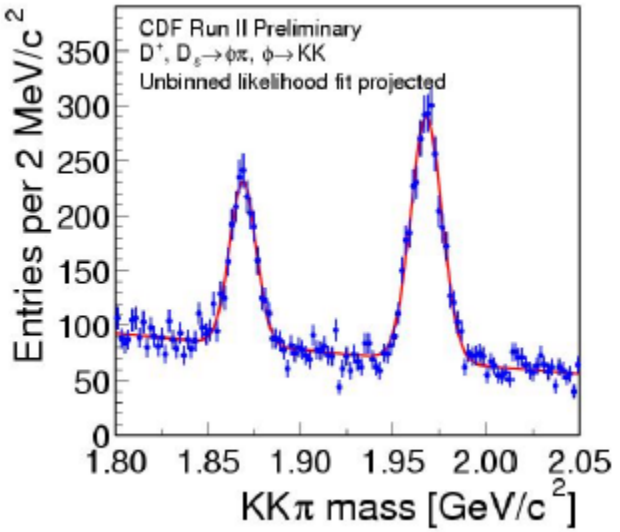
B-physics program at the Tevatron

- B^0_S mixing
  - New constraint on the unitarity triangle
  - CDF sensitivity
    - ~ SM level with few hundred pb^{-1}
    - $X_s \sim 70$ with 2 fb^{-1}

$B_s \rightarrow D_s\pi$; $D_s\pi\pi\pi$;
$D_s \rightarrow \varphi\pi$; K^*K; K_sK;

- CP asymmetry in $J/\psi K_S = \sin(2\beta)$ in SM
- CP asymmetries in hadronic modes
- measure lifetimes for B^+, B_s and Λ^0_b, and more . . .
- Extract γ from $B_S \rightarrow D_S K$
- Rare decays

- And, as a bonus, look forward to the world's largest charm meson sample in CDF



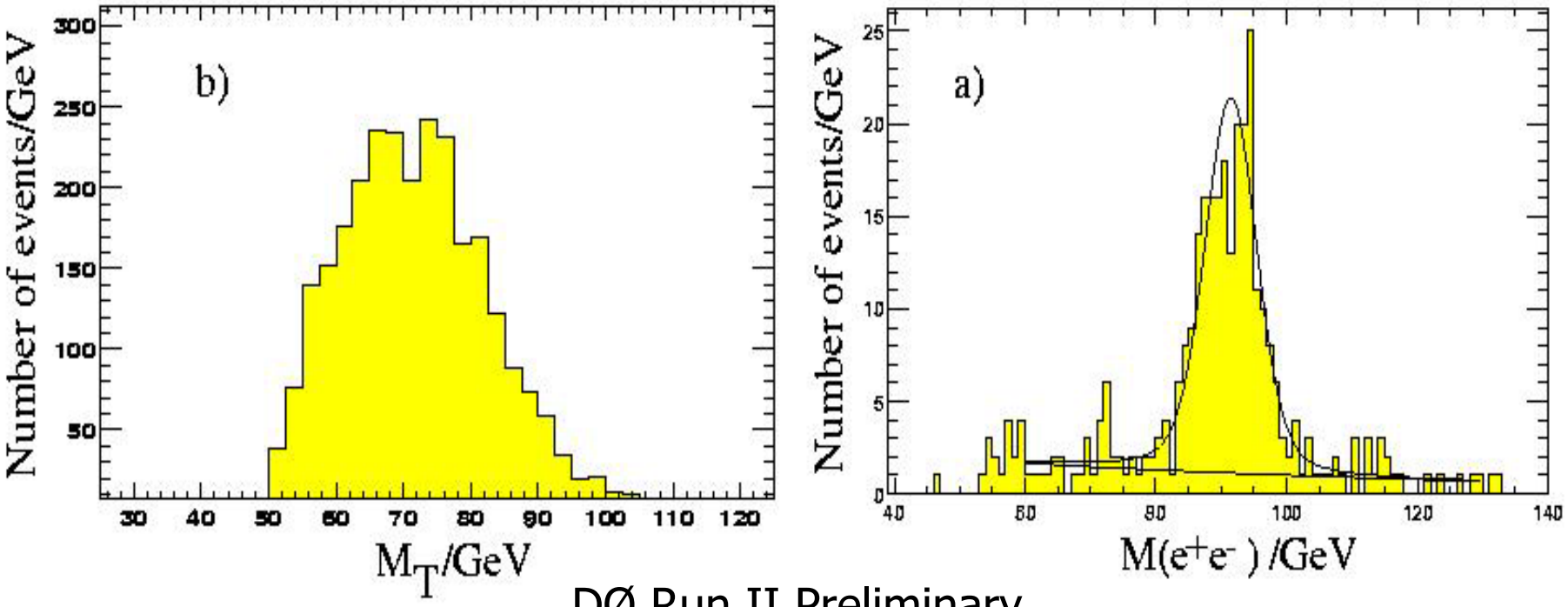
Electroweak

Indirectly constrain new physics

m_W, m_t

W and Z bosons at DØ

Andrew Alton

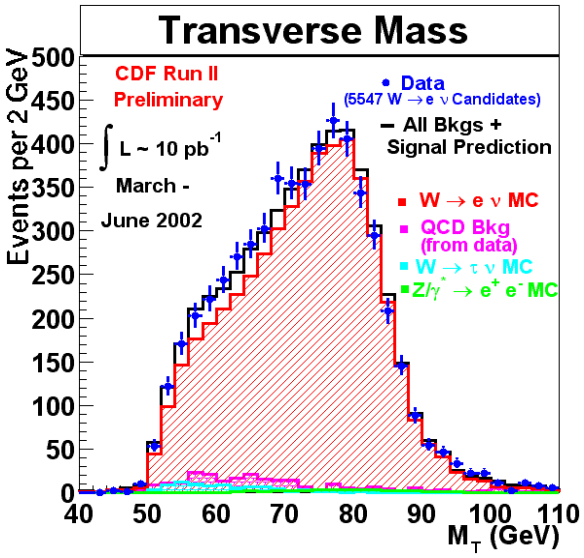


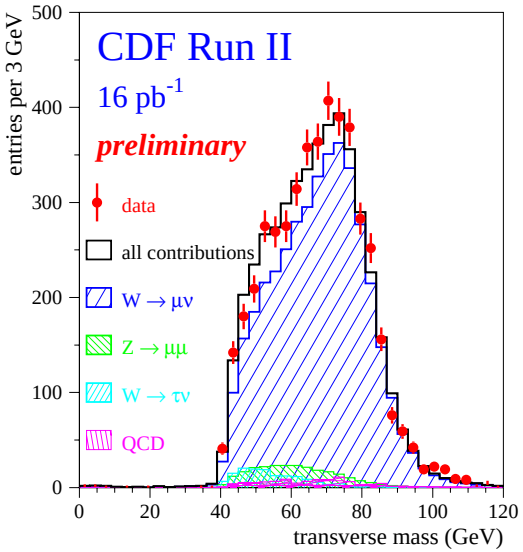
DØ Run II Preliminary

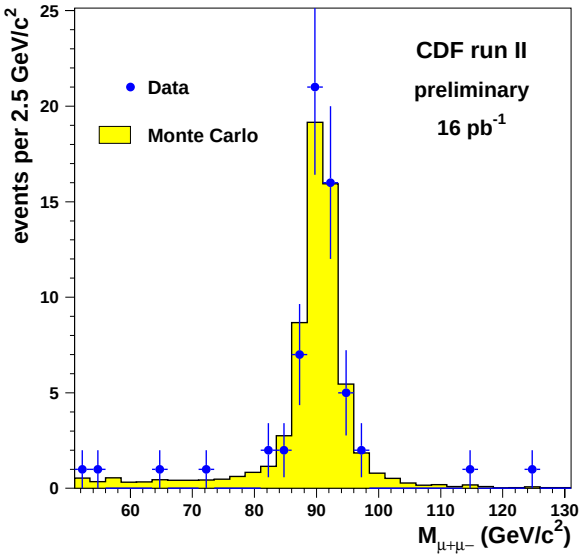
- $\sigma \cdot B\,(W \rightarrow e\nu) = 2.67 \pm 0.06\,(stat) \pm 0.33\,(sys) \pm 0.27\,(lum)$ nb
- $\sigma \cdot B\,(Z \rightarrow ee) = 266 \pm 20\,(stat) \pm 20\,(sys) \pm 27\,(lum)$ pb
- $R_e = 10.0 \pm 0.8\,(stat) \pm 1.3\,(sys)$
- $\Gamma_W = 2.26 \pm 0.18\,(stat) \pm 0.29\,(sys) \pm 0.04\,(theory)$ GeV

