First CDF Run II Results

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for the
CDF collaboration

Fermilab W&C
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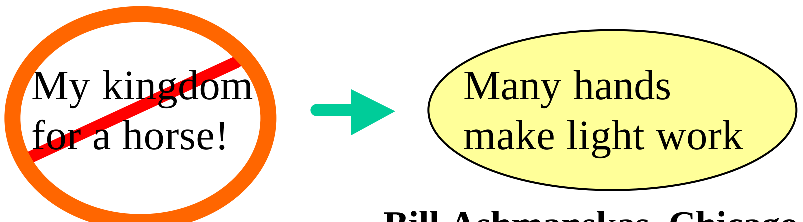
CDF-II detector is recording publication-quality data (ICHEP 2002)

- Stable physics running established in early 2002
  - intensive effort during fall 2001 shutdown had big payoff
  - silicon coverage, trigger came together very quickly
    - > 95% / 90% / 80% of L00/SVX/ISL now (summer 2002) regularly read out
    - L1/L2/L3 trigger 6400/145/25Hz @1.6E31, <1% deadtime (BW 40K/300/70)
  - trigger algorithms increased rapidly in sophistication; now quite stable
    - ~140 separate trigger paths (e, μ, τ, ν, γ, jet, displaced track, b jet, …)
- 33.0/pb delivered; 23.5/pb recorded January-June 2002
  - 10.0/pb pass the most stringent analyses’ “good run” criteria
  - we’re in a mode of very stable operation (stop by B0 and see!)
    - response to glitches (power supply failures, beam losses, silicon readout issues) has been quick and successful



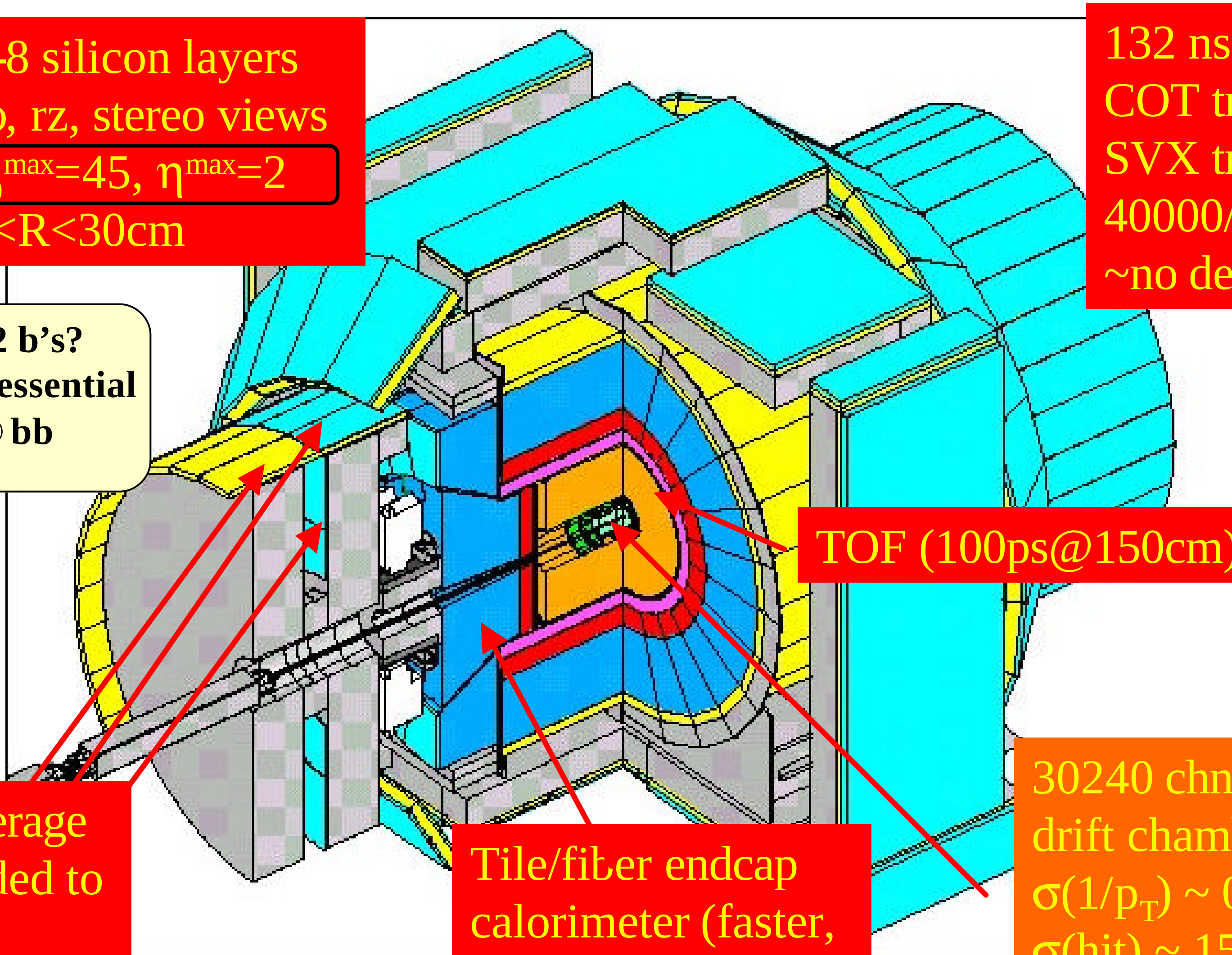
CDF Detector Run II Upgrades

All critical components are working well

7-8 silicon layers
rϕ, rz, stereo views
z_0^{max}=45, η^{max}=2
2<R<30cm

132 ns front end
COT tracks @L1
SVX tracks @L2
40000/300/70 Hz
~no dead time

2 b's or not 2 b's?
Double tags essential
for M_{top}, H ® bb



TOF (100ps@150cm)

μ coverage extended to η=1.5

Tile/fiber endcap calorimeter (faster, larger F_{samp}, no gap)

30240 chnl, 96 layer drift chamber
$\sigma(1/p_T)$ ~ 0.1%/GeV
σ(hit) ~ 150μm

Bill Ashmanskas, Chicago/CDF

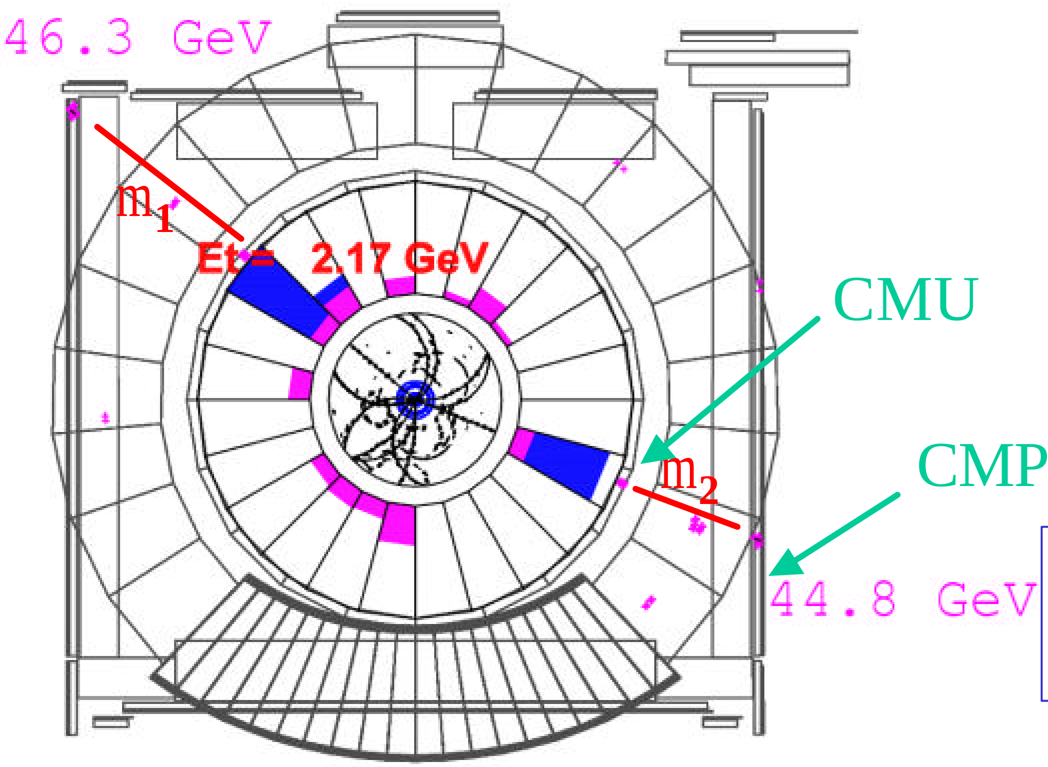
CDF Run II physics has begun!

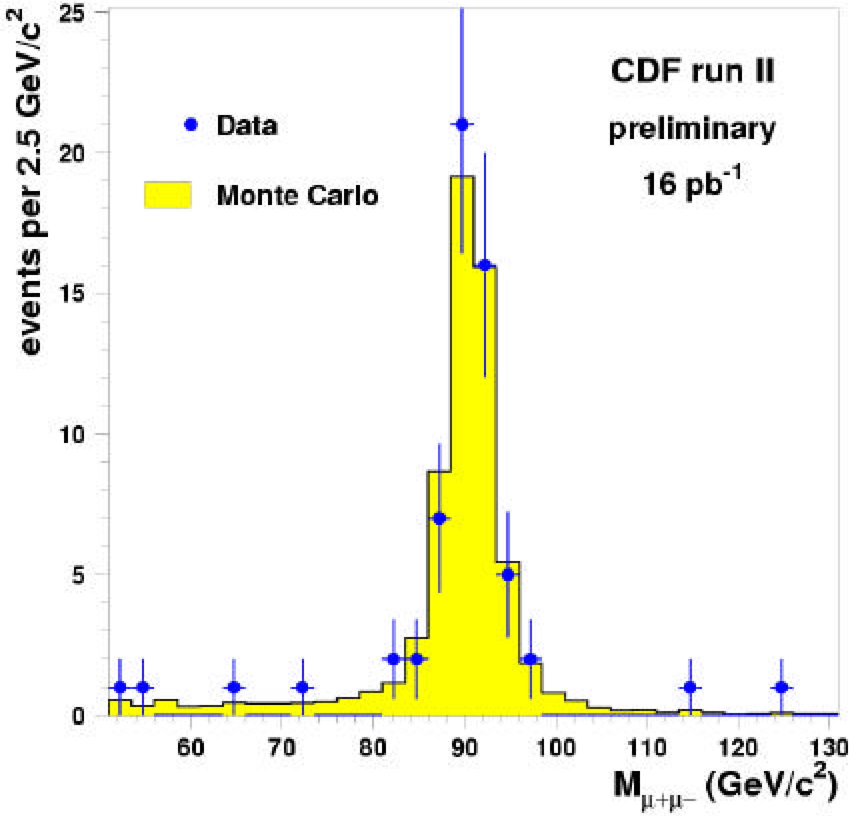
- Re-establish Run I physics signals
  - prepare for high-P_T program: M_{top}, M_W, Higgs, SUSY, Z', LED
  - reconstruct and model leptons, W's, Z's, jets, b's, …
  - essential feedback for detector/trigger/reconstruction/simulation
  - measure $\sigma(W)/\sigma(Z)$; measure D-Y angular distributions
- Calibrate precision track measurements
  - exploit high cross-section signals; measure B lifetimes, masses
  - begins B physics program (lifetimes, masses, B_s mixing, ~~CP~~, Λ_b, B_c, …)
  - provides calibration/tools for M_W, M_{top}, b jet tagging
- Exploit new trigger capabilities
  - Measure $\Delta M(Ds,D+)$; measure $B(D0 \rightarrow KK, \pi\pi) / B(D0 \rightarrow K\pi)$
  - Learn to model trigger for physics signals (later $\Rightarrow Z \rightarrow b\bar{b}$, $H \rightarrow b\bar{b}$)
  - Reconstruct fully hadronic B decays

Now is the winter of our discontents made
glorious summer by this sum of quarks

High-Pt muons: $Z \rightarrow m^+m^-$

- Clear $Z \rightarrow m^+m^-$ signal
  - **require COT•CMU•CMP**
  - CDF's purest muons: ~8λ





57 candidates 66<M<116 GeV

$N_Z = 53.2 \pm 7.5 \pm 2.7$

Measurement of σB(W→μν), R

4561 candidates in 16 pb^{-1}
(require COT•CMU•CMP)

12.5% background:

