B physics at the Tevatron

Fermilab,
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Summary

- B physics at the Tevatron
  - General features
  - Past experience in Run I
  - CDF and D0 upgrade for Run II
- Current status of CDF
- Prospects for B physics
  - Case studies:
    - Bs mixing
    - sin(2β) in Bd → J/ψ K^0_S
    - γ from B→ π π/K K
  - Conclusions

B production rates

- **Very large b cross section at hadron colliders with moderate S/N**
- **X-section, S/N, luminosity**
  - (some acceptance assumptions included)
  - $e^+ e^-$ machines

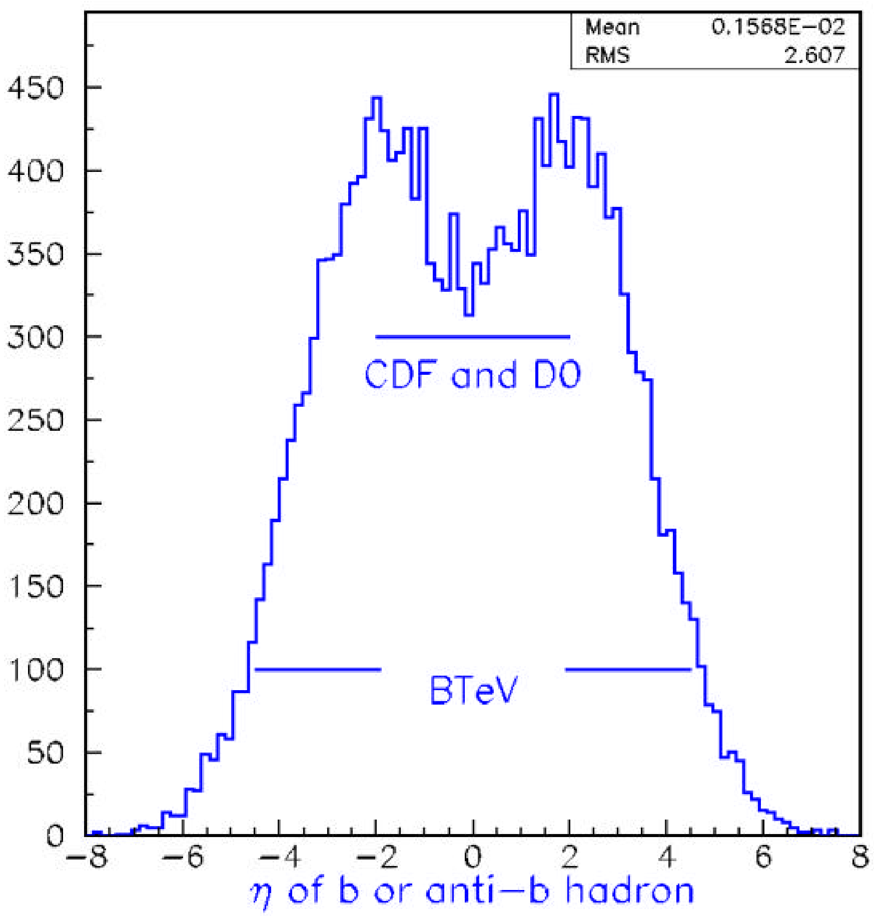
Name	Ecm GeV	*L* pb/y	σ_{bb}	$\frac{\sigma_{bb}}{\sigma_{tot}}$	N_{bb} y^{-1}
DORIS	10.6	200	1 nb	0.2	$2x10^5$
CESR	10.6	1000	1 nb	0.2	$1x10^6$
LEP	93	100	5 nb	0.14	$5x10^5$
SLAC	10.6	$3x10^4$	1 nb	0.2	$3x10^7$
KEK	10.6	$1x10^5$	1 nb	0.2	$1x10^8$

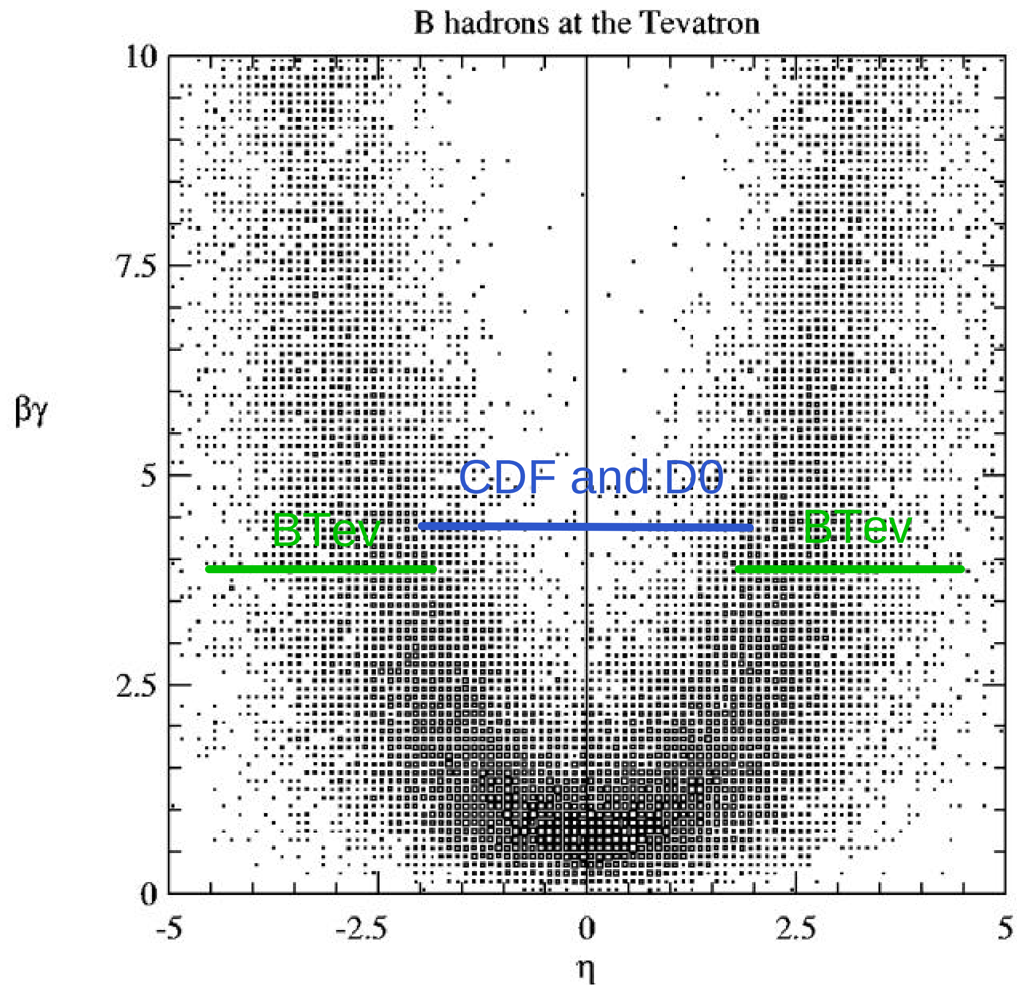
  - Hadronic machines

TevII	900*	100	~1 μb	10^{-6}	~10^8
TevI (R1)	1800	50	40 μb	10^{-3}	$2x10^9$
TevI (R2)	2000	1000	40 μb	10^{-3}	$4x10^{10}$
LHC-B	14TeV	1500	200 μb	$5x10^{-3}$	~ 10^{11}

B production kinematics

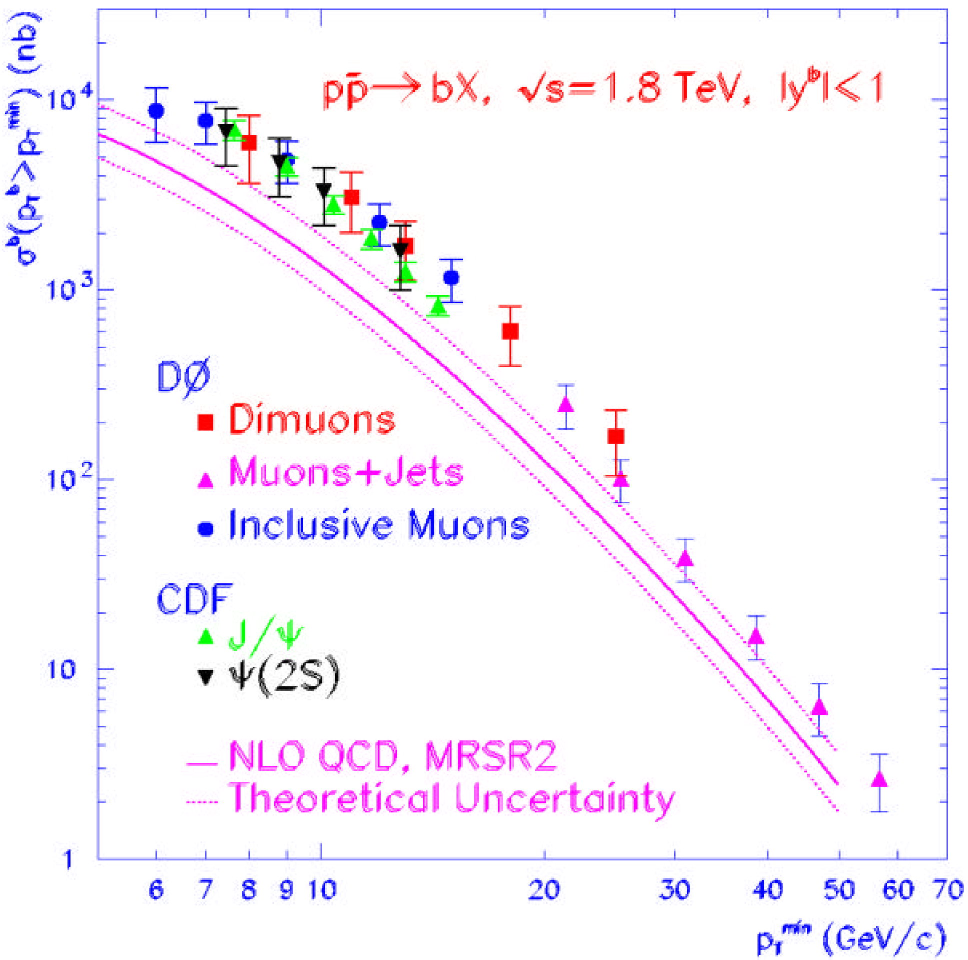
- Can loose much of the cross section due to acceptance (p_t, η)





B production kinematics

- Steep P_t dependence makes it challenging to trigger
  - Need low p_t thresholds if acceptance is in central region



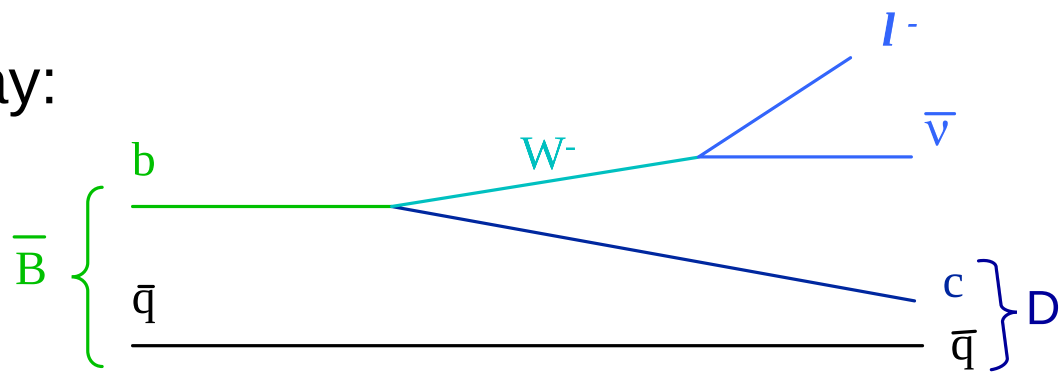
❖Trigger is based on decay products usually much softer than original b-quark (fragmentation + decay)

B production selection

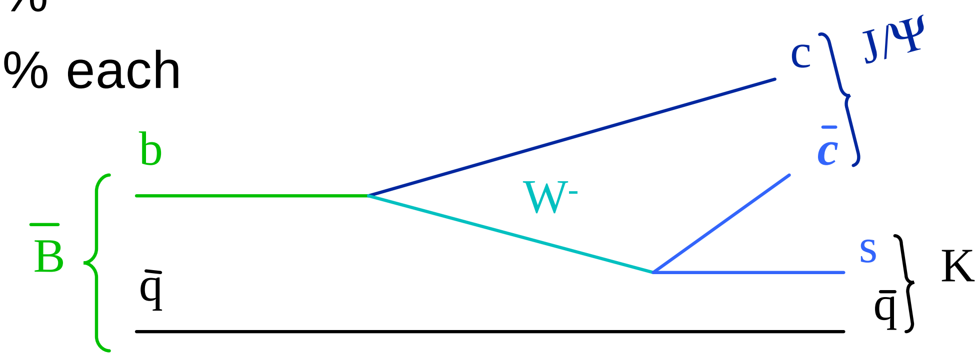
- Trigger and offline signal selection based on strong signatures to overcome QCD backgrounds
  - Inclusive leptons
  - Inclusive di-leptons (resonant [J/ψ, ψ'], and not)
  - Secondary vertices (Run II only)
  - Secondary vertices in association with leptons (Run II only)
- Reconstruction of invariant masses of b, c, s-hadrons at level 3 or offline provides improved S/N
  - E.g. Bs → Ds π, Ds→ ϕ π, ϕ → KK

B signatures

- Leptons from SL decay:
  - ~10% for each mode

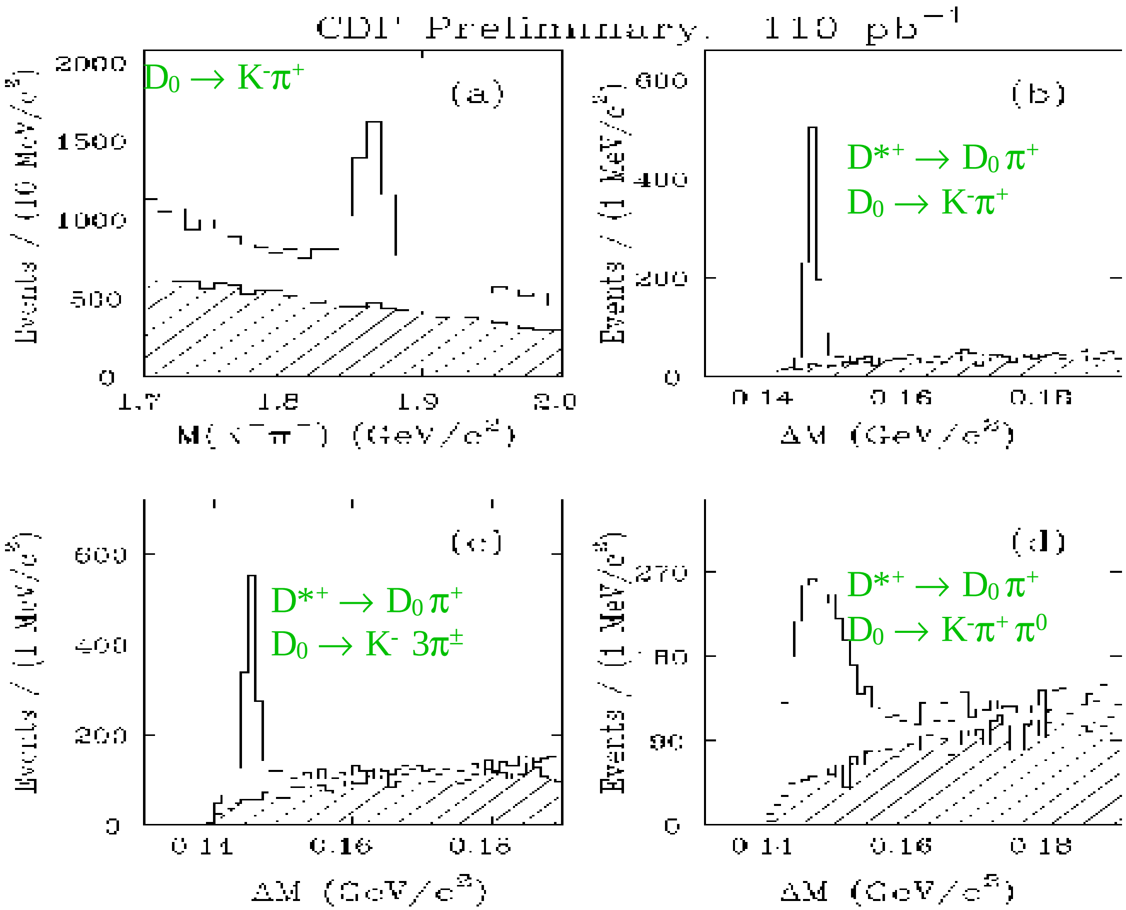


- Leptons from J/Ψ decay:
  - $B \rightarrow J/\Psi + X$ 1%
  - $J/\Psi \rightarrow \mu^+ \mu^-$, $e^+ e^-$ 6% each

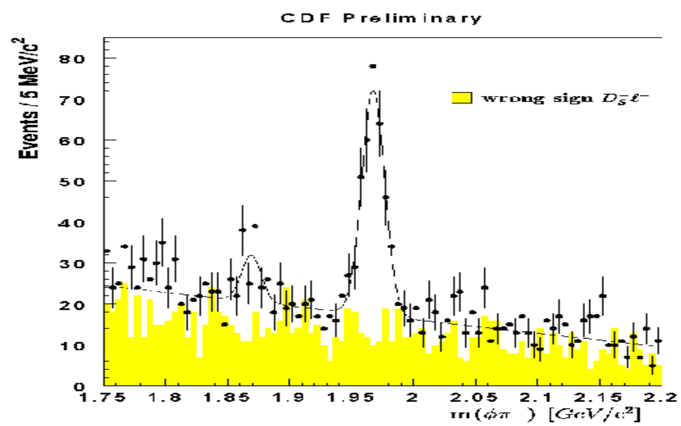


- Secondary vertex:
  - $c\tau$ ~ 450 μm
  - $<N_{ch}>$ ~ 5

Data sets: l + charm

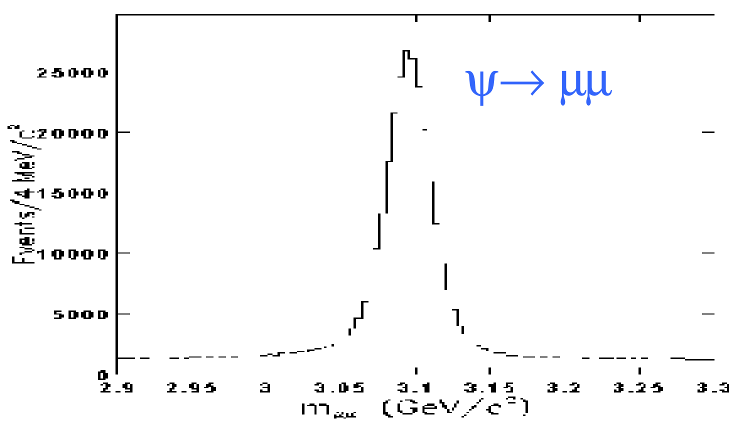


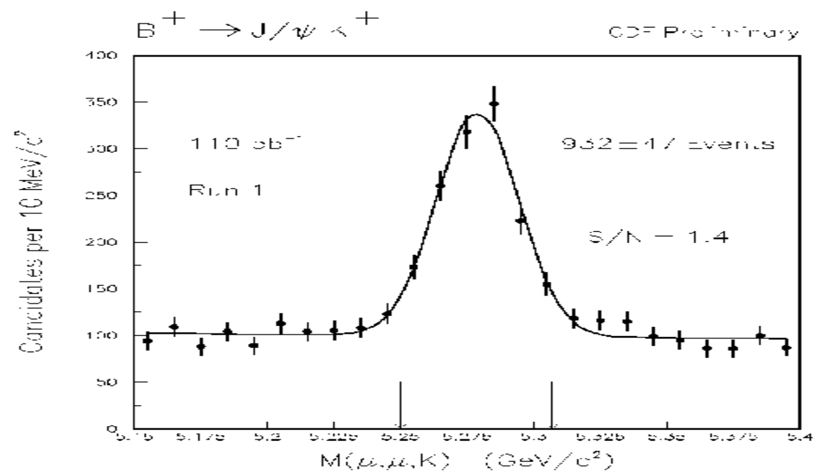
- Peaks observed in right-sign only

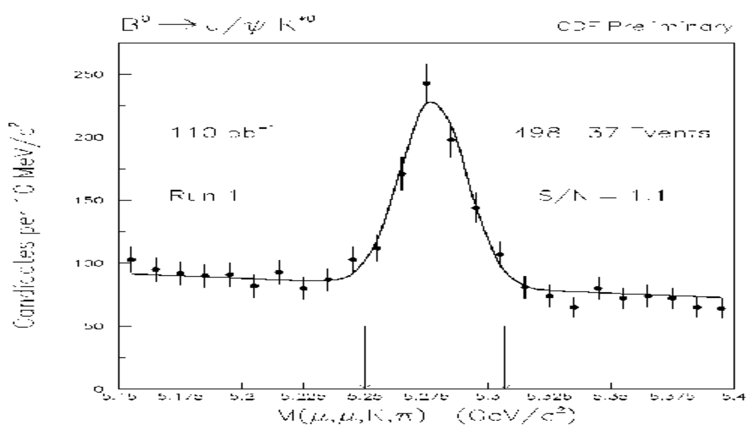


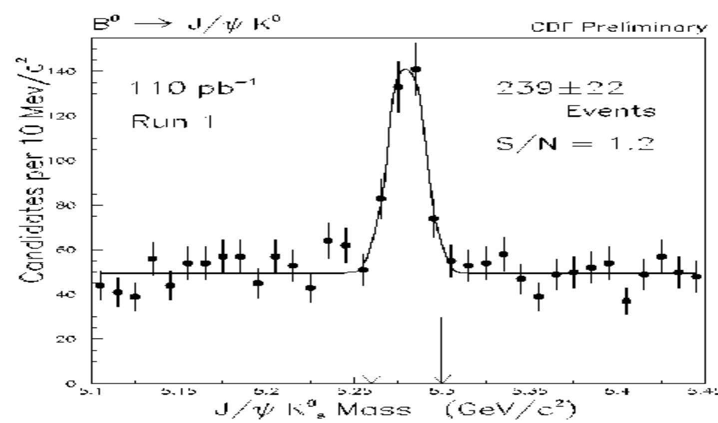
- 254 ± 21 Ds → φ π with right sign correlation

Data sets: ψ triggers



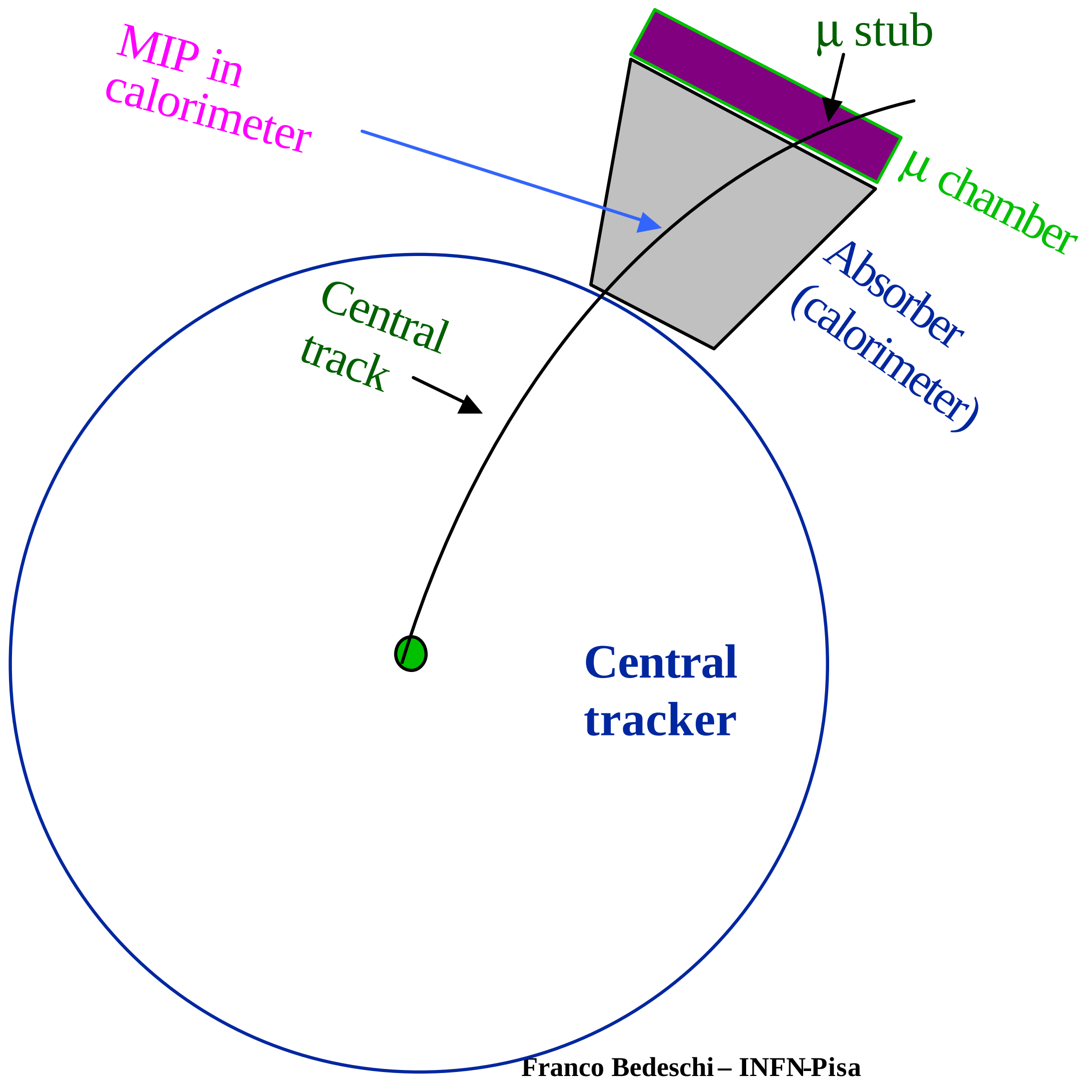




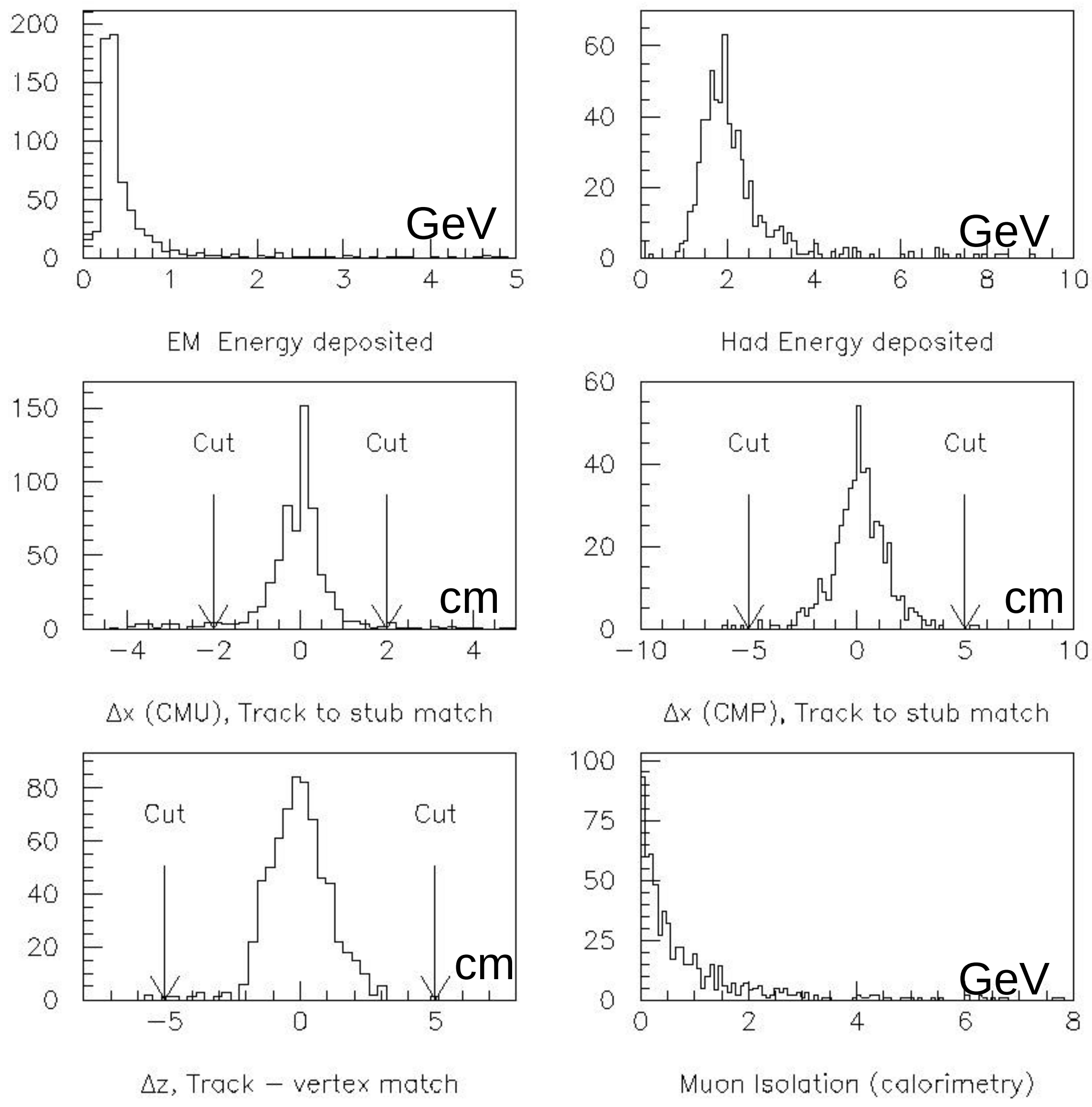


Muon signature

- Measurements:
  - Central tracking chamber:
    - Track momentum
    - Trajectory
  - Calorimeter:
    - Energy
  - Muon chambers:
    - Trajectory (stub)
- Require:
  - MIP in calorimeter tower pointed by central track
  - Position and angle match between track and stub
- Backgrounds:
  - decays in flight, punch-through

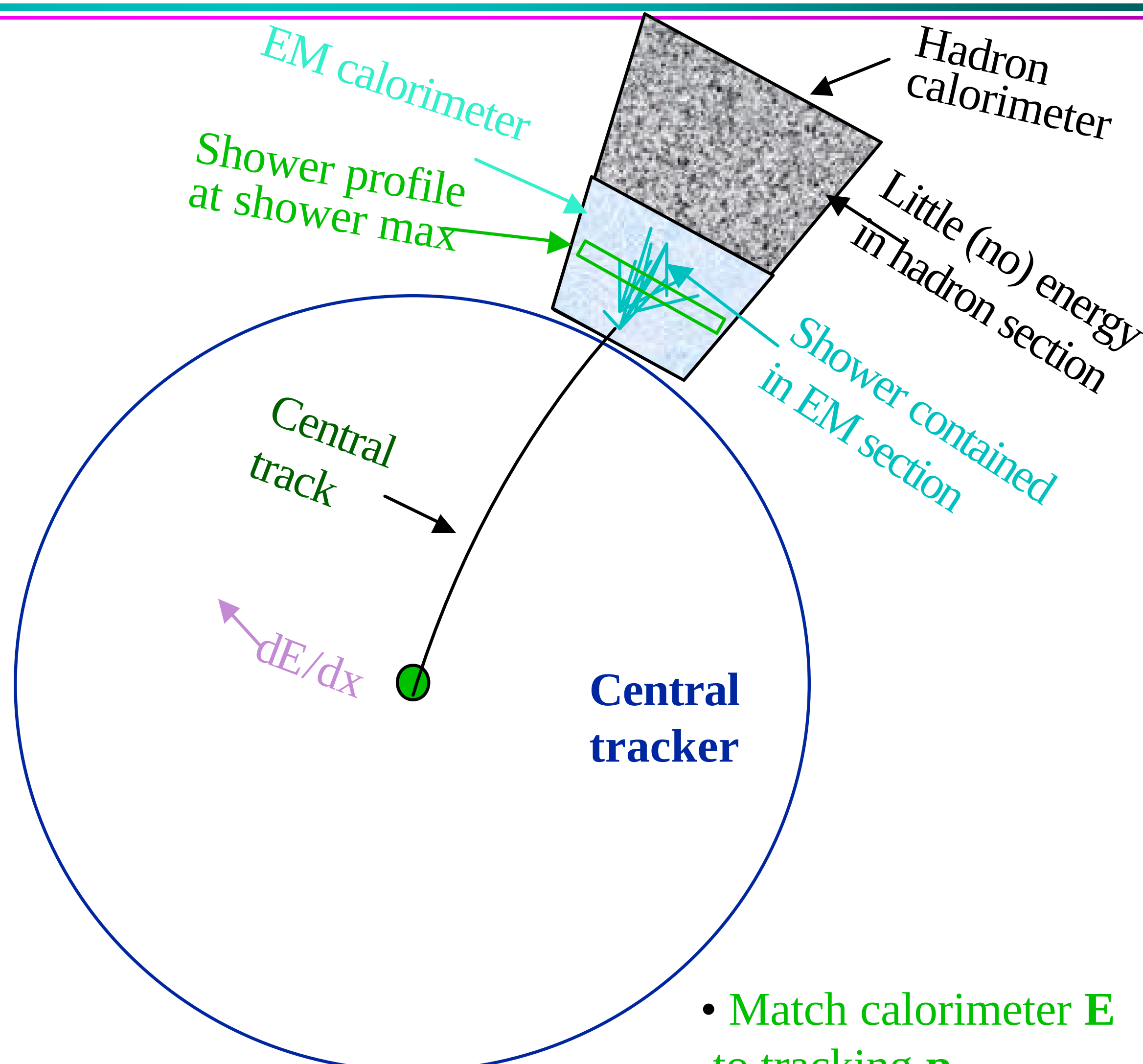


μ definition cuts



Electron signature

- Measurements:
  - Central tracking chamber:
    - Track momentum
    - Trajectory
    - dE/dx
  - Calorimeter:
    - Energy in EM and Hadronic sections
  - Shower max chambers:
    - Shower profile
- Require:
  - EM cluster
  - Small energy in H. section
  - Track matches EM cluster
  - Momentum/energy match
  - dE/dx and shower profile
- Background:
  - π_0, early int. hadrons, γ conversions



• Match calorimeter **E** to tracking **p**

$e^{\pm}$ definition cuts

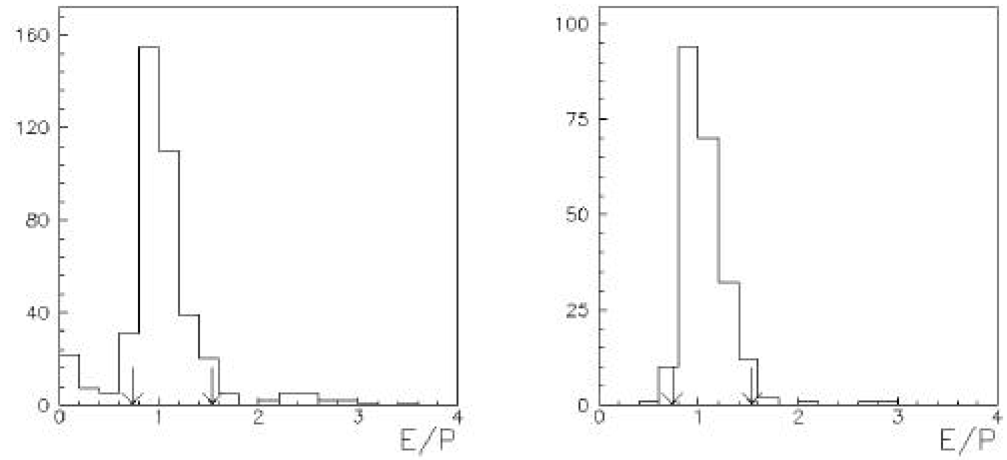


Figure 3: E/P for conversion electrons (a) without and (b) with fiducial cuts. The arrows indicate cut values.

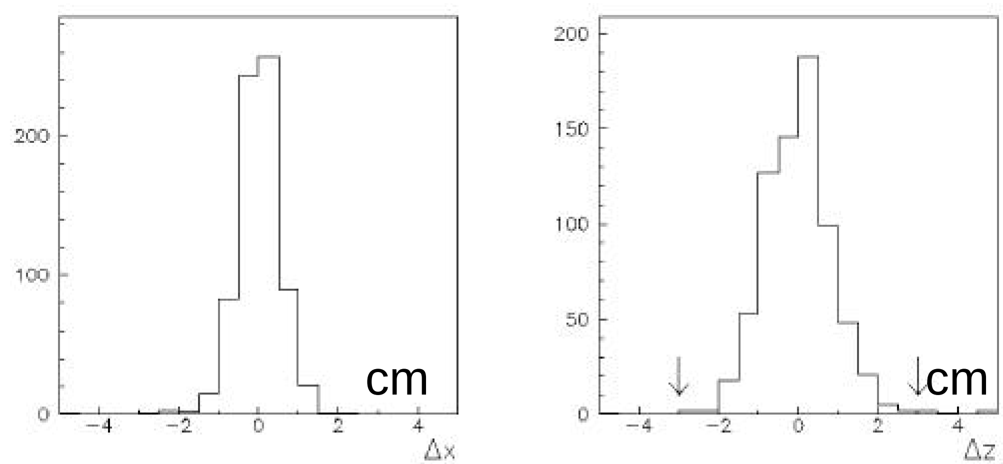
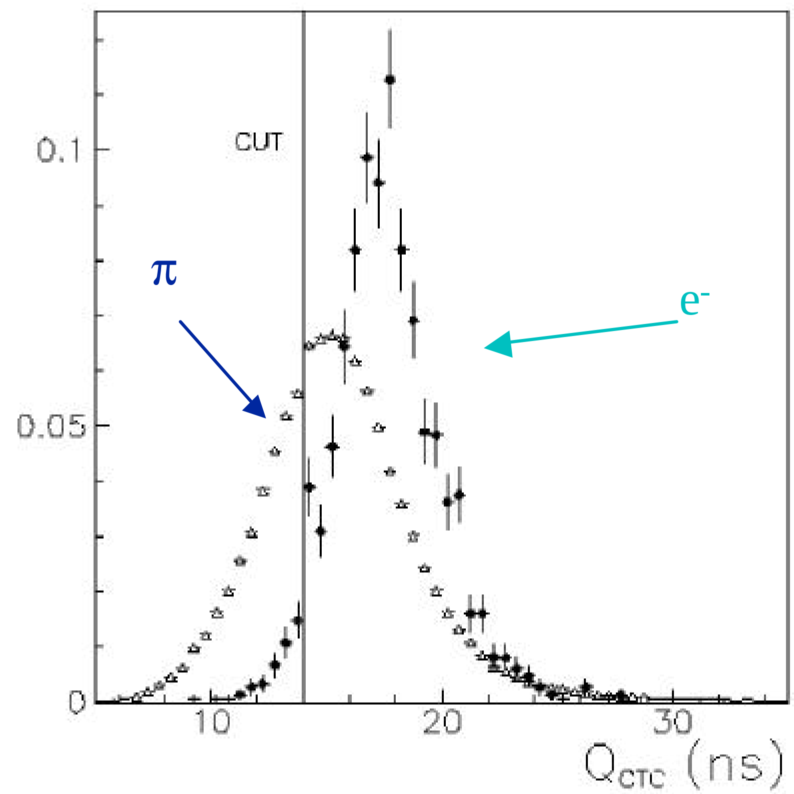
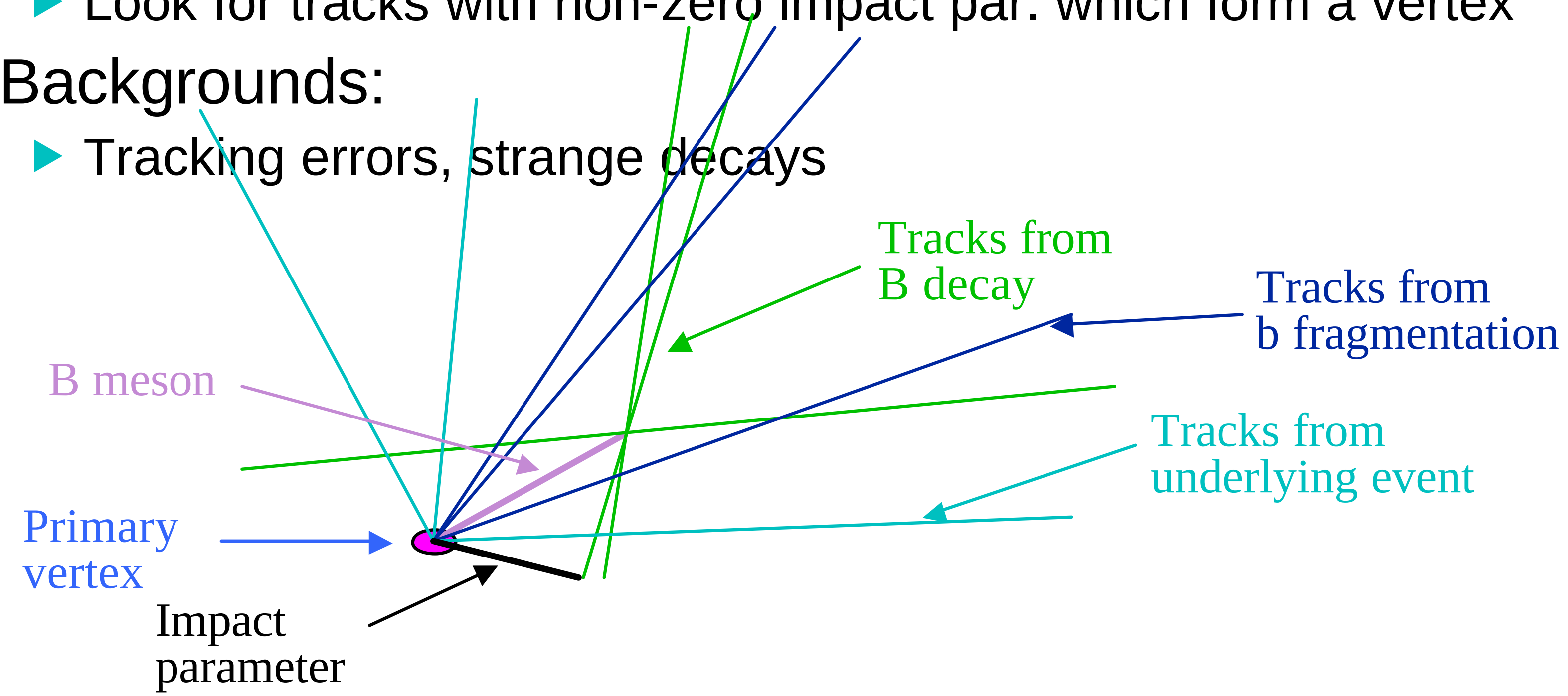


Figure 4: Track-CES matching for conversion electrons: (a) Wire View, (b) Strip View. Cut values are indicated by arrows.

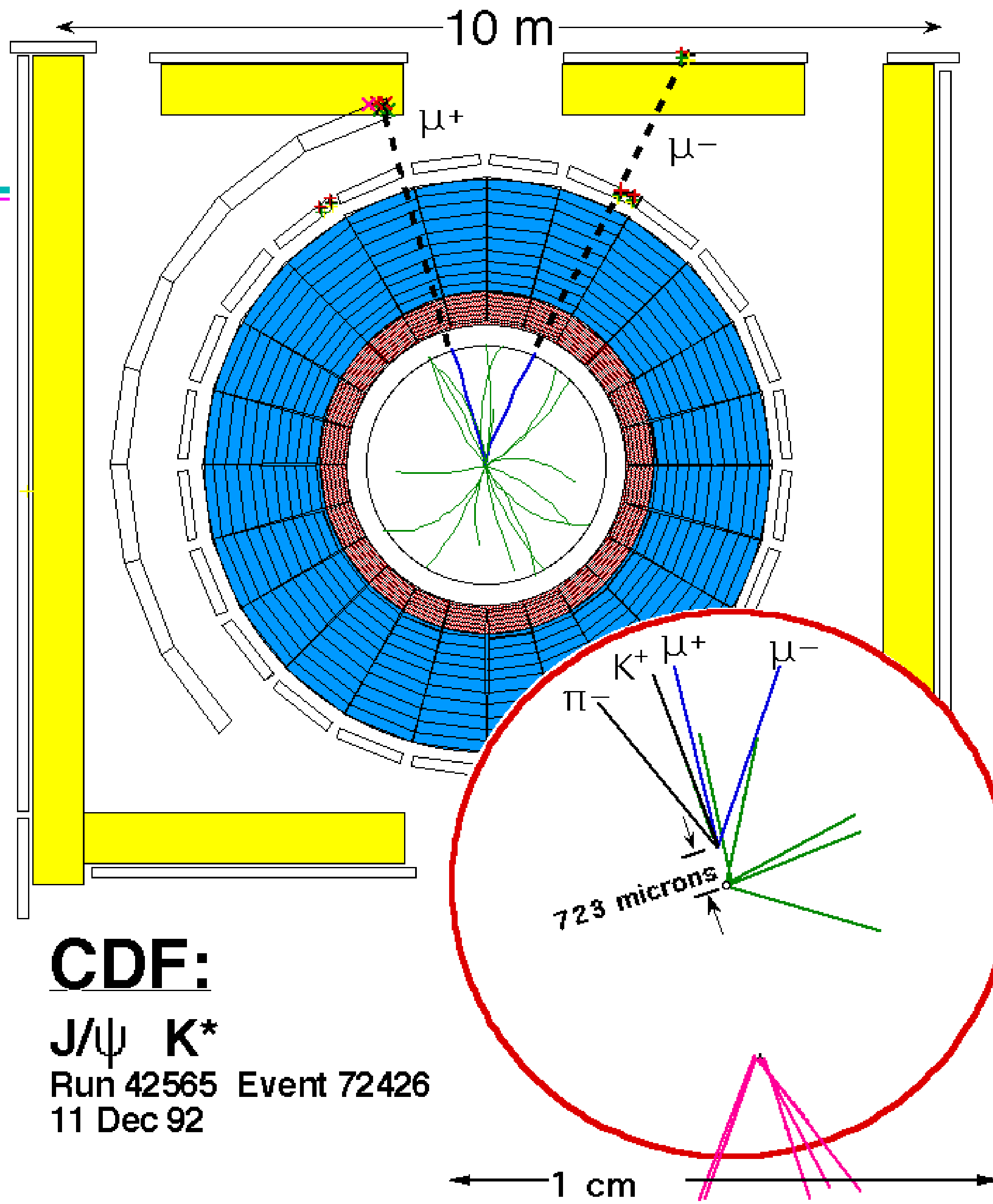


Secondary vertex signature

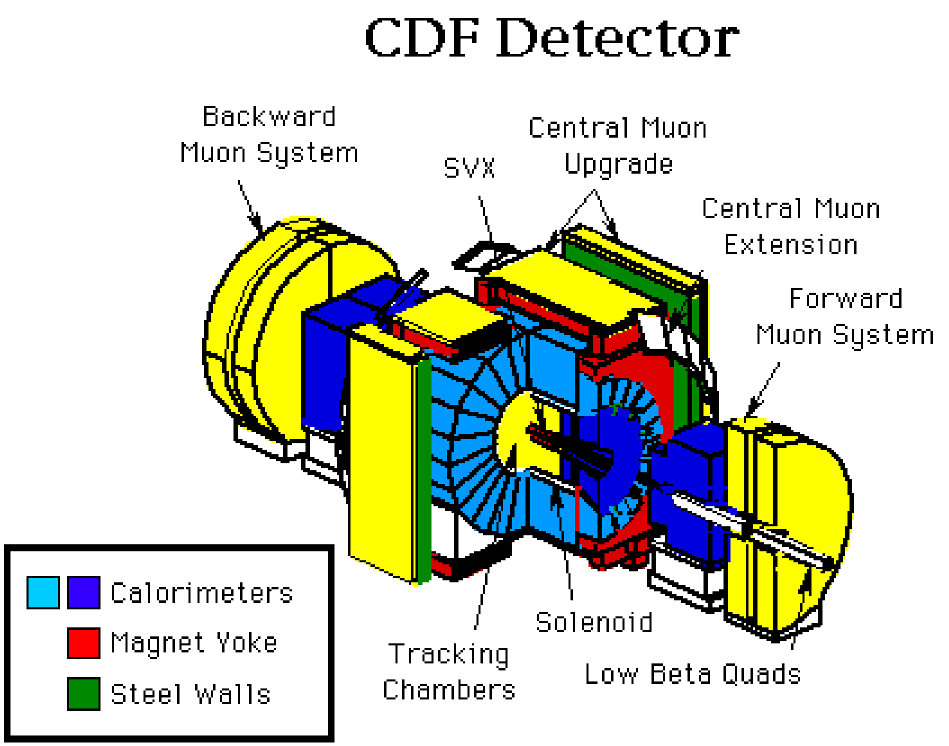
- Measurement:
  - Measure tracks with high precision vertex detector
- Required:
  - Look for tracks with non-zero impact par. which form a vertex
- Backgrounds:
  - Tracking errors, strange decays

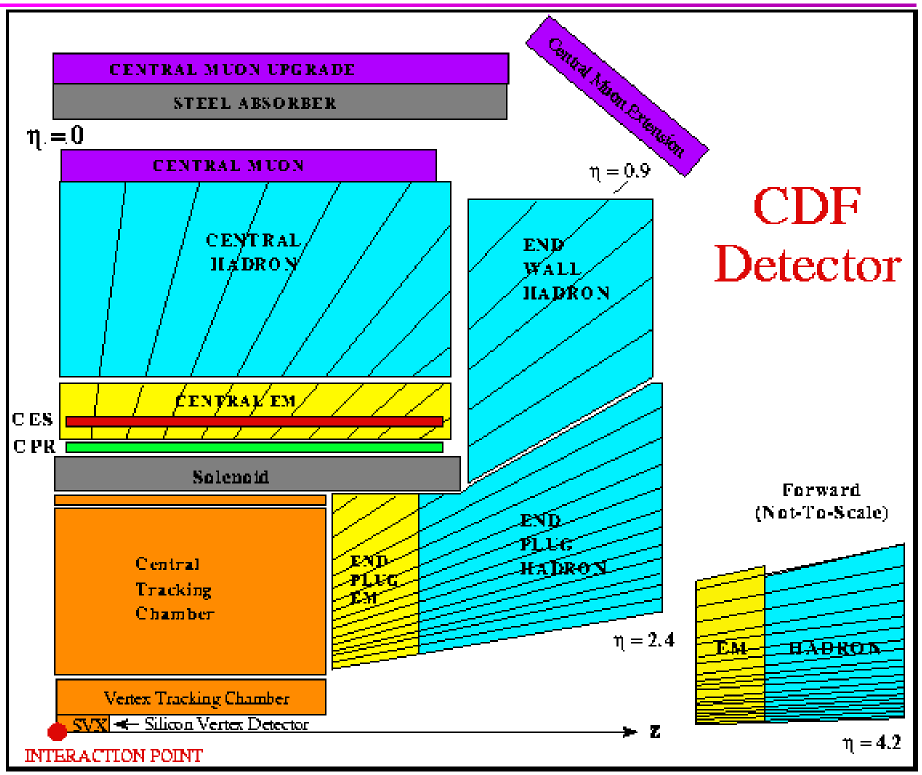


A real B event



CDF during Run I



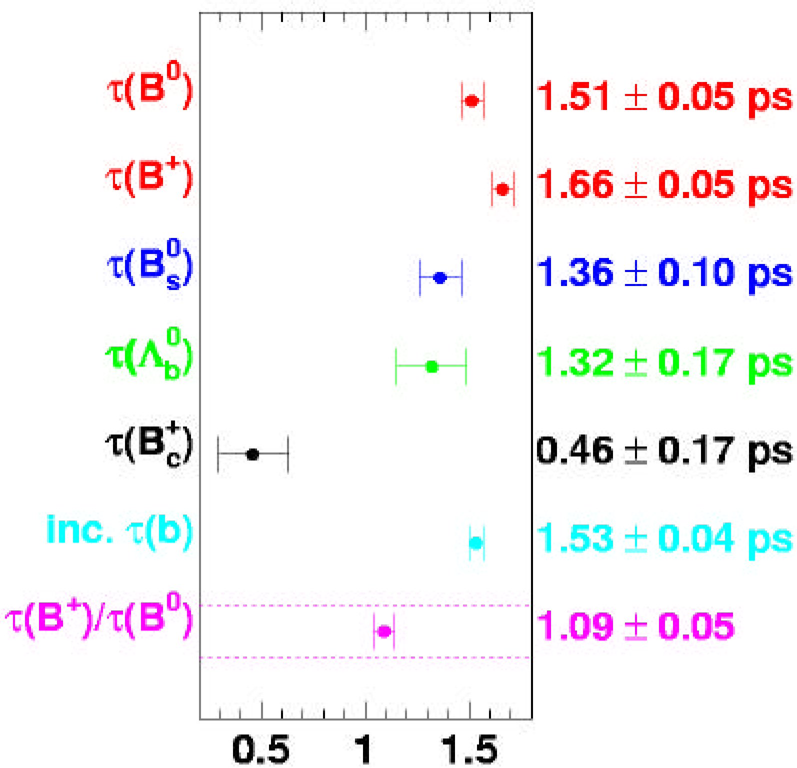


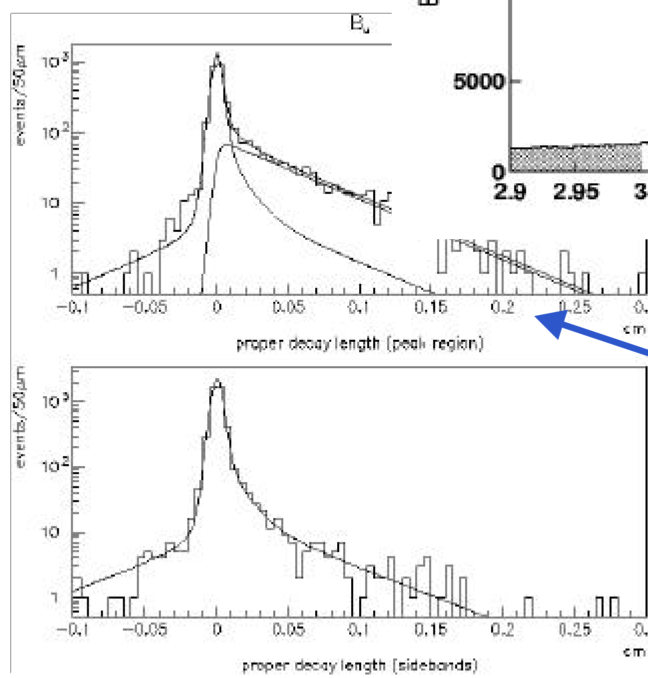
- 4 layer Si strip detector: 60% acceptance, σ_D = 13 μm
- CTC large drift chamber: B=1.4 T, N_{axial} = 60, N_{stereo} = 24, $\Delta p_t/p_t < 0.001\, p_t$
- Projective towers calorimeters: $\Delta\eta \times \Delta\phi$=0.1x0.3, lead/steel-scintillator(PWC)
- Central muon chambers: $|\eta| < 1$
- Forward calorimeters and muon up to η=4.2

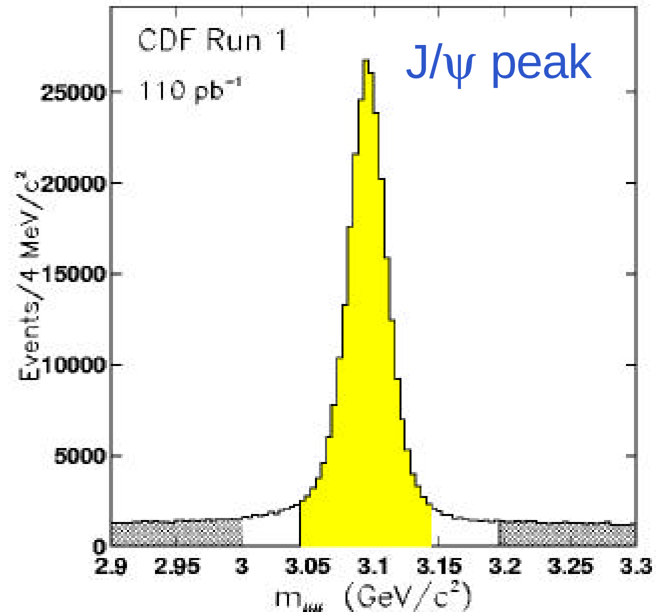
B Physics

- Learned how to use Vertex Detector
  - Precise lifetime measurements
  - Also with exclusive B→ ψ K channels
  - Accuracy comparable to LEP

CDF B Lifetimes



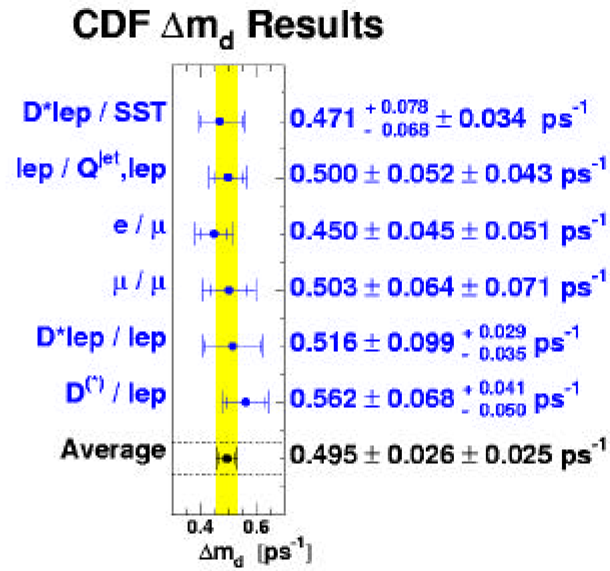


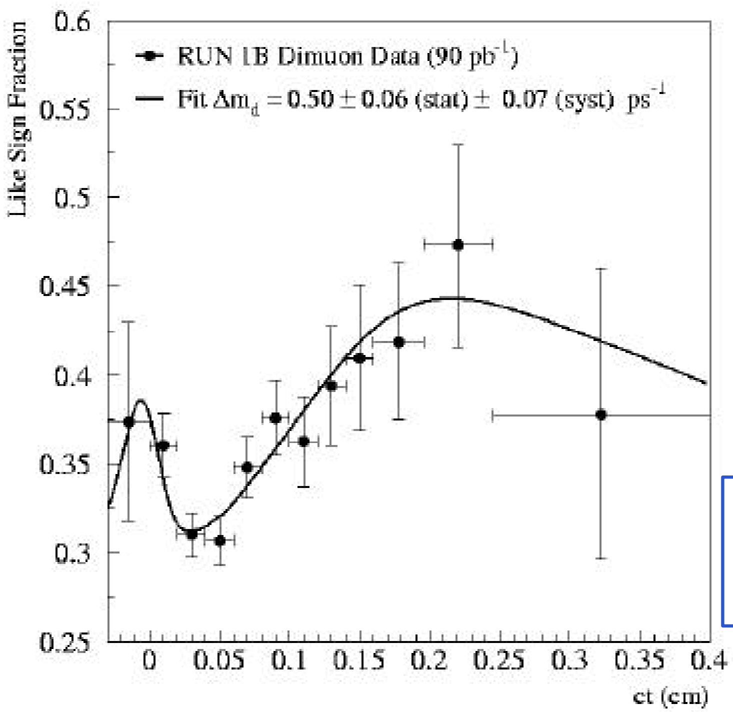


B^+ decay length distribution (exclusive decay)

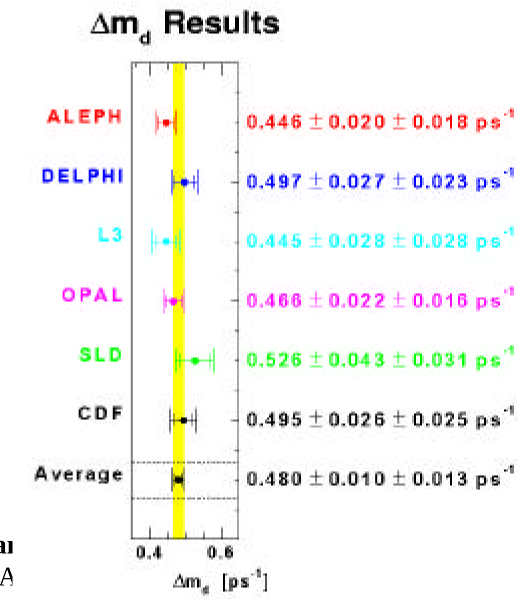
B Physics

- Second generation analyses
  - B0 – B0 mixing
    - Learn flavor tagging
    - Understand tagging dilutions:
      - ➔ **Efficiency and error rate**





Di-muon like-sign fraction vs. $c\tau$



Fra
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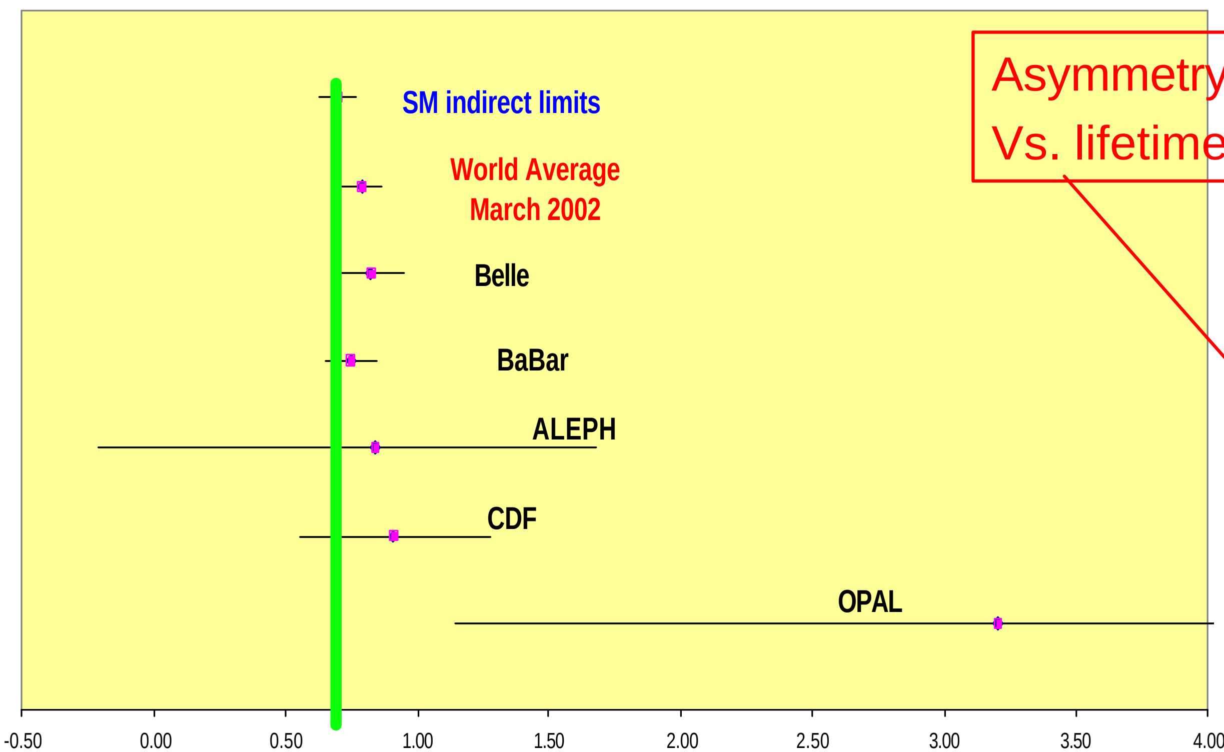
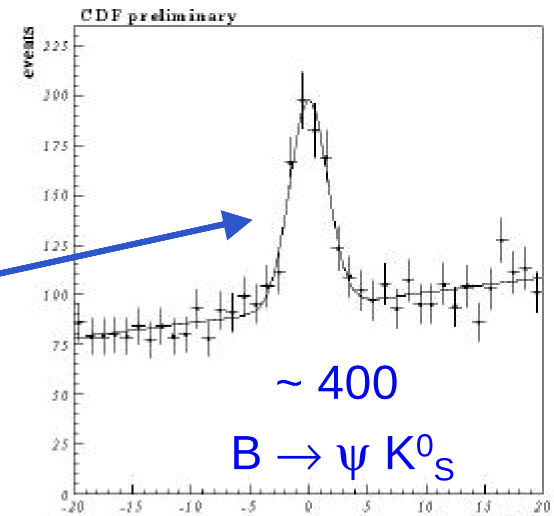
B Physics

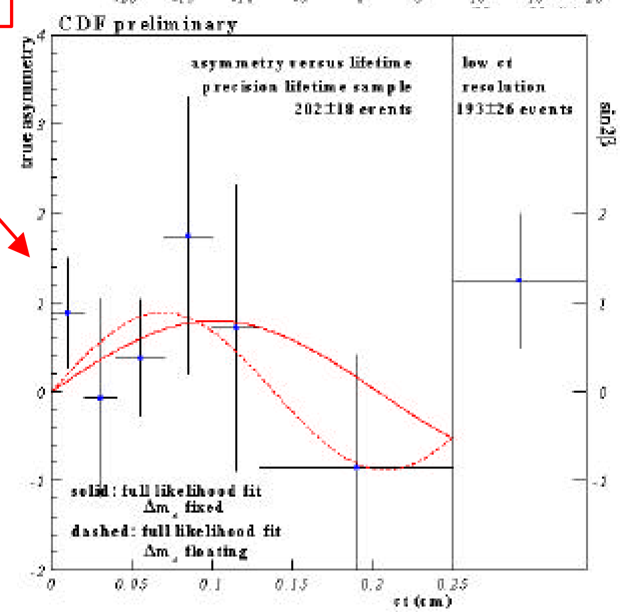
- Third generation analyses
  - CP violation with B → J/Ψ K^0_S
    - $\sin(2b) = 0.91^{+0.37}_{-0.36}$



B0 signal



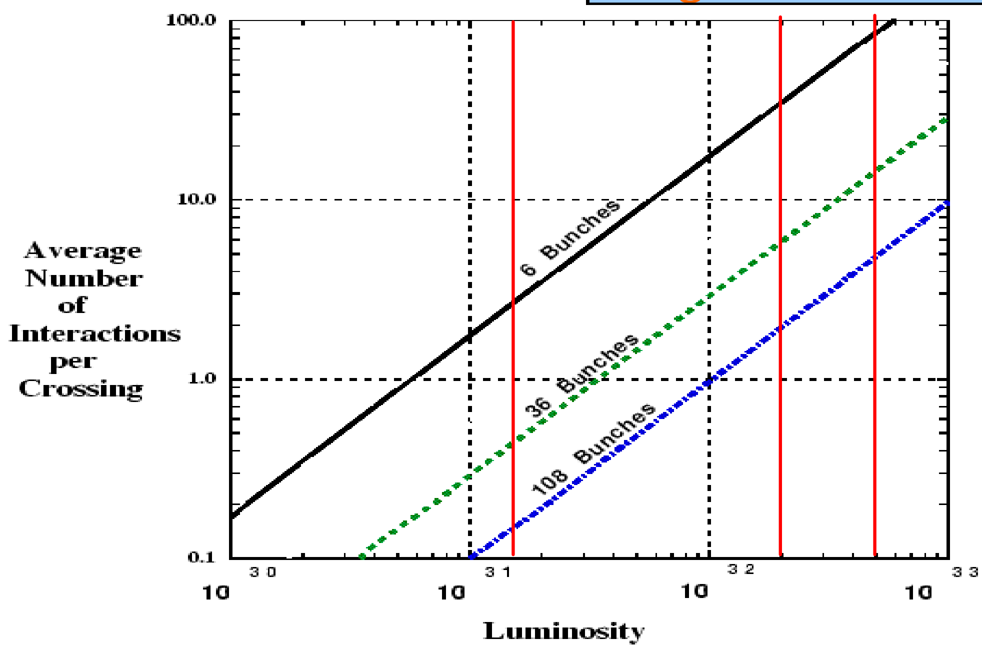
Asymmetry
Vs. lifetime



Tevatron Upgrade

- Tevatron parameters

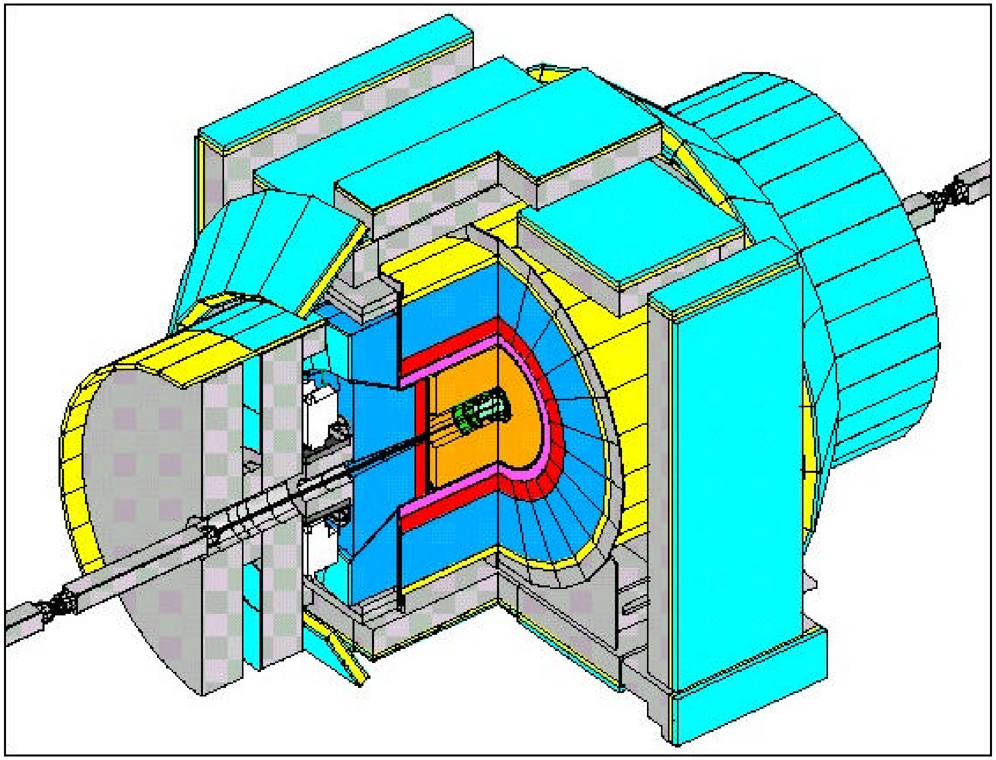
	Run 1B	Run IIa	Run IIb
Energy/beam	900 GeV	980 GeV	980 GeV
Peak Luminosity	1.6×10^{31}	2.0×10^{32}	5.0×10^{32}
Number of bunches	6	36/108	~ 108
Bunch spacing	3500 nsec	396/132 nsec	132 nsec
Interactions/crossing	2.8	5.8/1.9	4.9
Run period	1992-96	2001-03	2004-07
Integral Luminosity	118 pb^{-1}	2 fb^{-1}	13 fb^{-1}



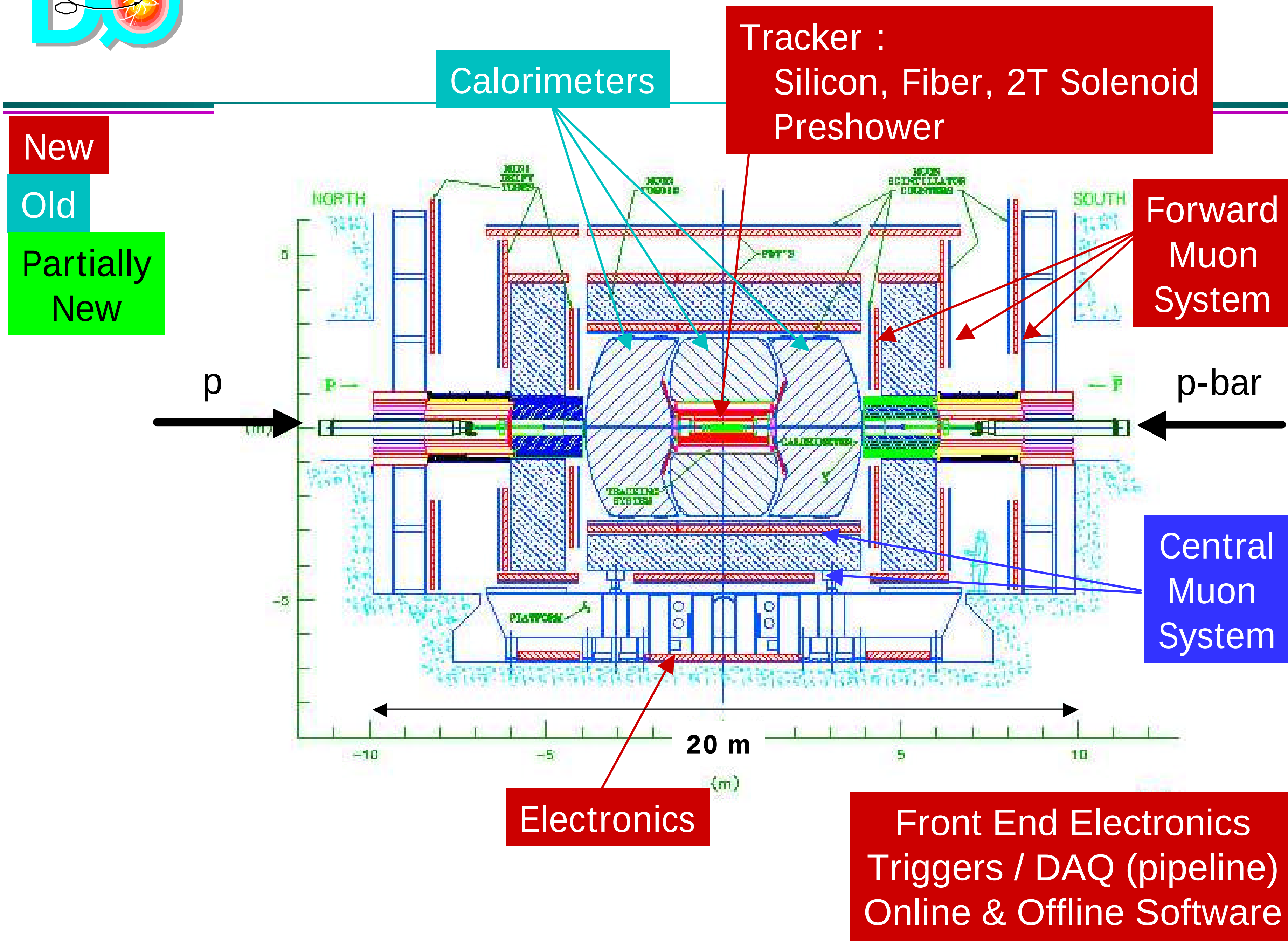
- Shorter inter-bunch implies major CDF electronics infrastructure redesign!!!
- Higher beam energy give up to 40% improvement in yield of high mass objects

CDF II

- CDF II:
  - All front-end, DAQ and trigger replaced!!!
  - **New** L1 tracking trigger
  - **New** L2 secondary vertex trigger
  - **New** Time of Flight



- **New** Full acceptance 7(8) layer silicon system: $|\eta|<2$ coverage
- **New** COT drift chamber: B=1.4 T, $N_{axial} = 48$, $N_{stereo} = 48$, $\Delta p_t/p_t < 0.001\ p_t$
- **New** Plug calorimeter has smaller inner hole
- Central muon chambers up to $|\eta| < 1.5$ – **Some new**
- Forward calorimeters and muons removed

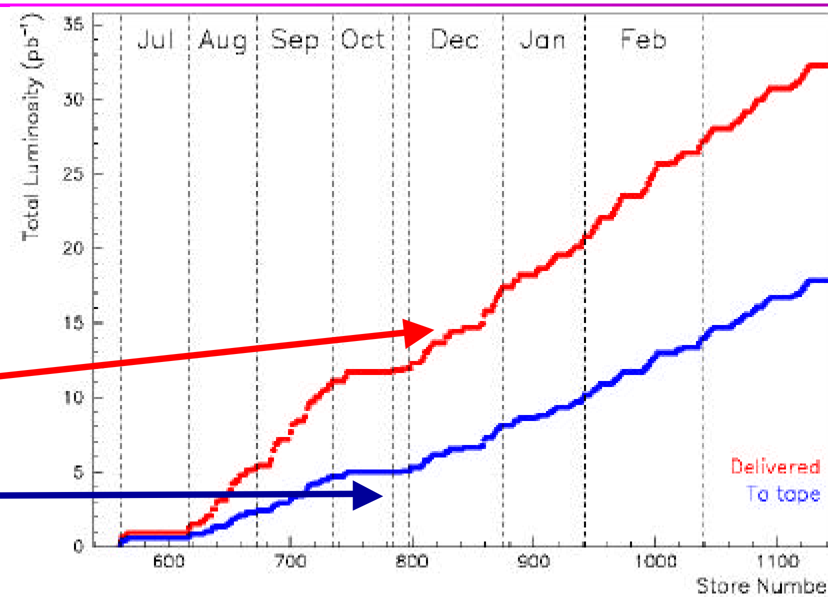

New
Old
Partially New
Calorimeters
Tracker :
Silicon, Fiber, 2T Solenoid
Preshower
Forward Muon System
Central Muon System
p
p-bar
NORTH
SOUTH
20 m
(m)
Electronics
Front End Electronics
Triggers / DAQ (pipeline)
Online & Offline Software

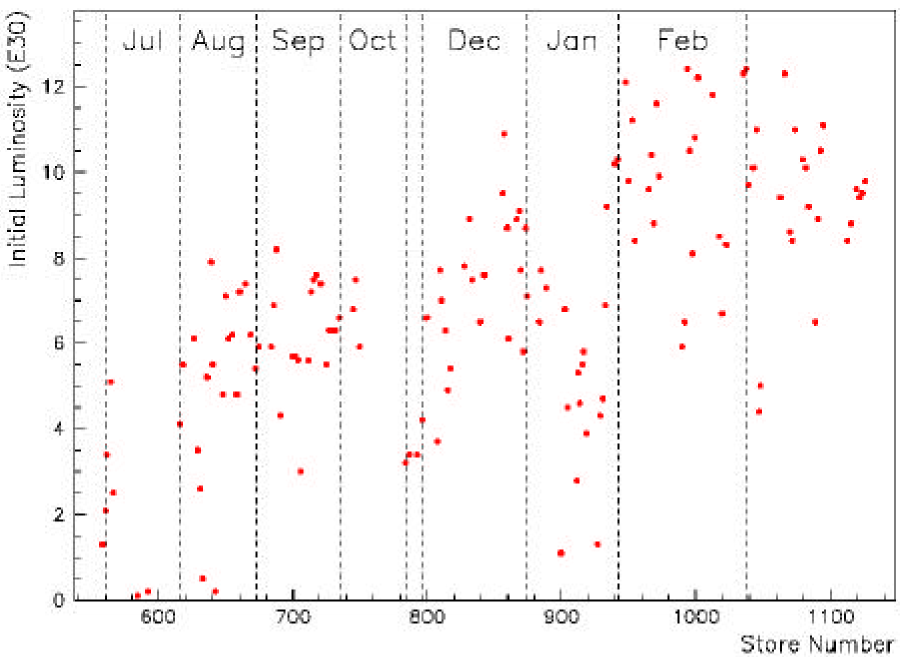
Run II: CDF

- Current status:
  - Silicon: >90% of the system is operational
  - COT: stable operation since commissioning run in 2000
  - TOF: stable operation
  - Calorimeters: stable operation
  - Muon systems:
    - Stable operations for CMU, CMP, CMX (excluding miniskirts)
    - Commissioning of forward muons is on-going
    - Beam losses are high and make central muon systems run in uncomfortable range
  - Trigger:
    - L1: stable operation including track trigger (XFT)
    - L2: stable cutting on jets, SVT, electrons and photons
    - L3: stable operation

Run II: Tevatron

- Luminosity profile
  - Delivered until October shutdown
    - 34 pb^{-1} delivered
    - 17 pb^{-1} on-tape





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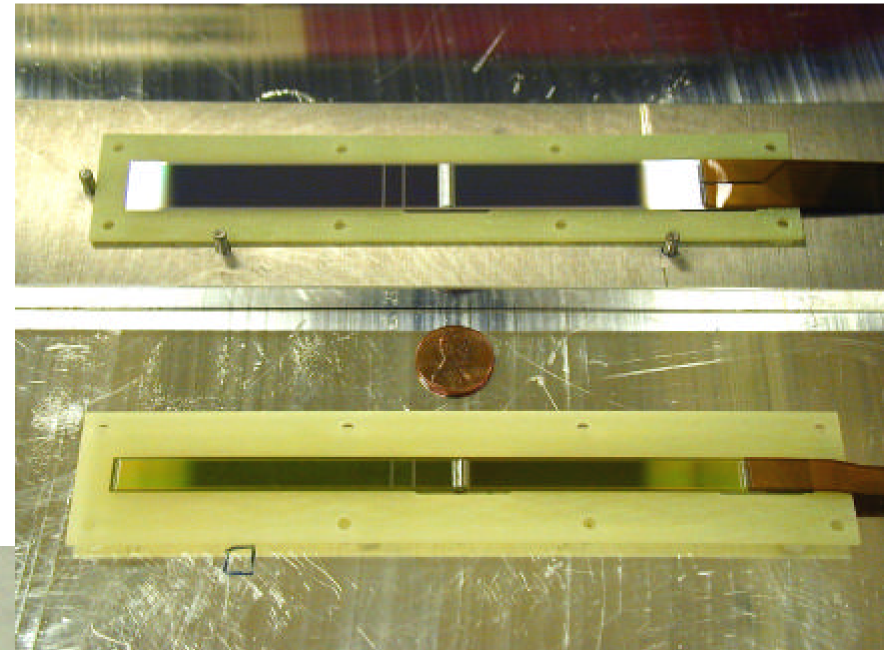
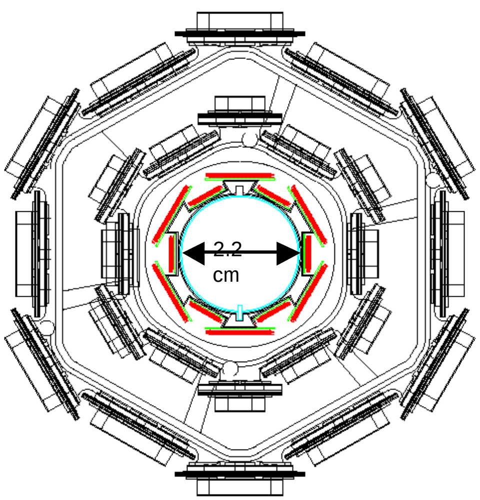
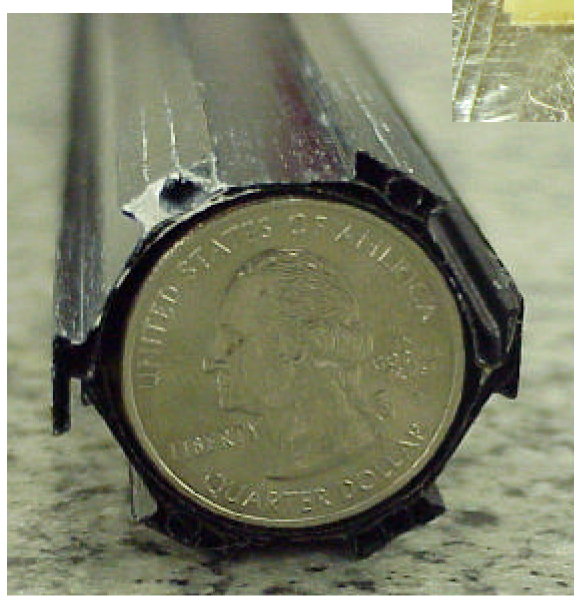
Silicon Detectors (L00)

- Completed and installed
  - ▶ Key to provide good σ_D
  - ▶ Key to x_s measurements and good tagging efficiency







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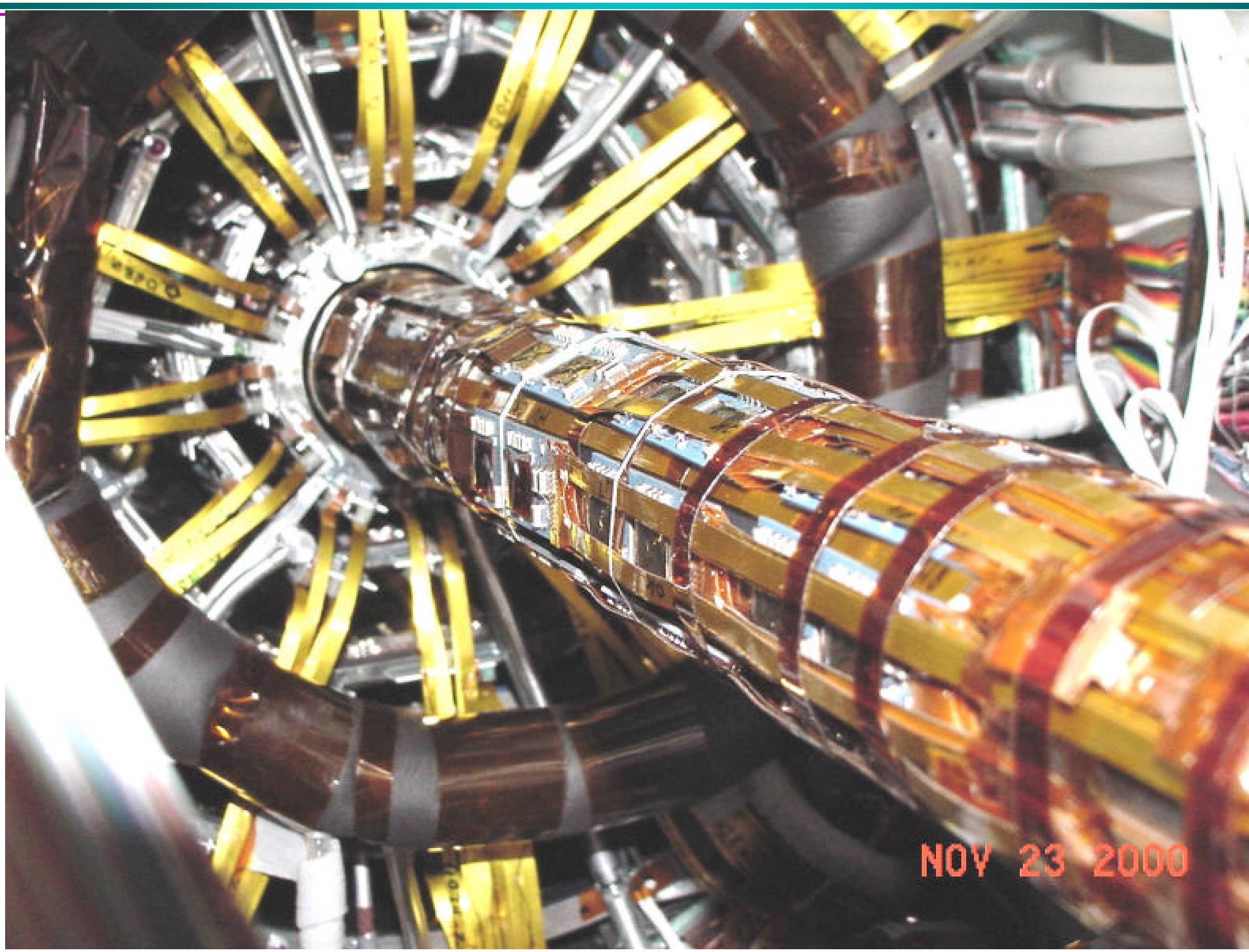
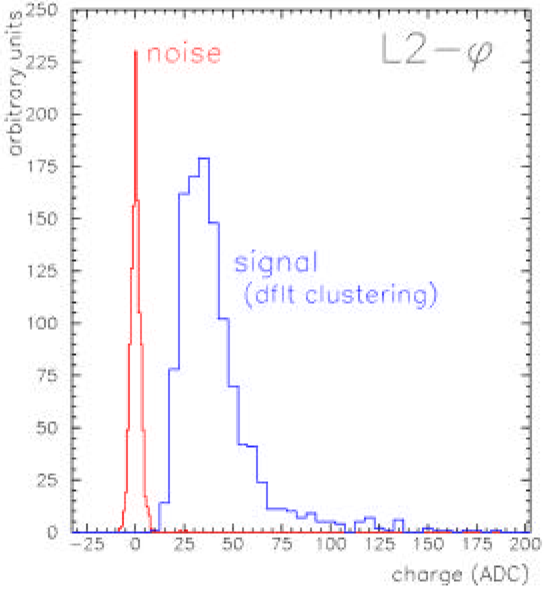
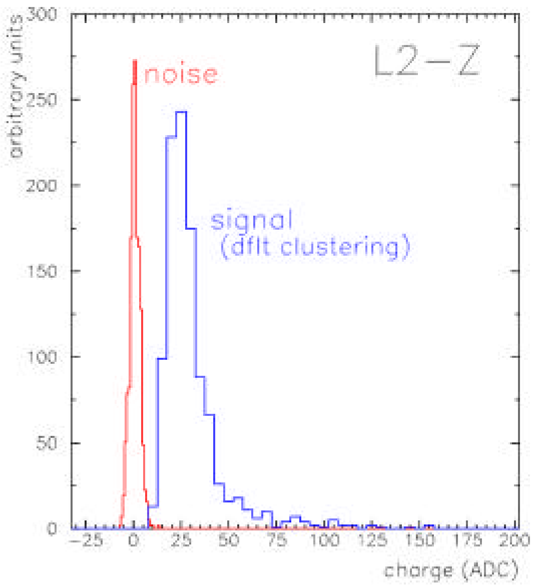
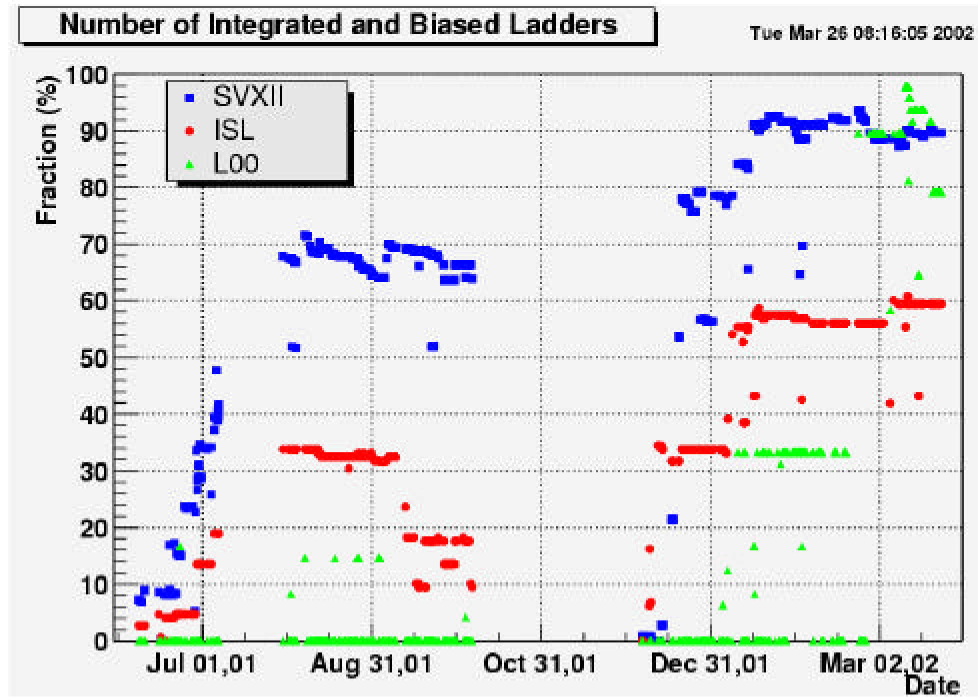
L00 insertion in SVX II



Silicon integration



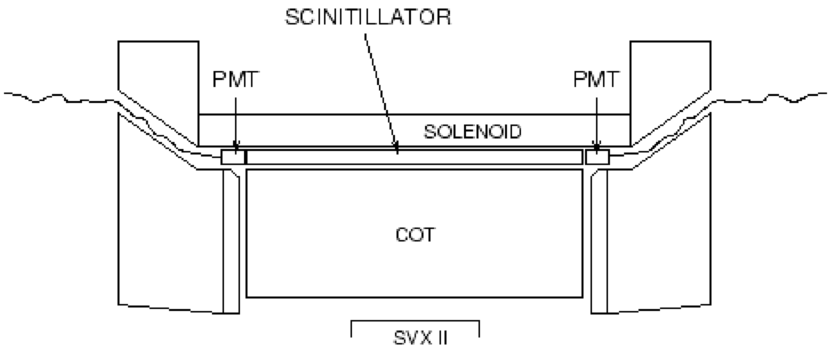


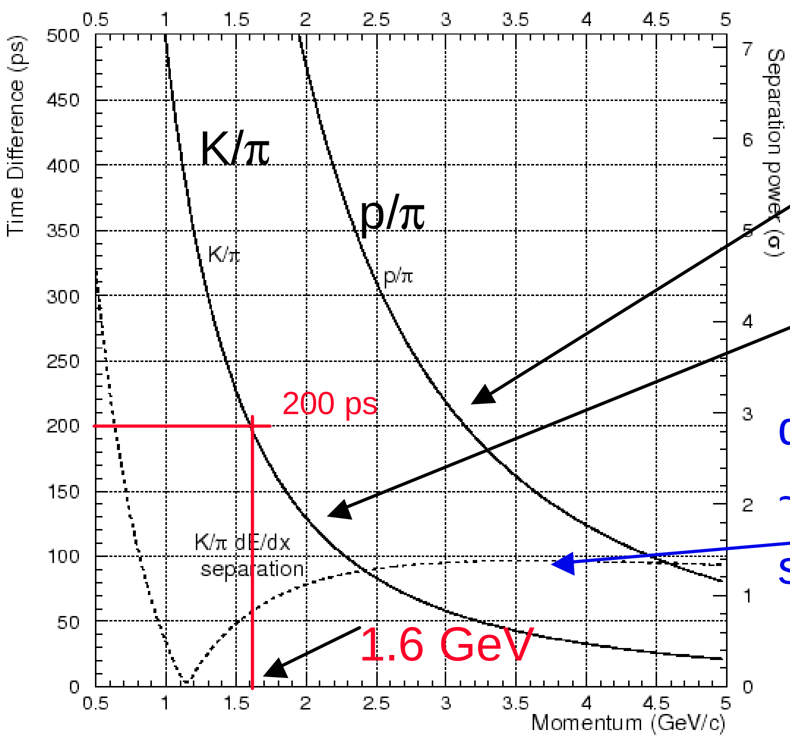


- Routinely reading out > 90% SVX/L00

ISL cooling will be fixed during the next long shutdown

Particle ID



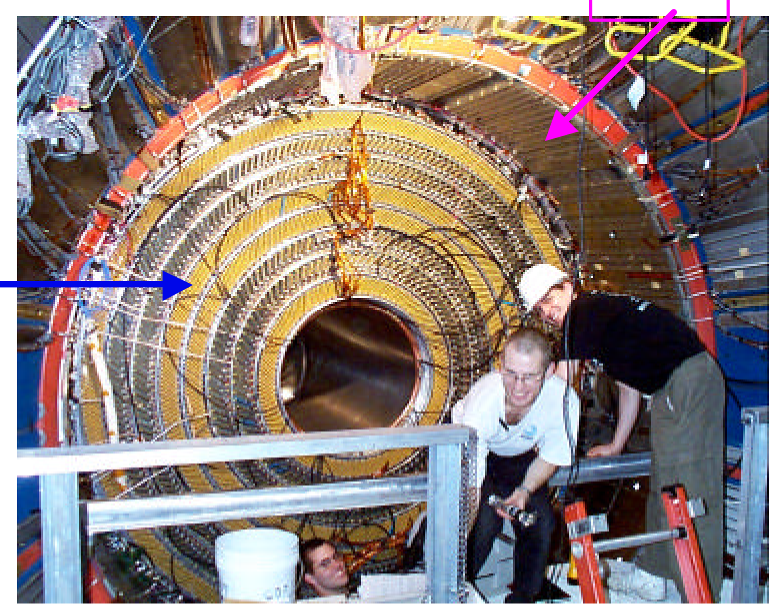


Time difference vs. p_t

dE/dx in COT ~ 1-1.5σ separation

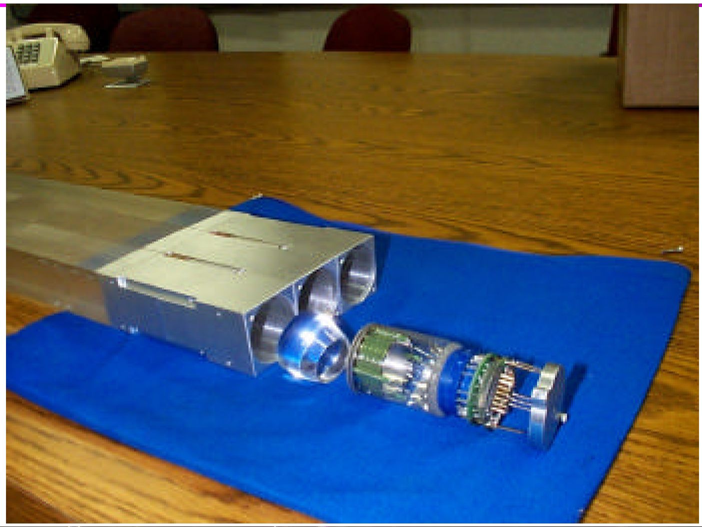
- TOF
  - 100 ps resolution
  - K/π separation >2σ up to p_t=1.6 GeV/c
- COT
  - 1-1.5 σ separation beyond p_t=2.0 GeV/c

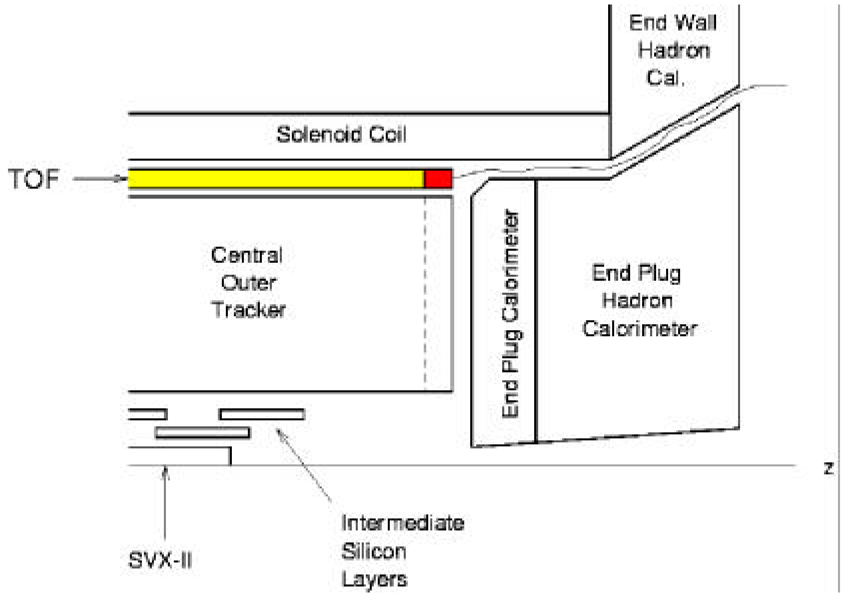
TOF

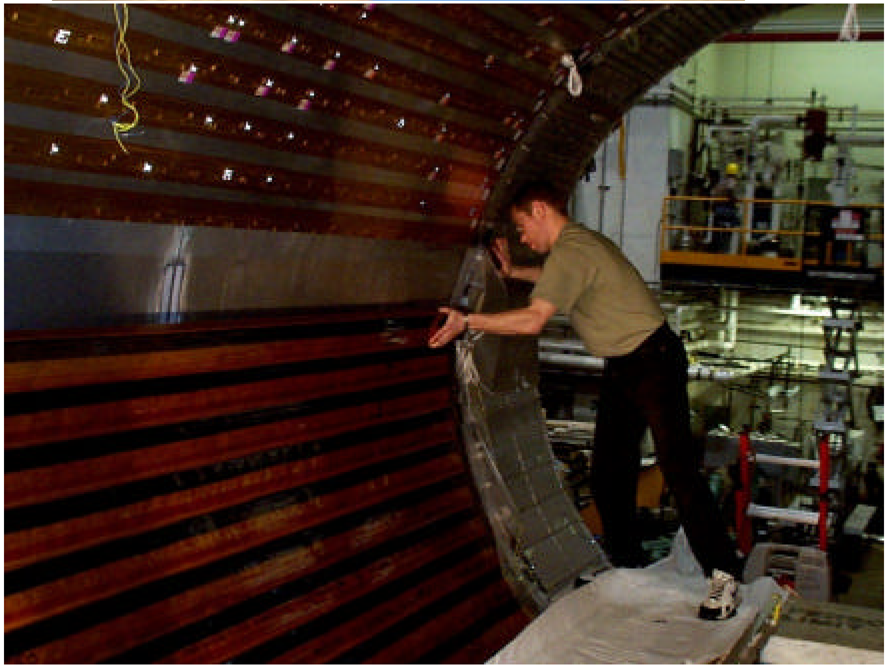


TOF

- Measure time to travel from interaction point to ~ end of tracking volume
  - 216 scintillator bars readout at **both ends** by fine mesh PMT (19 stage!)
  - Bar size: 4x4 cm^2 x 2.8 m
  - Very sophisticated electronics to achieve ~ 100 psec bar resolution

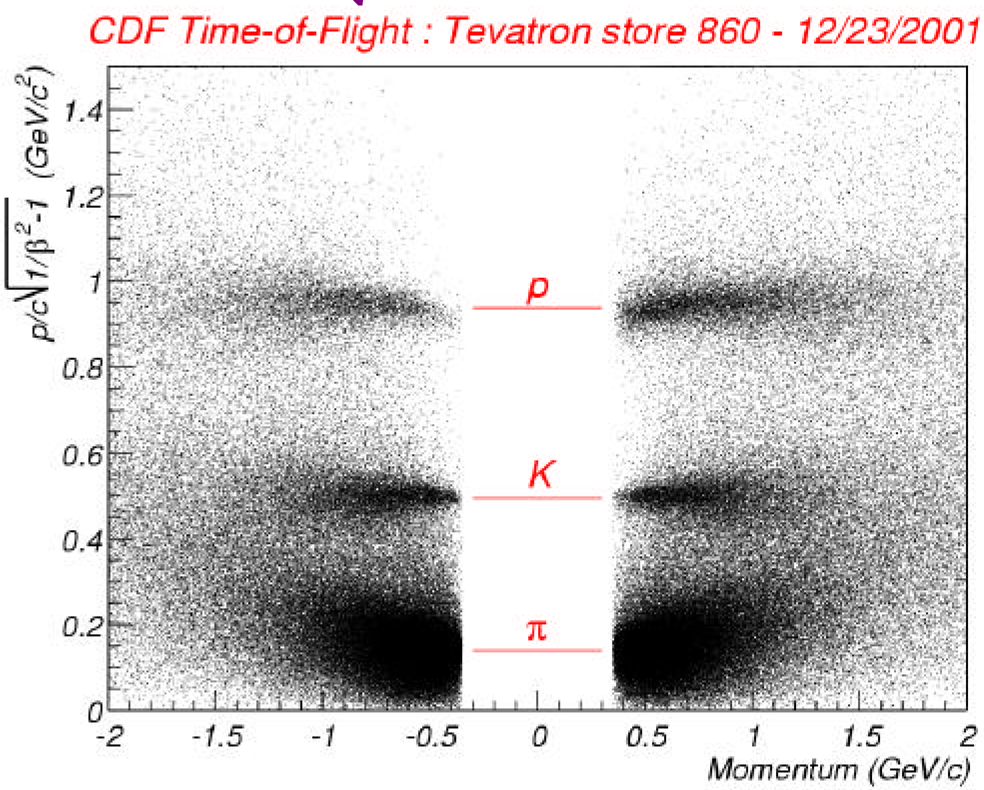


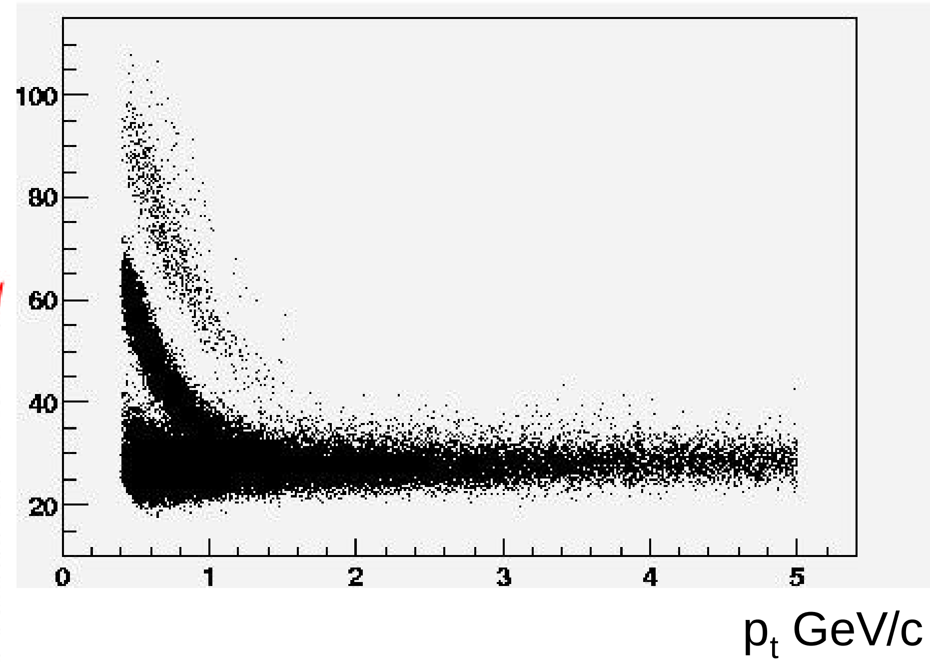




CDF: Particle ID

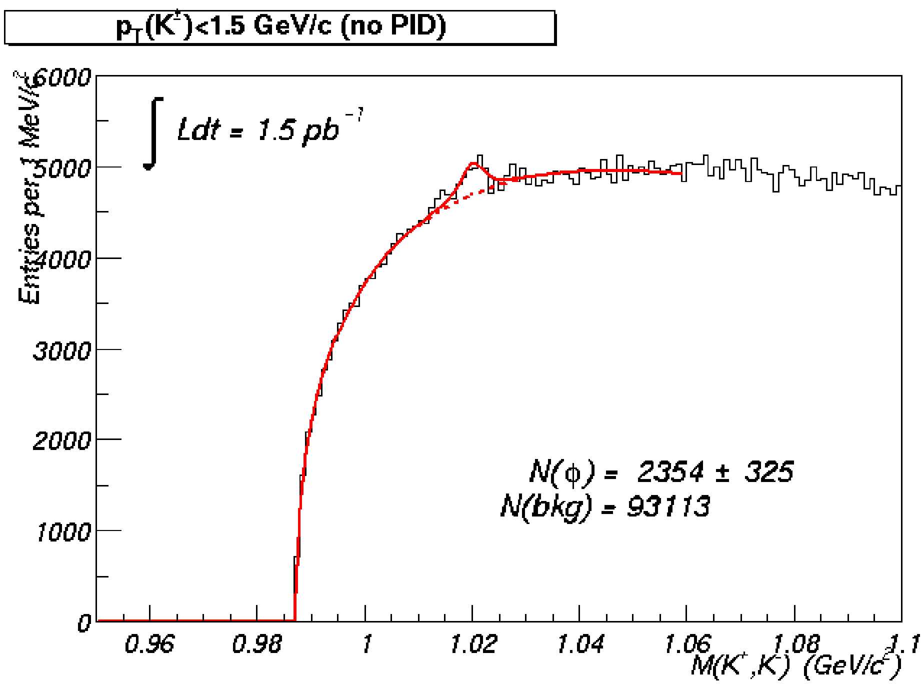
Preliminary TOF results

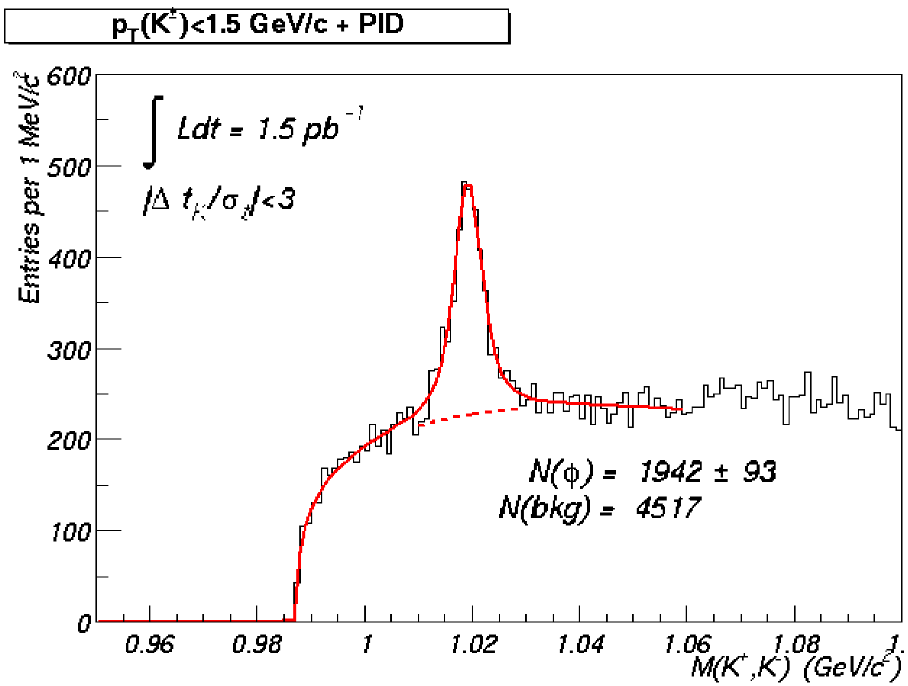




Preliminary dE/dx Measurements in COT

Time-of-Flight ID

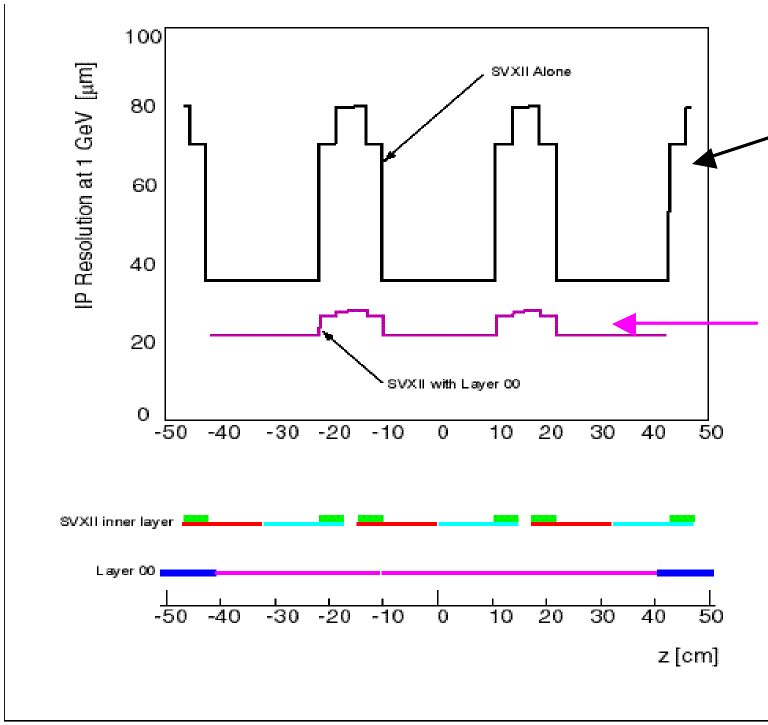




❖ Signal to noise improvement with high signal efficiency on sample of $\phi \rightarrow K^+K^-$

Layer 00

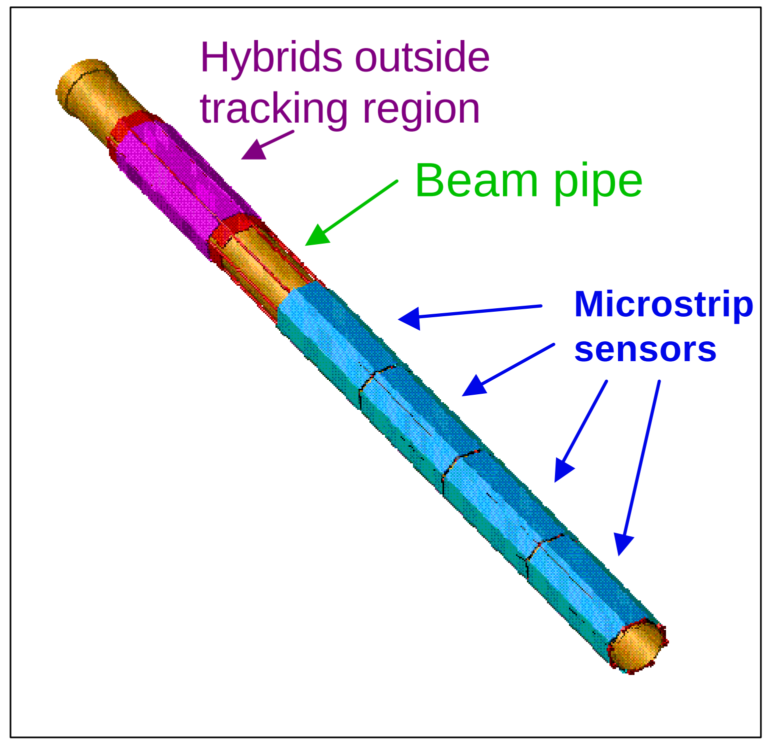
Impact parameter resolution at pt=1 GeV/c with and without L00



No L00

With L00

Goal: 45 fsec proper time resolution in B_s ® D_s p

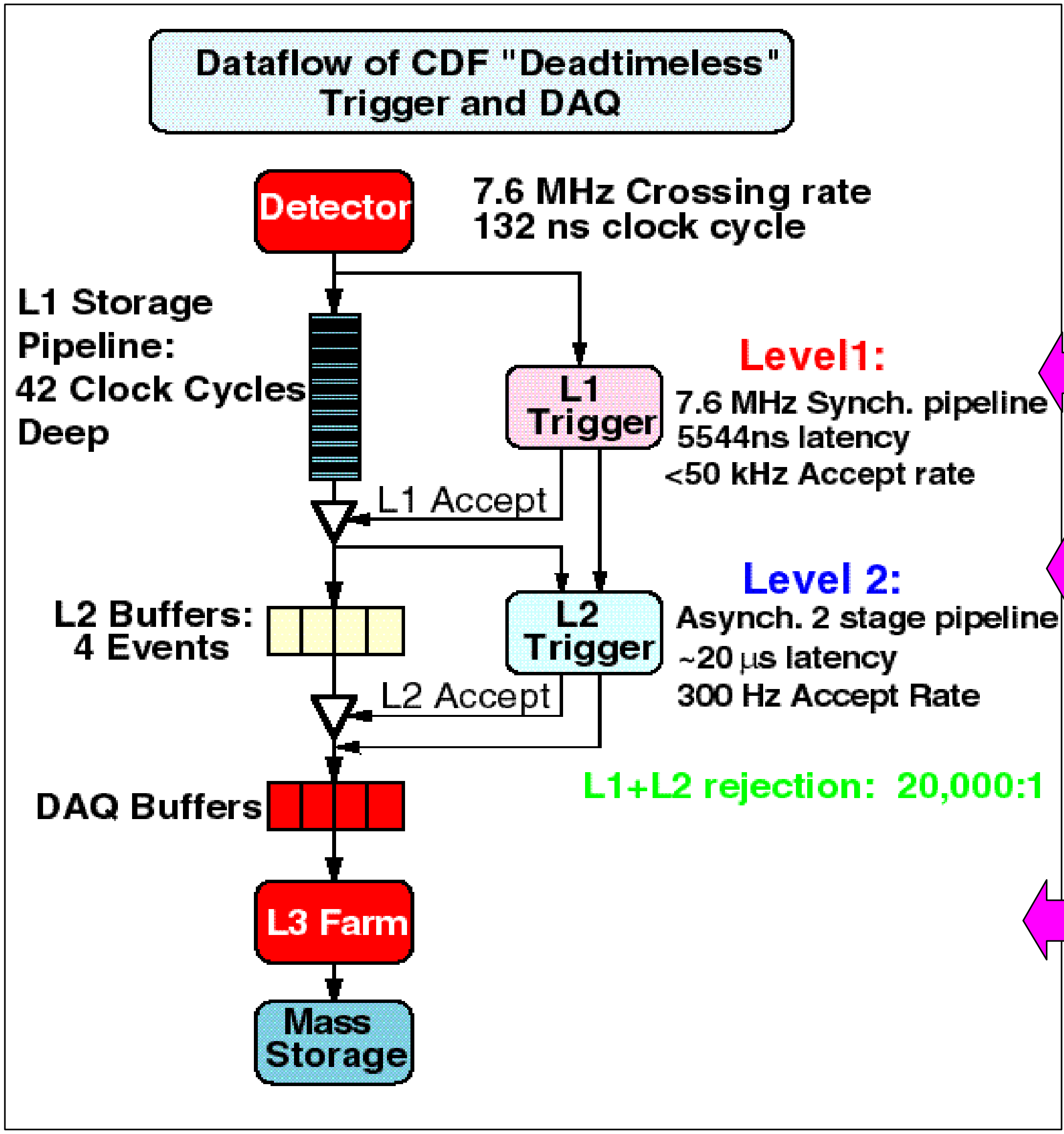


Conf.	a µm	b µm.GeV
SVXii	10	40/75
w. L00	7	22/30

$$\sigma_D = \sqrt{a^2+(b/p_t)^2}$$

Good/hybrid regions

Trigger and DAQ Upgrade



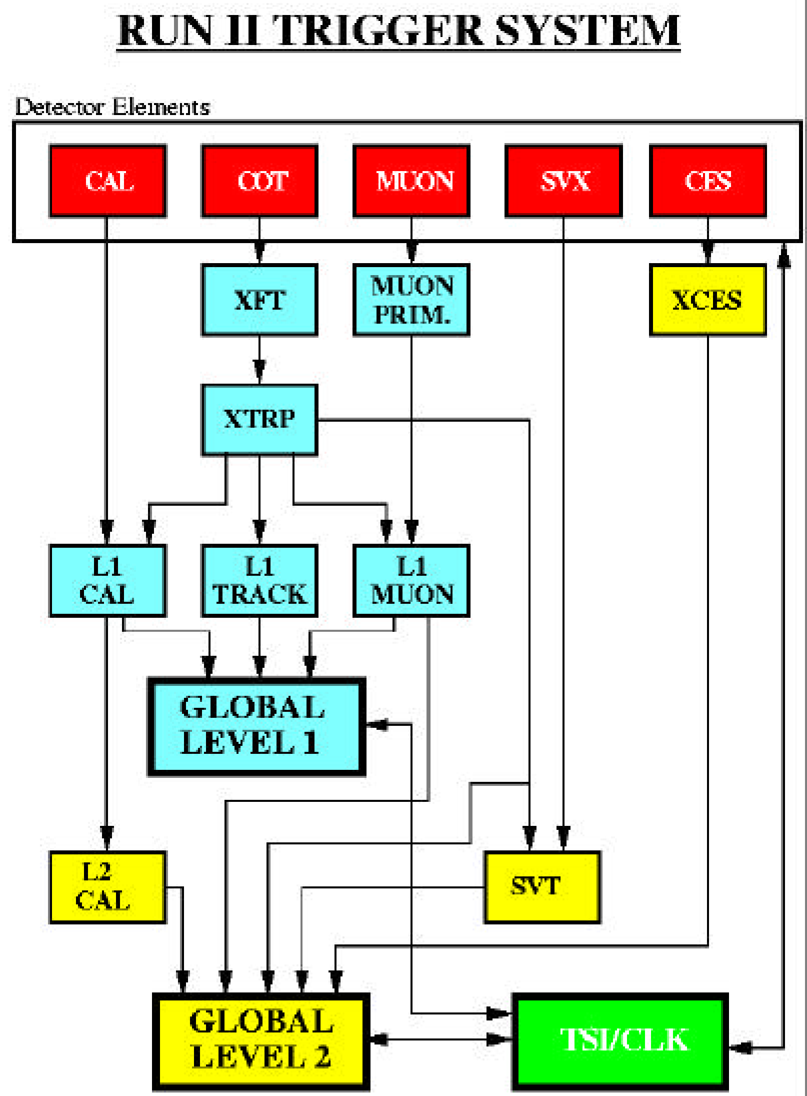
Calorimeter energy
Central Tracker (Pt, f)
Muon stubs

Cal Energy-track match
E/P, EM shower max
Silicon secondary vertex
Multi object triggers

Farm of PC's running fast versions of Offline Code → more sophisticated selections

Trigger

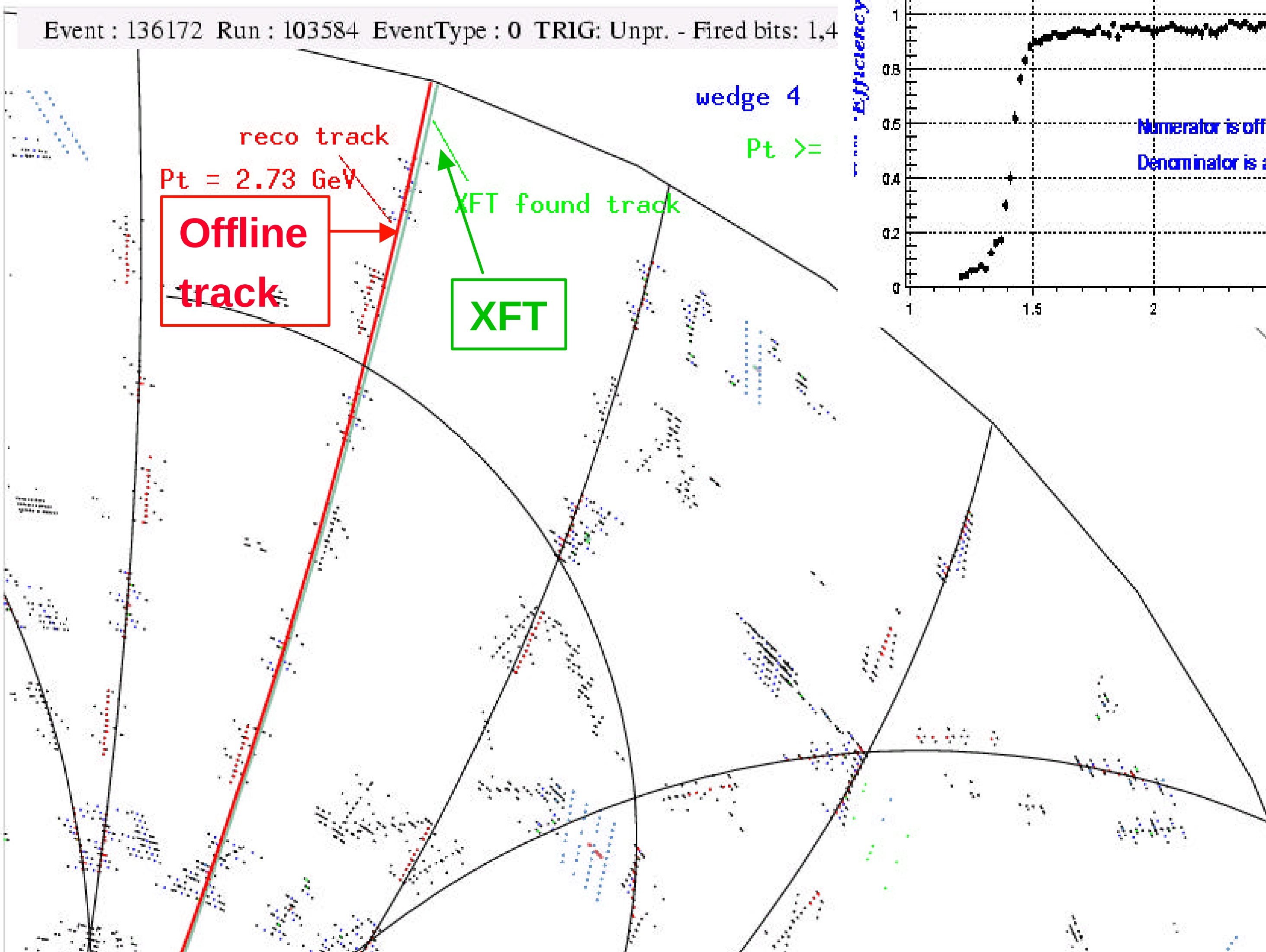
- All system except the silicon and the shower max detectors participate to the **level 1** decision
  - XFT COT tracks!
- At Level 2:
  - Sharpen jets with clustering
  - Tracks with offline D resolution with SVT
  - Electrons and photons improved with shower max and isolation information
- L1 and L2 all custom boards
- L3 has full software event reconstruction
  - ~120 dual CPU 1 GHz PC's

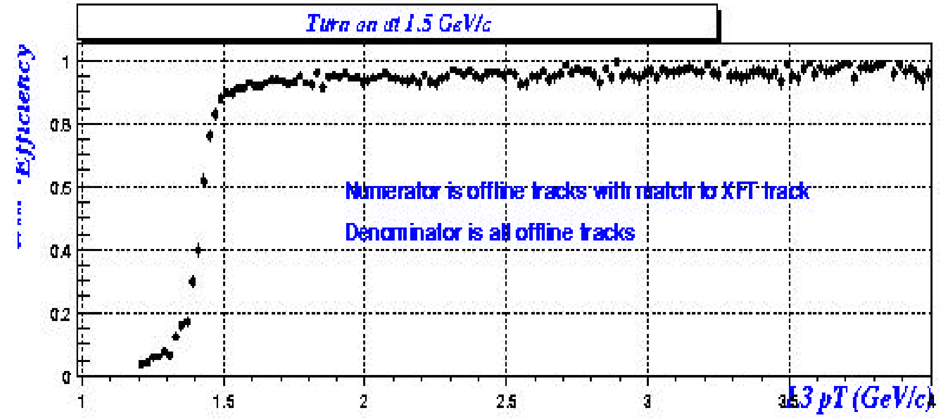


Trigger Status

- We are currently running with
  - L1A: 340 ub ⇨ 3.4 kHz @ 10^{31}
  - L2A: 22 ub ⇨ 220 Hz @ 10^{31}
  - L3A: 2.5 ub ⇨ 25 Hz @ 10^{31}
- Currently limited mainly by L2 accept rate and execution time
  - Work is in progress to understand and improve both
  - Substantial gain expected from better L2 algorithms
    - See e.g. SVT L2 triggers

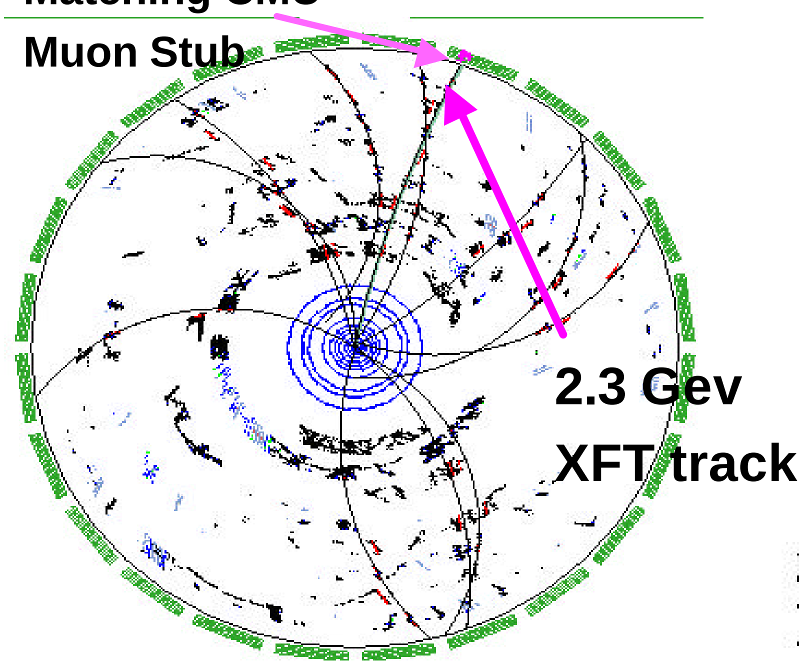
COT / XFT reconstruction



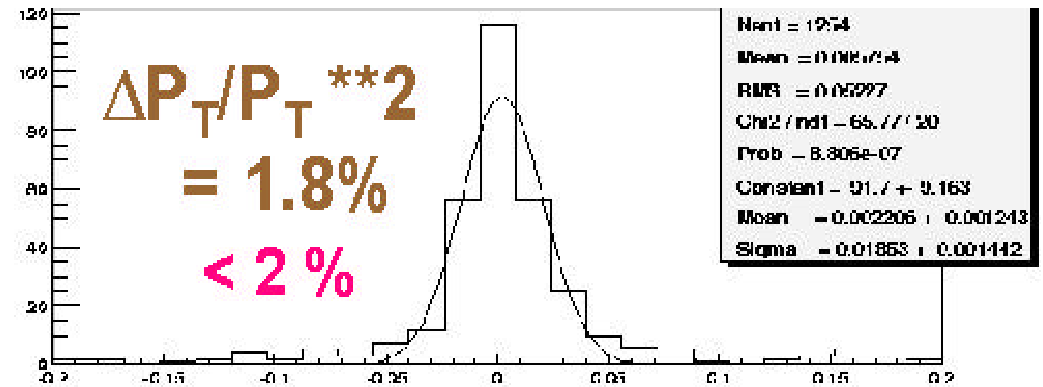


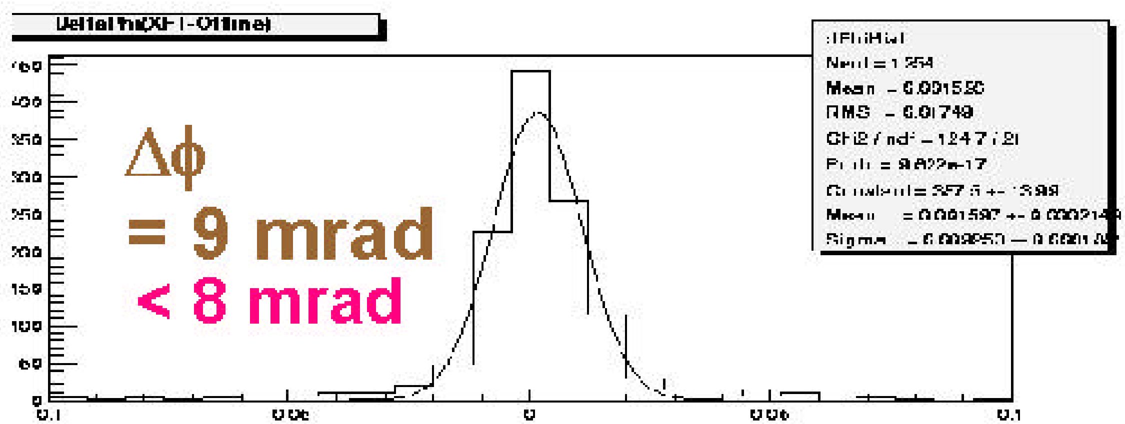
Efficiency curve:
XFT cut at
P_T = 1.5 GeV/c

L1 COT / XFT tracking



Event triggered on XFT- muon match





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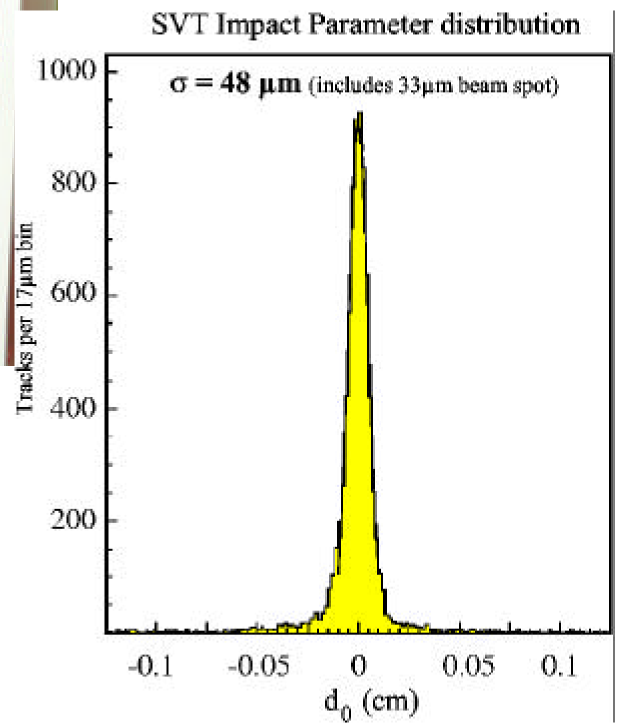
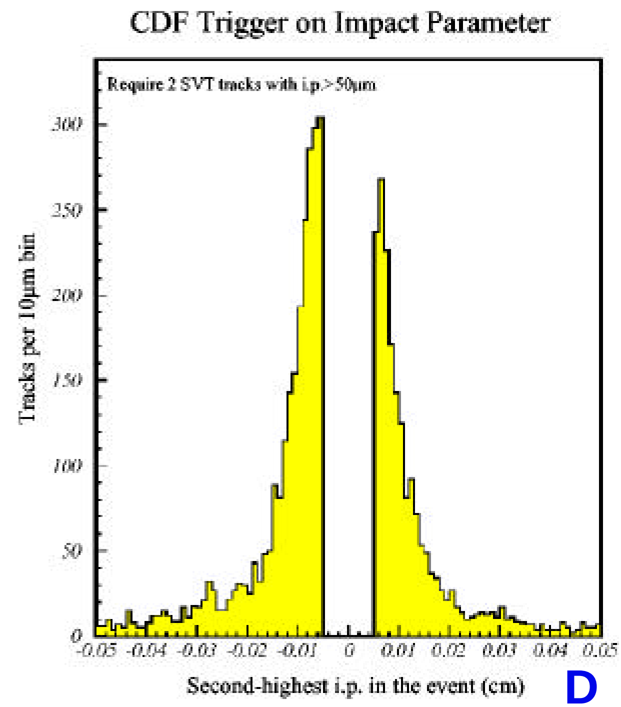
CDF: SVT

- SVT trigger performance
  - Online fit of primary Vtx
  - Beam tilt aligned
  - D resolution as planned
    - 48 μm (33 μm beam spot transverse size)

Online D resolution



L2 cut on SVT



D

Offline tracks after 50 mm SVT cut at L2

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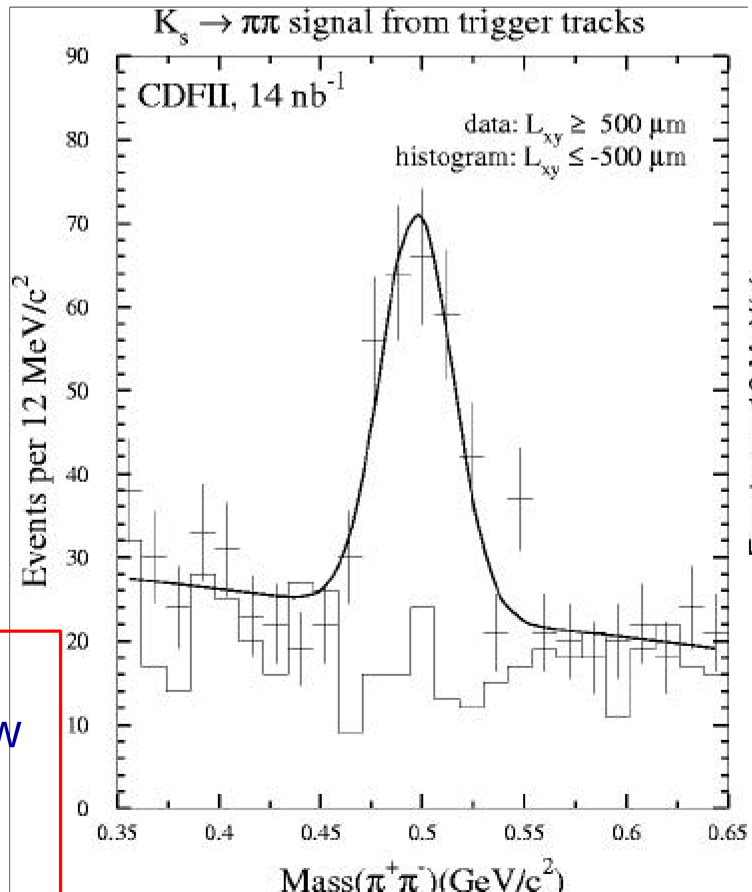
SVT Trigger Rates

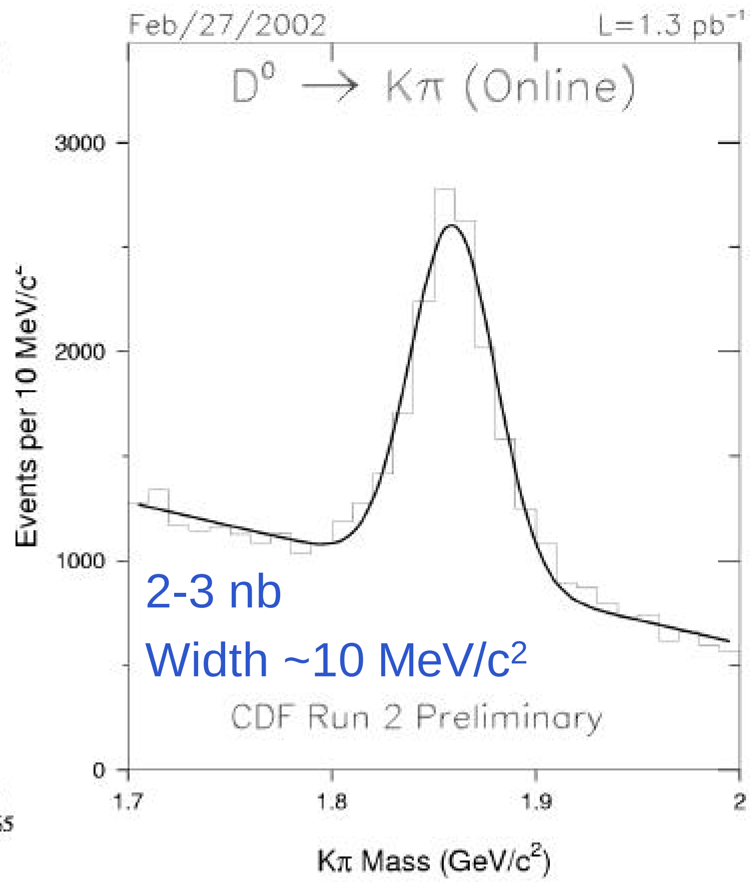
- Two SVT L2 triggers are defined in internal trigger guide
  - B_pipi: 360 nb
    - 2x (d > 100 um), Delta-phi > 20^0, Lxy > 0, d_B < 140 um
  - B_charm: 394 nb (200 nb overlap)
    - 2x (d > 120 um), 2^0 < Delta-phi < 90^0, Lxy > 0
- Simple requirement of two tracks with d > 100 um is currently used at L2
  - L2_TWO_TRK2_D100: 3200 nb
- L2 cuts are simulated offline on data from a L3 auto-accept prescaled path

	All	simulate	x $(72/56)^2$	Expected
B_pipi	3200 nb	287 nb	474 nb	360 nb
B_charm	3200 nb	391 nb	646 nb	394 nb

CDF: SVT

These plots available at L3





2-3 nb

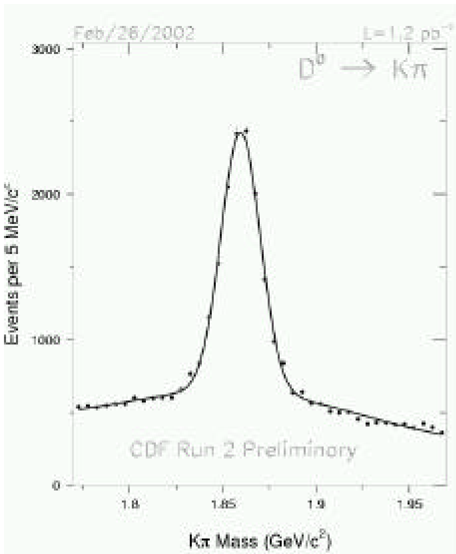
Width ~10 MeV/c^2

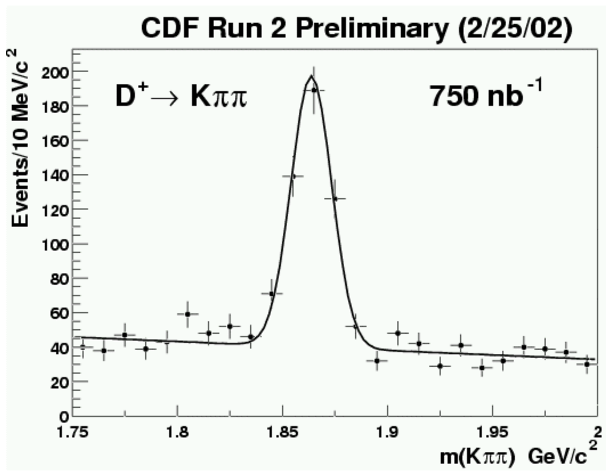
SVT track pair invariant mass show clear evidence of strange and charm after decay length cut

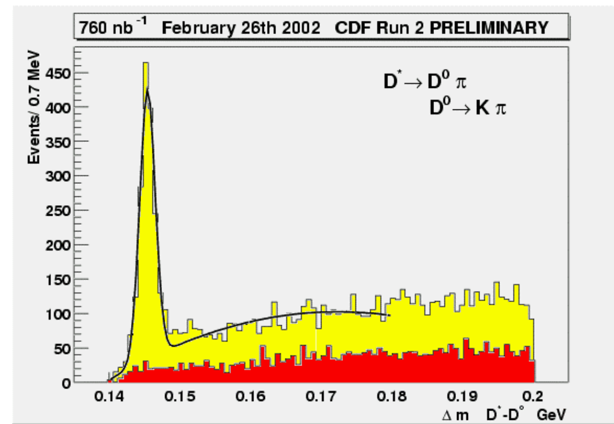
Peaks can be used to monitor SVT

So much Charm!!!

- Getting much more charm than expected with SVT!!!





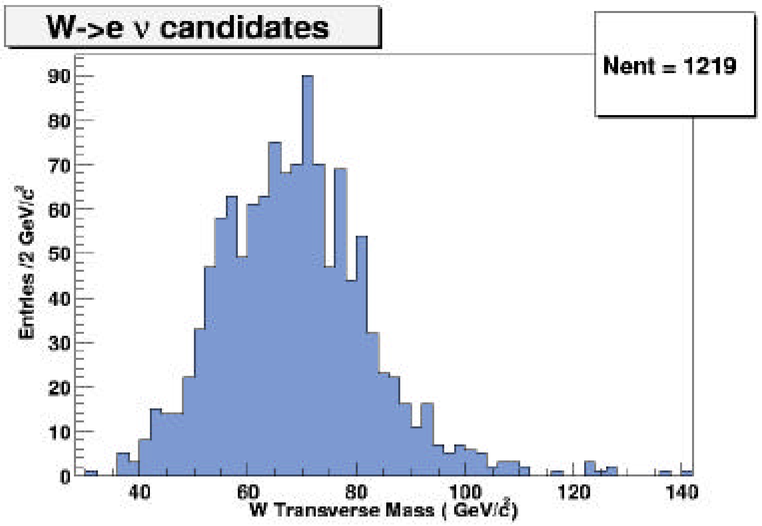


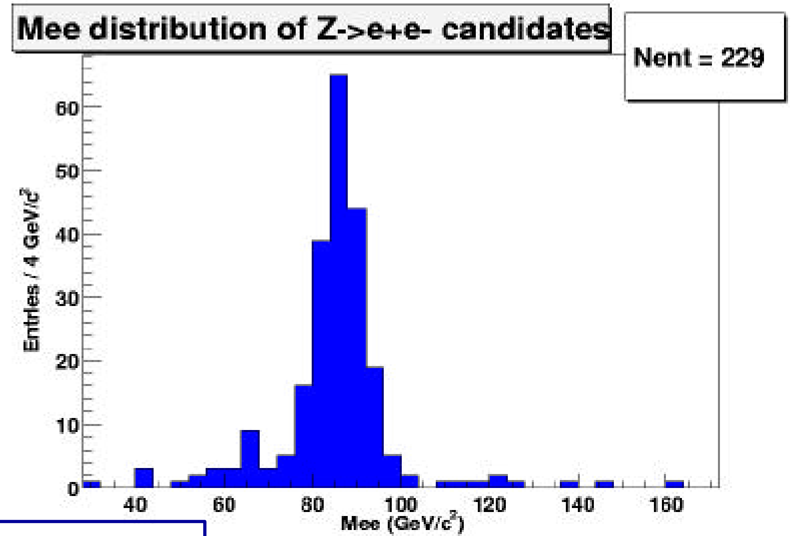
$D^0 \rightarrow K^- p^+$ yields:

50 pb^{-1}	2 fb^{-1}	E791	FOCUS	Y(4S)/100 fb^{-1}
500K	20M	40K	120K	1M

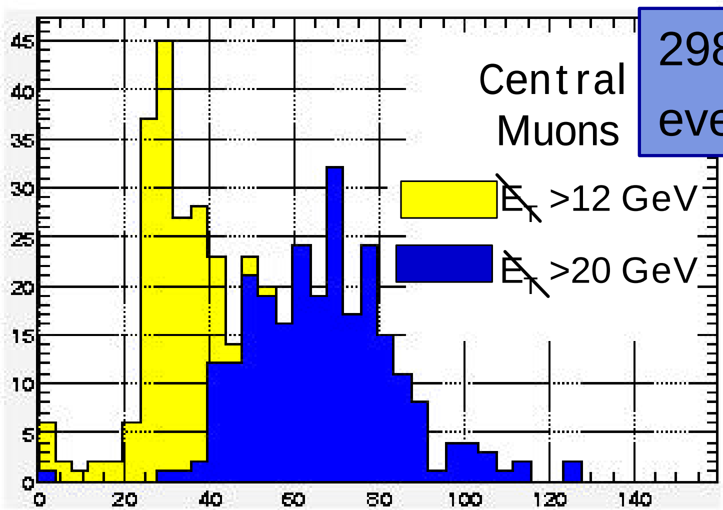
Large yield, but poor PID, biased trigger, prompt & secondary charm……….
Need to understand how to make best use of it

W and Z's

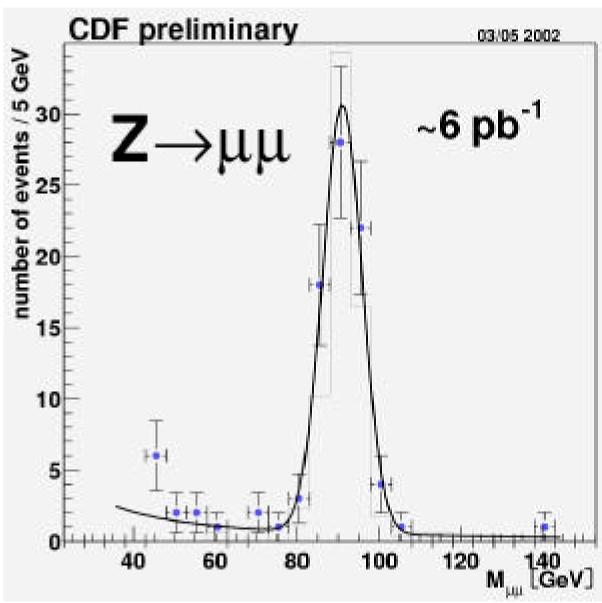




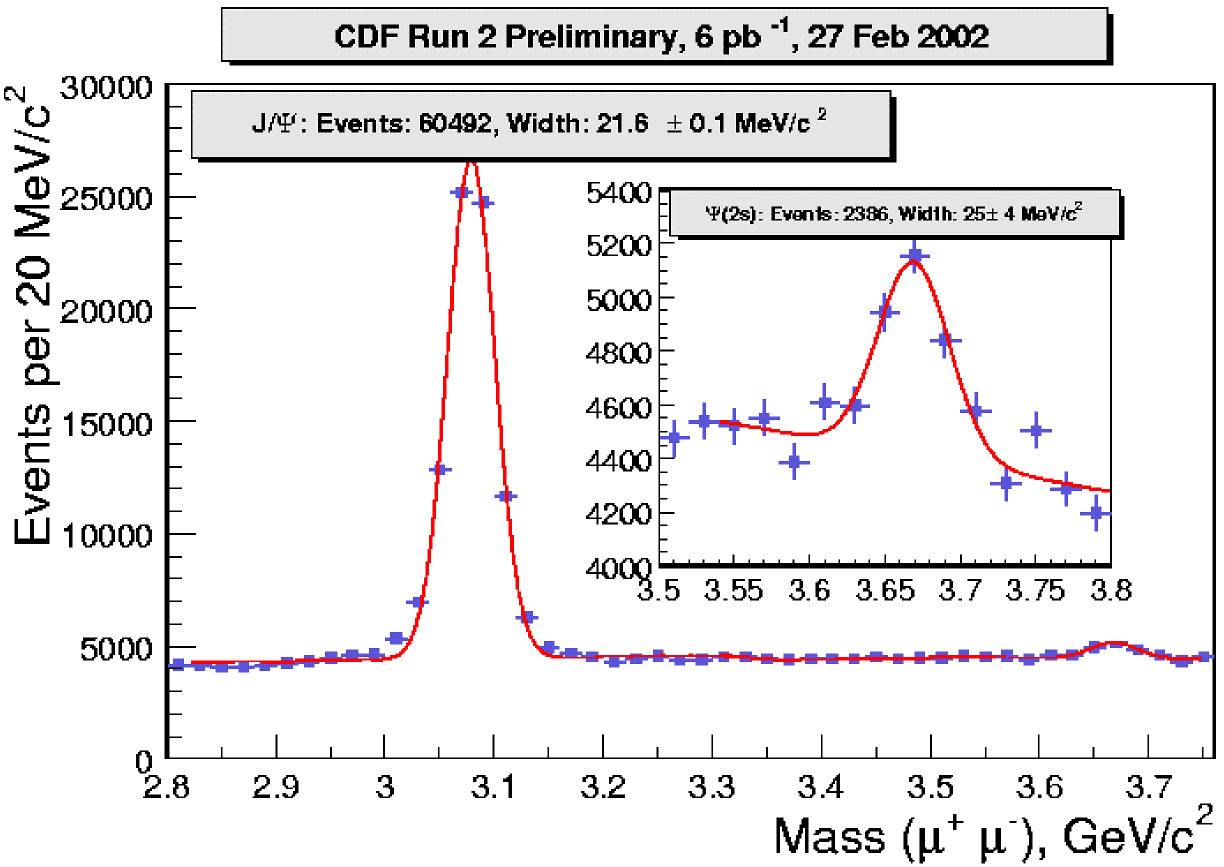
From 3.65 pb-1



298 W events

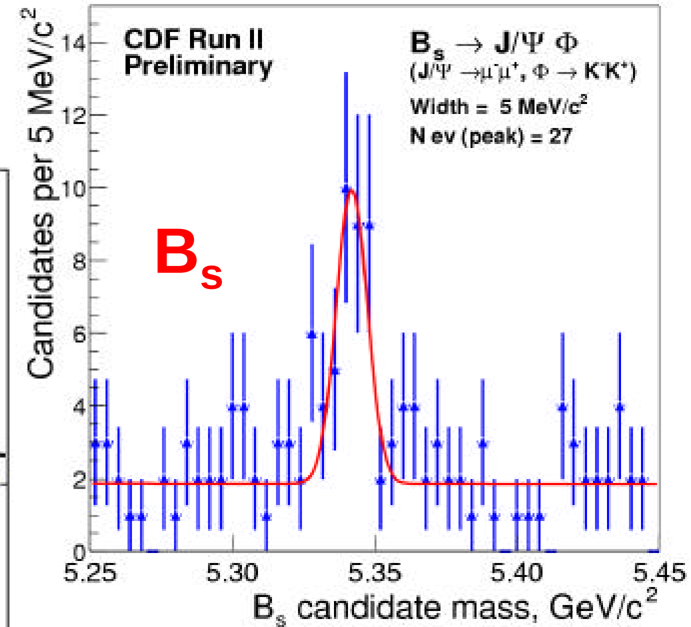


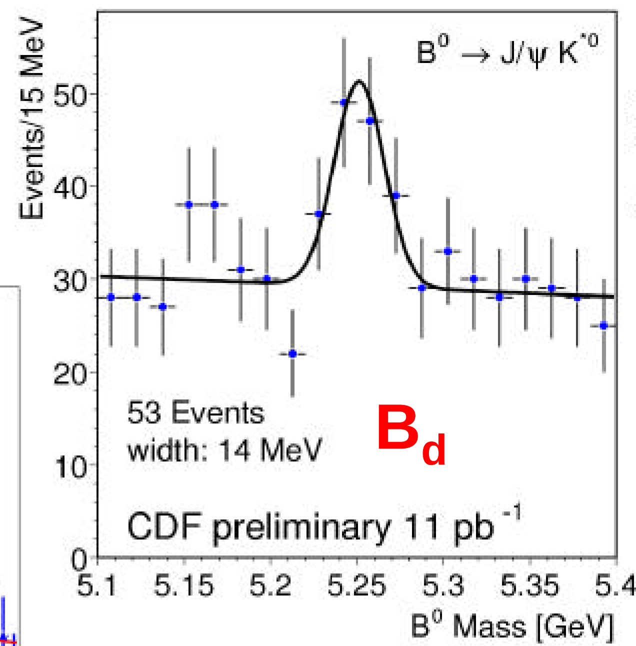
CDF: $J/\psi \rightarrow \mu^+\mu^-$

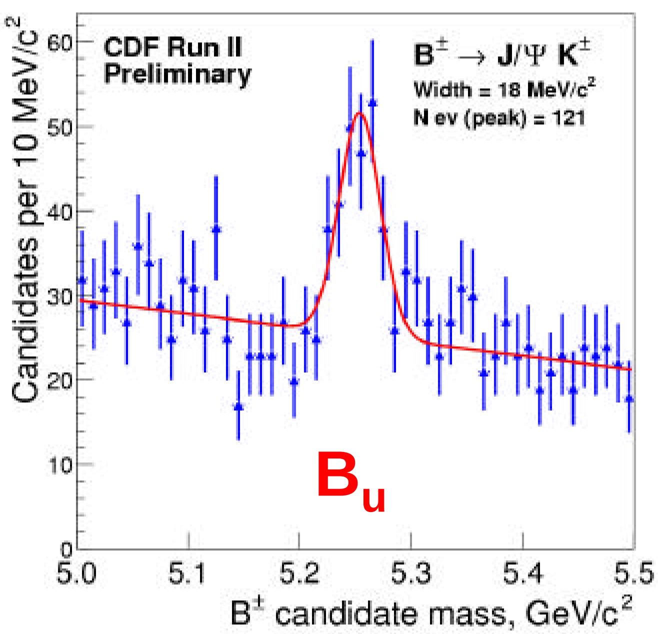


- Clear J/ψ signal
  - CMU or CMX
    - ~ 60,000 ψ's
    - σ = 21 MeV/c^2 (16 with SVX II)
    - J/ψ x-section ~9nb as expected

First B signals





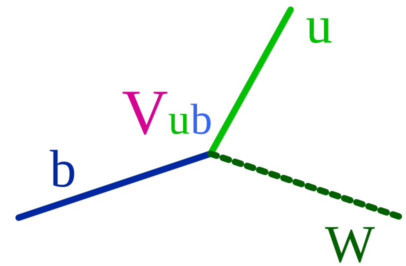


What physics with b's?

- QCD:
  - Calculations of production cross sections and correlations screened by rather large b-quark mass
- Precision measurement of CKM matrix elements
  - Deviations from unitarity are indication for new physics
    - $B_0 – B_0$ Mixing
    - CP violation
- Processes that occur at higher orders
  - Sensitive to additional loops involving non-SM particles
    - $B_0 – B_0$ Mixing
    - Rare decays

CKM matrix elements

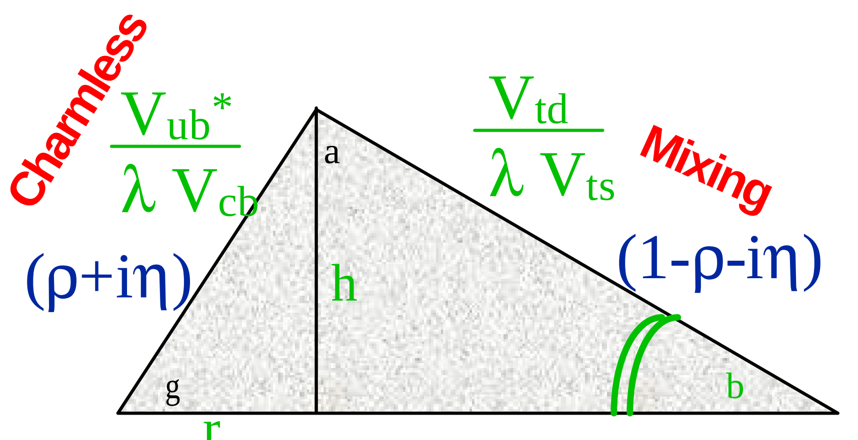
- CKM matrix describes flavor mixing in charged weak currents
- Wolfenstein Representation $O(\lambda^3)$
  (4 par: λ, A, ρ, η)



$$\begin{pmatrix} V_{ud} & V_{us} & V_{ub} \\ V_{cd} & V_{cs} & V_{cb} \\ V_{td} & V_{ts} & V_{tb} \end{pmatrix} \approx \begin{pmatrix} 1-\frac{\lambda^2}{2} & \lambda & A\lambda^3(\rho-i\eta) \\ -\lambda & 1-\frac{\lambda^2}{2} & A\lambda^2 \\ A\lambda^3(1-\rho-i\eta) & -A\lambda^2 & 1 \end{pmatrix}$$

$V_{ub} = |V_{ub}|e^{-i\gamma}$

$V_{td} = |V_{td}|e^{-i\beta}$



Angles: CP violation

Measurement of CKM elements allows test of unitarity

1st, 3rd col.: $V_{ud}V_{ub}^*+V_{cd}V_{cb}^*+V_{td}V_{tb}^*=0$

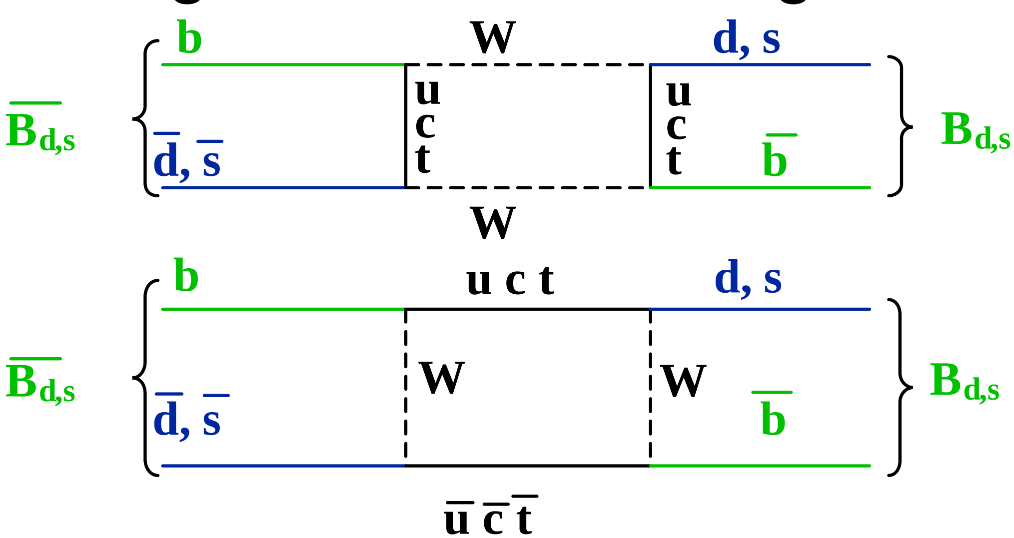
Let: $V_{ud} = 1$, $V_{cd} = -\lambda$, $V_{tb} = 1$

$V_{ub}^* + V_{td} = \lambda V_{cb}^*$ $\qquad O$ (3%)

Divide by $A\lambda^3 = \lambda V_{cb}^* = -\lambda V_{ts}$

Basic mixing theory

- Some probability that a B_0 turns into a $\overline{B}_0$ due to higher order box diagrams

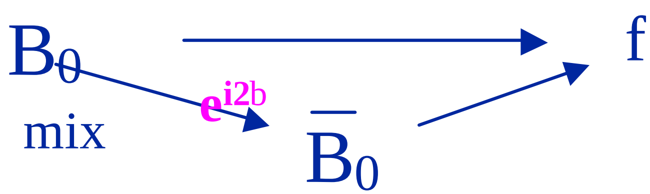


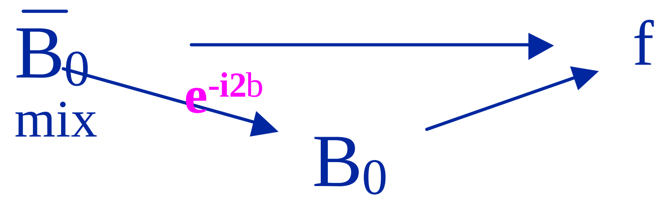
- ❖ $Dm\ \mu\ m_t^2\ |V_{td,s}|^2$
- ❖ $x = t\ Dm$

$$P(B_0 \rightarrow \overline{B_0}) = |\langle \overline{B_0} | B_0(t) \rangle|^2 = \frac{e^{-t/t}}{2t}[1-\cos(\Delta m t)] = \frac{e^{-t/t}}{2t}\left[1-\cos\left(x\frac{t}{t}\right)\right]$$

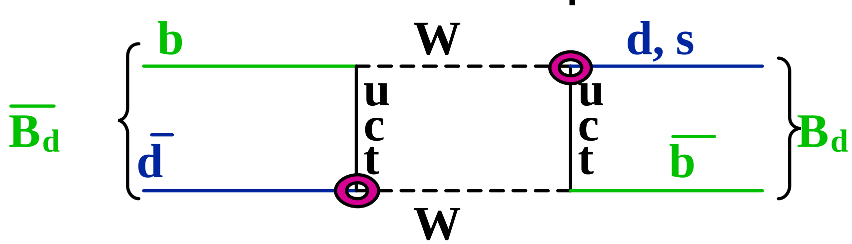
CP violation

- CP violation: $\Gamma(B \rightarrow f) \neq \Gamma(\overline{B} \rightarrow \overline{f})$
- Special simplest case f is CP eigenstate
  - e.g. f = $J/\psi\ K^0_S$





- Direct and mixed path interfere



$A(B_d \rightarrow \overline{B}_d) \propto m_t^2\ V_{td}^2 \sim |A|e^{i2\beta}$

$A(\overline{B}_d \rightarrow B_d) \propto m_t^2\ V^*_{td}{}^2 \sim |A|e^{-i2\beta}$

- Asymmetry measures $\sin(2\beta)$

- $A_{CP} = \dfrac{\Gamma(\overline{B}_0 \rightarrow f) - \Gamma(B_0 \rightarrow f)}{\Gamma(\overline{B}_0 \rightarrow f) + \Gamma(B_0 \rightarrow f)} = \sin(2\beta)\sin(\Delta m_d t)$

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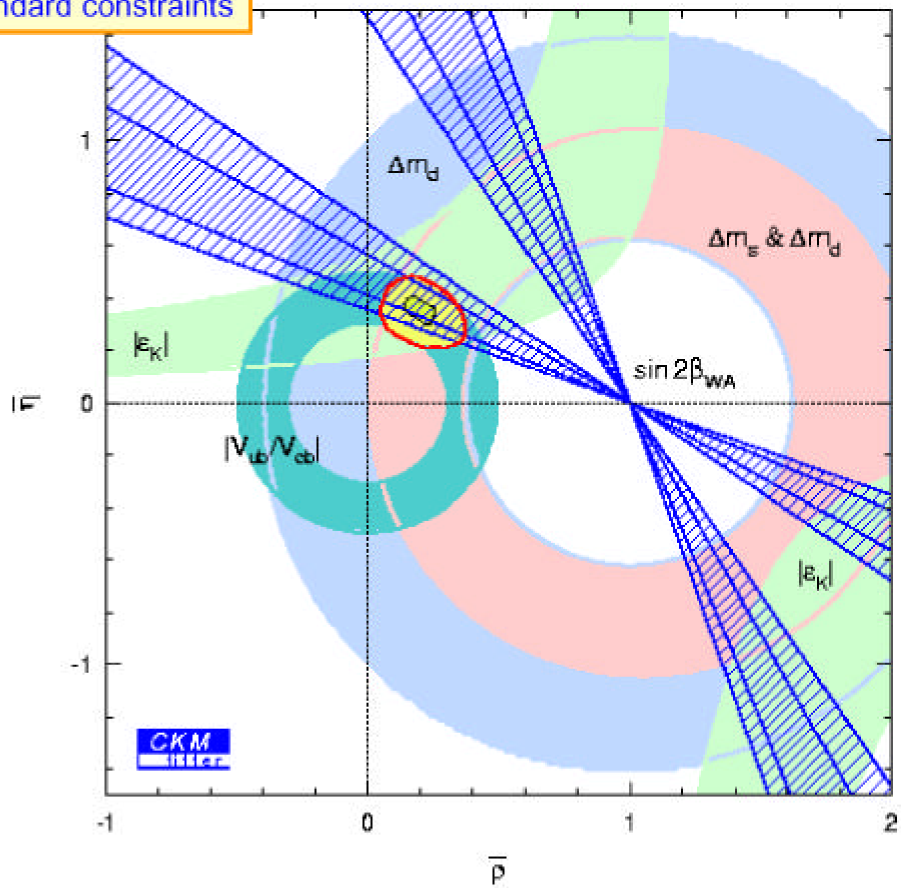
CKM matrix bounds

The standard constraints



Does not include sin2β

Current level of understanding of CKM parameters (S. Laplace, Moriond EWK, March 2002)

Compatibility between various measurements indicates consistency with SM predictions

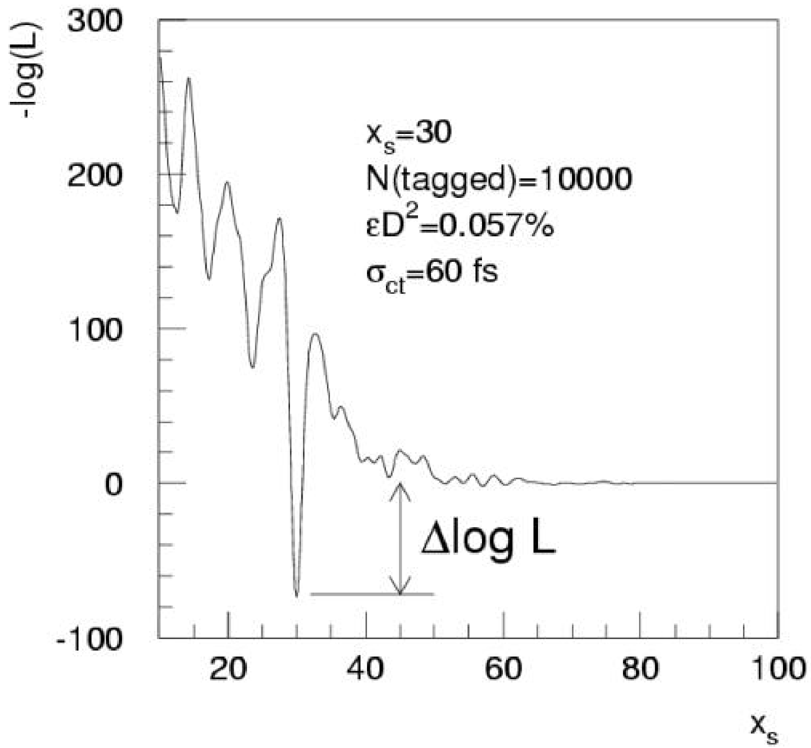
CDF

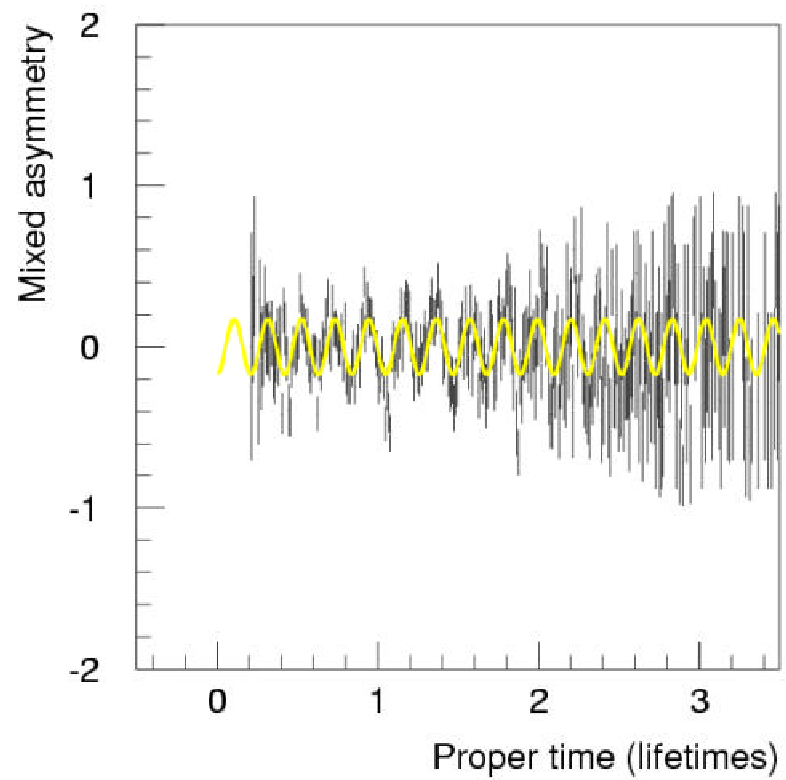
Some key measurements

- Discuss in detail 3 key measurements:
  - B_s mixing: **x_s**
  - CP violation with $B_d \rightarrow J/\psi\ K^0_S$: **sin(2**b**)**
  - CP violation with $B^0 \rightarrow h^+h^-$: g

Bs mixing

- Measure mixing asymmetry
  - $A_{mix}(t) = \dfrac{N_{nomix}(t) - N_{mix}(t)}{N_{nomix}(t) + N_{mix}(t)}$
- Fit to $a(t) = D \cos(x_s\, t/\tau)$



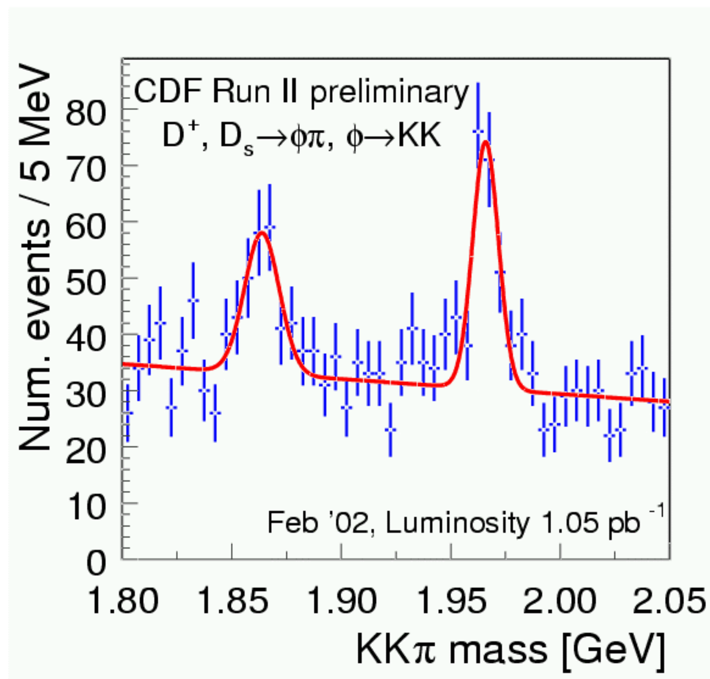


Significance of measurement related to depth of likelihood minimum relative to $x = \infty$

Bs mixing

$$Signif(x_s) = \sqrt{2\Delta \ln(L)} = \sqrt{\frac{NeD^2}{2}} e^{-\frac{(x_s s_t/t)^2}{2}} \sqrt{\frac{N}{N+B}}$$

- Signal (N):
  - Need all charged hadronic mode for resolution and statistics → secondary vertex trigger is essential
    - $B_s \rightarrow D_s\, \pi^{\pm}$, $D_s\, 3\pi^{\pm}$
    - $D^+_s \rightarrow \phi\, \pi^+$, $K_0^*\, K^+$, $K^0_S\, K^+$
  - Expectations in 2 fb^{-1}:
    - 20,000 events (P-909)
    - 75,000 Yellow Book
- S/B:
  - ~ 1:1 from Run I extrapolations
    - Assume 1:2 – 2:1 range
    - Small effect on significance

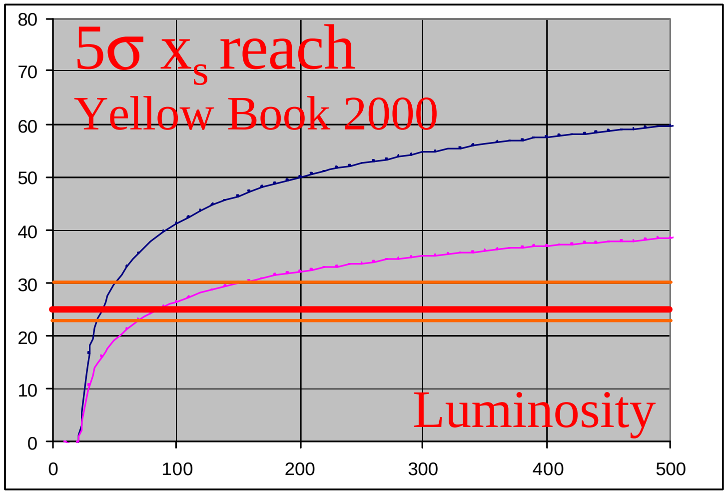


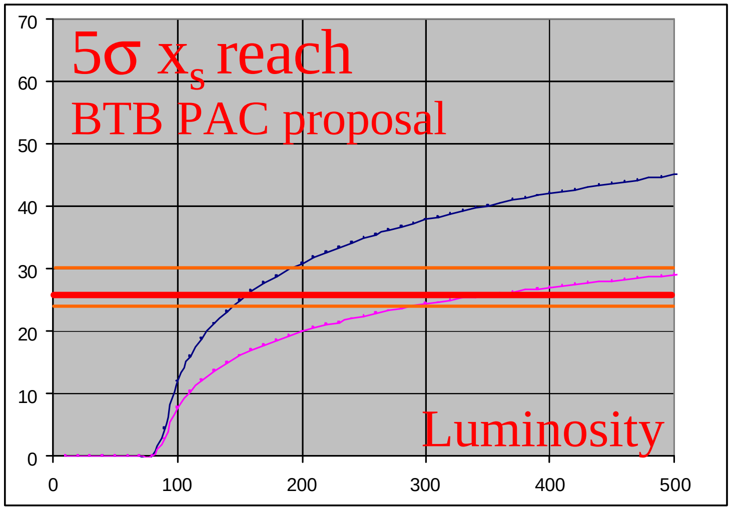
Bs mixing

- Flavor tagging εD^2:
  - Expect 5.7 % from Run I (6.3% measured in sin(2β) analysis)
  - +3.2% (SS Kaon) + 2.4% (OS Kaon) = 11.3% total
- Time Resolution:
  - Assume 45 fsec (perfect L00) to 70 fsec (L00 doesn't work)

CDF x_s expectations

- 5s x_s significance as a function of the available luminosity
  - Xs mixing parameter should be within reach rather soon
    - The two curves refer to two extreme values of the cτ resolution:
      - ➔ **L00 proposal**
      - ➔ **L00 not usable**
  - Red line is the SM central value
  - Orange line are current 95% CL limits from combined analyses (hep-ph/0112133)
- With 2 fb-1 expect reach ~ 60 with conservative assumptions





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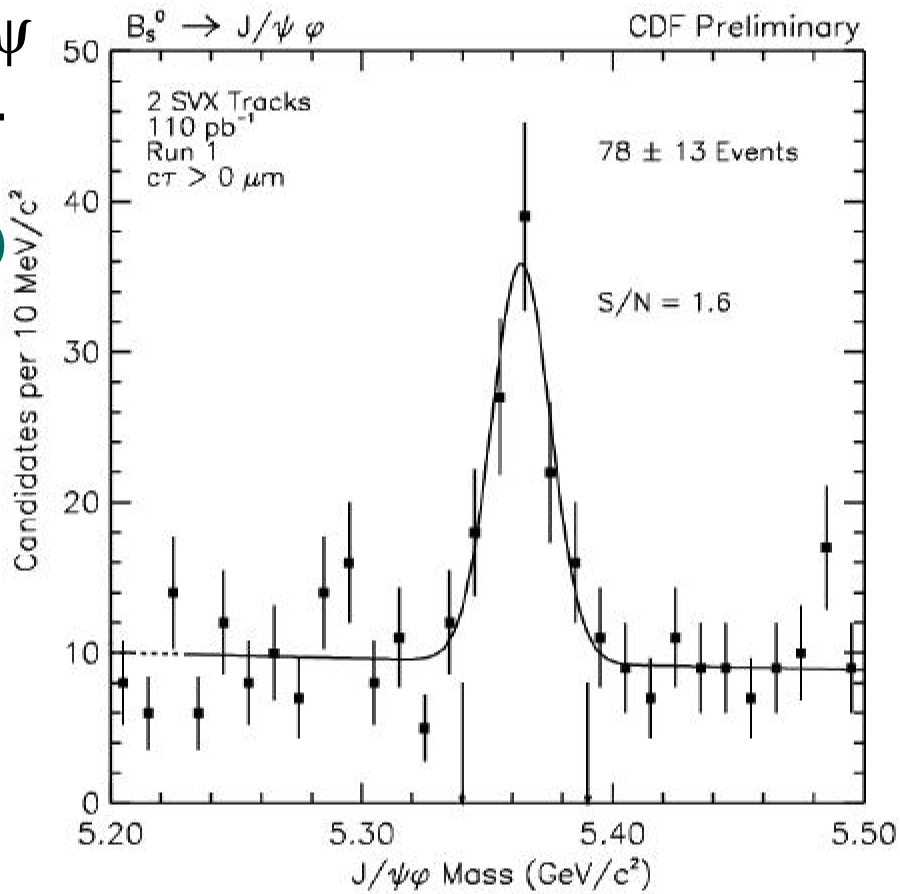
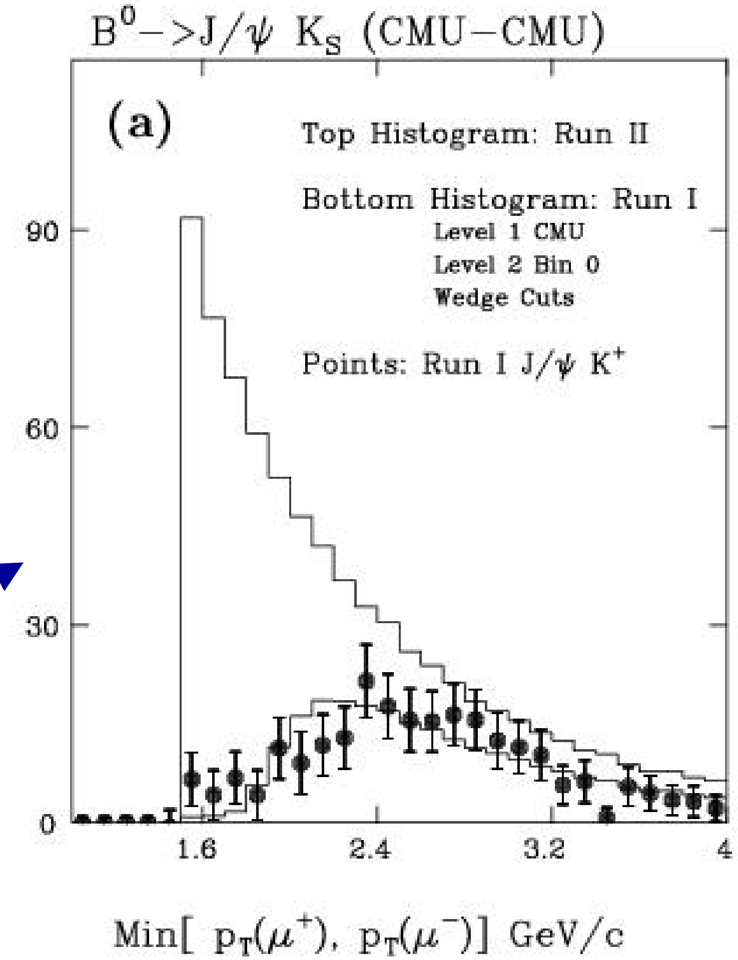
CP in Bs → J/ψ φ

- Large CP asymmetry in Bs → J/ψ φ is an indication of new physics.
  - Assume:
    - N(Bs → J/ψ φ) = 40% N(Bd → ψK^0_S) = 8,000 in 2 fb^{-1} (scale Run I)
    - Xs = 25 (currently preferred value)
    - S/N = 1.6 (Scale Run I)
  - Expect error ~ 0.15 on true CP asymmetry → 0.06 with 15 fb^{-1}



sin(2β)

- Measure CP asymmetry
  - $A_{CP}(t) = \frac{N[\bar{B} \rightarrow \psi K^0_S](t) - N[B \rightarrow \psi K^0_S](t)}{N[\bar{B} \rightarrow \psi K^0_S](t) + N[B \rightarrow \psi K^0_S](t)}$
- Fit to $a(t) = D \sin(2\beta) \sin(x_d\, t/\tau)$
- Key point is getting much statistics and good flavor tagging
  - Luminosity
  - Trigger improvements
  - Kaon tagging



sin2β with ψK^0_S

❖ Scale from Run I
- ϵD^2 (NO K-tag)
- S/N ratio 1.2

$$\delta(\sin(2\beta)) \approx \frac{1+x_d^2}{x_d}\frac{1}{\sqrt{\epsilon D^2 N}}\sqrt{\frac{N+B}{N}}$$

➢ Assume 2 fb^{-1}

➢ Systematic~0.5xstatistical

Time integrated error: better with time evolution

Scenario	ϵD^2	$N(\psi Ks)$	Time integrated $\sigma(\sin 2\beta)$	Time dependent $\sigma(\sin 2\beta)$
Run I	6.3%	400	0.57	0.46
Run II, No tag improvements	6.3%	20,000	0.08	0.07
Run II, with Kaon tagging	9.1%	20,000	0.07	0.05

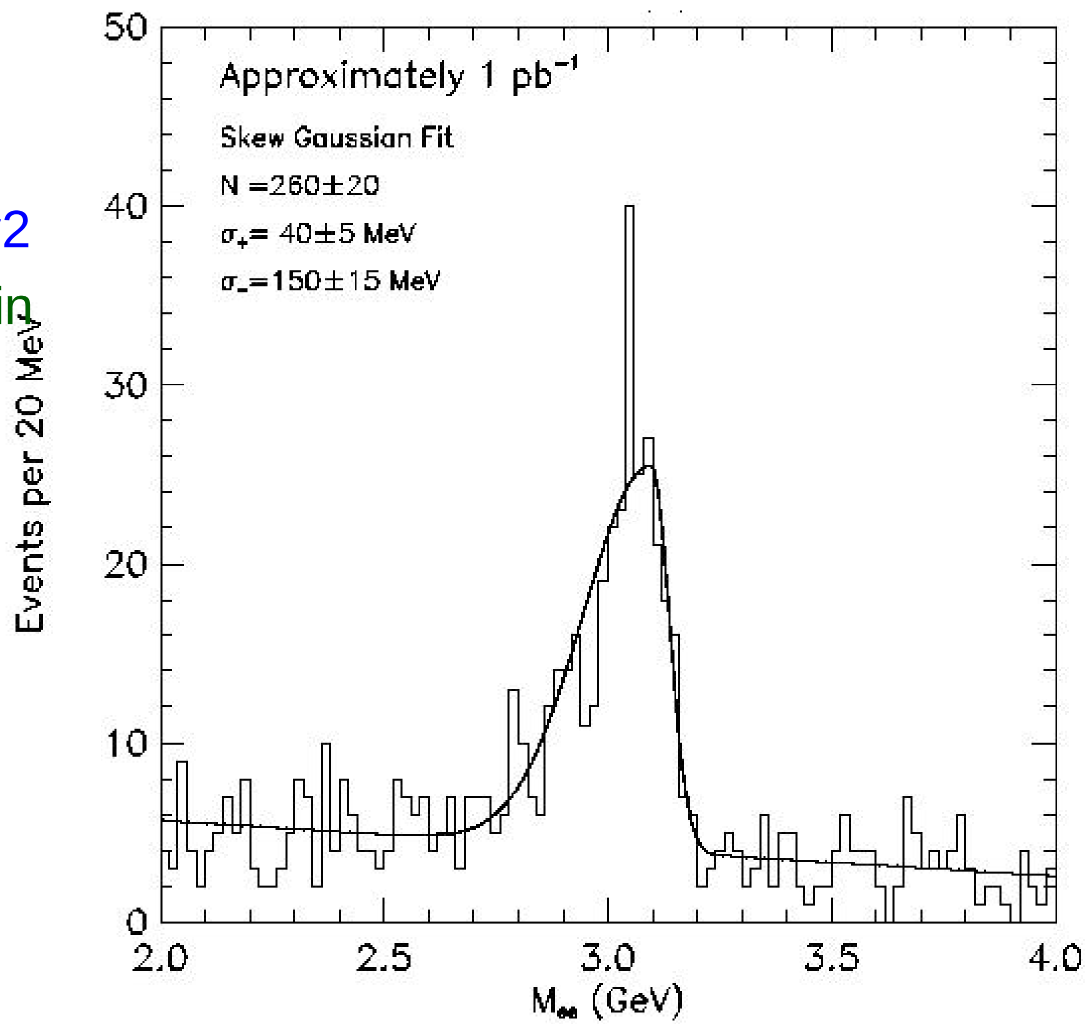
- **$N(\psi K_s)$ from scaling run I data**
  - x20 luminosity 8,000 events
  - x2.5 trigger improvements 20,000 events
  - (Trigger on $\psi \to e^+e^-$ 5,000 events) → ~ 1000

J/ψ yield	Run I extrap.	Run II observ.
CMU-CMU	8.5 nb	9.3 nb
CMU-CMX	3.0 nb	1.8 nb

$\sin 2\beta$ with ψK^0_S

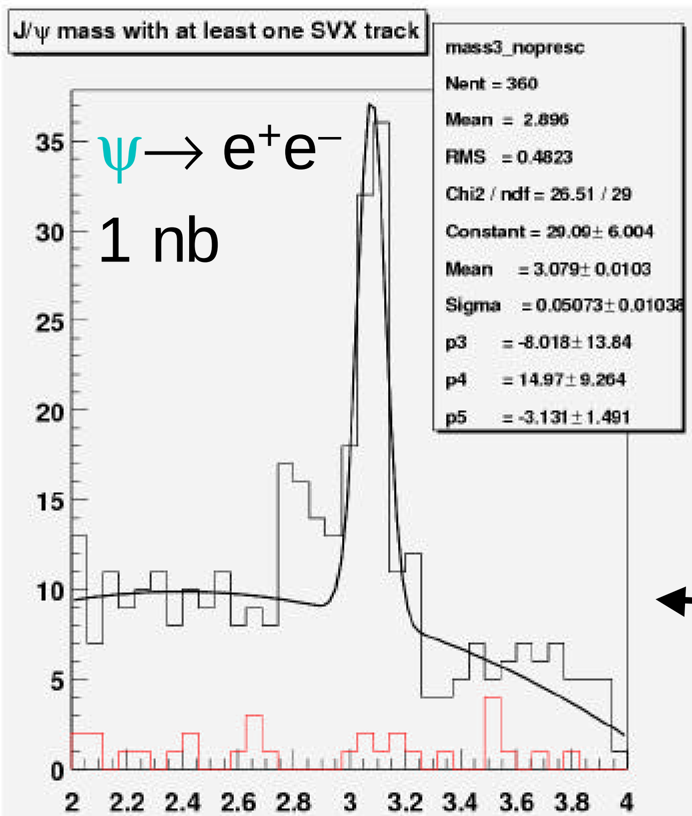
- Test run made in Run I to check feasibility $\psi \to e^+e^-$ of trigger:
  - test using tracking at Lv2
  - will use tracking at Lv1 in run II

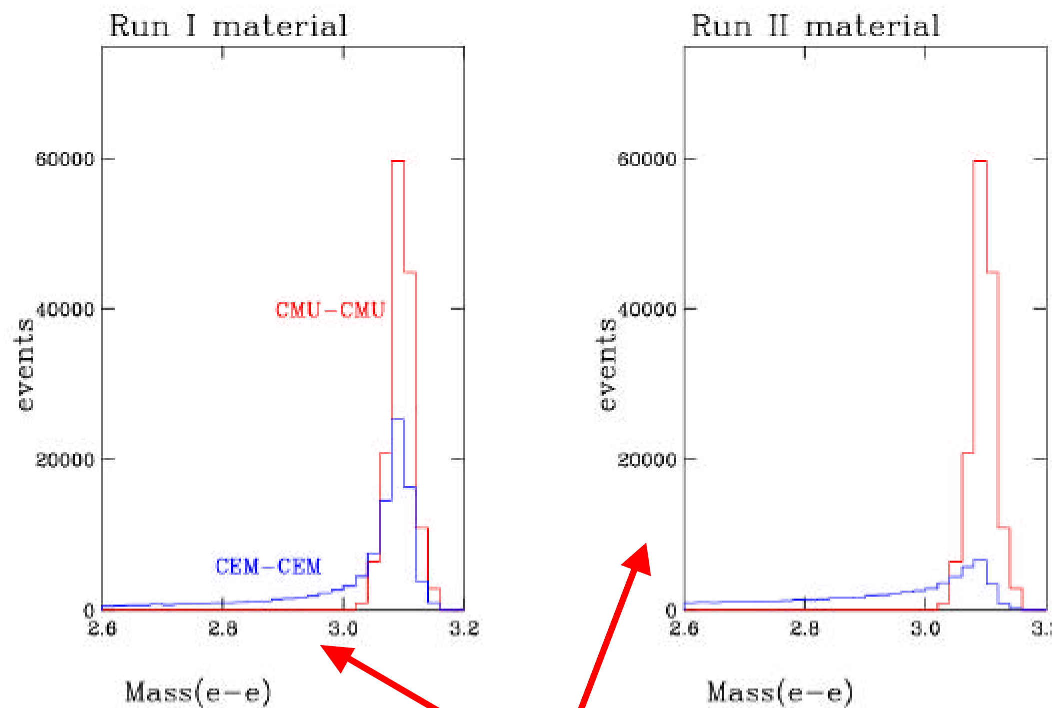
…forgot that we had much more material in vertex detector!



sin 2β

- Electron trigger suffers for excess of material



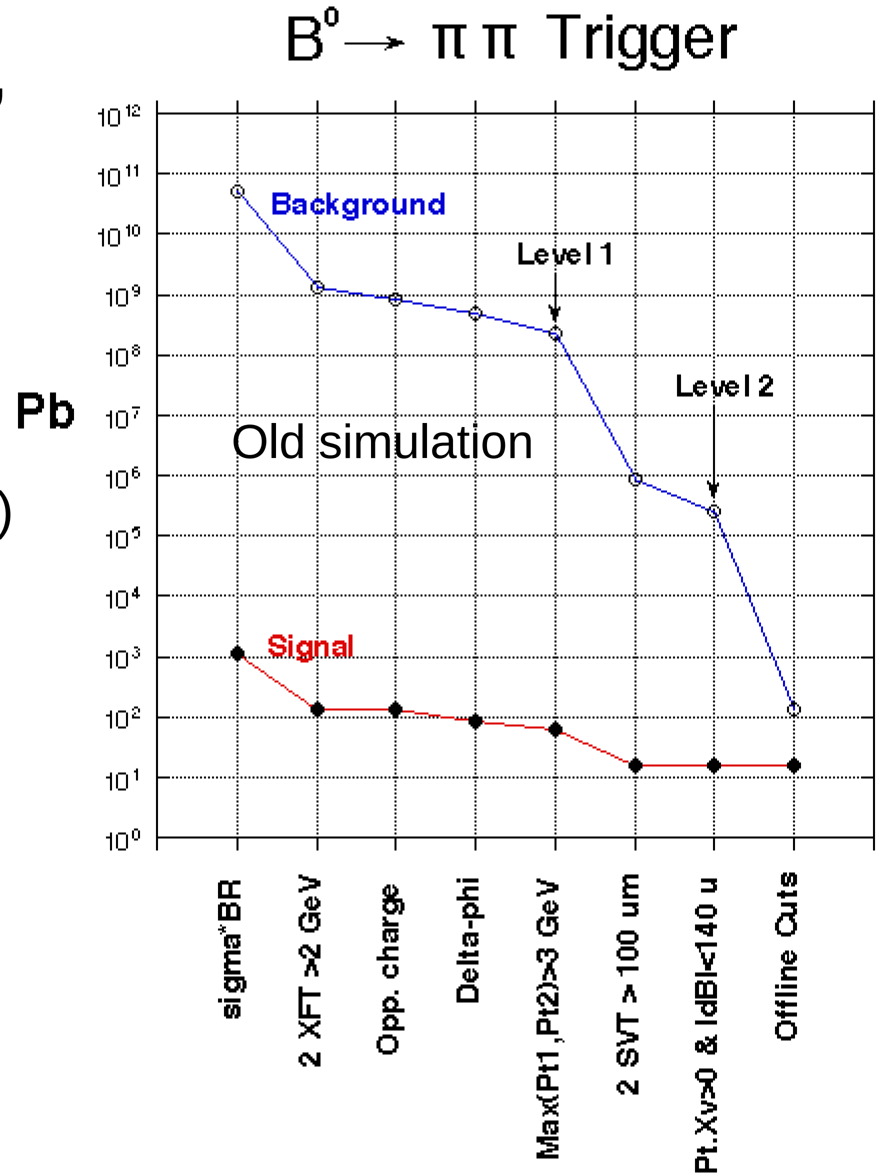


Simulation

Run II data

Measuring γ

- Use $B_d \rightarrow \pi\pi$, $K\pi$ and $B_s \rightarrow K\pi$, KK
  - Trigger on displaced impact parameter (gains factor 1000)
  - Signal (will use lower bound):
    - 5-10x10^3 $B_d \rightarrow \pi\pi$ (BR~5×10^{-6})
    - 20-40x10^3 $B_d \rightarrow K\pi$
    - 2.5-5x10^3 $B_s \rightarrow K\pi$
    - 10-20x10^3 $B_s \rightarrow KK$
  - S/N assume ½ for $B_d \rightarrow h^+h^-$
    - New data consistent with 1/1 as suggested by simulation
    - Few hundred events by summer allow S/N measurement



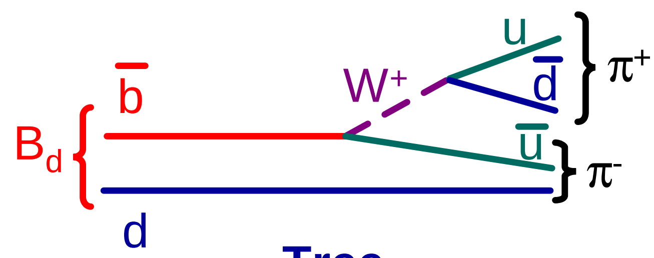
Measuring γ

- Disentangling channels
  - Separate contributions in a statistical way. Use:
    - Particle ID (dE/dx in COT 1 – 1.5 σ separation) → fractions of $\pi\pi$, $K\pi$, KK
    - Invariant mass (σ_M ~ 25 MeV)
    - Oscillation frequency of CP asymmetry:
      - Dm_d — $B_d \rightarrow pp$
      - **NO CP oscillation** — $B_d \rightarrow Kp$
      - **NO CP oscillation** — $B_s \rightarrow Kp$
      - Dm_s — $B_s \rightarrow KK$

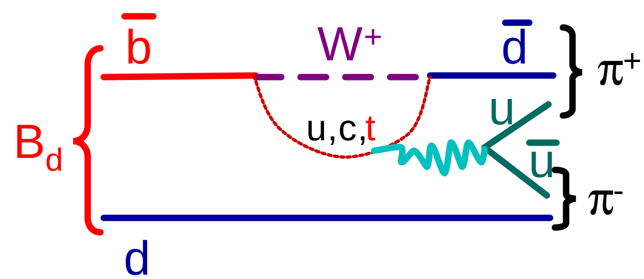
    Combined invariant mass and lifetime fit
- Fit CP asymmetry vs lifetime for B_d and B_s in the form
  - $A_{cp}(t) = A_{cp}^{dir} \cos(\Delta m\, t) + A_{cp}^{mix} \sin(\Delta m\, t)$
- Expected errors on A_{CP} assuming 2 fb^{-1}:
  - $A_{mix}(\pi\pi) \sim 0.13$ — $A_{mix}(KK) \sim 0.09$
  - $A_{dir}(\pi\pi) \sim 0.11$ — $A_{dir}(KK) \sim 0.10$

Measuring γ

- Interpretation of asymmetries (Fleischer, PLB459, 1999)
  - Parameterize in terms of
    - CKM phase γ, β
      - ➔ b **from** y $\mathbf{K^0_s}$
    - $d\,e^{i\theta}$ = hadronic Penguin/Tree
  - Assume SU(3) symmetry
    - $d\,e^{i\theta}$ same for $B_d \rightarrow \pi\pi$, $B_s \rightarrow KK$ (~ 20%)
    - $A^{dir}(\pi\pi) = -2d \sin\theta \sin\gamma + O(d^2)$
    - $A^{dir}(KK) = \dfrac{2\lambda^2}{d(1-\lambda^2)} \sin\theta \sin\gamma + O((\lambda^2/d)^2)$
    - $A^{mix}(KK) = \dfrac{2\lambda^2}{d(1-\lambda^2)} \cos\theta \sin\gamma + O((\lambda^2/d)^2)$
    - $A^{mix}(\pi\pi) = \sin 2(\beta+\gamma) + 2d \cos\theta \times (\cos\gamma \sin 2(\beta+\gamma) - \sin(2\beta+\gamma)) + O(d^2)$



Tree



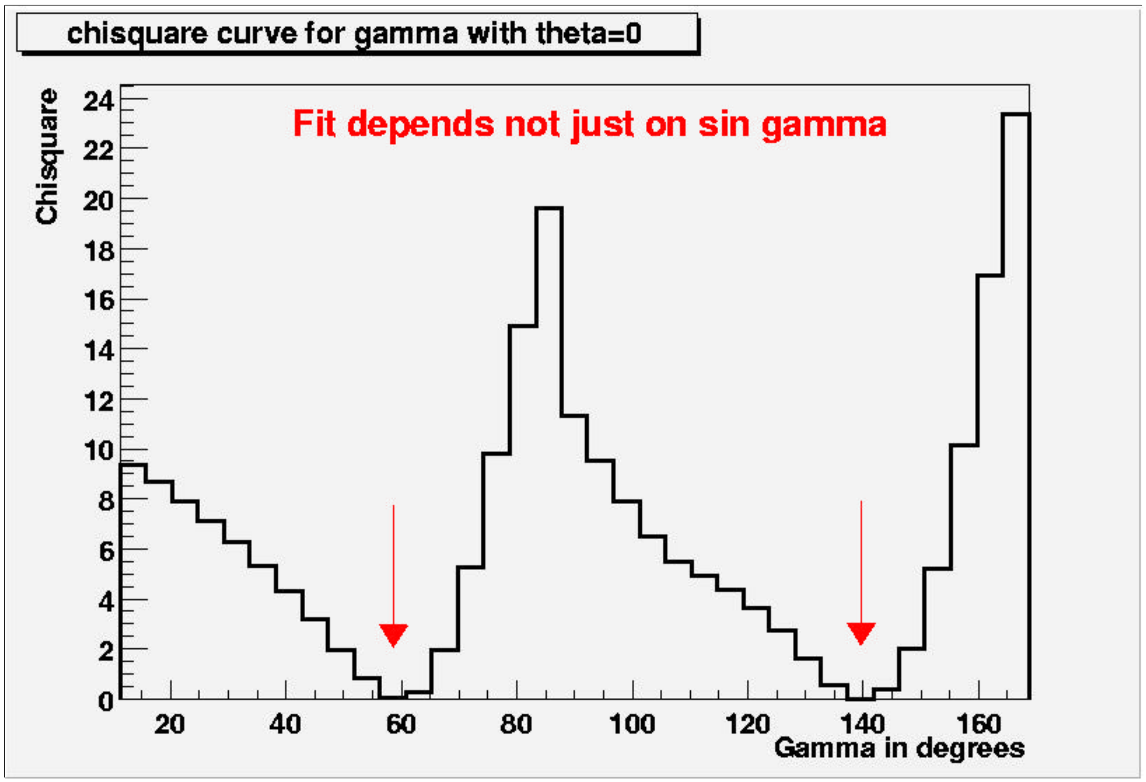
Penguin

d ~ 0.3

q **????**

Measuring γ

- Can solve for d, θ and γ
  - Worse case when $\sin\theta \sim 0$ assumed
  - Fit result when
    - $\gamma = 60°$, $\beta = 22.2°$, $\theta = 0$
    - $\sigma_\gamma = +5.4/-6.8 \pm 3$ degrees



SU(3) breaking effects

❖ With 15 fb-1 this measurement will be limited entirely by theory uncertainties

Conclusion

- The CDF detector is working well at the current luminosity
  - Main concern is getting enough data!
- Very exciting B physics measurement are possible with as little as a few pb^{-1}
- The interest of the B physics program continues and is enriched as the luminosity grows up to the limits of the Tevatron capabilities