W and Z bosons at CDF

Eric James





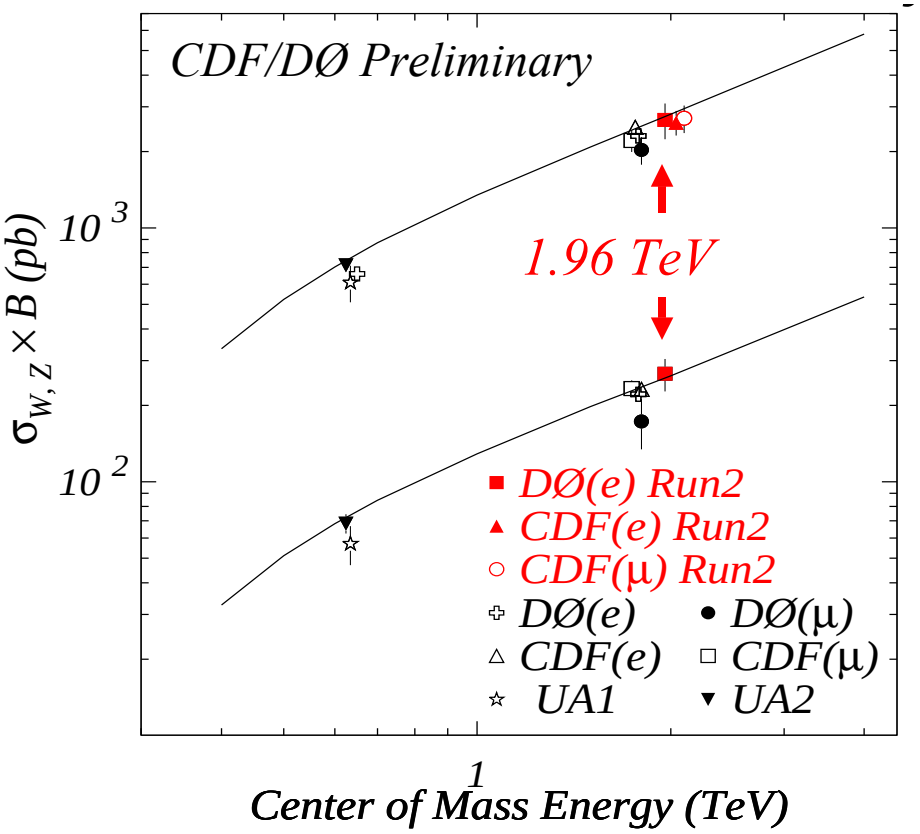


CDF Run II Preliminary

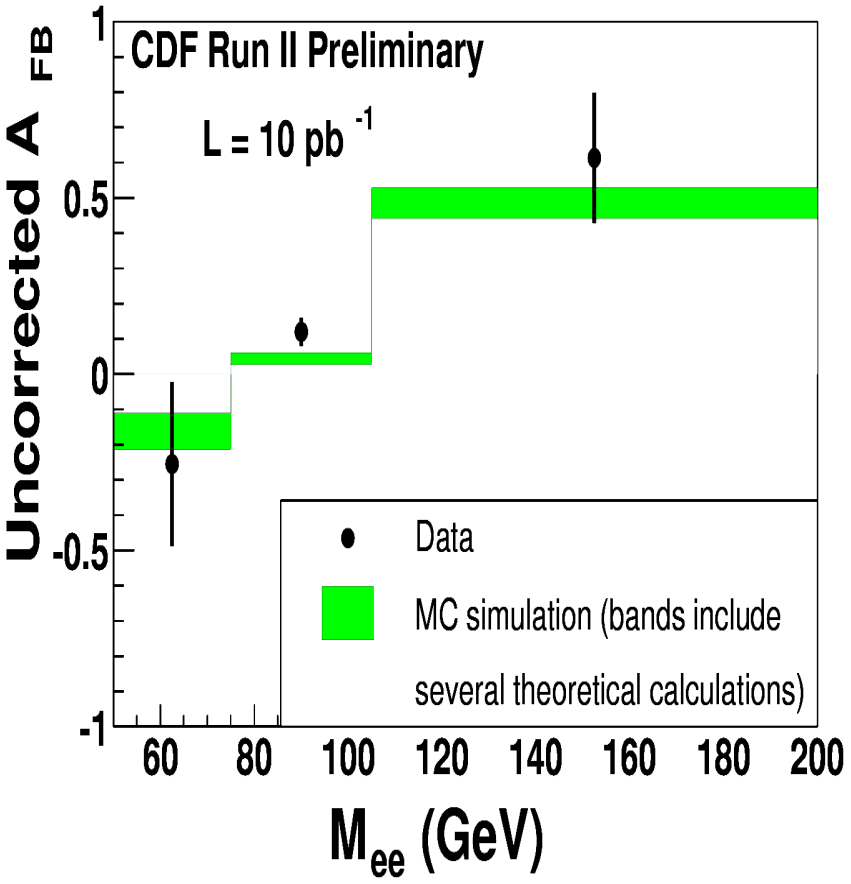
- $\sigma \cdot B\,(W \rightarrow e\nu) = 2.60 \pm 0.03\,(stat) \pm 0.13\,(sys) \pm 0.26\,(lum)$ nb
- $\sigma \cdot B\,(W \rightarrow \mu\nu) = 2.70 \pm 0.04\,(stat) \pm 0.19\,(sys) \pm 0.27\,(lum)$ nb
- $R_\mu = 13.66 \pm 1.94\,(stat) \pm 1.16\,(sys)$

Run II electroweak measurements

W and Z cross sections at new √s



Forward-Backward asymmetry



Prospects for the LHC

Dominique Pallin

- Will be possible to exploit the huge statistics of W and top production at the LHC to further improve precision on electroweak measurements
  - If needed…

The Top Quark

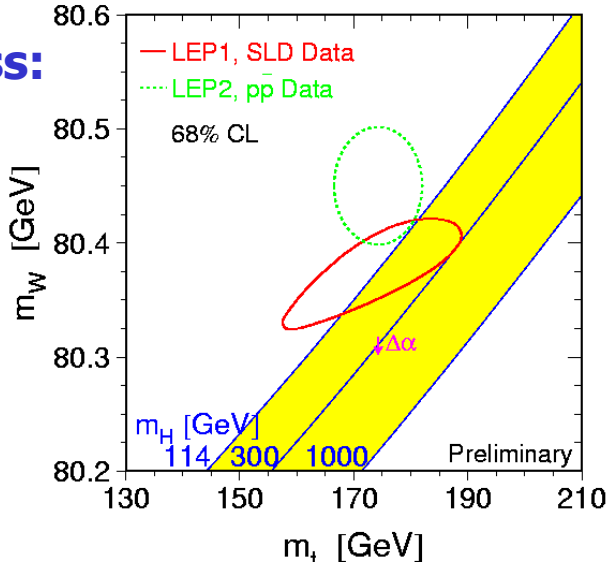
Measure its properties with greatly increased statistics