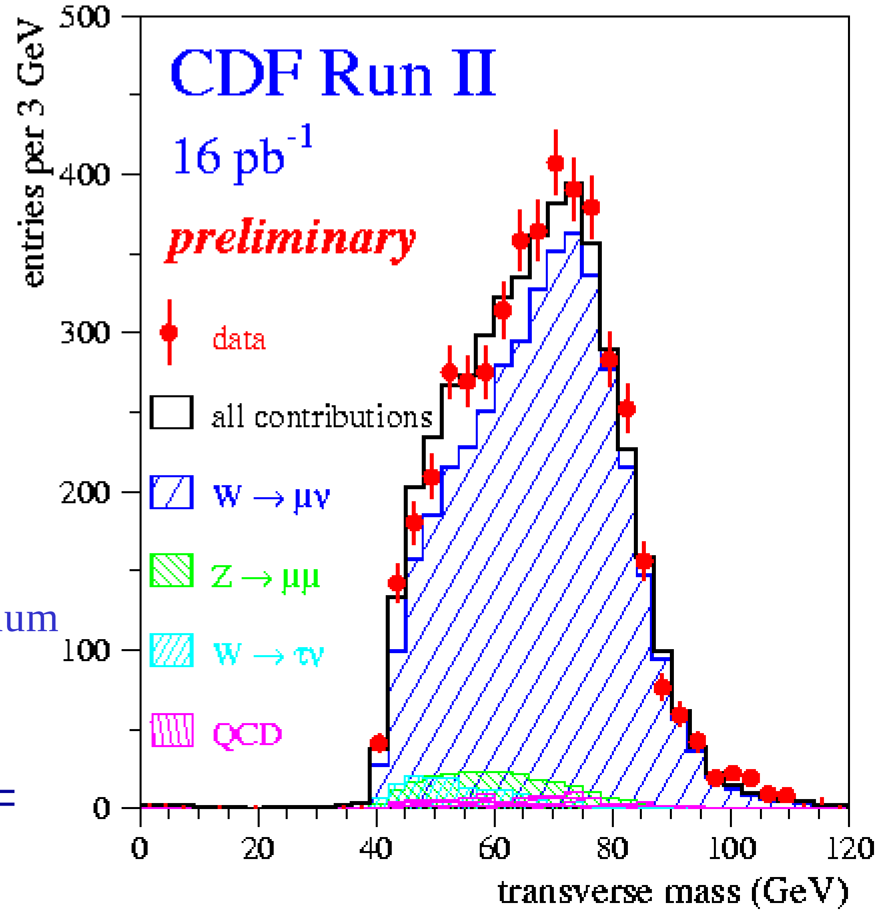
- **Z →mm:** 247 ± 13
- **W→tn:** 145 ± 10
- **QCD:** 104 ± 53
- **Cosmics:** 73 ± 30

$\sigma \bullet B(W \rightarrow \mu\nu) = 2.70 \pm .04_{stat} \pm .19_{syst} \pm .27_{lum}$

Many uncertainties, e.g. lumi, cancel in ratio:

R = s •B**(W→**mn**)** / s •B**(Z→**mm**)** =
13.66±1.94$_{stat}$±1.12$_{syst}$ (1.5σ from SM)

Þ G**(W)** = 1.67±0.24$_{stat}$±0.14$_{syst}$



M$_T$

Measure a precisely predicted ratio ⇒ establish tight feedback loop on muon detection, reconstruction, and simulation

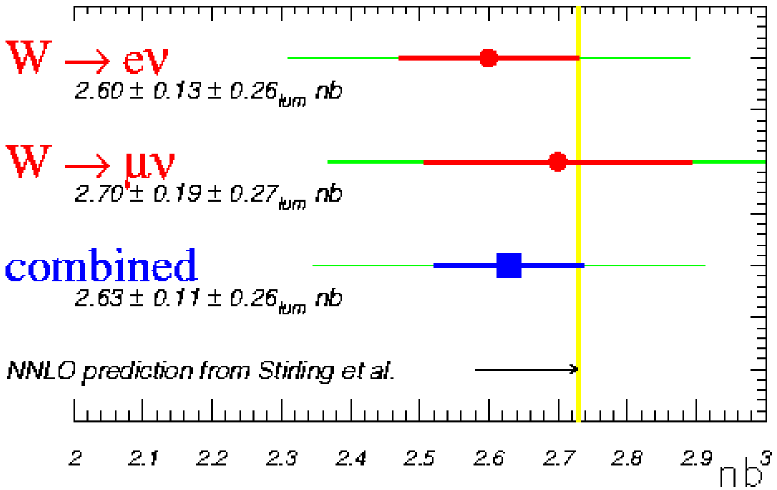
Measure σ•B(W→eν)

W cross section:

σ_W*BR(W→eν) (nb) =

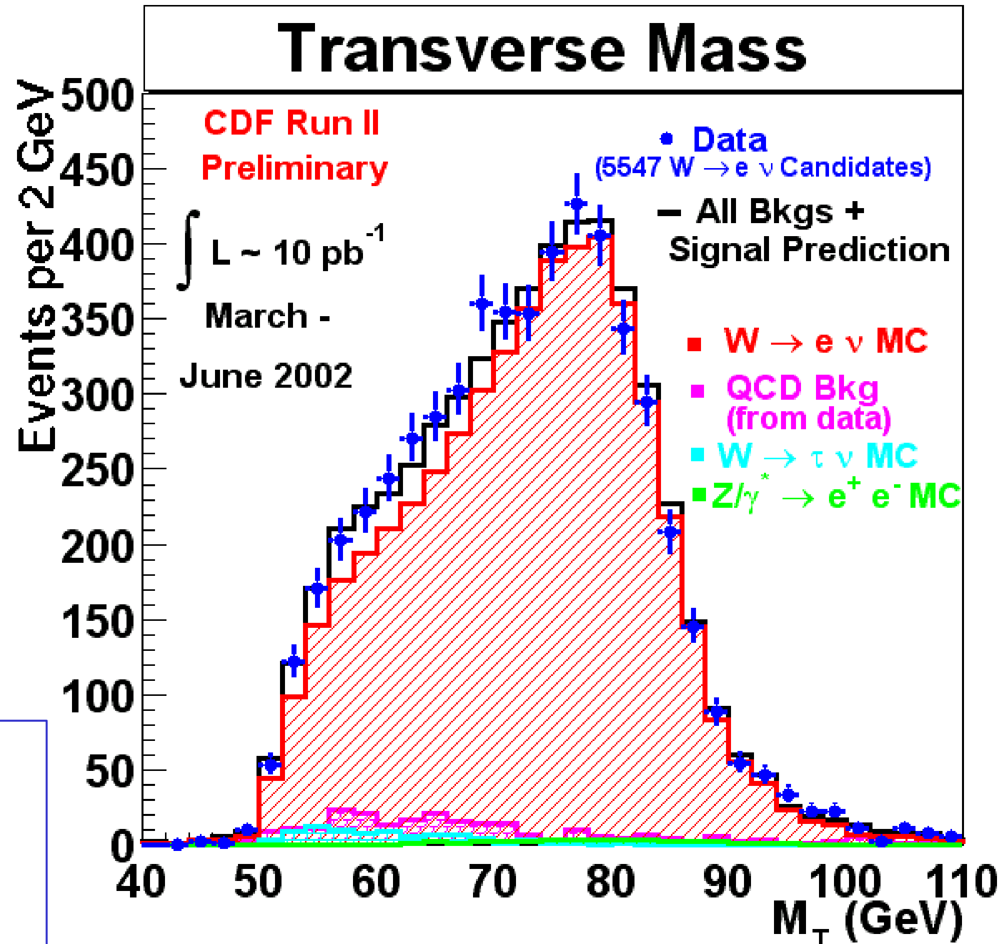
$2.60 \pm 0.07_{stat} \pm 0.11_{syst} \pm 0.26_{lum}$

0.16 soon!



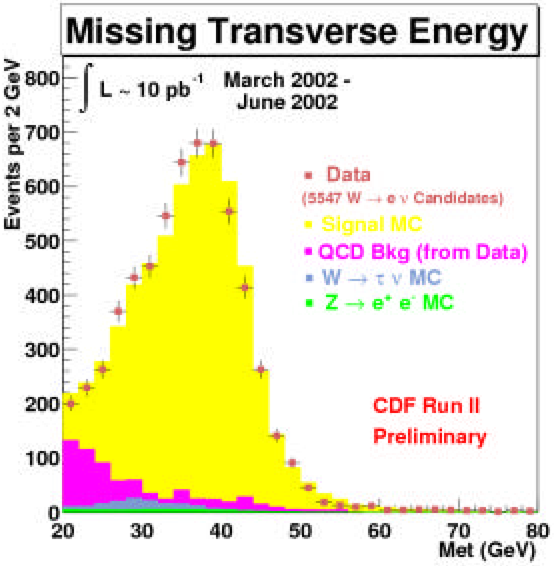
Background (8%):

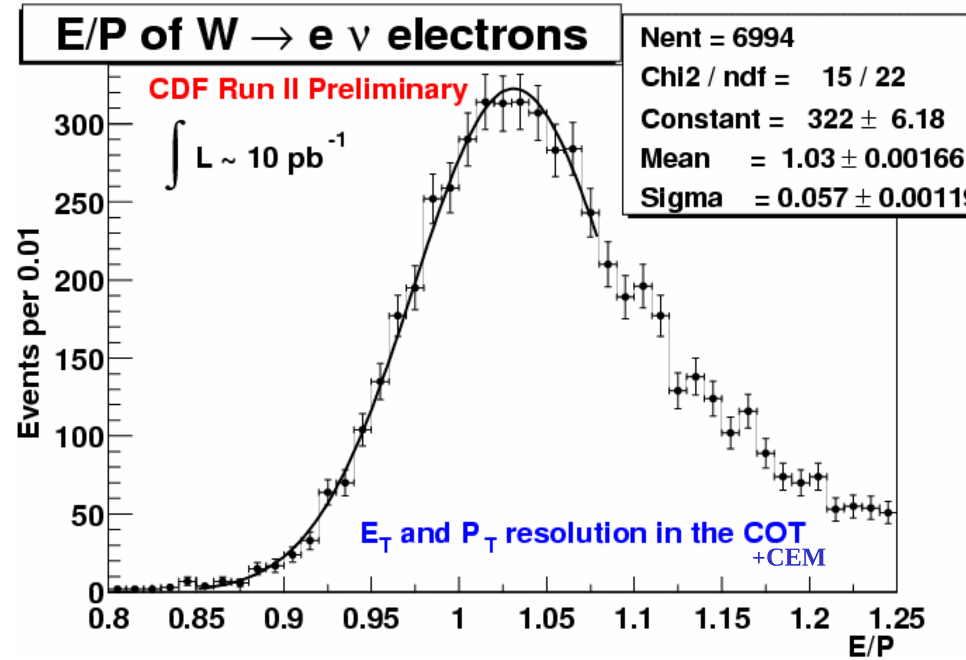
- **QCD:** 260 ± 34 ± 78
- **Z →ee:** 54 ± 2 ± 3
- **W→tn:** 95 ± 6 ± 1

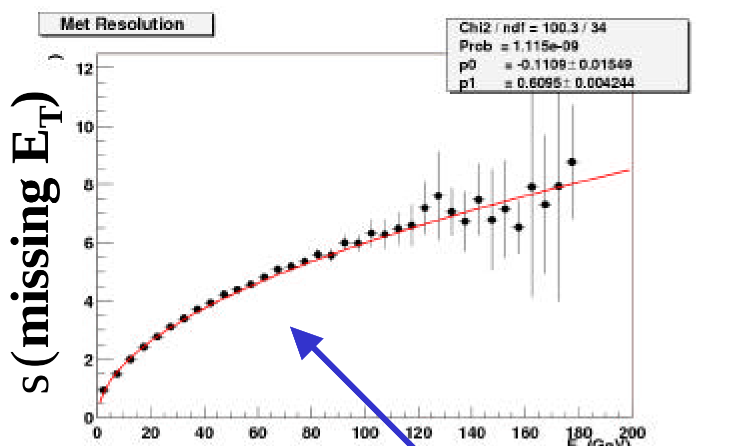


5547 candidates in 10 pb^{-1}

Modeling W→eν calibrates e,ν,tracks, ...