The Top Quark

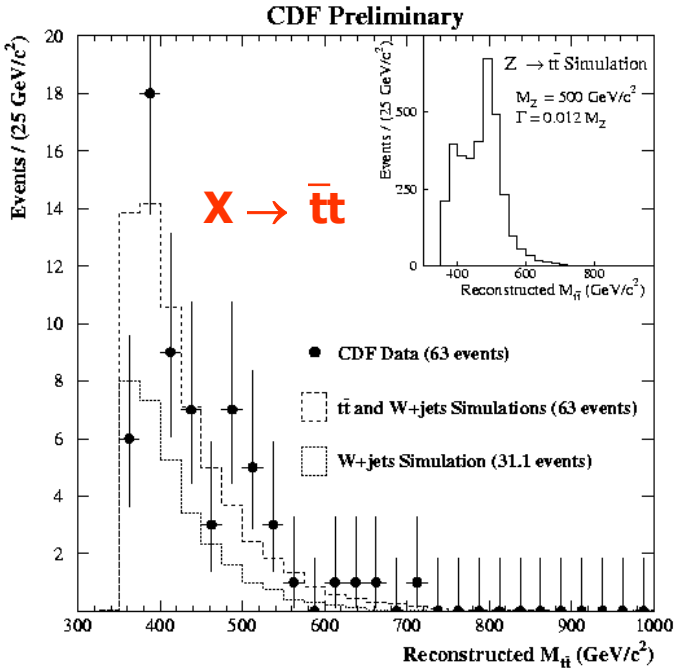
Elizabeth Simmons

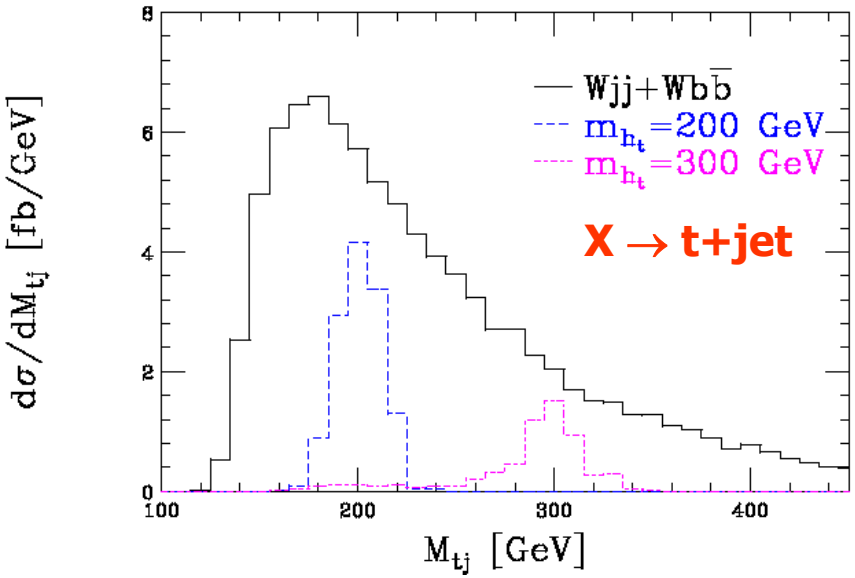
Top provides insight into electroweak symmetry breaking

Constrain the Higgs mass:



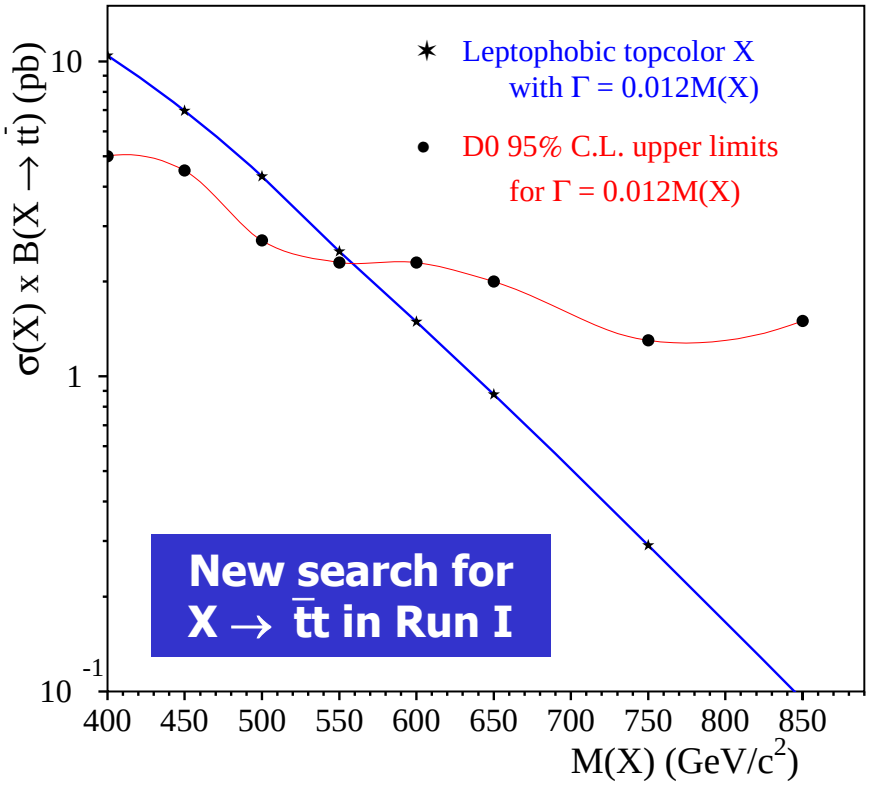
BSM theories predict unusual top properties and states visible at Run II & LHC, such as Z′ (below) or top-higgs with FC decays.

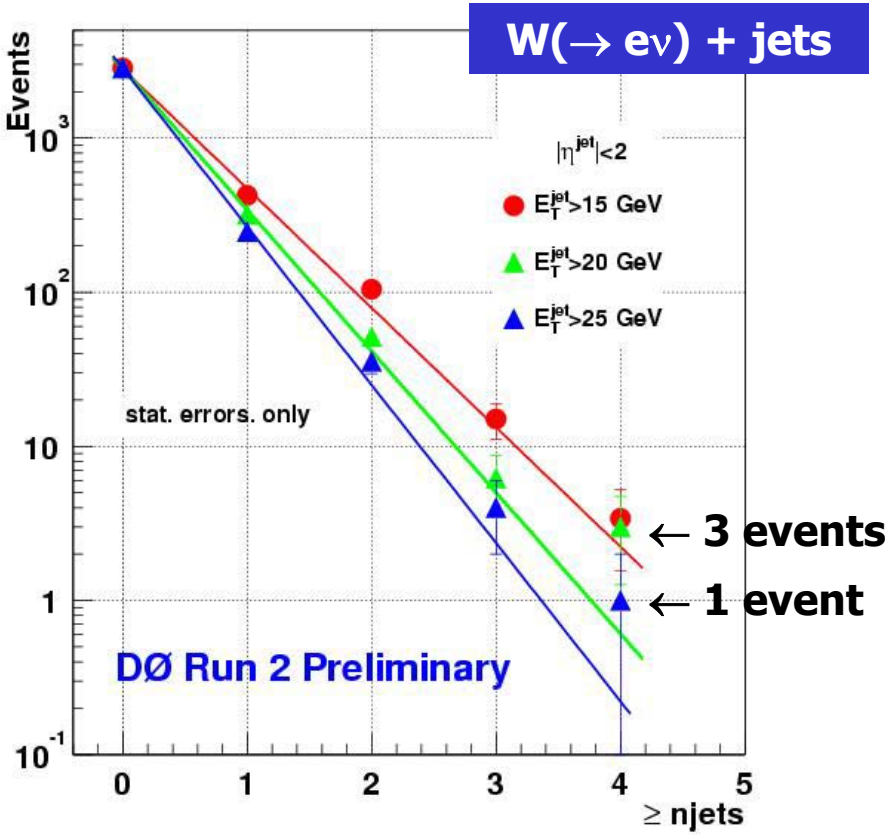




The Top Quark at DØ

Ken Johns

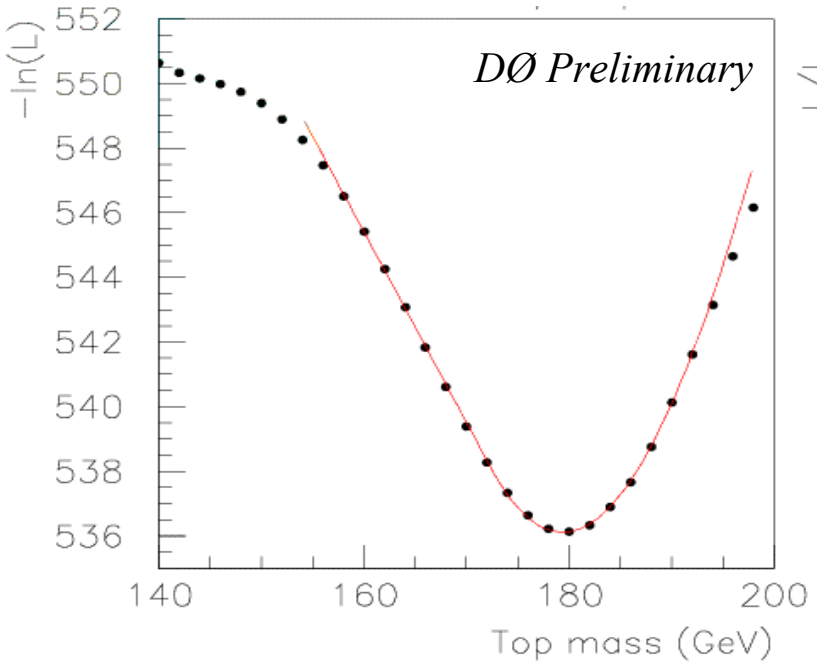


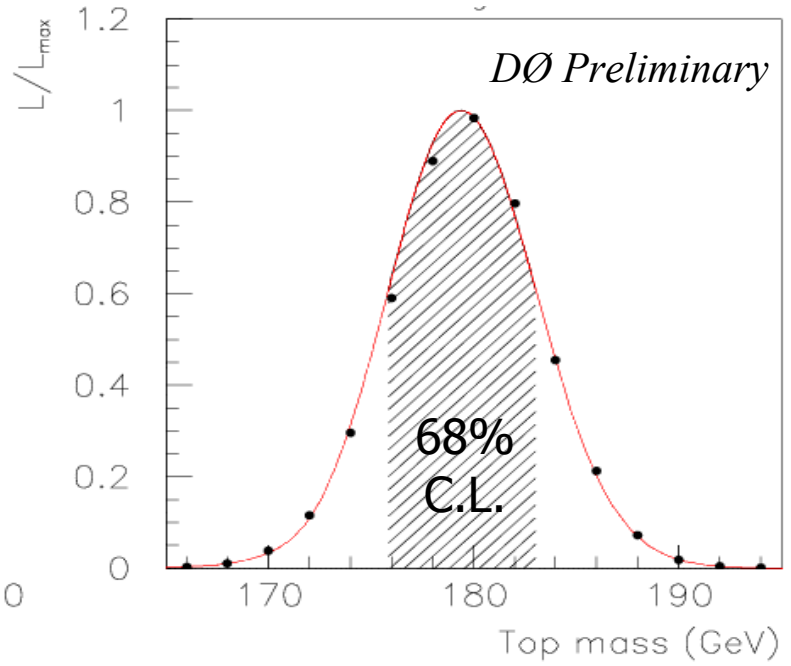


- **Exclude a narrow, leptophobic X boson with $m_X < 560$ GeV/c^2**
- **W→ eν + jets scaling in Run IIa data: a school figure on the way to re-discovering top**

New Top Mass from Run I data

Juan Estrada





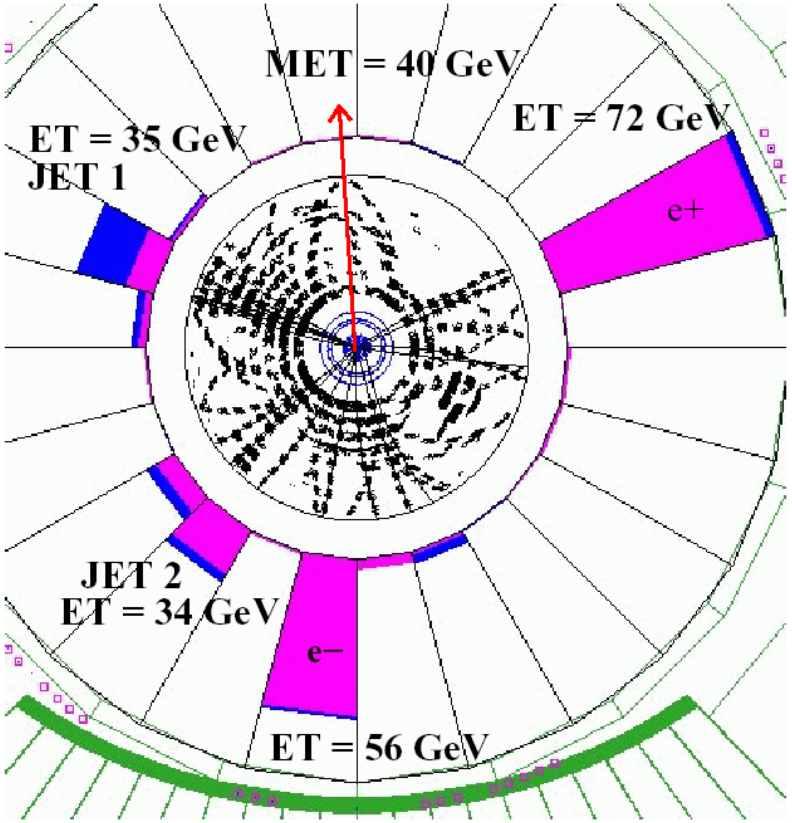
m_t = 179.9 ± 3.6 (stat) ± 6.0 (sys) GeV *preliminary*

- **New technique makes use of more information per event**
- **Better discrimination between signal and background**
- **Improves statistical error from 5.6 GeV [PRD 58 52001, (1998)] to 3.6 GeV: equivalent to a factor of 2.4 in the number of events**
- **22 events pass final cuts (from fit: 12 S + 10 B)**

Prospects for Top Quark Physics at CDF in Run 2a

Wolfgang Wagner

First di-lepton events:



$M_{ee} = 118$ GeV/c^2 and $H_t = 255$ GeV

Run 2a Top Quark Prospects

- $\approx$ 800 b-tagged $t\bar{t}$ lepton+jets events
- $\delta\sigma_{t\bar{t}}/\sigma_{t\bar{t}} < 7\%$
- $\Delta m_{top} = 2 - 3$ GeV/c^2
- observe single-top production ➜ $|V_{tb}|$
- $\mathrm{BR}(t \to \gamma(Z^0)q) < 0.3\%(1.5\%)$
- $t\bar{t}$ spin correlation
- soft gluon radiation in $t\bar{t}$ events

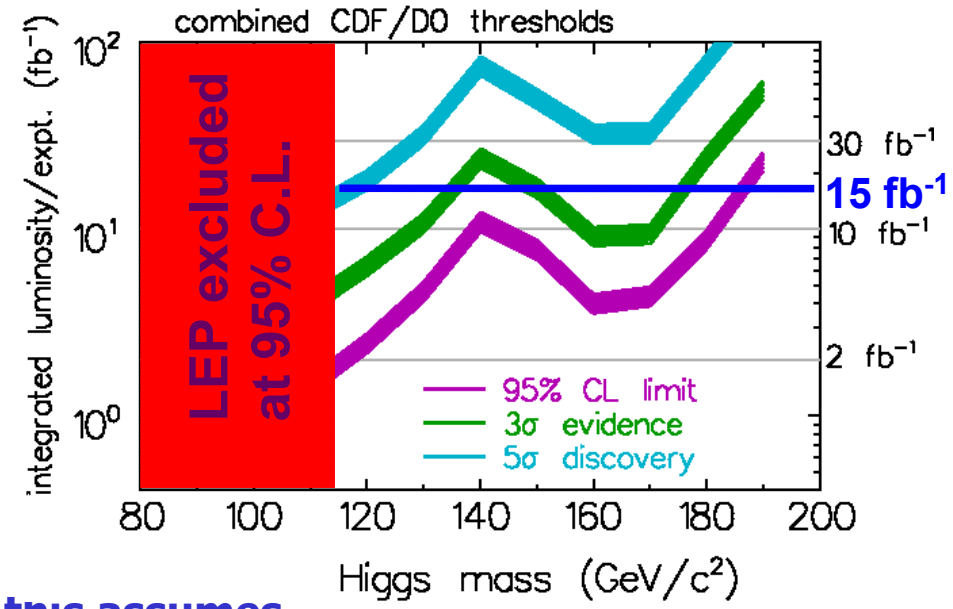
The Higgs Boson

Discover (or exclude)
Constrain its properties

The Higgs boson at the Tevatron

Pasha Murat

Suyong Choi

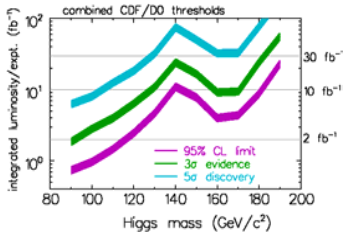
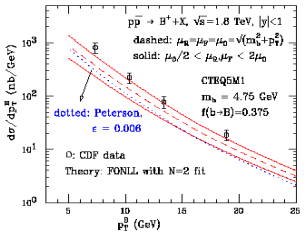
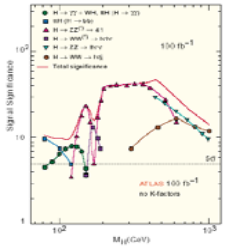
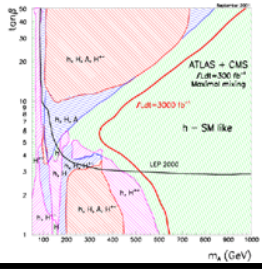