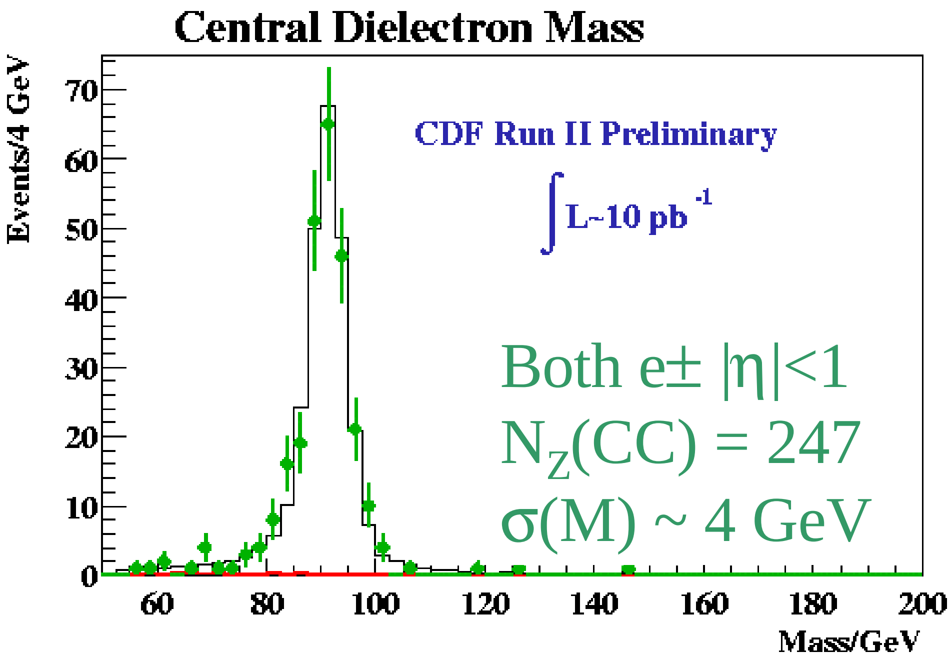


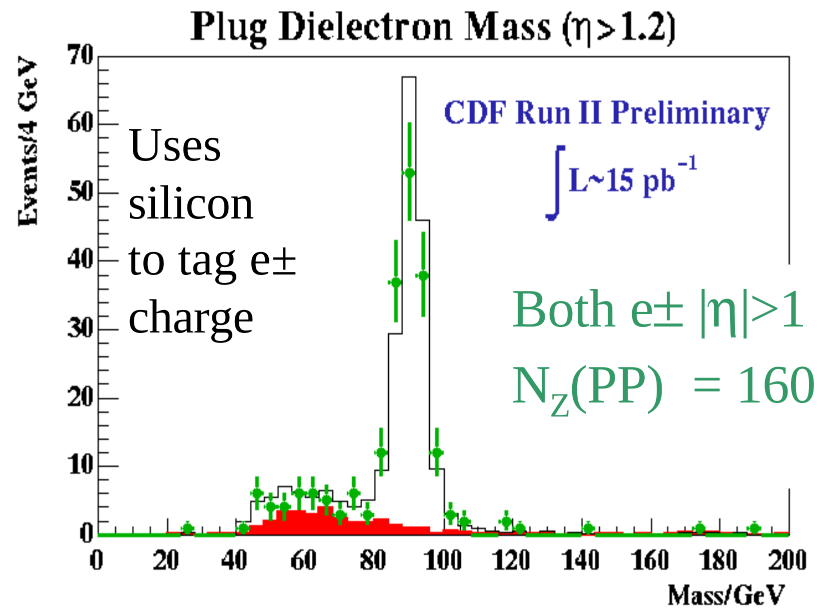
$\sigma(E/p) \sim 5.7\%$ (cal ⊕ track)
(within 20% of Run I resolution)

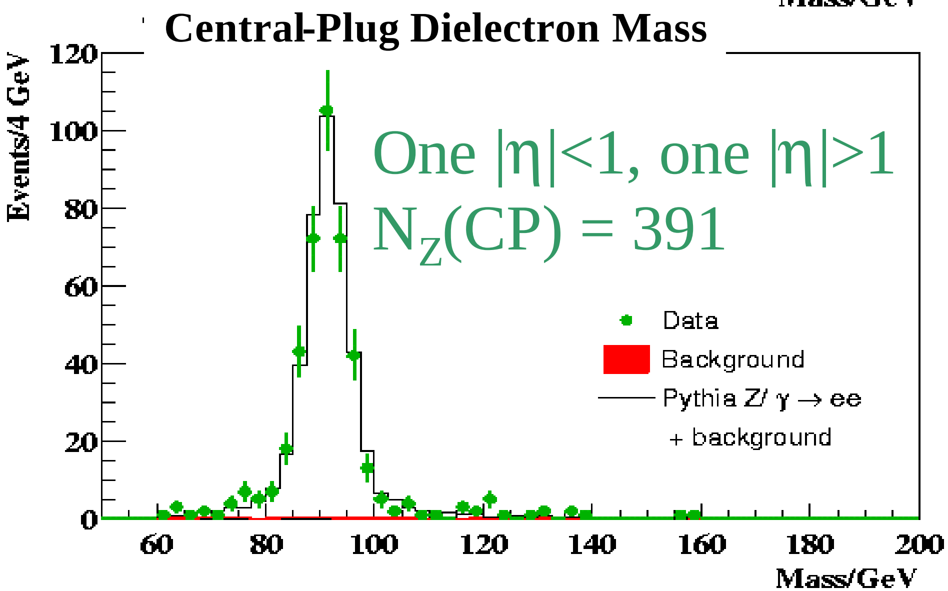
expect improvements as calibrations continue

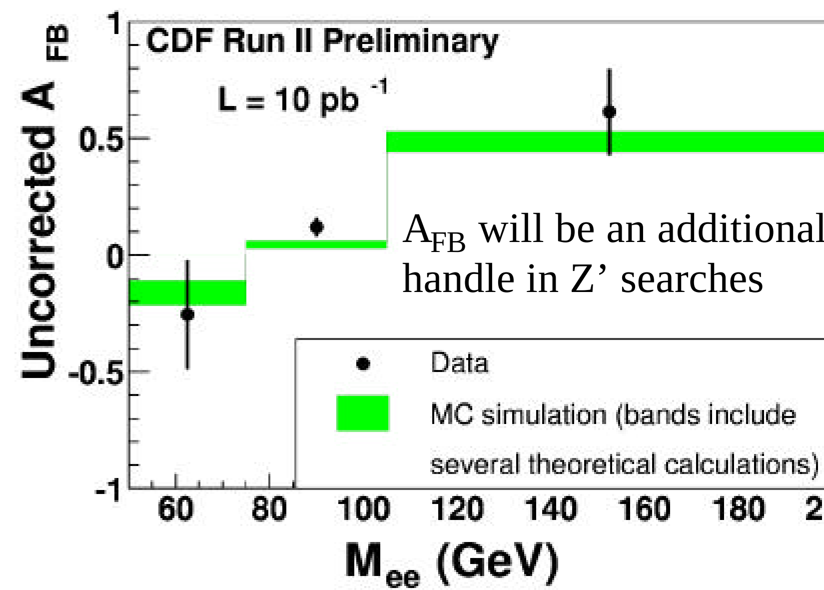
Missing energy resolution from minimum-bias data consistent with Run 1

Reconstruct Z → ee; measure A_{FB}



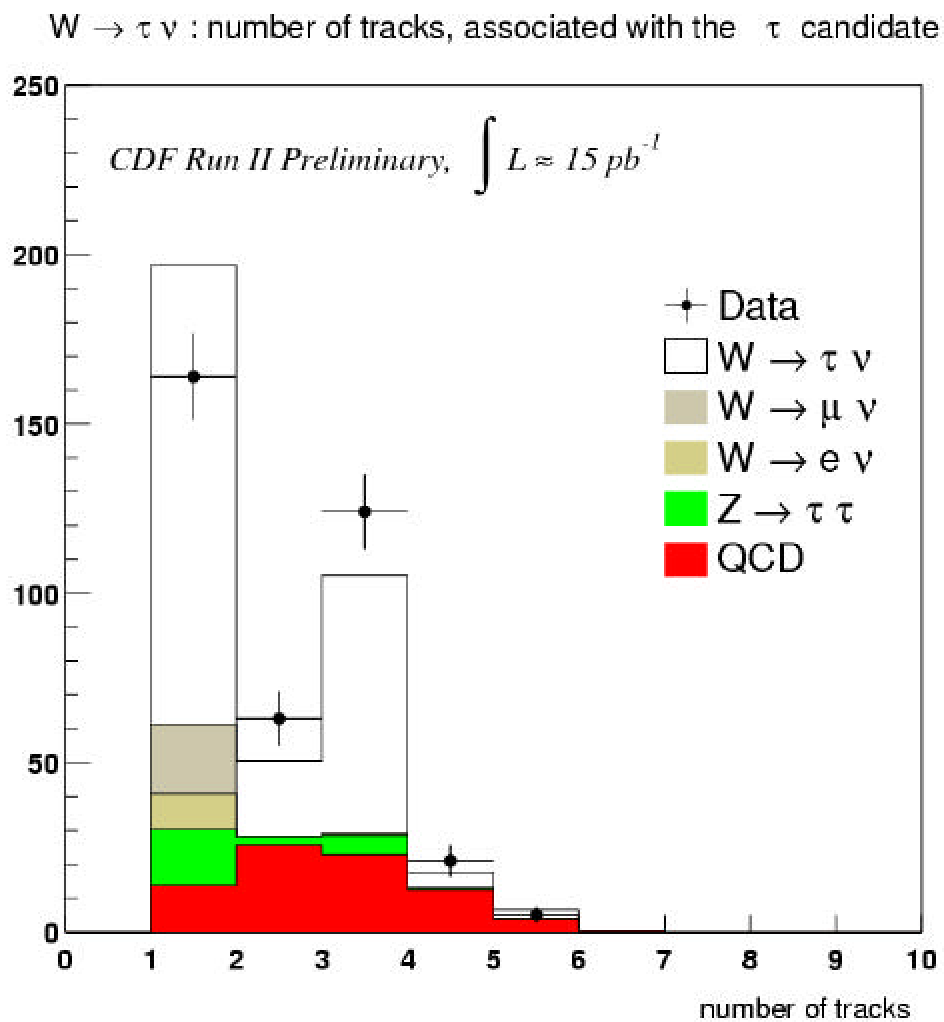






W → τ ν

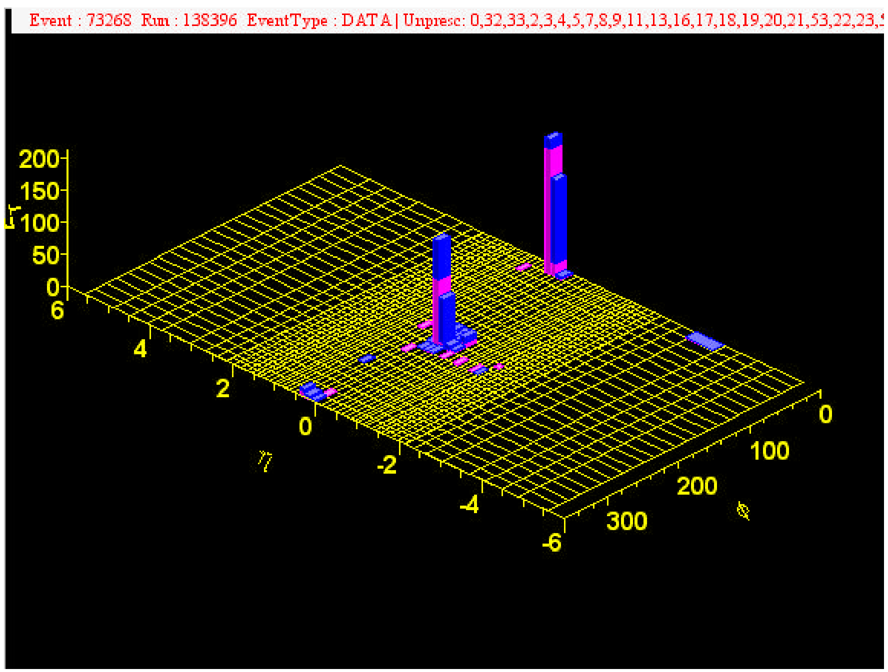
- Evidence for typical τ decay multiplicity in W→ τ ν selections
- τ channel important for new physics searches

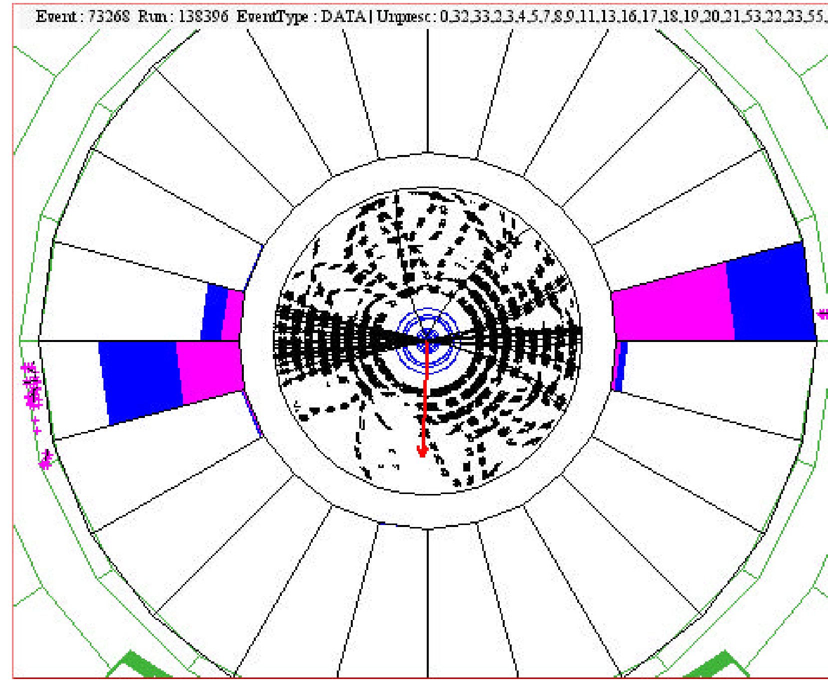


Jet reconstruction/measurement essential for M_{top}, searches ...