- **Remember, this assumes**
  - **Two experiments (OK)**
  - **Resolutions at least as good as Run 1**
  - **Good b-jet and lepton identification**
  - **Trigger efficient at high luminosities**
  - **Good understanding of all the backgrounds**

What the experiments are working on

- **Silicon, trigger and DAQ upgrades for CDF and DØ (2005) are moving towards approval**

Just for fun

	Plot	Number of showings
Tevatron Higgs reach		**8**
Tevatron B-cross section		**6**
LHC Higgs sensitivity		**5**
LHC SUSY Higgs m_A, tan β		**3**

Theoretical Progress on Higgs Production

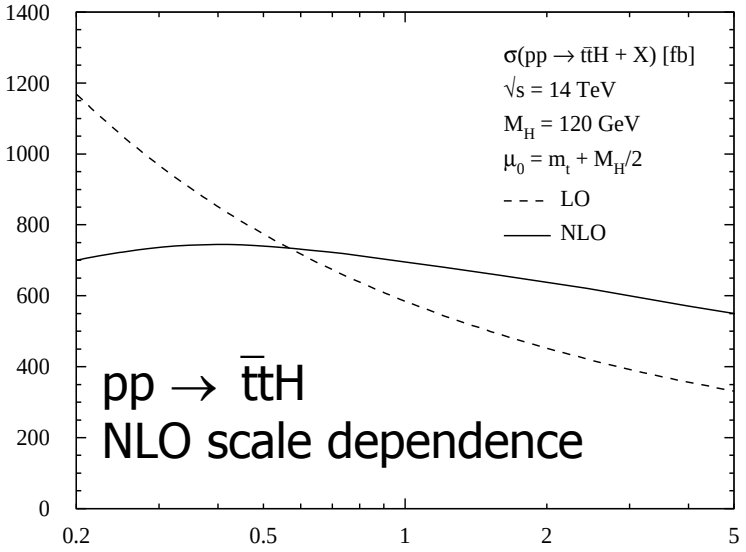
Robert Harlander

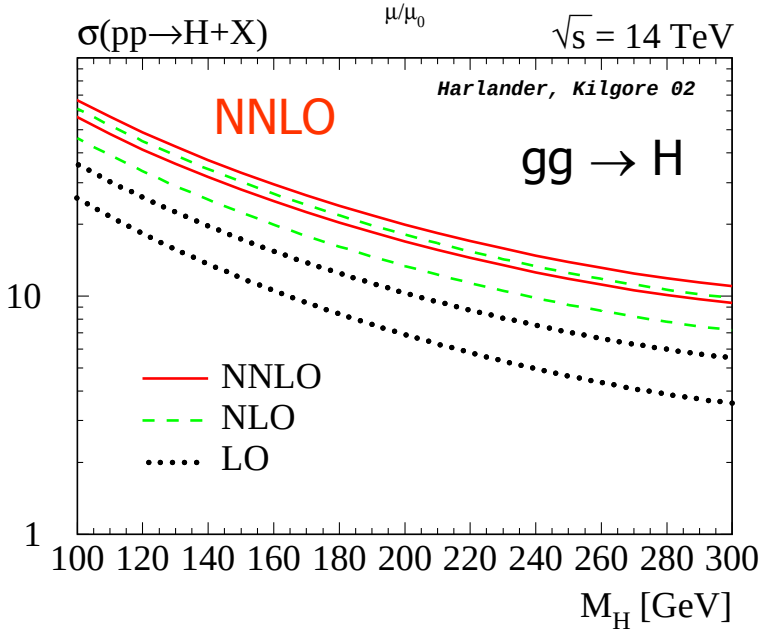
Greatly improved predictions both for signals and for backgrounds

- **Background calculations at NLO**
  - **MCFM, DIPHOX**
- **Weak-boson fusion process at LHC**
  - **Higgs discovery and coupling measurements**
  - **access bb, ττ decays**

Bruce Mellado

- **ttH**
  - **ttH Yukawa coupling**
  - **NLO complete**
    - **Tevatron –20%, LHC +20%**
- **gg → H**
  - **NNLO complete**
- **p_T, y distributions to NLO**





Searches

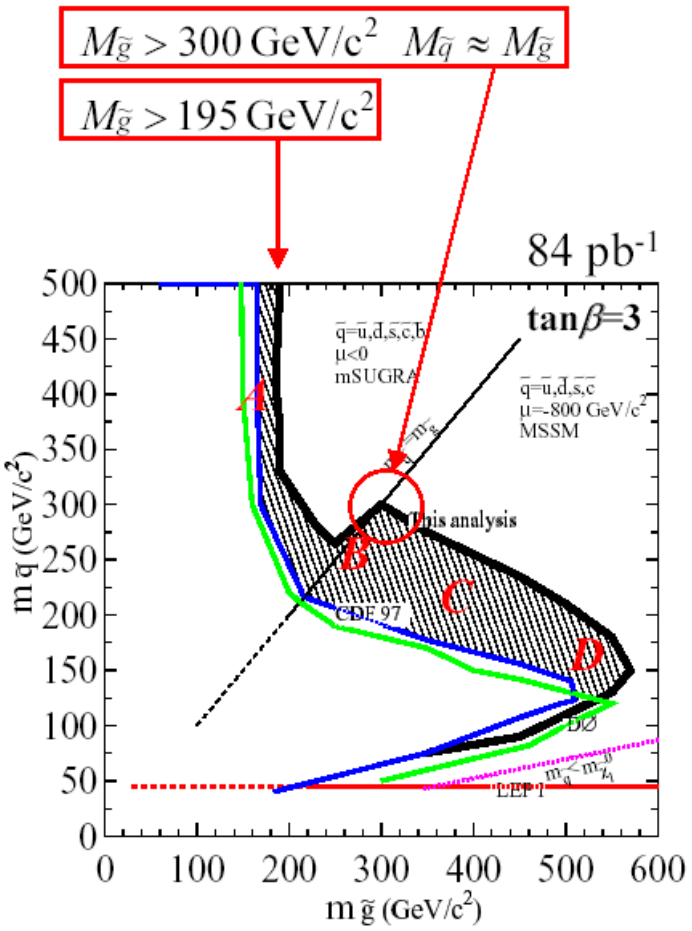
Find phenomena outside the SM

Searches at the Tevatron

Hyunsoo Kim

- **In Run I, CDF and DØ carried out extensive searches for SUSY**
  - **Squarks/gluinos → Missing E_T + jets (+ lepton(s))**
  - **Charginos/neutralinos → multileptons**
  - **GMSB → Missing E_T + photon(s)**
  - **Stop, sbottom**
  - **RPV signatures**
- **Searches for other new phenomena**
  - **leptoquarks, dijet resonances, W′,Z′, massive stable particles, extra dimensions . . .**

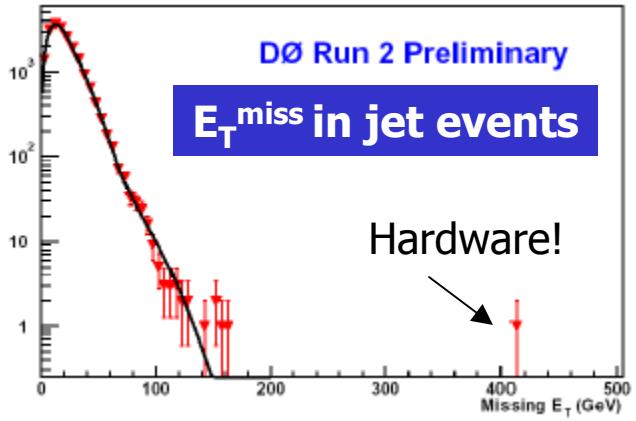
No sign of new physics



Note: CDF report possible disagreement between observed and expected number of $l\gamma+ME_T$ events. HCP2004?

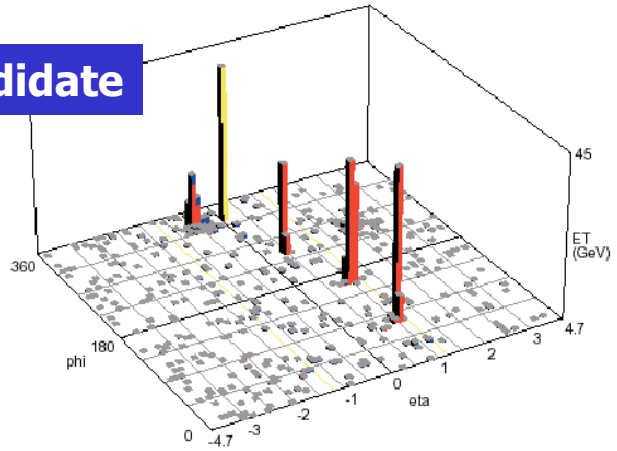
SUSY searches in Run II

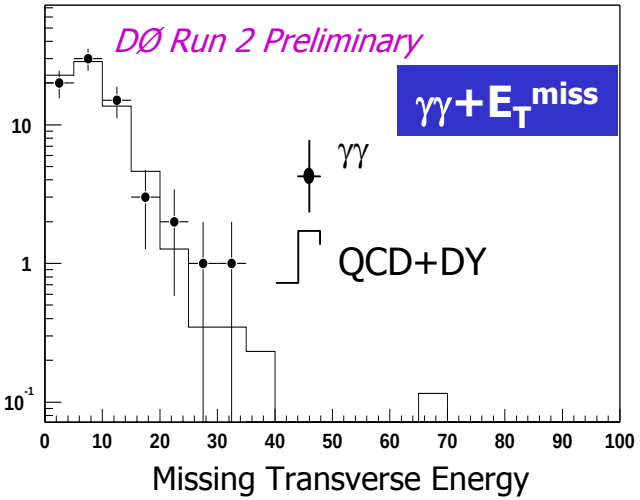
Andrei Nomerotski



Missing Transverse Energy

Trilepton candidate





Missing Transverse Energy

First Run II SUSY limit

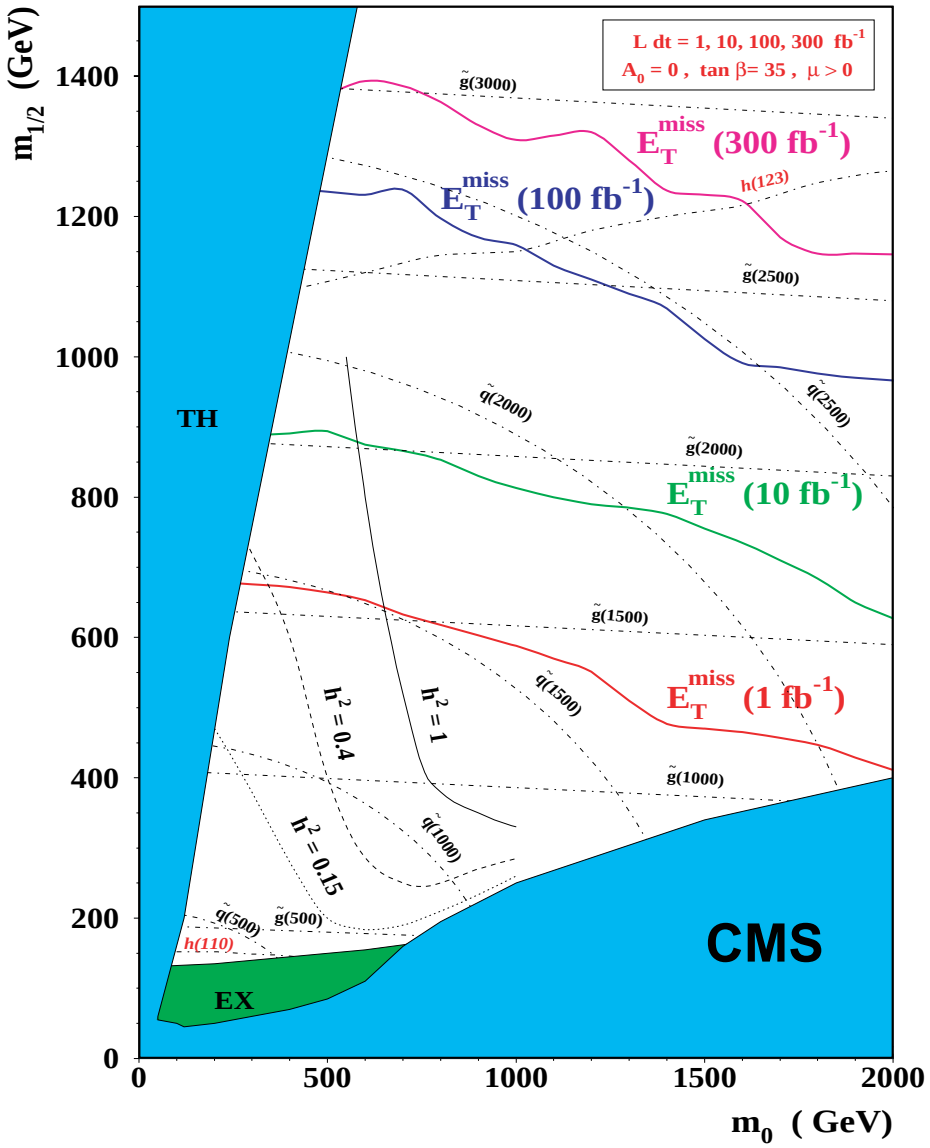
Gauge mediated SUSY $\bar{p}p \rightarrow \gamma\gamma+E_T^{miss}$