Jet 1: E_T = 403 GeV

Jet 2: E_T = 322 GeV

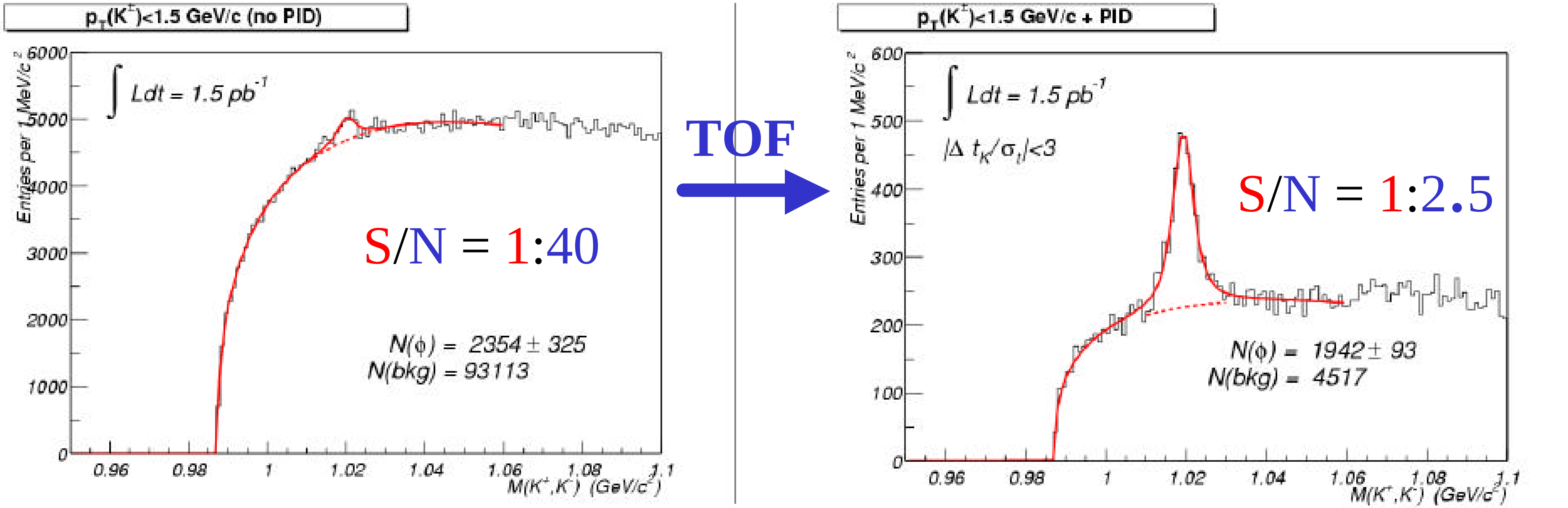




Run II jet energy calibrations in progress. In |η|<1 region, we reproduce Run I calibrations to ~5% level thus far.

Brand new detector: TOF!

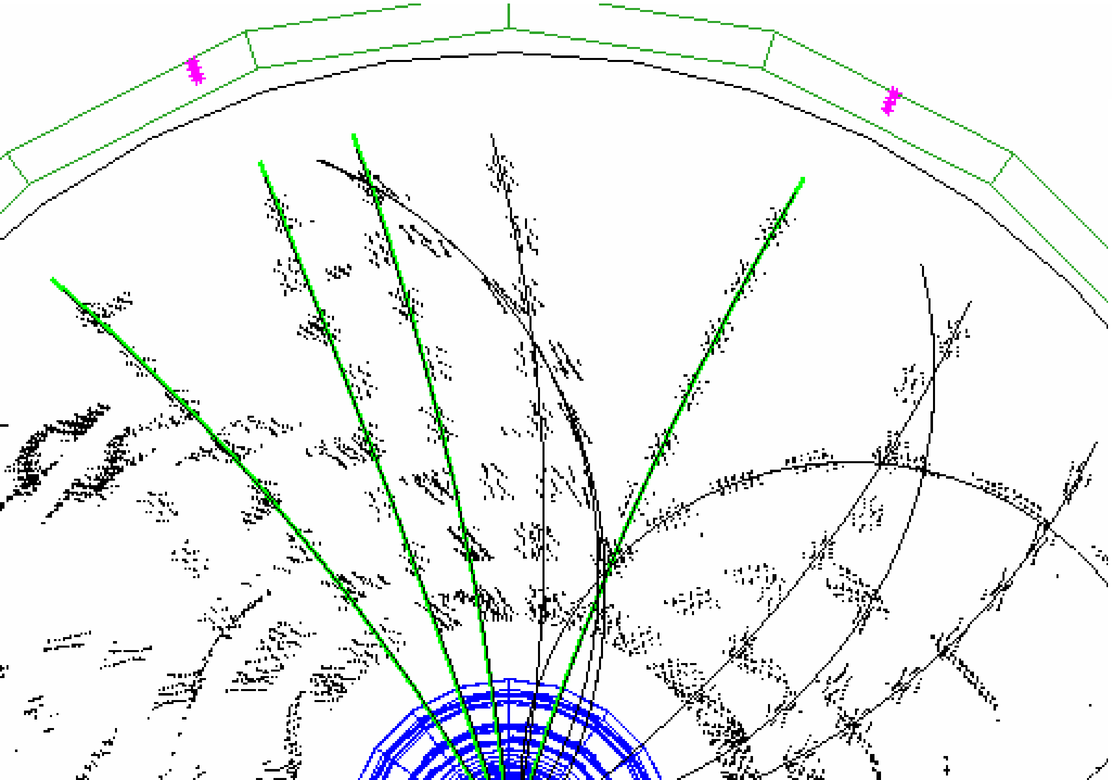
TOF resolution within 10–20% of 100 ps design value (calibration ongoing)

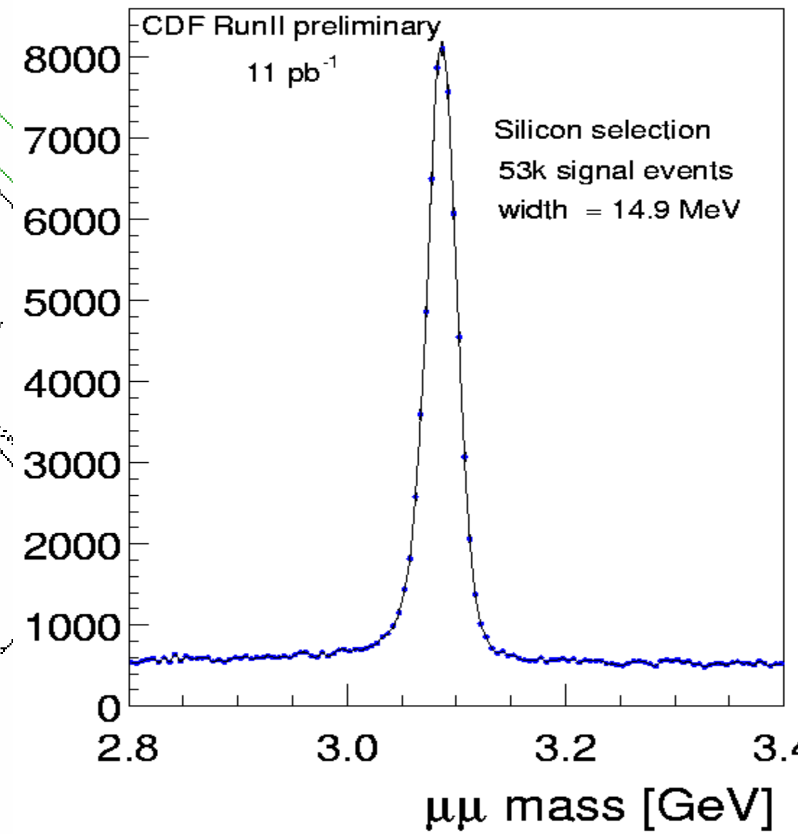


Novel uses (beyond K tagging) in the works:

- CHAMPS search (large flight time)
- magnetic monopole trigger (large pulse height)

Precision momentum measurement





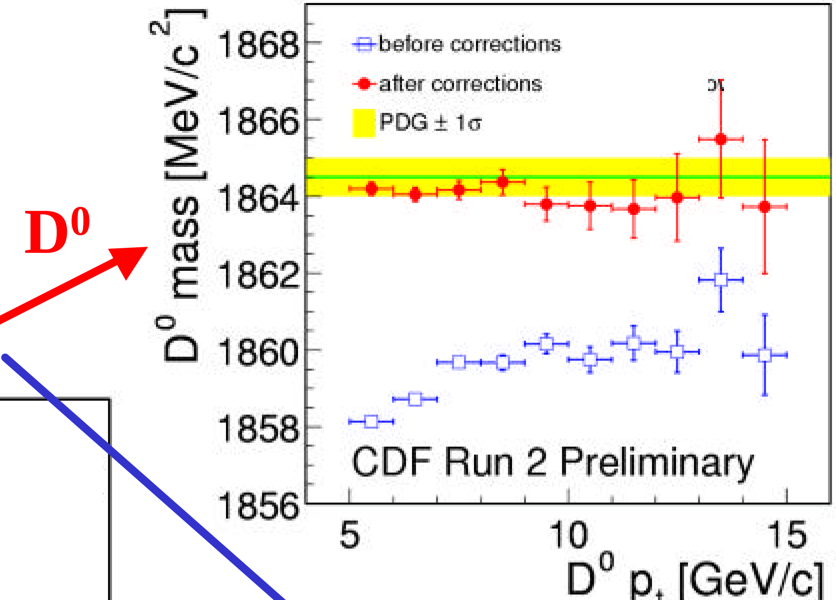
COT tracking (measured)

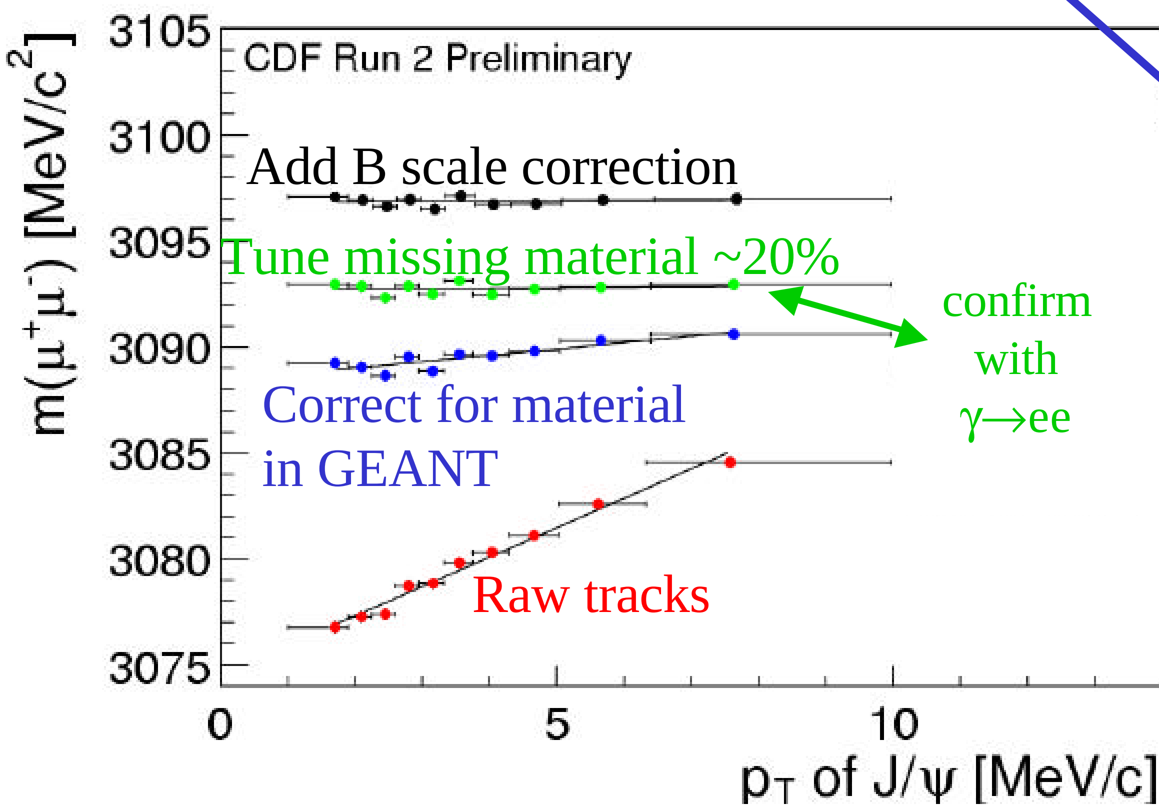
- $\varepsilon = 99\pm1\%$ (L3/offline reco)
- $\varepsilon = 96.1\pm0.1\%$ (L1 trigger)
- $\sigma(1/p_T) < 0.13\%$/GeV (offline)
- $\sigma(1/p_T) = 1.74\%$/GeV (L1 trigger)

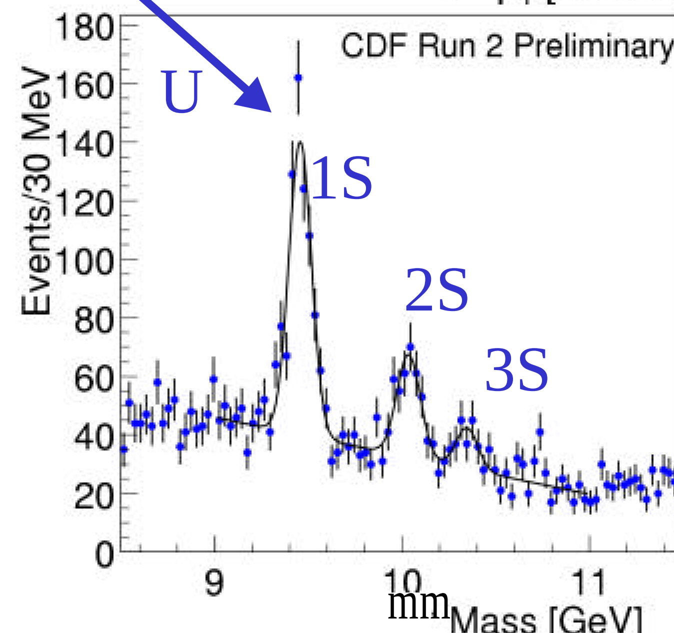
Run II trigger efficient down to $p_T(\mu)$=1.5 GeV

Material & Momentum Calibration

- Use J/ψ's to understand E-loss and B-field corrections
  - σ(scale)/scale ~ 0.02% !
- Check with other known signals



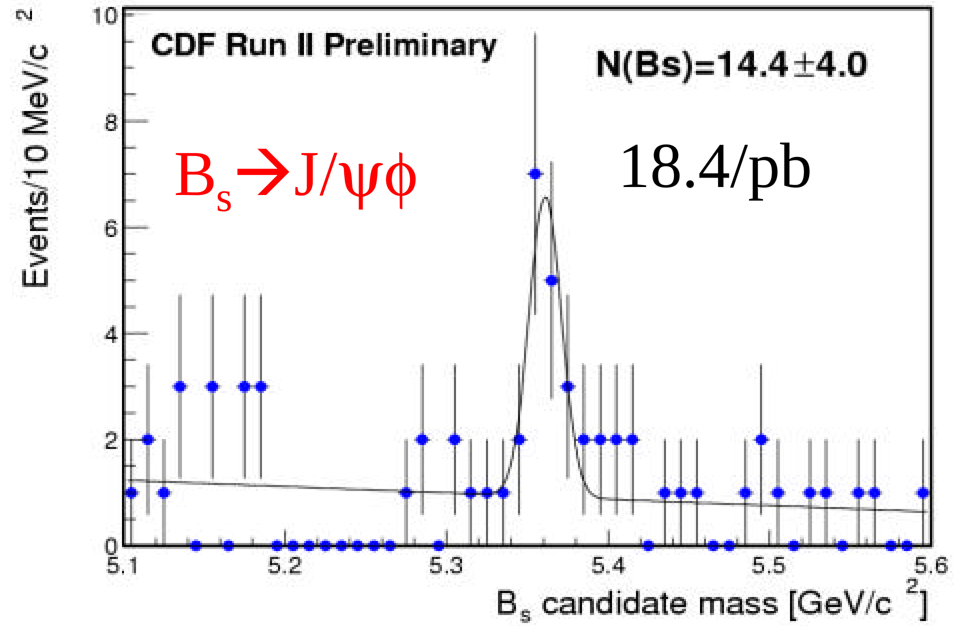


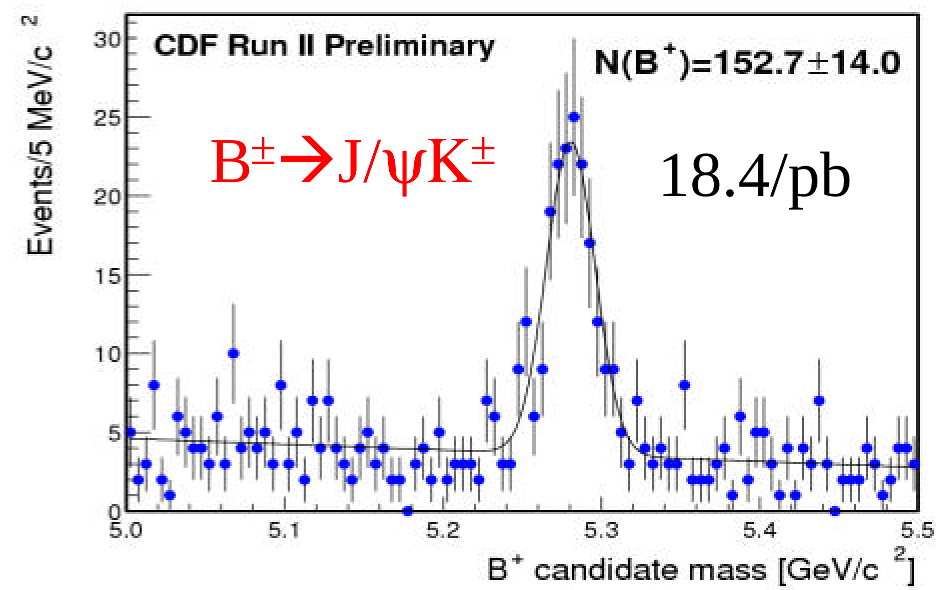


Meson mass measurements

- B masses:
  - $\psi(2S) \rightarrow J/\psi\ \pi^+\pi^-$ (control)
  - $B_u \rightarrow J/\psi\ K^+$
  - $B_d \rightarrow J/\psi\ K^{0*}$ $(K^{0*} \rightarrow K^+\pi^-)$
  - $B_s \rightarrow J/\psi\ \phi$ $(\phi \rightarrow K^+K^-)$

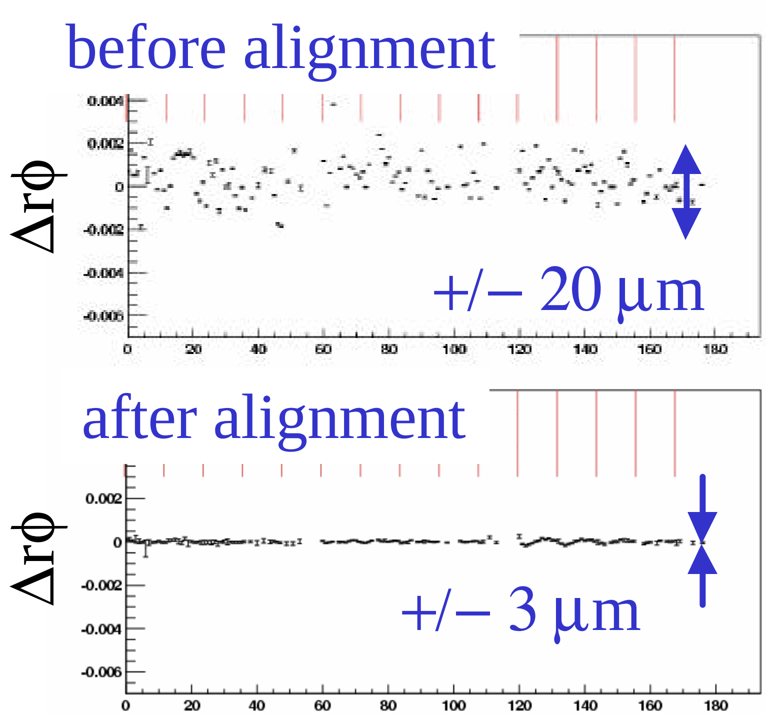
	CDF 2002	D**PDG**/ s
ψ(2S)	3686.43 ±0.54	0.9
Bu	5280.6 ±1.7 ±1.1	0.8
Bd	5279.8 ±1.9 ±1.4	0.2
Bs	$5360.3 \pm 3.8 \pm^{2.1}_{2.9}$	-2.1

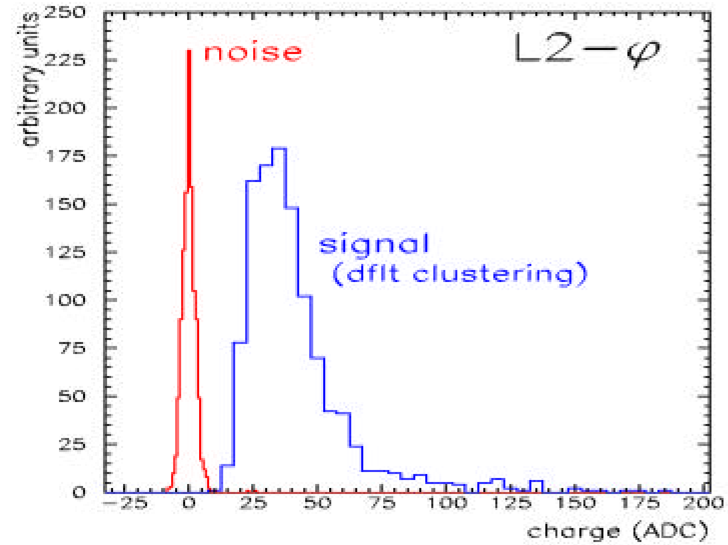


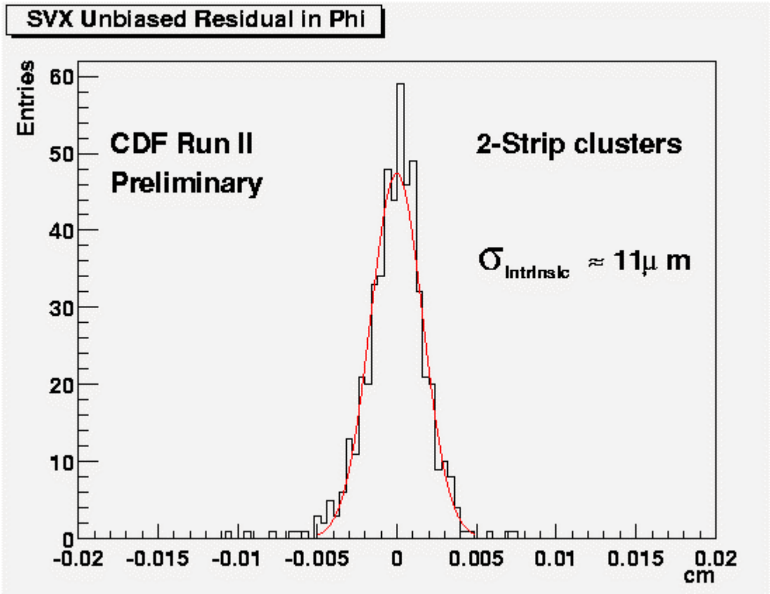


Precision vertex measurement

- Silicon detectors:
  - Typical S/N ~12
  - Alignment in R-ϕ mature
  - Hit resolution as expected







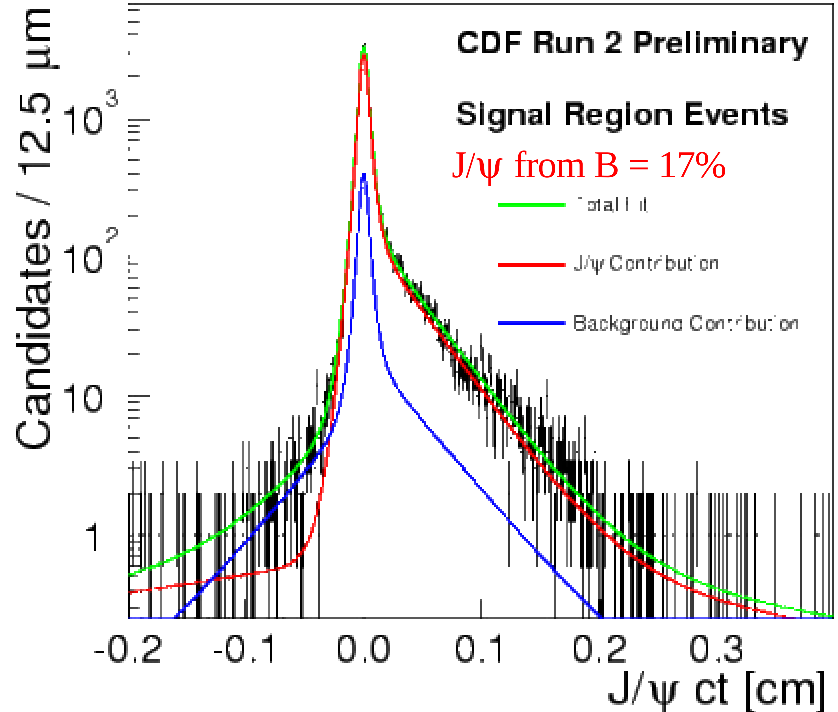
B hadron lifetimes

- Inclusive B lifetime with J/ψ's

  Fit pseudo-$c\tau = L_{xy}^{\psi} * F_{MC} * M^{\psi} / p_T^{\psi}$

  $c\tau = 458 \pm 10_{stat.} \pm 11_{syst.}$ μm

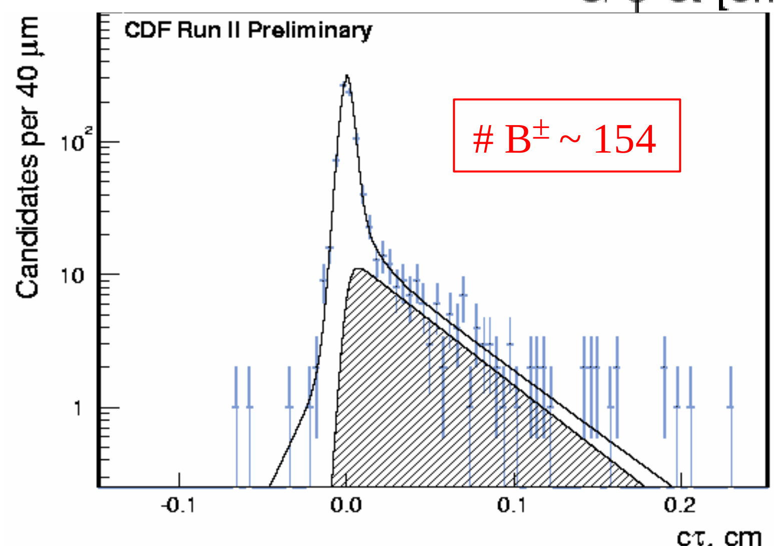
  (PDG: 469±4 μm)



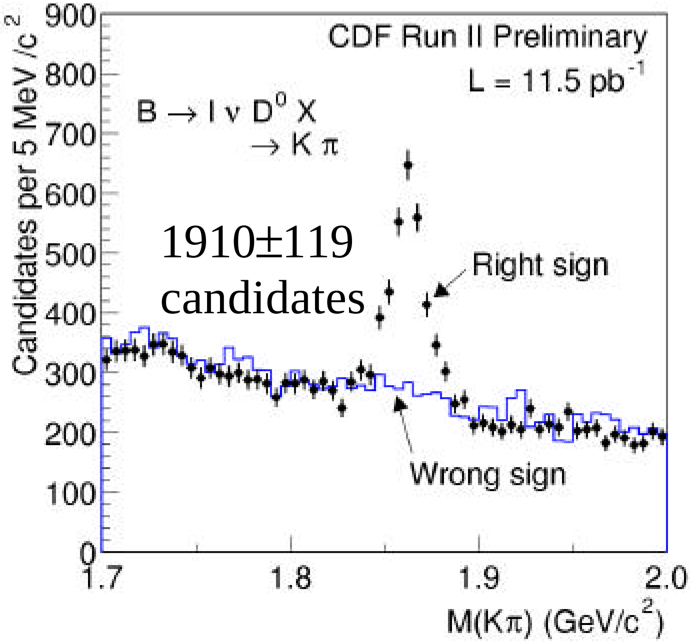
- Exclusive $B^+ \to J/\psi K^+$ lifetime

  $c\tau = 446 \pm 43_{stat.} \pm 13_{syst.}$ μm

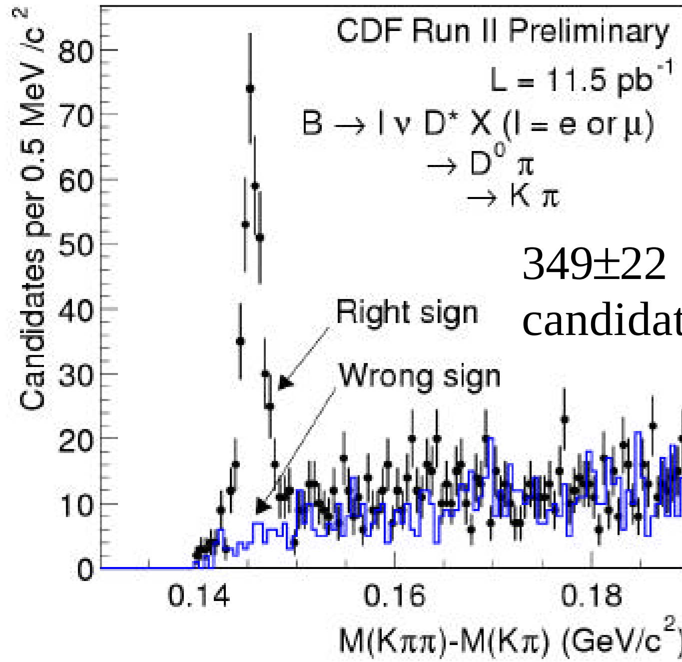
  (PDG: 502±5 μm)



Trigger selects B's via semileptonic decays ...

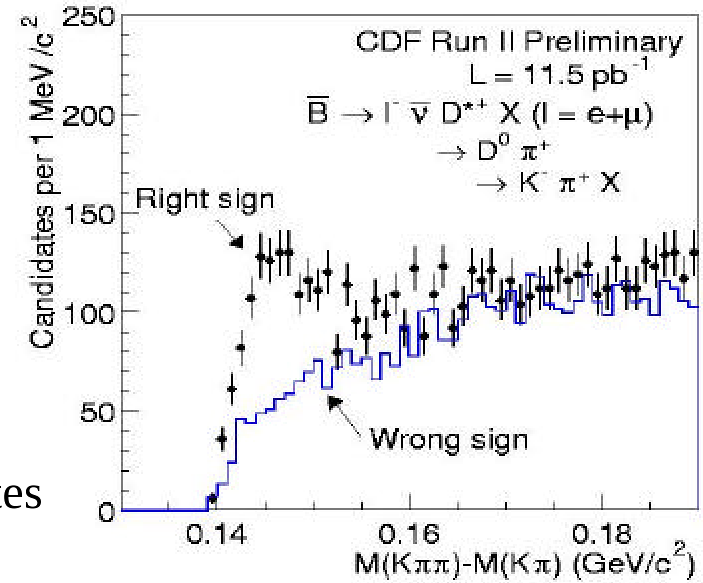


1910±119 candidates



349±22 candidates

Run II trigger & silicon =>
~3× yield/luminosity as in Run I
(and likely to improve further with optimization)

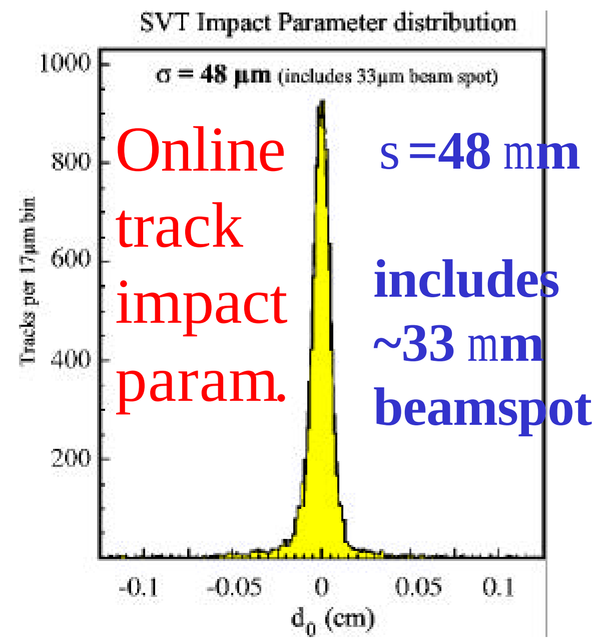


616±47 candidates

Hadronic B trigger (revolutionary!)

~150 VME boards find & fit silicon tracks, with offline accuracy, in a 15 μs pipeline

The wisest are the most annoyed by the loss of time. -Dante



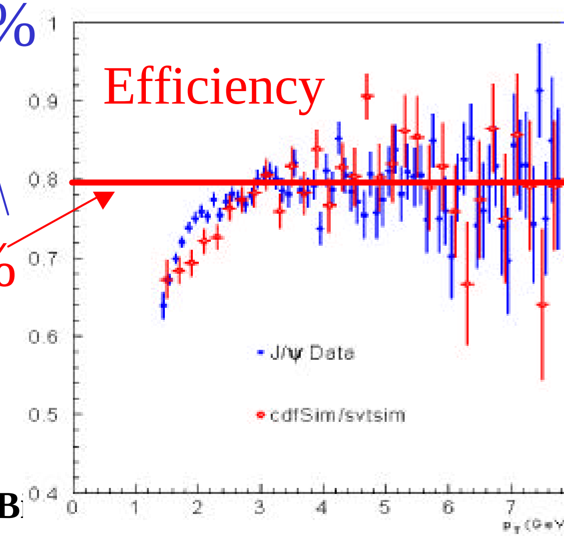
❖ **S**econdary **V**ertex L2 **T**rigger

- D resolution as planned
  - 48 mm (33 mm beam spot transverse size)
- Online fit/subtraction of beam position
  - reports to ACNET page C82 !
- Rφ only ⇒ need beamline || silicon

>90%

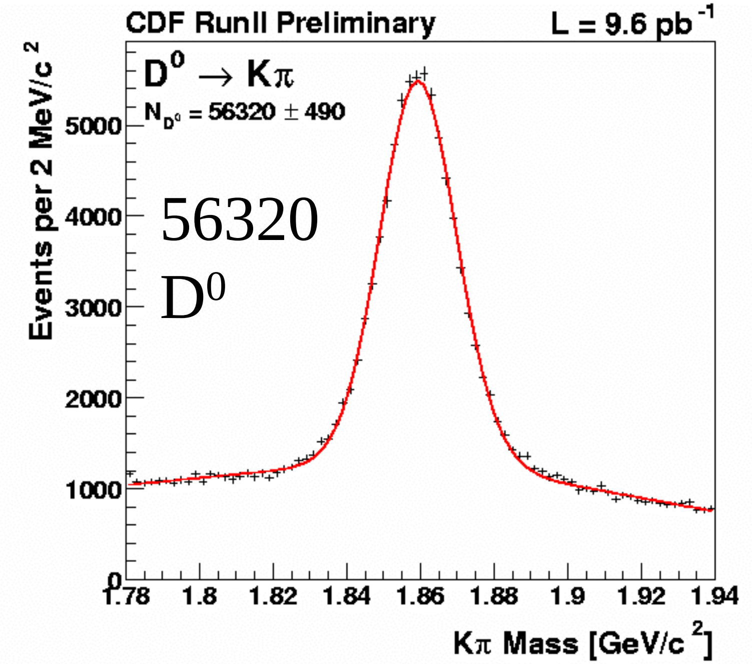
soon

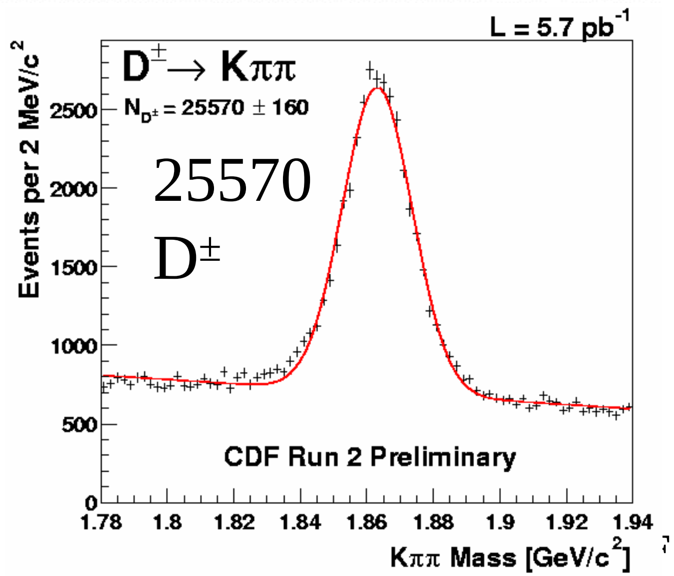
80%



SVT selects huge charm signals!

- L2 trigger on 2 tracks:
  - pt > 2 GeV
    - |D| > 100 μm (2 body)
    - |D| > 120 μm (multibody)
- Whopping charm samples!
  - Will have O(10^7) fully reconstructed decays in 2/fb data set
    - FOCUS = today's standard for huge: 139K $D^0 \to K^-\pi^+$, 110K $D^+ \to K^-\pi^+\pi^+$
  - A substantial fraction comes from b decays (next slide)





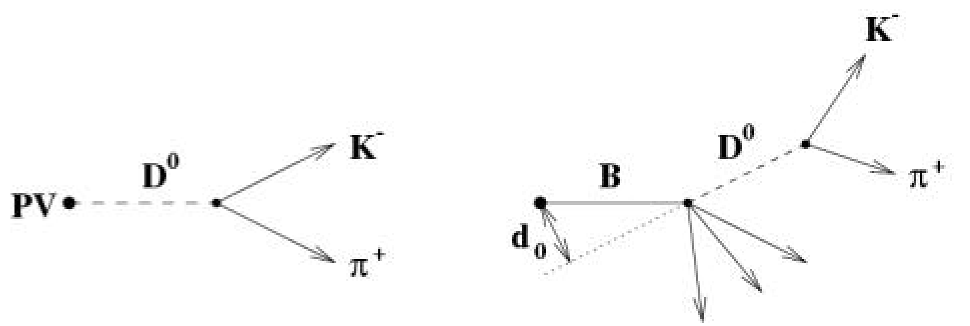
Some are born to discover J/ψ,
some achieve photoproduction of charm,
and some have charm physics thrust upon 'em

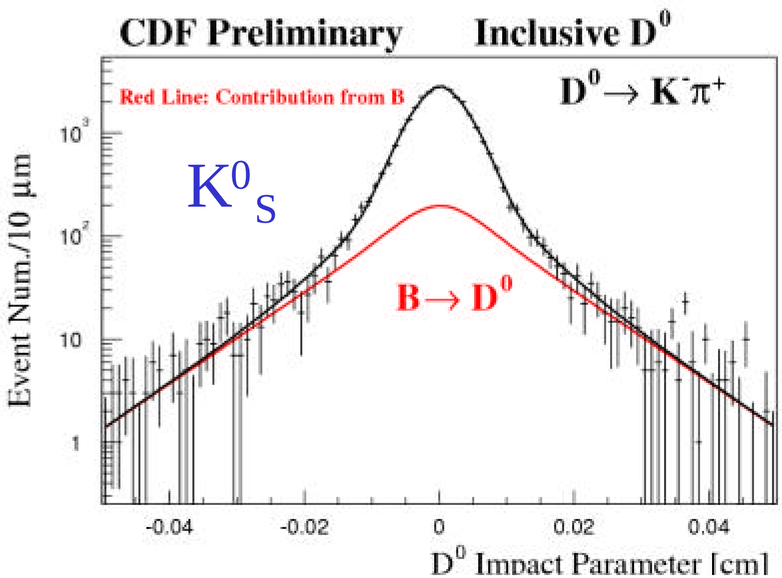
Fraction of charm from b decays

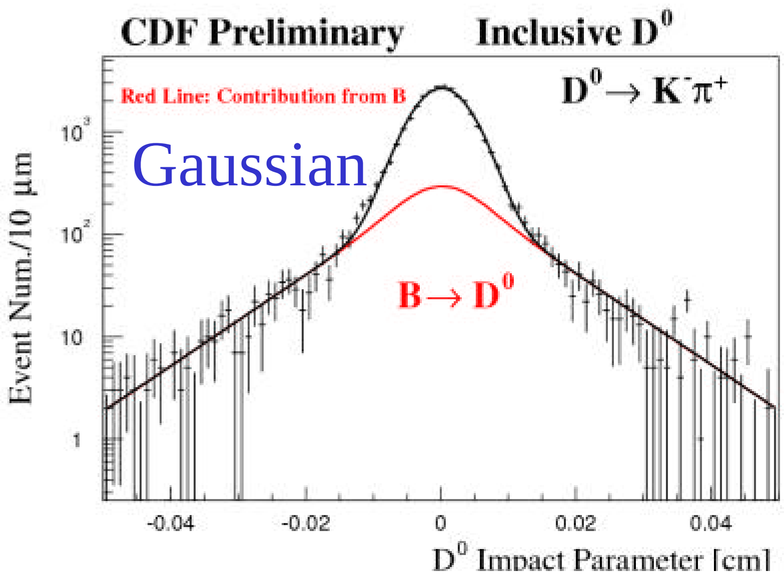
- D mesons:
  - What fraction from B?
    - D0: 16.4-23.1%
    - D^{*+}: 11.4-20.0%
    - D^{+}: 11.3-17.3%
    - D_s^{+}: 34.8-37.8%

Direct Production — D points back to PV

Secondary Production — D has finite impact parameter

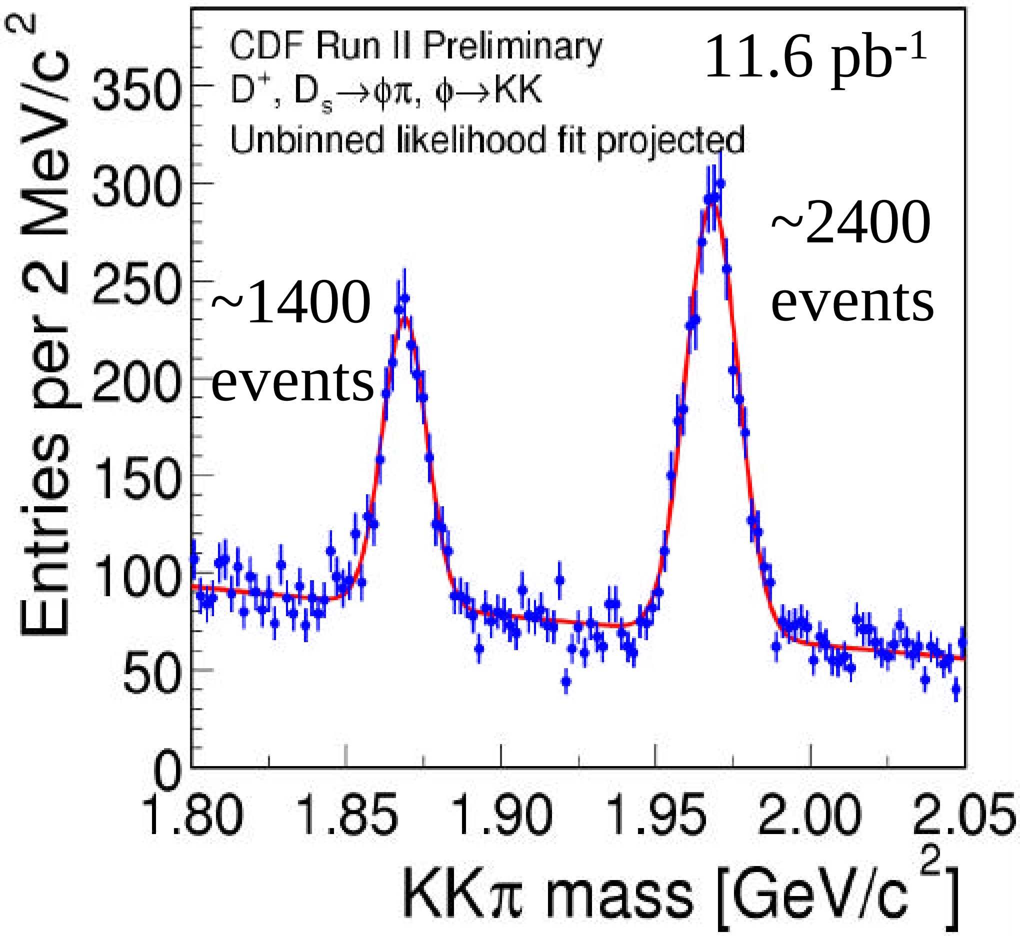






Measure Ds, D+ mass difference

- $D_s^\pm$ - $D^\pm$ mass difference
  - Both D → $\phi\pi$ (ϕ→KK)
  - Δm=99.28±0.43±0.27 MeV
    - PDG: 99.2±0.5 MeV (CLEO2, E691)
  - Systematics dominated by background modeling



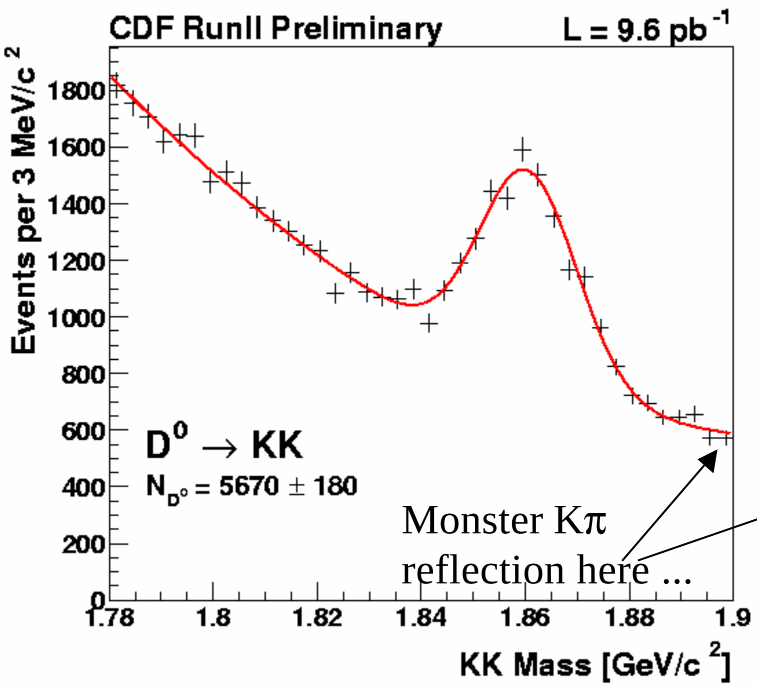
Brand new CDF capability

Measure Cabibbo-suppressed decay rates

- $\Gamma(D \rightarrow KK)/\Gamma(D \rightarrow K\pi) = (11.17 \pm 0.48 \pm 0.98)\%$ (PDG: 10.83 ± 0.27)
  - Main systematic (8%): background subtraction (E687, E791, CLEO2)
- $\Gamma(D \rightarrow \pi\pi)/\Gamma(D \rightarrow K\pi) = (3.37 \pm 0.20 \pm 0.16)\%$ (PDG: 3.76 ± 0.17)
  - several ~2% systematics

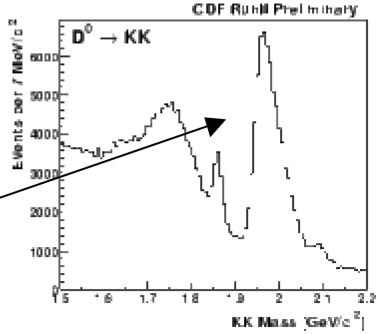
Already comparable!

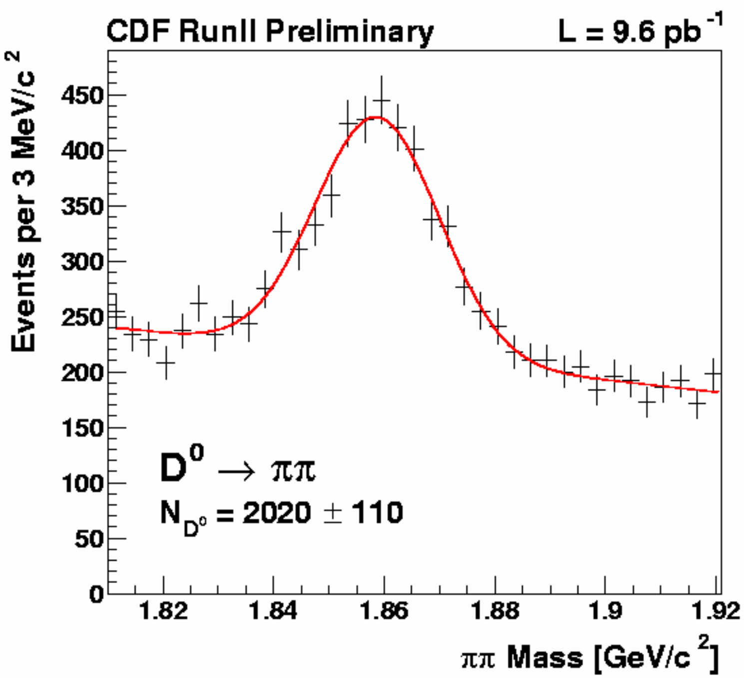
- This measurement has pushed the state of the art on modeling SVT sculpting--essential simulation tools for both B physics program and e.g. high-p_T b-jet triggers



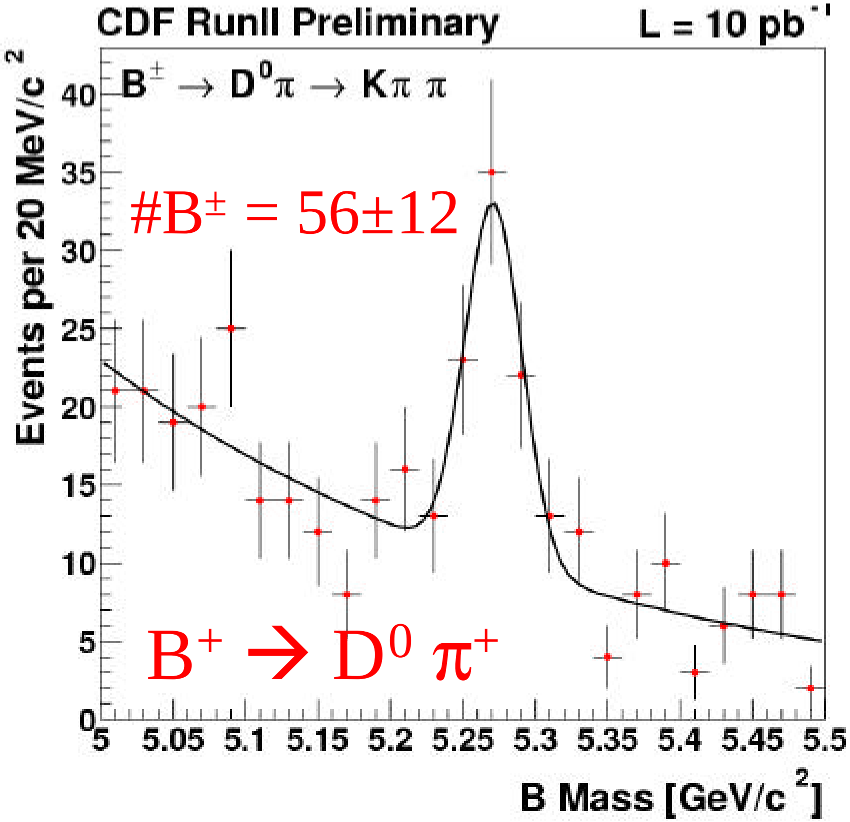
Monster Kπ reflection here ...

Future?
- CP violation
- mixing
- rare decays





Toward B_s mixing!



$$c\tau = \frac{L}{\gamma\beta}$$

$$\sigma_{c\tau} = \left(\frac{\sigma_L}{\gamma\beta}\right) \oplus \left(\frac{\sigma_{\gamma\beta}}{\gamma\beta}\right)\cdot c\tau$$

≈constant

multiplicative error
~ 15% (semileptonic)
~ 0.5% (hadronic)

Need fully reconstructed (hadronic) decays to see past first couple of oscillation periods

We observe hadronic B decays!

Yields understood to ~20% level from detailed simulation

Next steps:

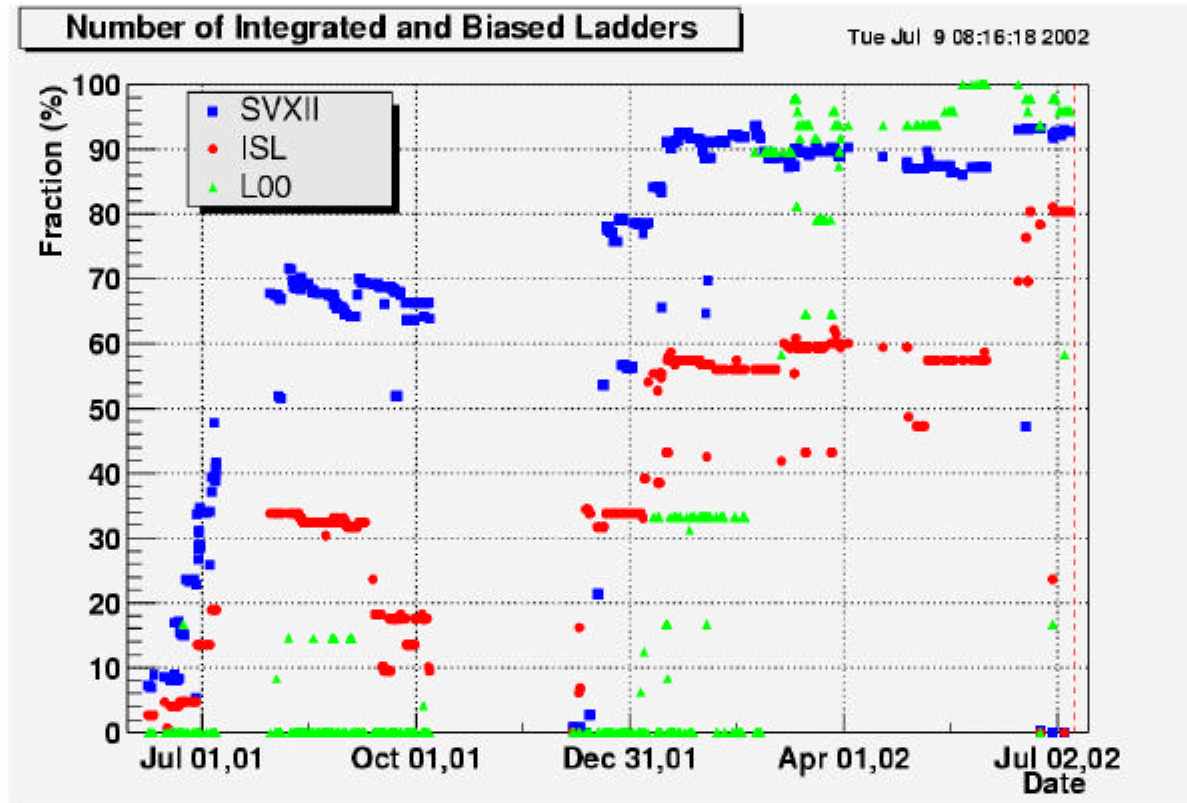
- Reconstruct $B_s \rightarrow D_s\pi$, $D_s \rightarrow \phi\pi$
- Flavor tagging algorithms
- Exploit $\geq \times 3$ SVX acceptance, SVT efficiency improvements

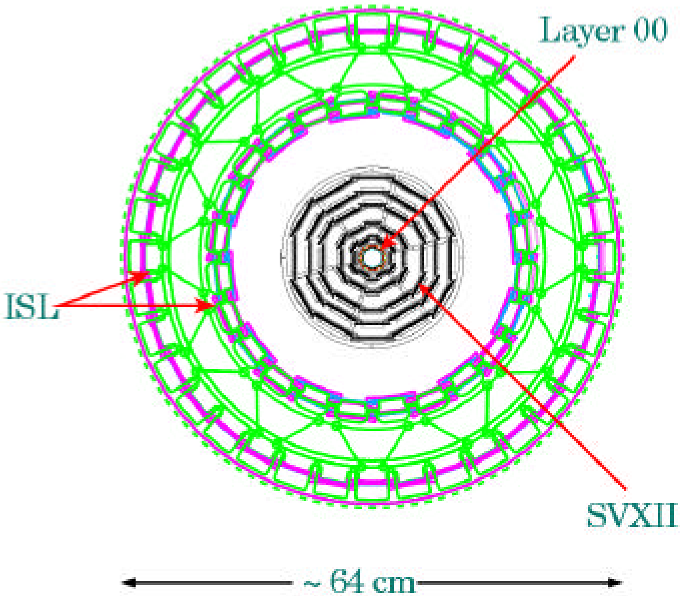
Our remedies oft in ourselves do lie

Full silicon acceptance is in sight …

The last 10% of the job takes the second 90% of the effort (but not time!)

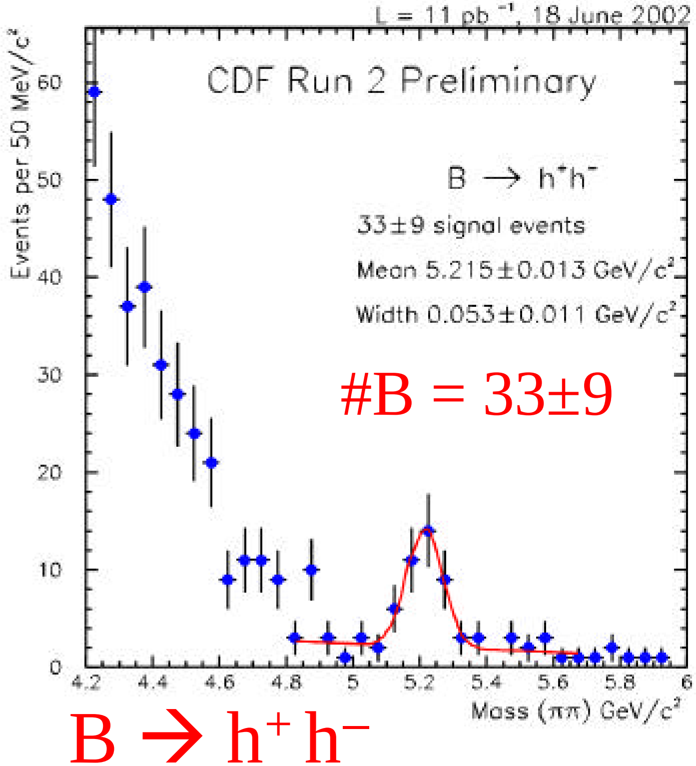
- Commissioning:
  - **L00** > 95%
  - **SVXII** > 90%
  - **ISL** > 80%
    - ISL completing cooling work

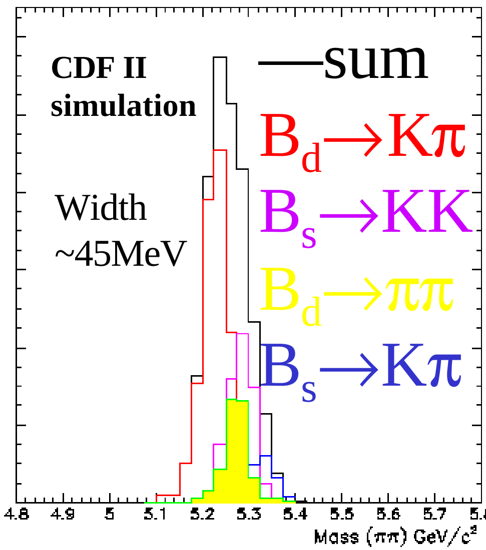




% of silicon ladders powered and read-out by silicon system vs. time

2-body hadronic B decays observed!!





- Yield lower than expected (now improved); S/N better than expected
- With 2 fb^{-1} sample, measuring γ to ~10° may be feasible, using Fleischer's method of relating $B_s \to KK$ and $B_d \to \pi\pi$, and using β as input

CDF is better than ever before!

- Taking publication-quality data since early 2002
- Understanding of detector is advanced
  - e.g. tracking is coming together much faster than in Run I
- Many new capabilities of detector and trigger
  - Each Run II pb^{-1} worth much more than each Run I pb^{-1}!
  - And of course 9% more W,Z; 35% more $t\bar{t}$ at 1.96 TeV
- Many early physics results, some already competitive
  - $\sigma B(W \to l\nu)$, $\sigma B(W \to \mu\nu) / \sigma B(Z \to \mu\mu)$
  - m(B), τ(B), ΔM(Ds,D+), BR(D0 →KK,ππ)
- Tooling up for M_W, M_{top}, SUSY searches, Higgs search
- By focusing work on achieving physics goals, we've made outstanding progress in 2002. **CDF is back!**

We are such stuff as dreams are made on?