Cross section for $\gamma\gamma+E_T^{miss} > 0.9$pb

Run II limits are not yet competitive, but show we are ready for this physics

Supersymmetry at the LHC

Darin Acosta

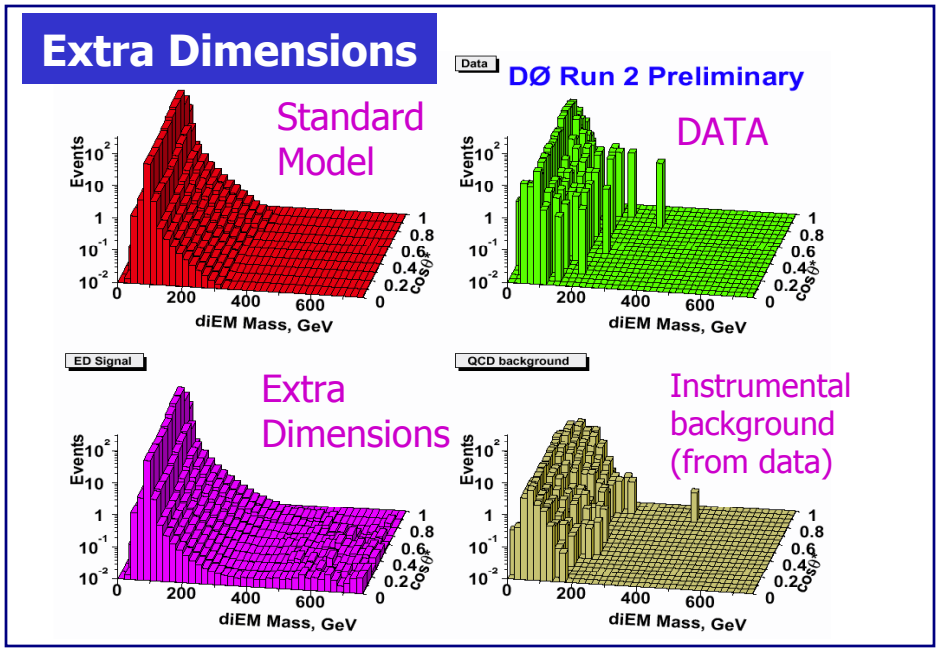


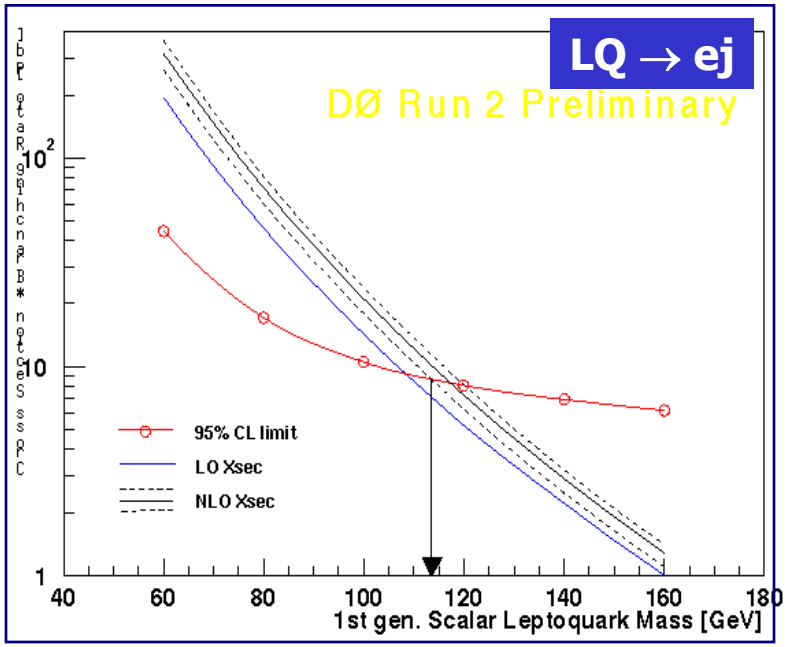
$\tilde{q}$, $\tilde{g}$ Reach in Jets+ME_T vs. $\mathcal{L}$

- 5σ discovery reach in inclusive mSUGRA search
- Squarks/gluinos probed to ~1.5 TeV with 1 fb^{-1}
- Up to 2.5 TeV at design luminosity (100 fb^{-1})
- Exclusive mass reconstruction demonstrated for several benchmark points

Other new phenomena in Run II

Andrei Nomerotski





Run II limits from $\bar{p}p \rightarrow ee, \mu\mu, \gamma\gamma$

M_S(GRW) > 0.92 TeV ($ee/\gamma\gamma$)

M_S(GRW) > 0.50 TeV ($\mu\mu$)

(first limit from a hadron collider in this channel)

First generation leptoquark Run II mass limit

M_{LQ} > 113 GeV for B(LQ → ej) = 1

Other new phenomena at LHC

Pamela Chumney

Combination of 100 fb^{-1} and 14 TeV gives potential to observe almost any new physics associated with the TeV scale

- Not a theorem, but "proof by enumeration"
  - Extra dimensions and TeV scale gravity
    - Effects can be indirect (virtual gravitons) or direct and spectacular (black hole production!)
  - Compositeness (up to 20-40 TeV)
  - Excited quarks
  - Technicolor
  - Strong WW scattering
  - Leptoquarks
  - New gauge bosons
  - Heavy RH neutrinos
  - . . .

Searches at HERA

Yves Sirois

- "There does exist possibly exciting new physics which could lead to acceptable and striking signals at HERA"
  - e.g. RPV SUSY stop $\rightarrow$ sbottom +W
  - FCNC in top sector (single top production)
  - Doubly charged higgs (dilepton signatures)
  - Extra dimensions
  - Compositeness, leptoquarks, lepton flavour violation…
- Exhaustive searches done at HERA-I
- HERA-II benefits from
  - Increased luminosity + perhaps $\sqrt{s}$
  - Polarization to disentangle any eventual signal
- Complements searches that will be carried out at the Tevatron on the same timescale

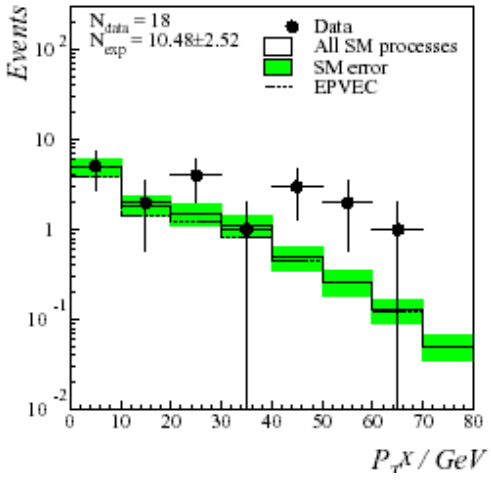
Isolated leptons at HERA

Elisabetta Gallo

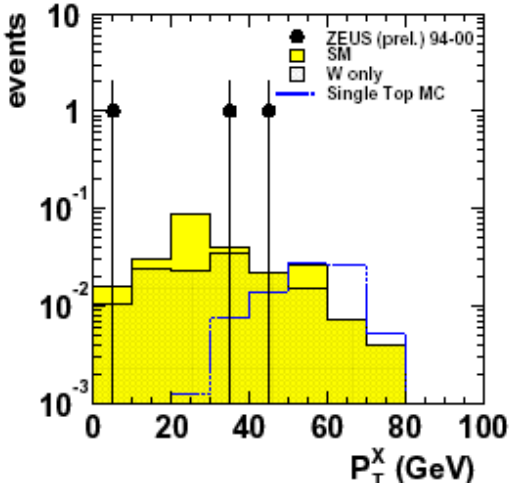
H1 preliminary 94-00 e^+p (101.6 pb^{-1})	Electron obs./exp. (W)	Muon obs./exp. (W)
$p_T^X > 25$ GeV	4 / 1.29 ± 0.33 (1.05)	6 / 1.54 ± 0.41 (1.29)
$p_T^X > 40$ GeV	2 / 0.41 ± 0.12 (0.40)	4 / 0.58 ± 0.16 (0.53)

ZEUS preliminary 94-00 $e^\pm$p (130.5 pb^{-1})	Electron obs./exp. (W)	Muon obs./exp. (W)	Tau obs./exp. (W)
$p_T^X > 25$ GeV	1 / 1.14 ± 0.06 (1.10)	1 / 1.29 ± 0.16 (0.95)	2 / 0.12 ± 0.02 (0.10)
$p_T^X > 40$ GeV	0 / 0.46 ± 0.03 (0.46)	0 / 0.50 ± 0.08 (0.41)	1 / 0.06 ± 0.01 (0.05)

H1(e and μ events)



ZEUS



Compatibility with "new physics" explanation?

look forward to HERA-II

Also: excess of 3eee and 3ee events w/ $m_{12} > 100$ GeV in H1; not seen in ZEUS

Our future

Wandering in the wilderness . . .

- Whichever side of the Atlantic we are on, hadron collider physics seems to be beset by problems
  - technical, financial, management, schedule, politics . . .
- Important to remember that the physics remains the best in the world
- Clear from this meeting that we also have a vibrant, enthusiastic community of young physicists

Keep the faith!

Why we fight . . .

Scott Willenbrock

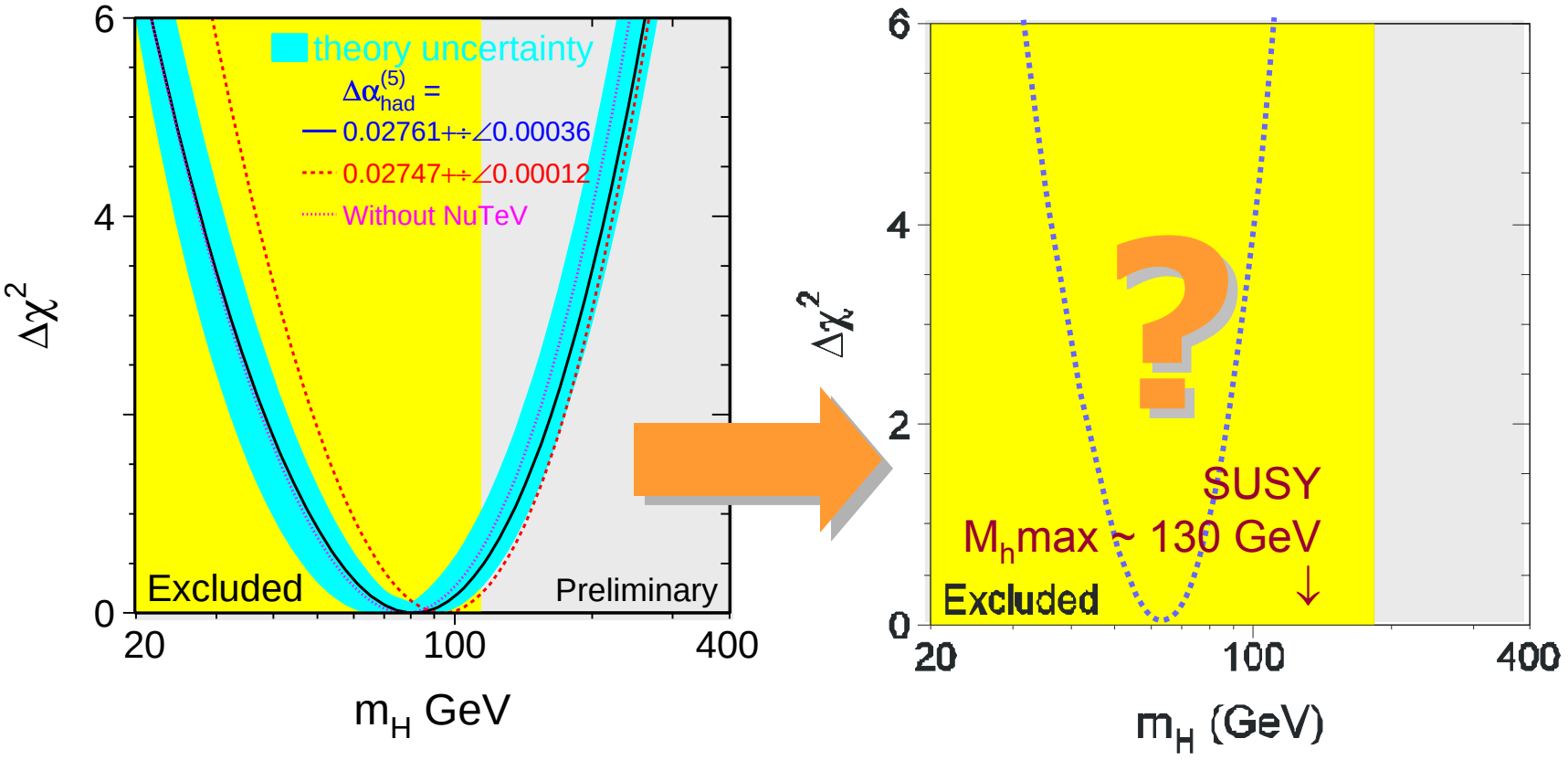
- **Seven anomalies that point to physics beyond the SM**
  - **Massive ν**
    - **new scale » 246 GeV**
  - **Gravity**
  - **astrophysics/cosmology**
    - **dark matter, dark E, baryon asym., inflation**
  - **precision EW fits poor**
  - **Why mass spectrum? Why mixing angles small (q)/large(ν)**
  - **Unification**
    - **Why is charge of electron = charge of proton?**
  - **Hierarchy problems**
    - **why 246 GeV?**

- **The Higgs is central to all of these**
  - **the key question for the SM**
  - **Window to beyond-the-SM physics**

Short term prospects

- **By next summer (LP2003 at Fermilab), we expect physics results from Run II with a few hundred pb^{-1}**
  - **significantly increased sample over Run I with improved detectors and a higher center of mass energy**
    - **B_s mixing**
    - **Top quark measurements with increased statistics and purity**
    - **Jet cross section at high E_T (constrain gluon PDF)**
    - **New limits on physics beyond the SM**
      - e.g. MSSM A/H at large tan β
    - **. . .**

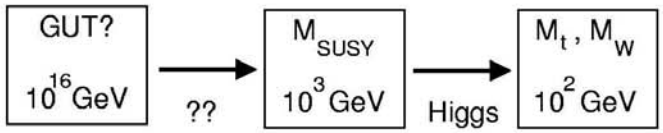
Prospects for Run II

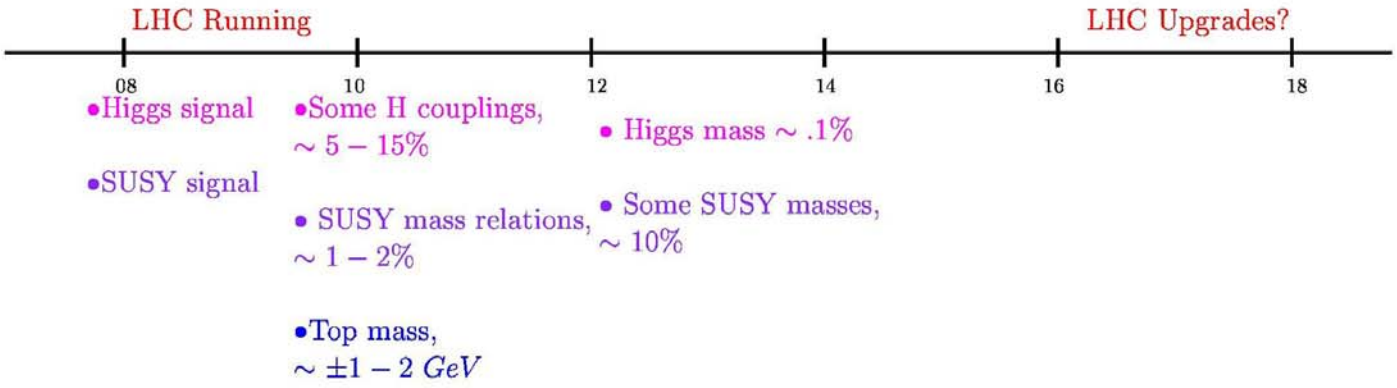


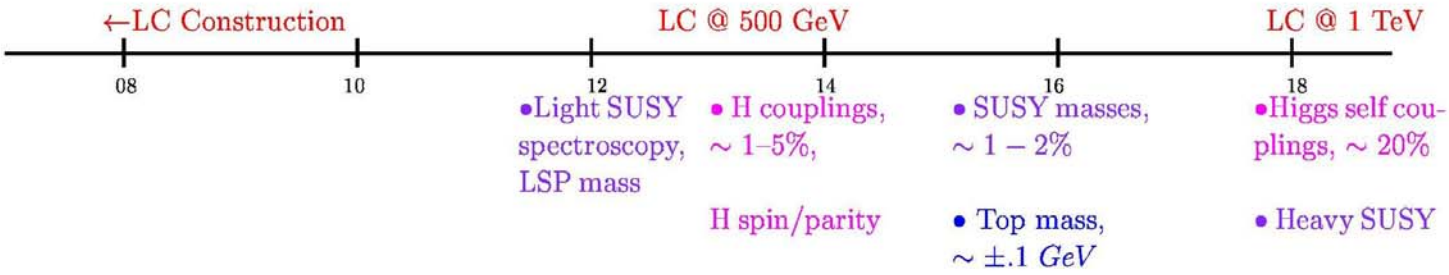
Grünewald, Heintz, Narain, Schmitt, hep-ph/0111217
Assumes current central values
$\delta\Delta\alpha^{(5)}_{had}(M_Z^2) = 10^{-4}$, δM_W = 20 MeV, δm_t = 1 GeV

LARGE HADRON COLLIDER AND LINEAR COLLIDER PHYSICS

Possibility...A world with a light Higgs boson and TeV scale supersymmetry







Sally Dawson

See you in 2004

- I wish everyone a safe trip home
- I myself will be riding steam trains tomorrow: