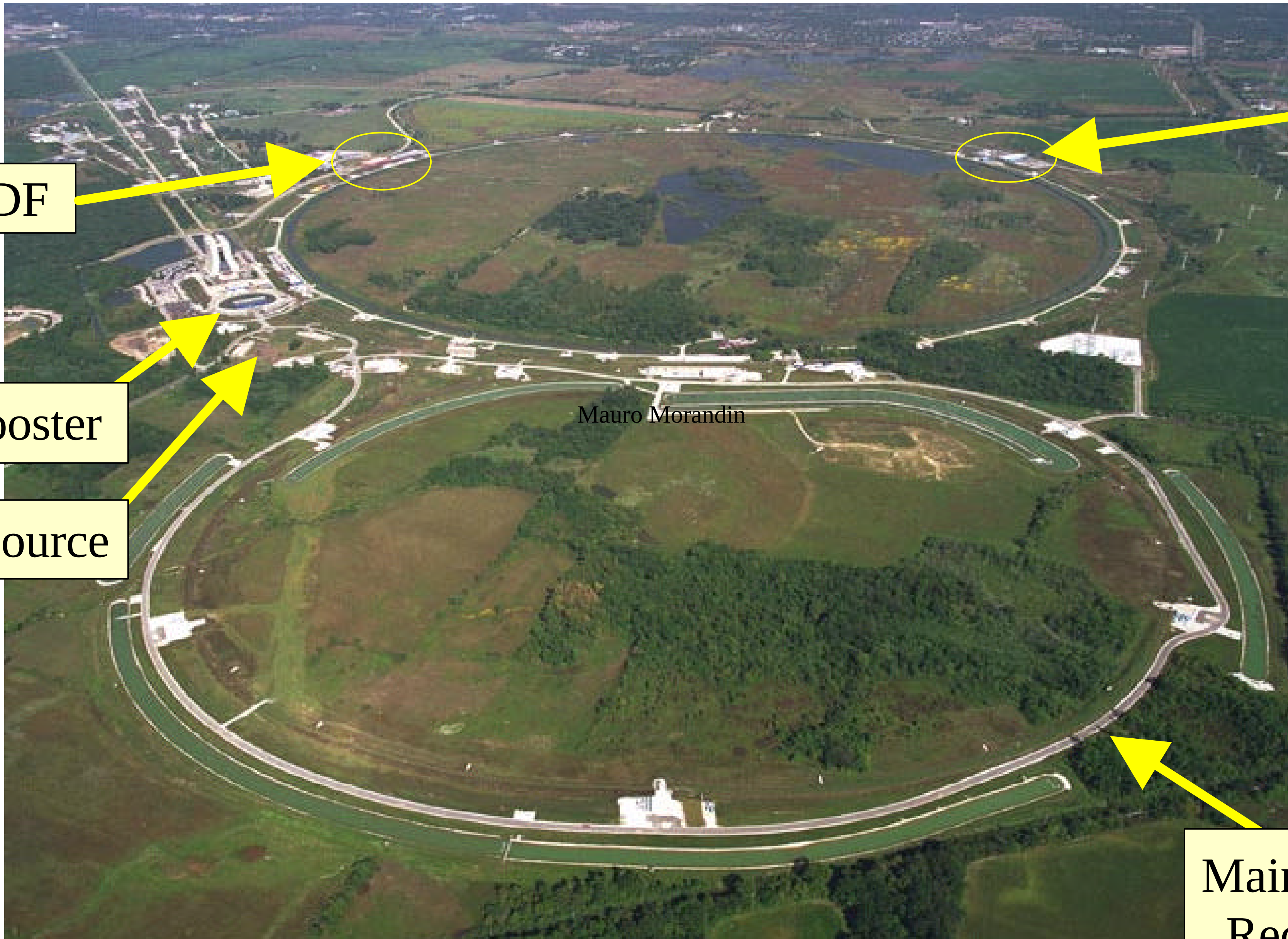
Fisica del B all'esperimento CDFII

Padova, 21 maggio 2002

D. Lucchesi

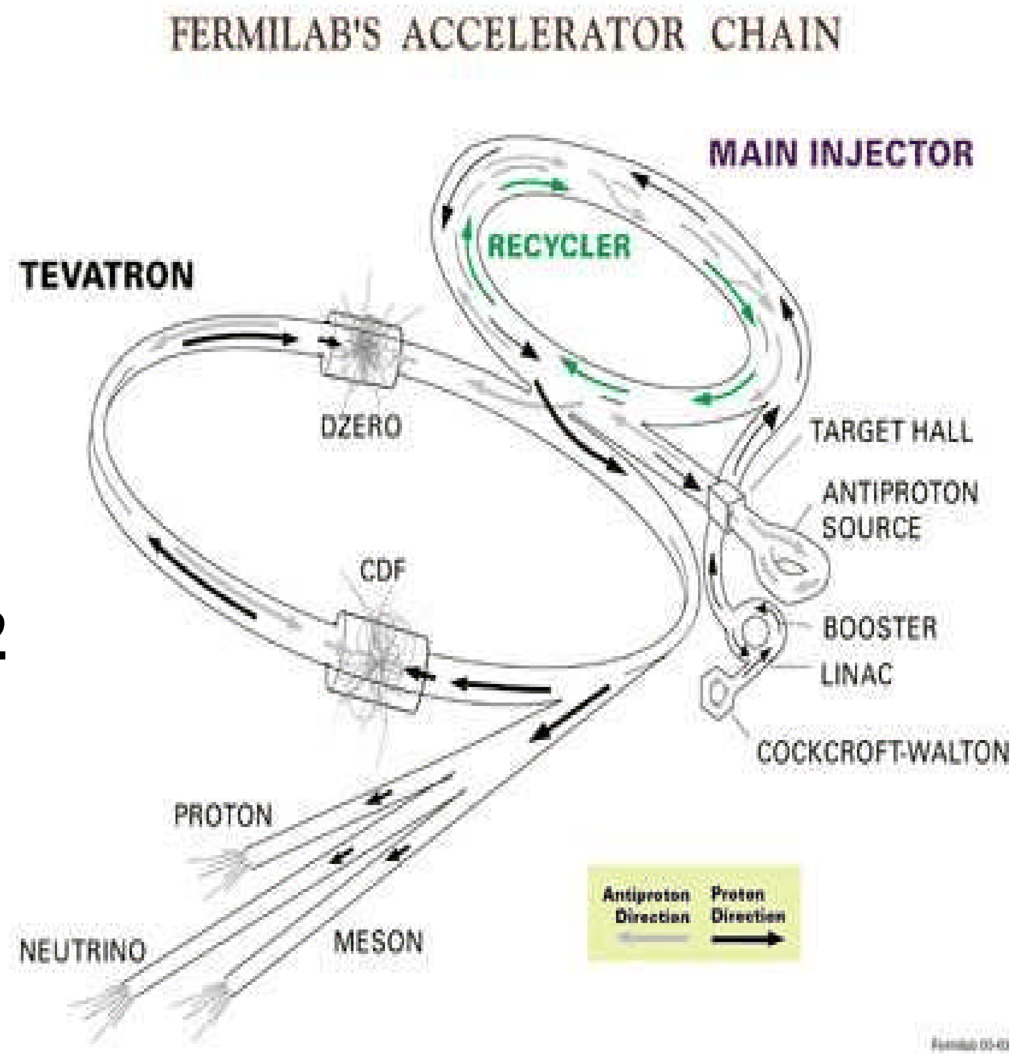
- Tevatron status and prospects
- CDFII status
- Preliminary results from first data
- Plans for short and long term future

The new machine



The accelerator complex

1. **Run I (1992-1995): 110pb^{-1}**
2. **Run IIa (2001-2004): 2 fb^{-1}**
   - Main Injector: x5
     150 GeV p storage ring
   - Recycler: x2-3 (2003-4)
     Re-cools p from Tevatron
   - N bunches 36 (396 ns)
     108 (132
   - Beam energy : 980 GeV
3. **Run IIb (2005-2007):15** fb^{-1}
   - electron cooling, crossing
     angle, electron lens

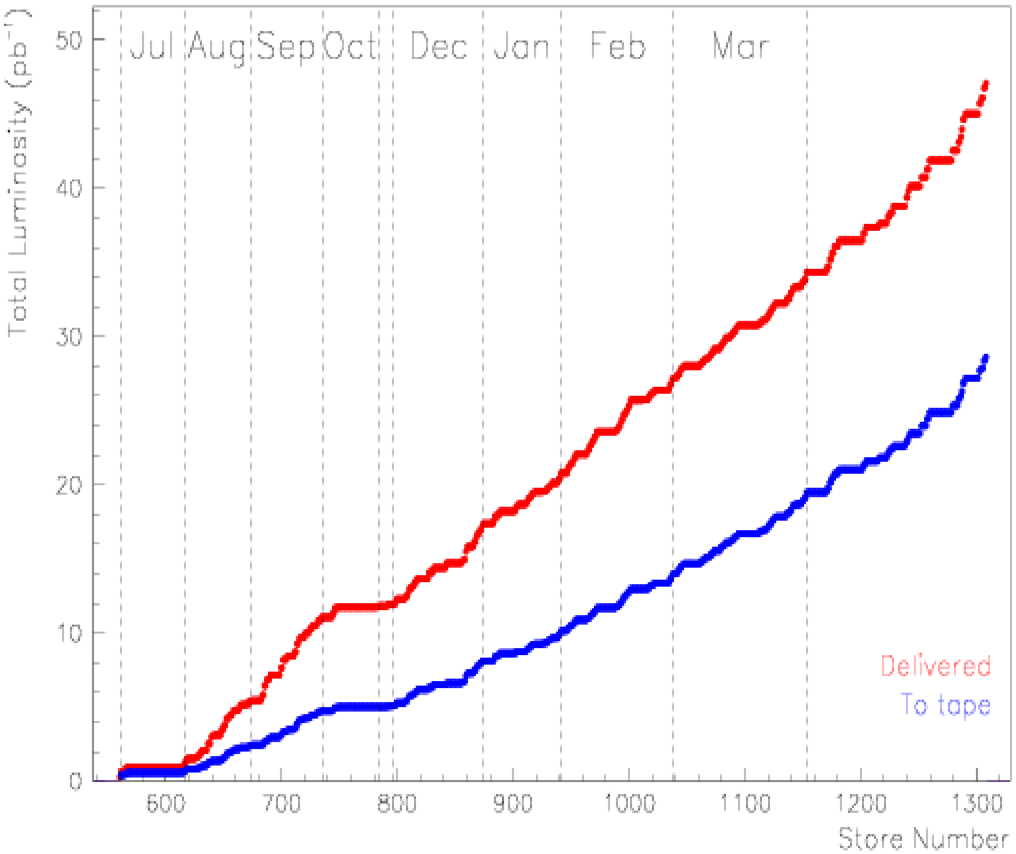


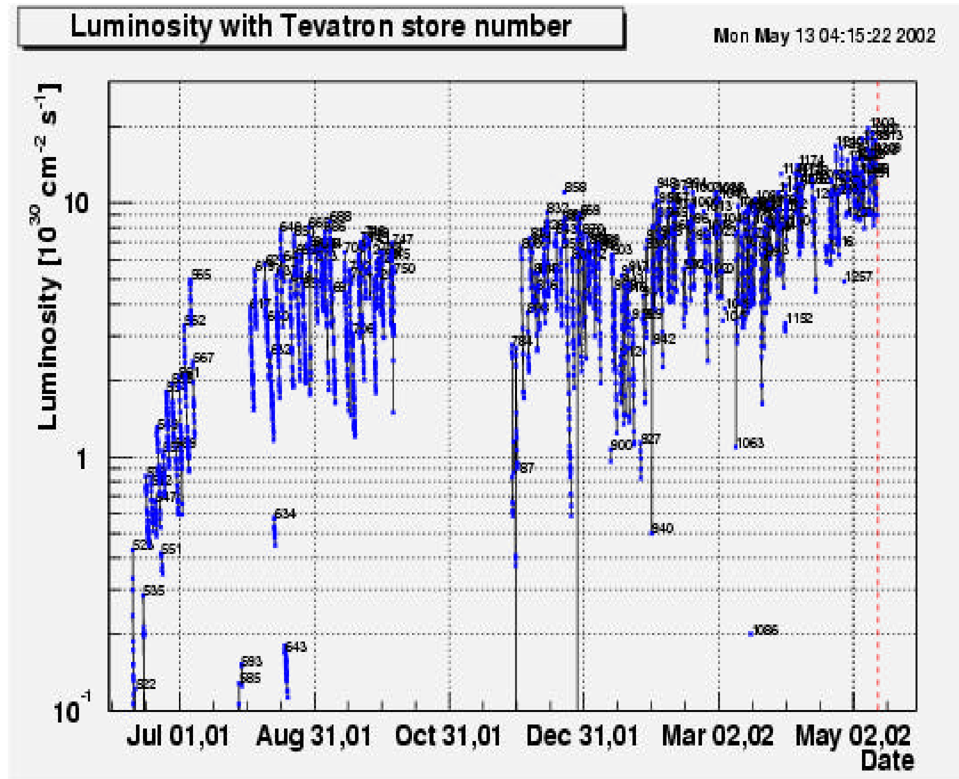
Tevatron Improvement

Run	Ib(93-95) (6x6)	IIa (36x36)	IIa (140x103)	IIb (140x103)	
N_p	2.3×10^{11}	2.7×10^{11}	2.7×10^{11}	2.7×10^{11}	
$N_{\bar{p}}$	5.5×10^{10}	3.0×10^{10}	4.0×10^{10}	1.0×10^{11}	
$N_b N_{\bar{p}}$	3.3×10^{10}	1.1×10^{12}	4.2×10^{12}	1.1×10^{13}	
$\bar{p}$ prod. rate	6.0×10^{10}	1.0×10^{11}	2.1×10^{11}	5.2×10^{11}	hr^{-1}
L_{peak}	0.16×10^{31}	0.86×10^{32}	2.1×10^{32}	5.2×10^{32}	$cm^{-2}s^{-1}$
Bunch spacing	~3500	396	132	132	ns
N_{int}/crossing	2.5	2.3	1.9	4.8	

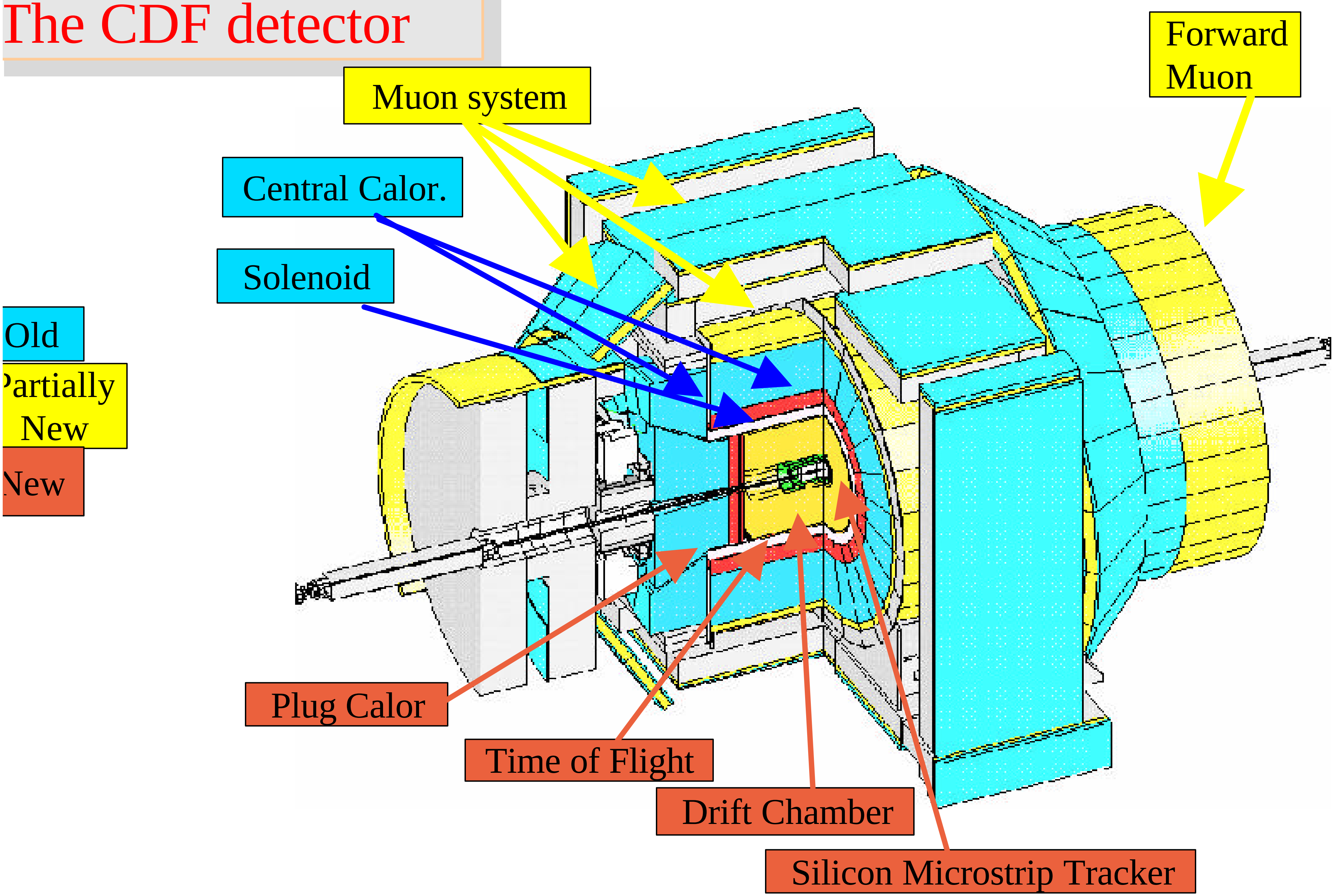
2001-2004 2005-7

Recent Machine performance

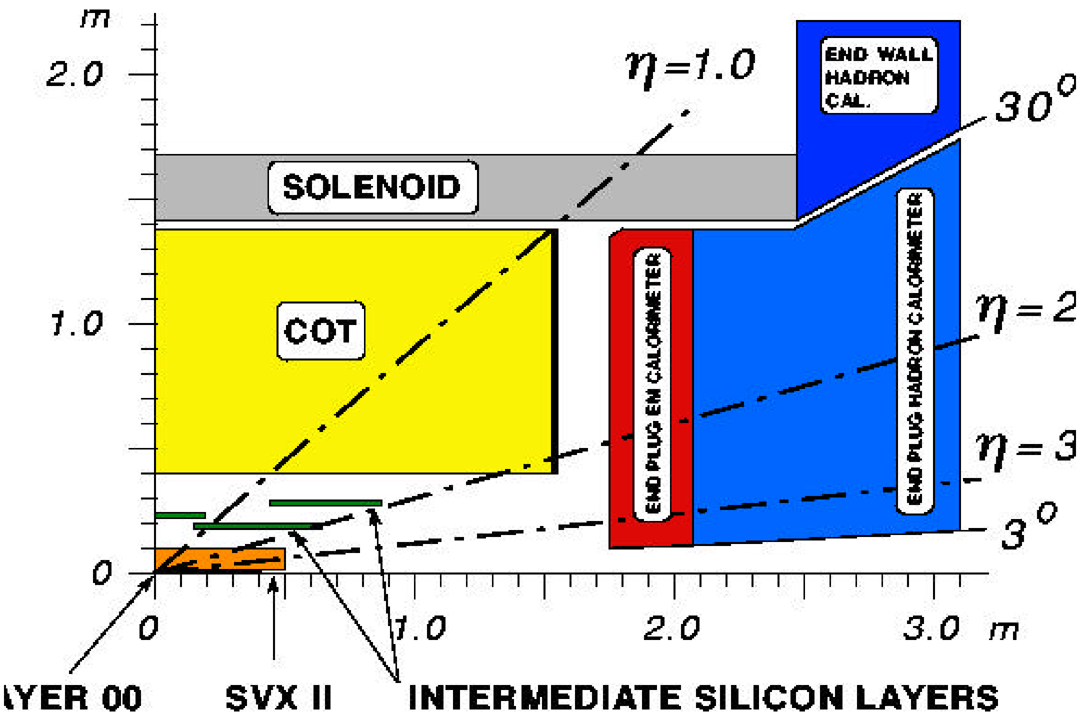




The CDF detector



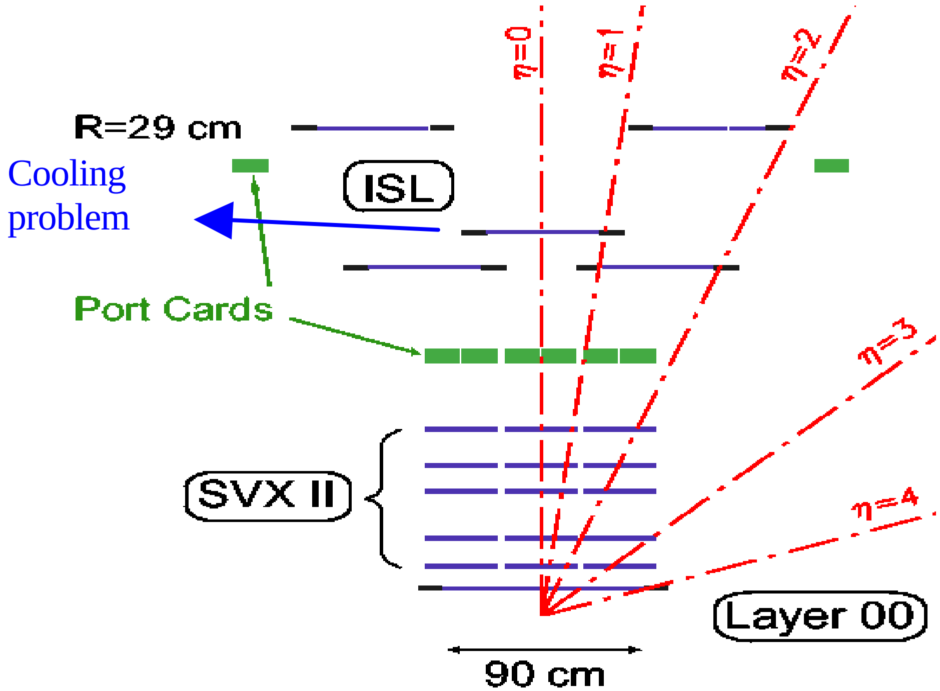
Tracking System: COT

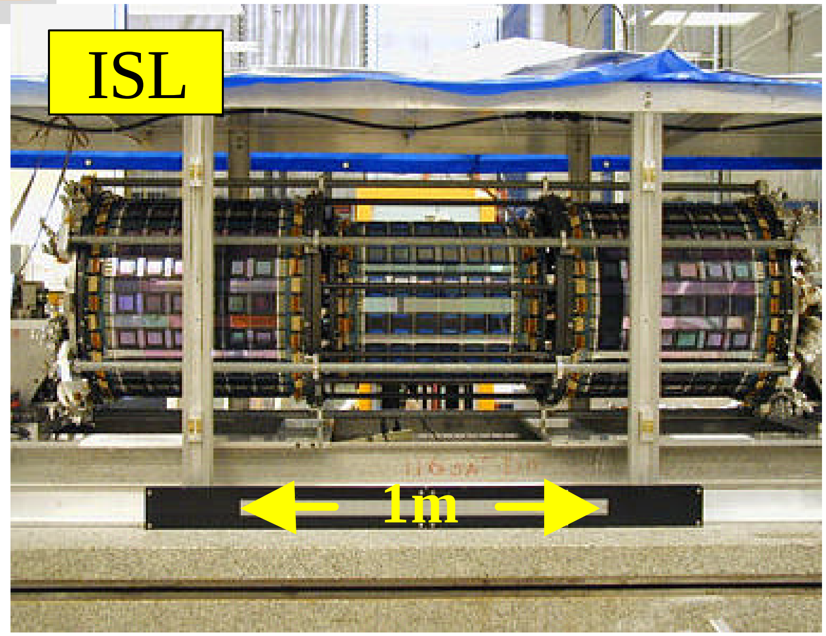


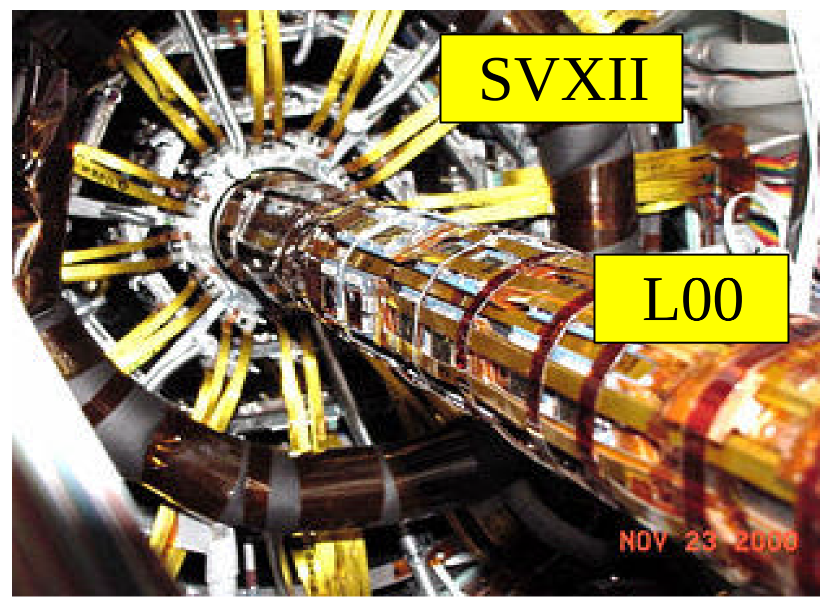
N of layers: 96(8 SL -12 L/SL)
Angles: +3 0 –3 0 +3 0 –3 0
Lorentz angle 35°
Max. drift time 100 ns
Gas: Ar-Et-CF_4 (50:35:15)
Instrumented for dE/dx

Hit resolution ~200 μm
$\delta p_t/p_t^2$~0.3% $(GeV/c)^{-1}$
z0 resolution ~5 mm

Tracking System:Silicon Tracker







Double sided microstrip

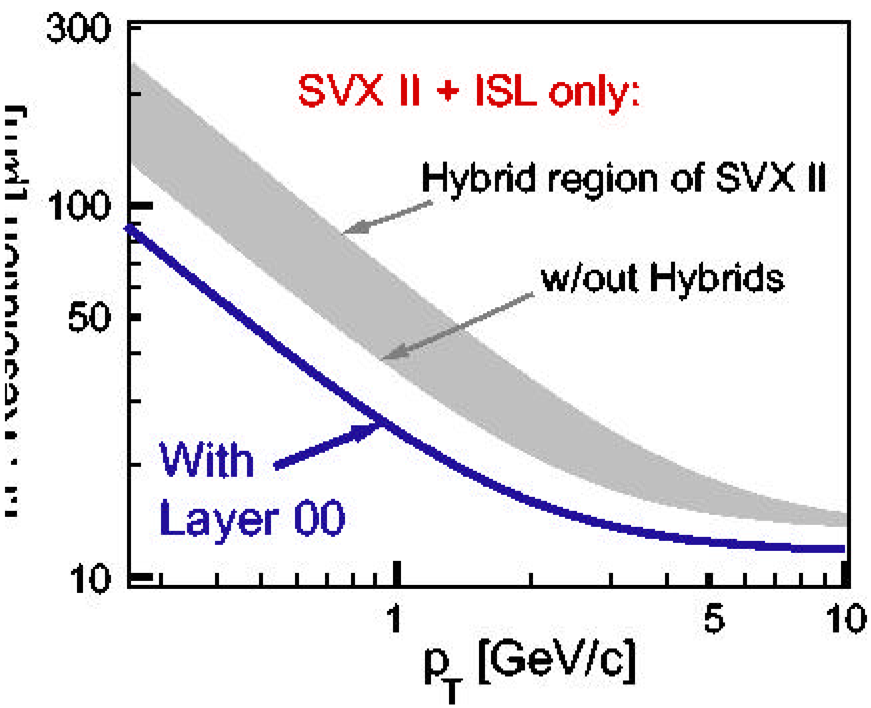
Increased z coverage

L00 (single sided) r^{in}=1.35 cm

Impact parameter resolution

σ_{Φ}<30 μm σ_z<60 μm

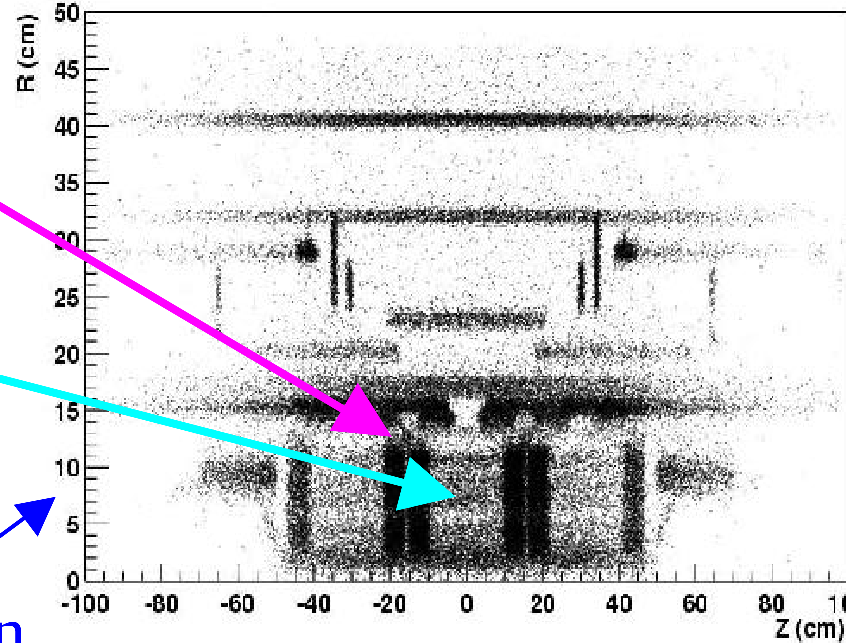
Tracking Performances

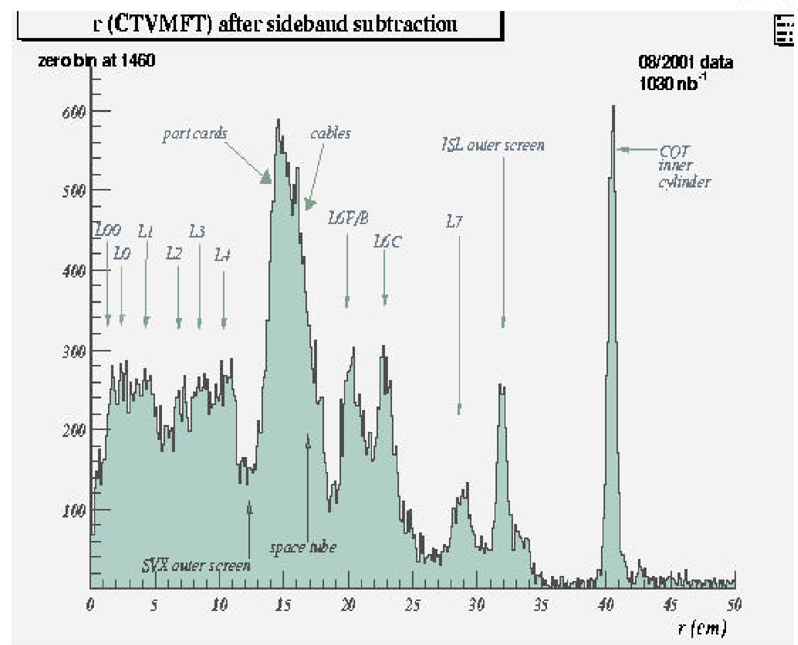


~35%X_0

~10%X_0

Material distribution



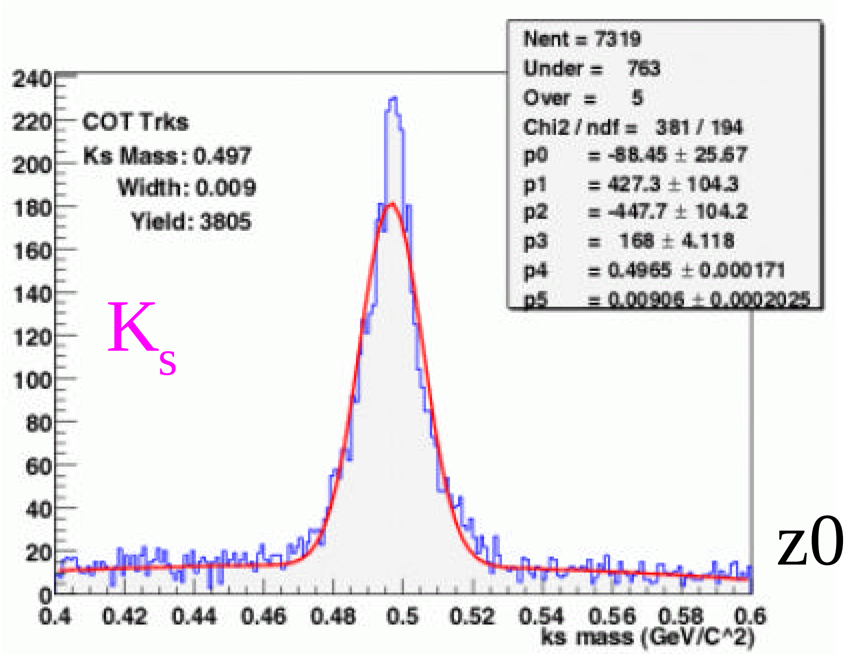


L00 still commissioning

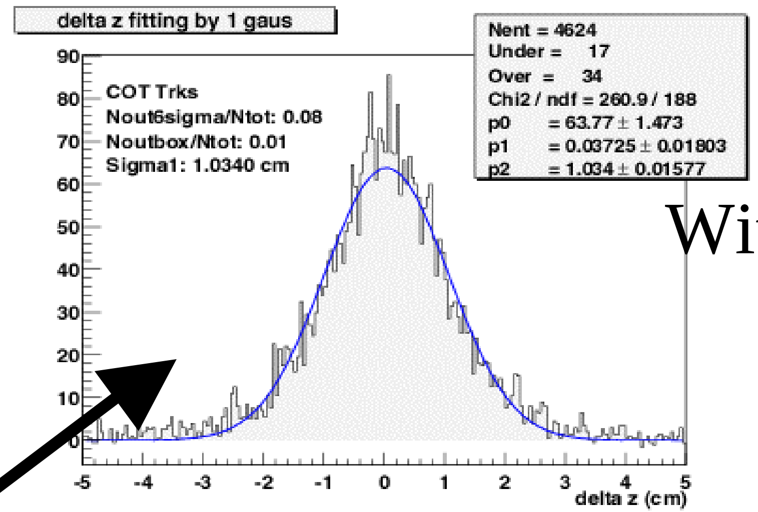
SVXII not yet stable

Tracking under optimization

Tracking Performances



K_s

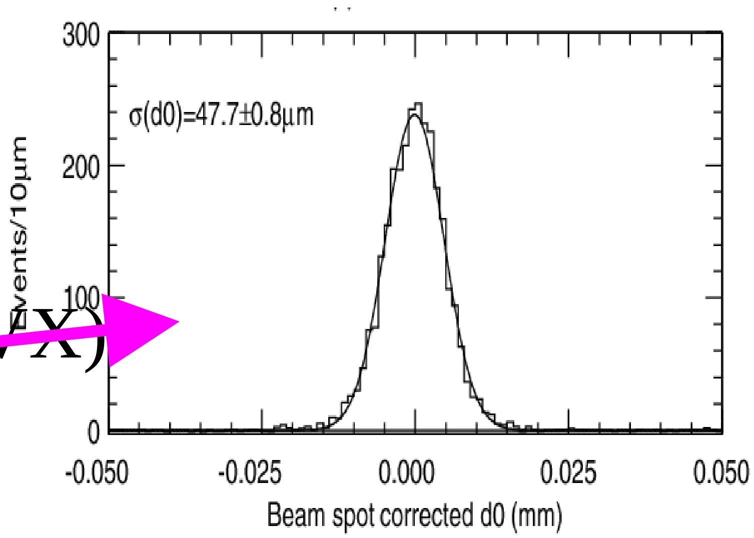


With Si ~2 mm

z0 resolution

Impact Parameter resolution
COT ~400 μm

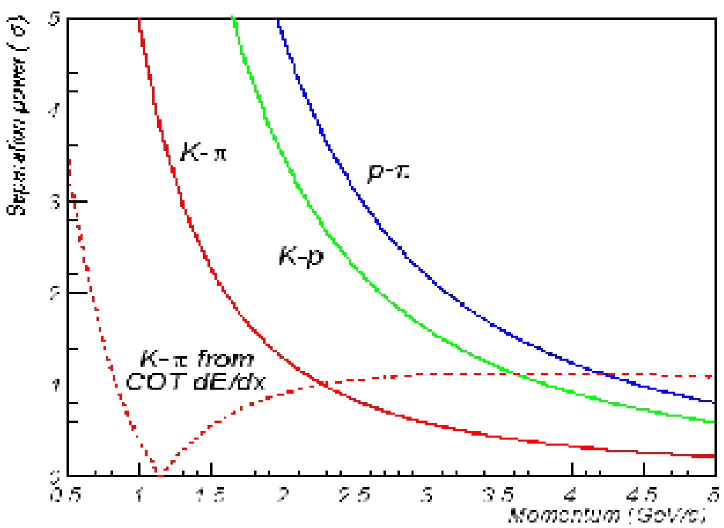
J/ψ→μμ(SVX)



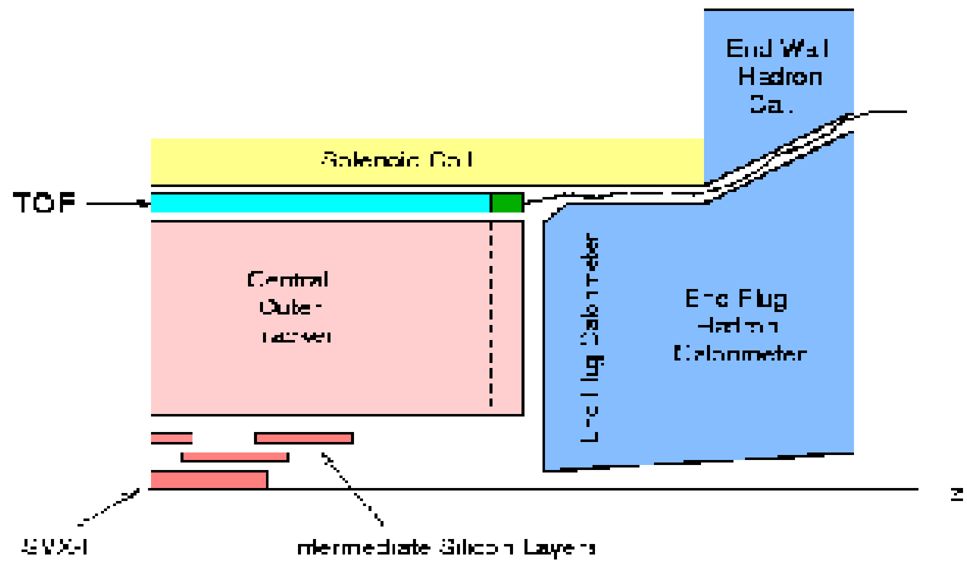
Z→μμ
σd~33 μm

Particle Identification

1) TOF: scintillator bars
216x2 PMT channels
resolution: 100ps



2) COT wires:
96 pulse height meas.
dE/dx from pulse width



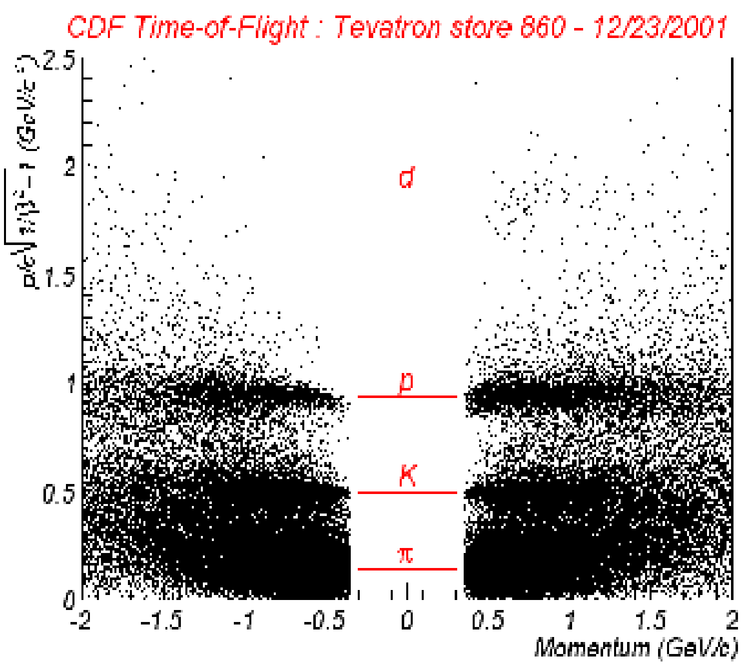
Goal on K/π separation:
moderate P_t: separation>1σ
TOF+dE/dx

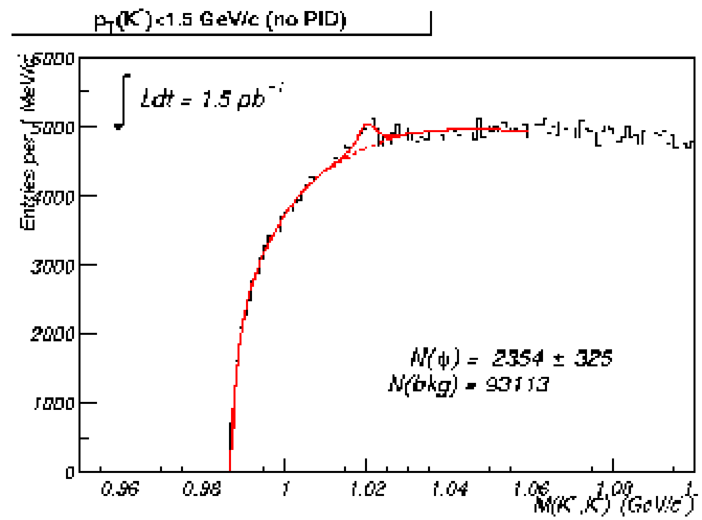
P_t<1.6: separation >2σ
TOF

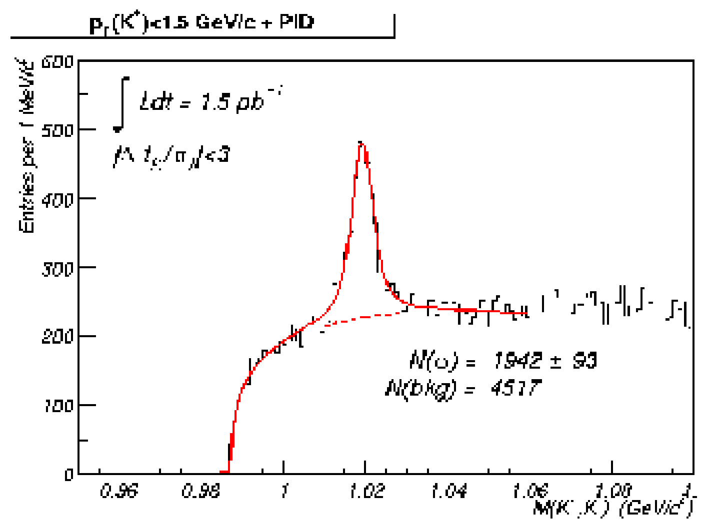
Particle Identification performance

dE/dx under calibration

TOF results:







Trigger Overview

Raw Data — Crossing rate:1.7 Mhz
Inelastic cross sect.:56mb

↓

L1 Trigger — L1 Acceptance Rate
40 kHz (400 μb)

↓

L2 Trigger — L2 Acceptance Rate
300 Hz (3 μb)

↓

L3 Trigger — L3 Acceptance Rate
75 Hz (750 nb)

↓

Data Set — Average size
60 kbytes/event

1 Level 1:

A Calorimeter:

O Object triggers:

$E_{\text{single towers}}$ >threshold

O Global triggers:

? $E_{\text{all towers}}$ >threshold

A eXtremly Fast Tracker

A Muons

1 Level 2:

= Calorimeter Clustering

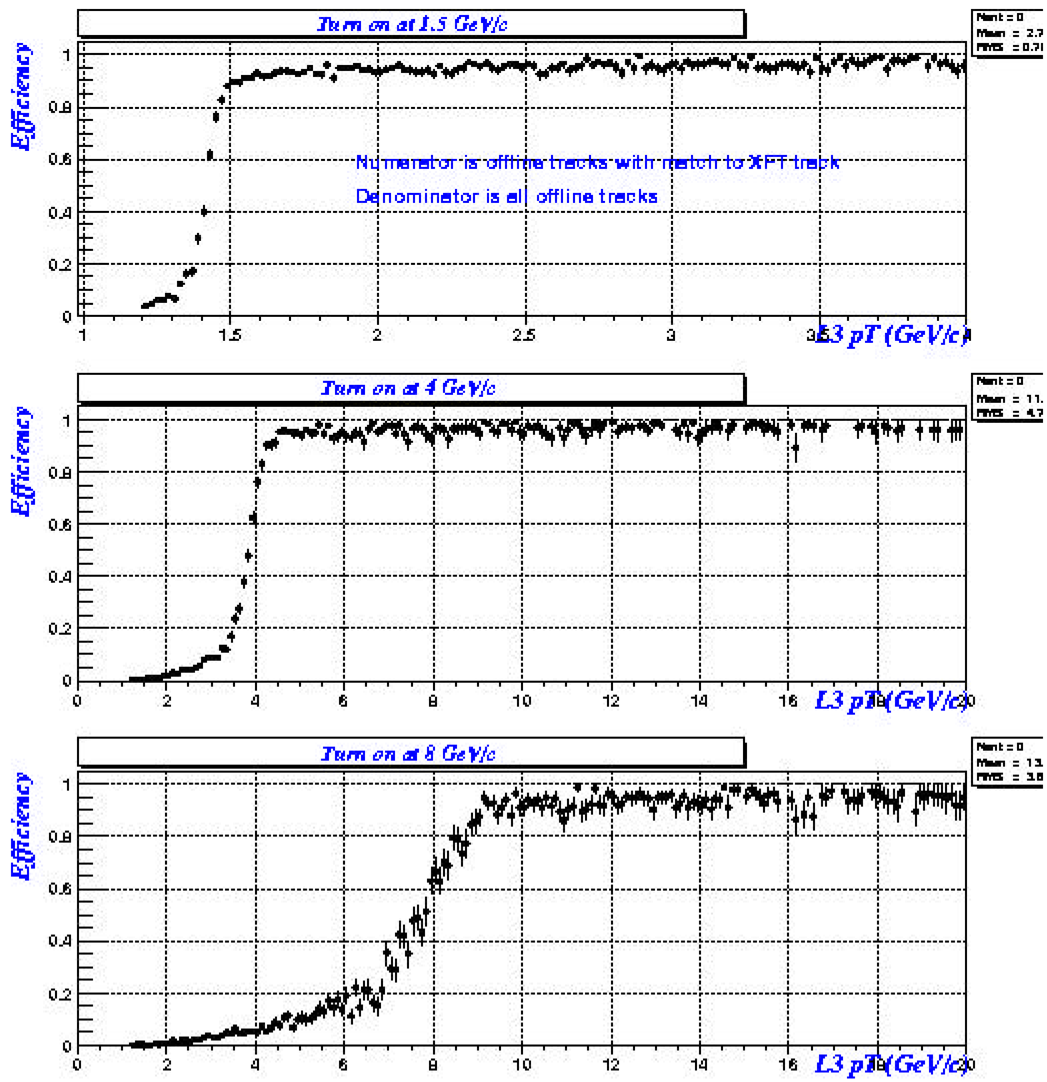
= Silicon Vertex Tracker

1 Level 3:

" Offline-like

L1 track trigger: XFT

Use of COT axial hits (4 SL)
Finder: looks for segment in each SL
Linker:match 4 segments



Requirements:

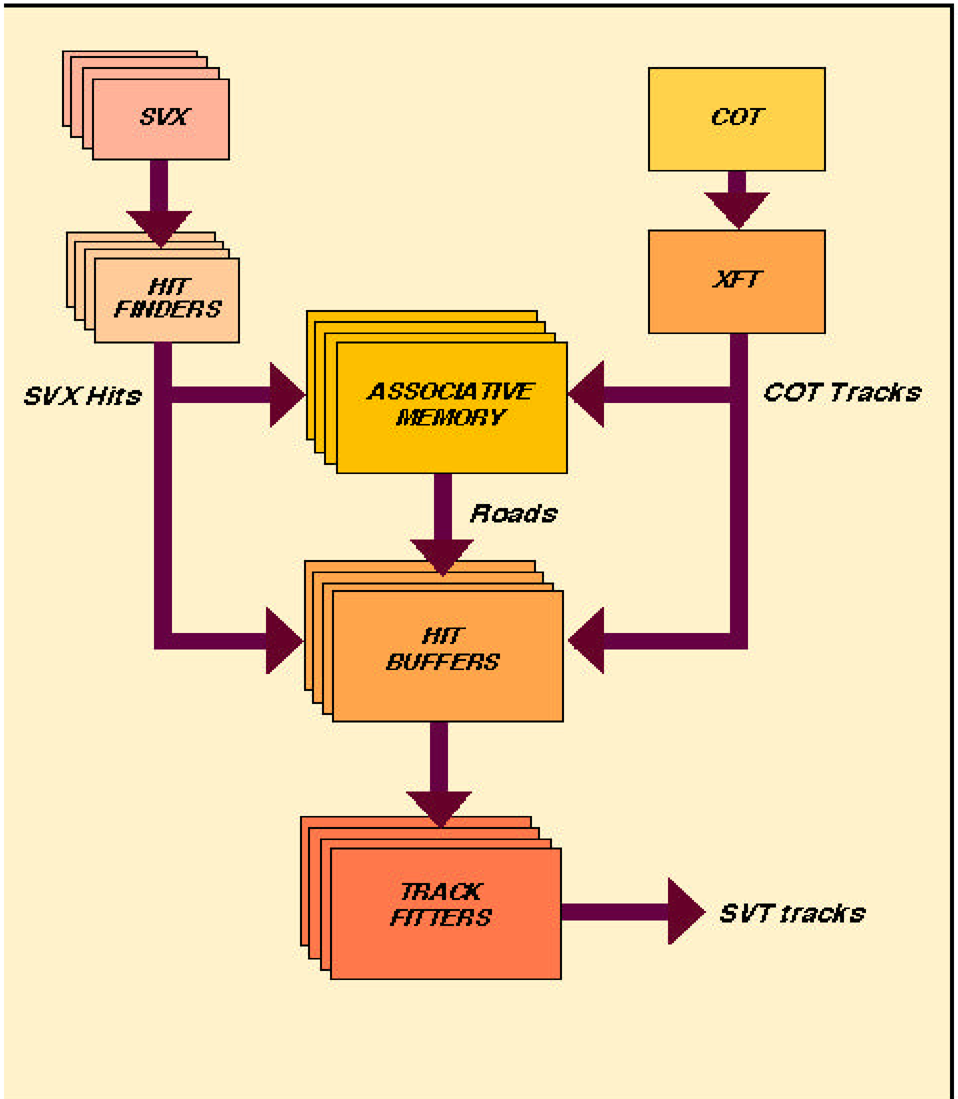
2 Tracks P_t>2 GeV
opposite charge
$\Delta\Phi$<135
$P_t^1+P_t^2$>5.5 GeV

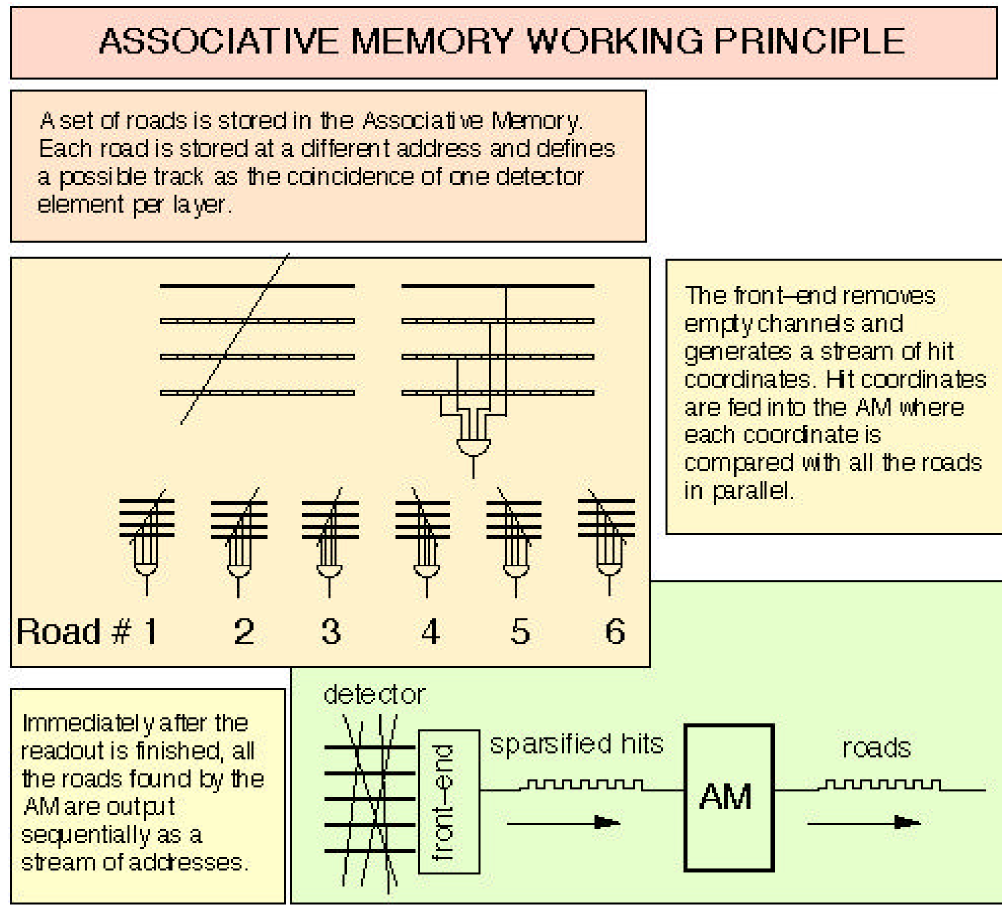
Performances:

$\delta P_t/P_t^2$=1.65% (GeV)$^{-1}$ (2)
$\delta\Phi$=5.1 mrad (8)

L2 track trigger: SVT

SVT architecture





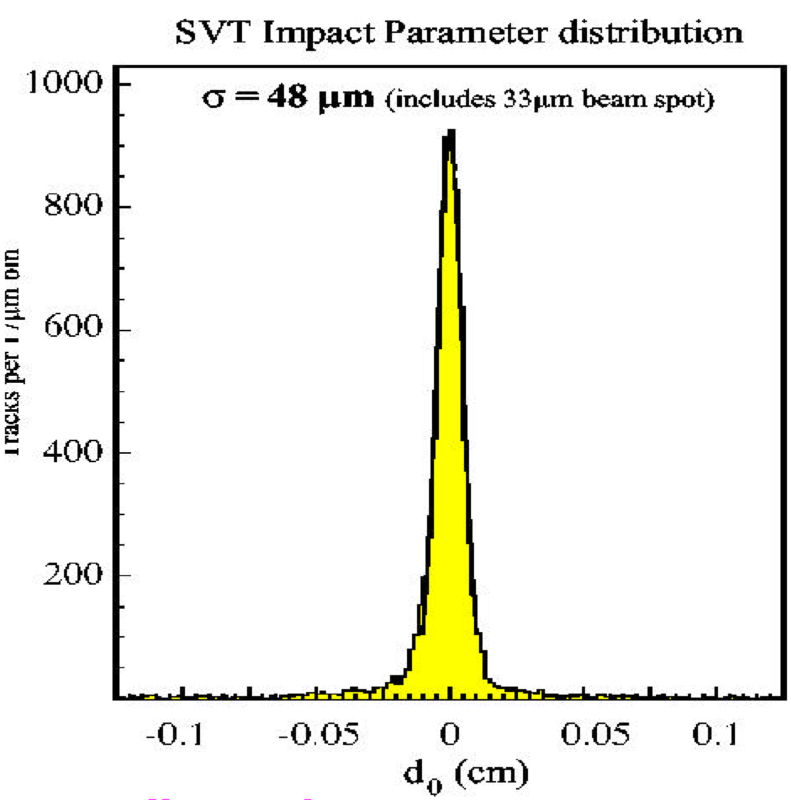
L2 Track Trigger:SVT Performances

Requirements:

2 Tracks P_t>2 GeV

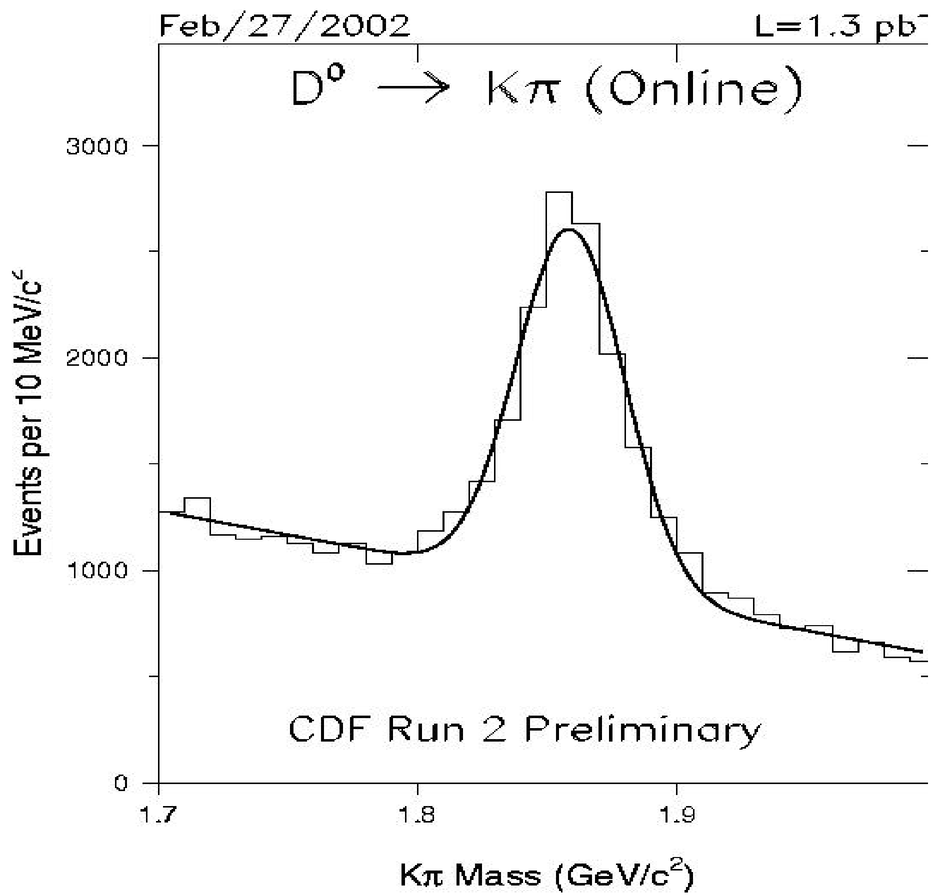
100 µm <|d|<1 mm

2<ΔΦ<135



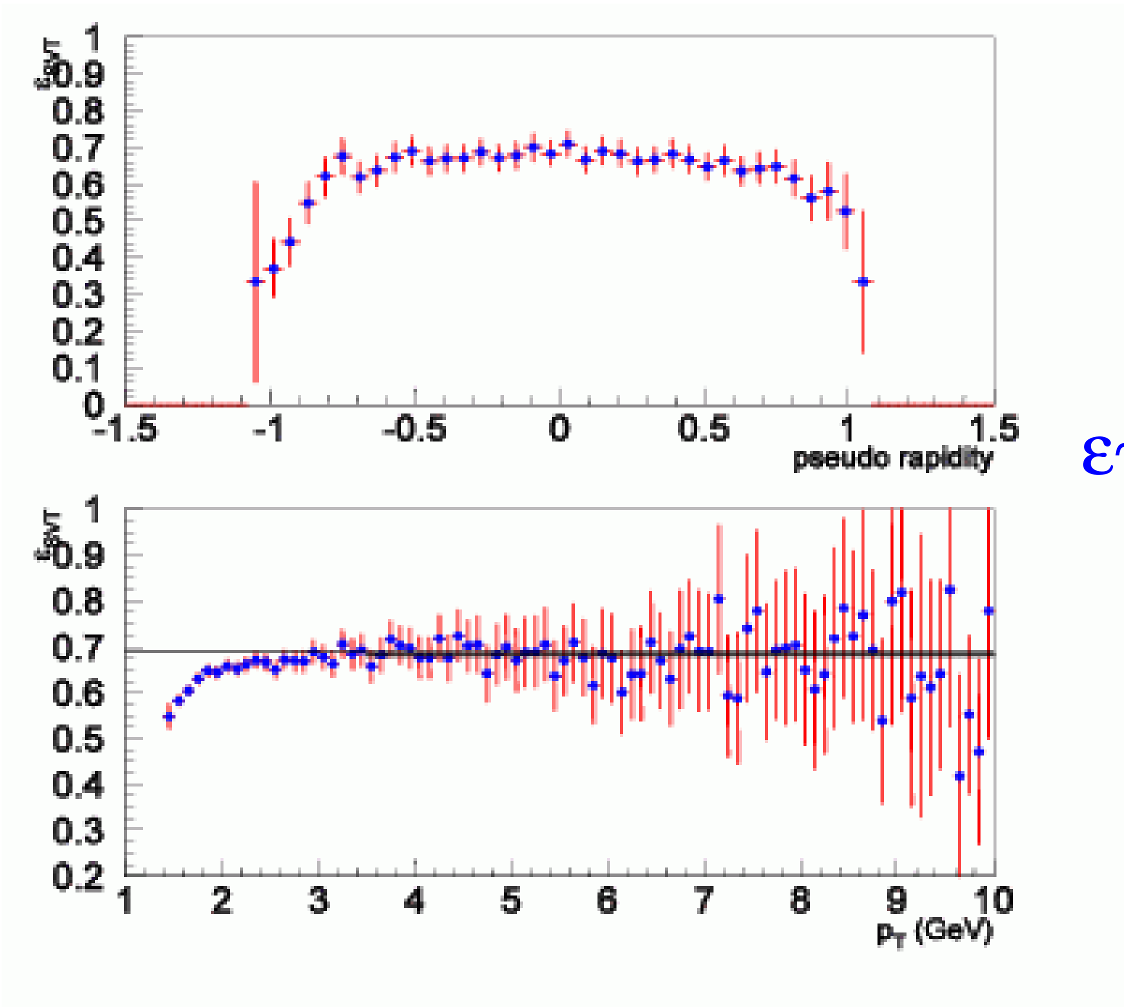
~8 events every nb^{-1}

D^0 peak: trigger monitor



L2 track trigger: SVT Efficiency

SVT tracking efficiency measured with data: $J/\psi \rightarrow \mu\mu$



ε~70%

Charm reconstruction: Two bodies

D^0 reconstruction cuts:

: Pt>1.5 GeV

: |d|>100 μm

: COT hits≥20(ax.) & 20(st.)

: SVX hits≥3 (only axial)

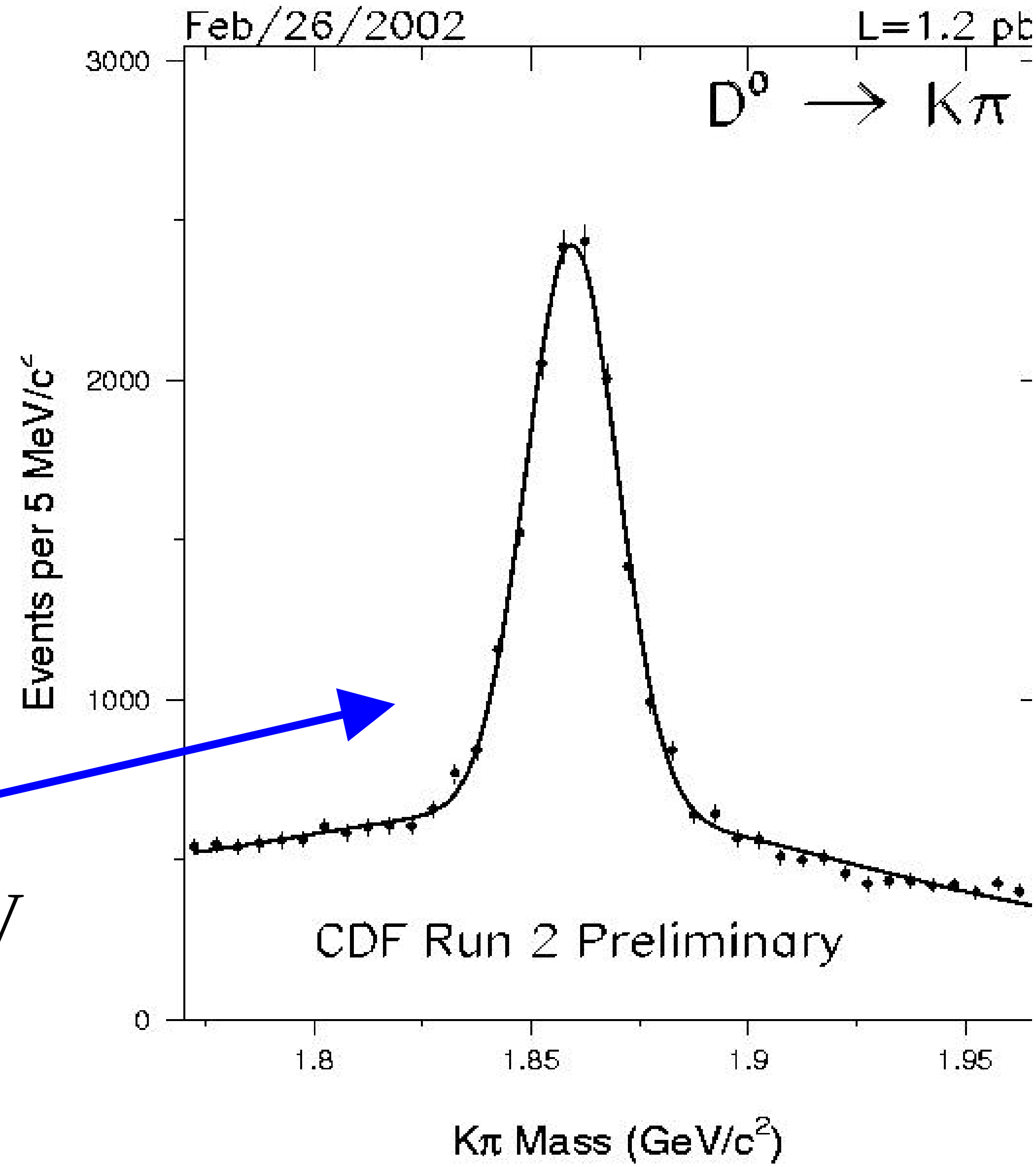
: $\Delta z<5$ cm

: Lxy>0

: $\Delta R<2 \quad \Delta R=?\,\overline{\Delta\eta^2+\Delta\varphi^2}$

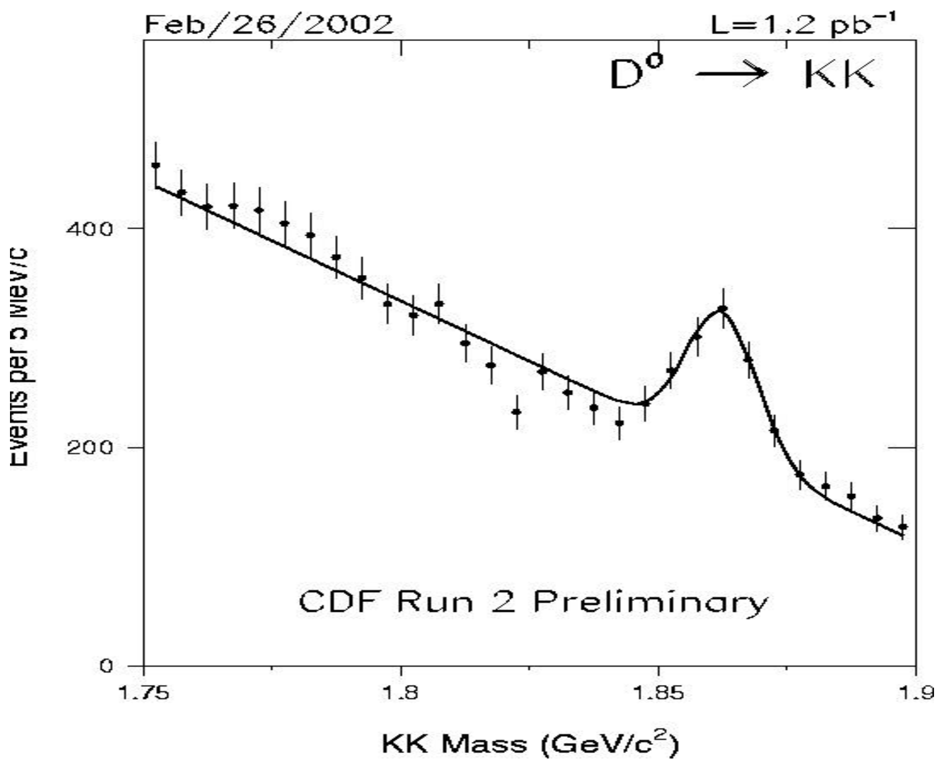
S/N>3

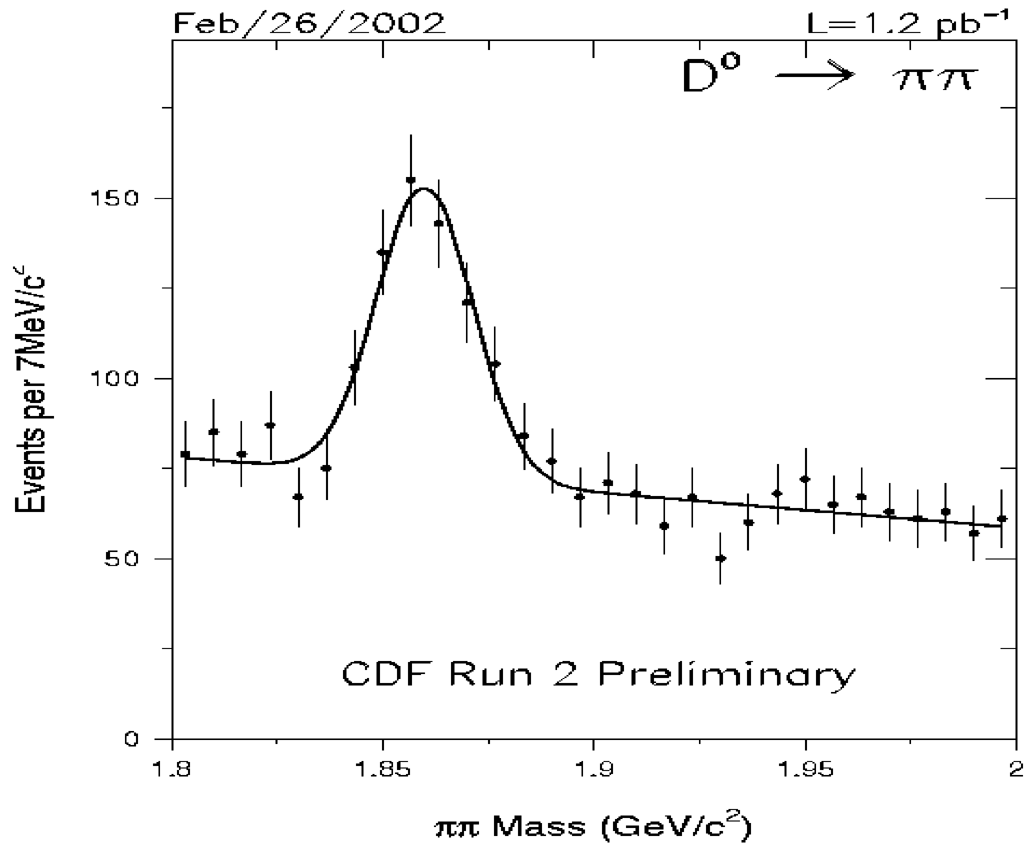
Mass resolution:~10 MeV



Charm reconstruction: Two bodies

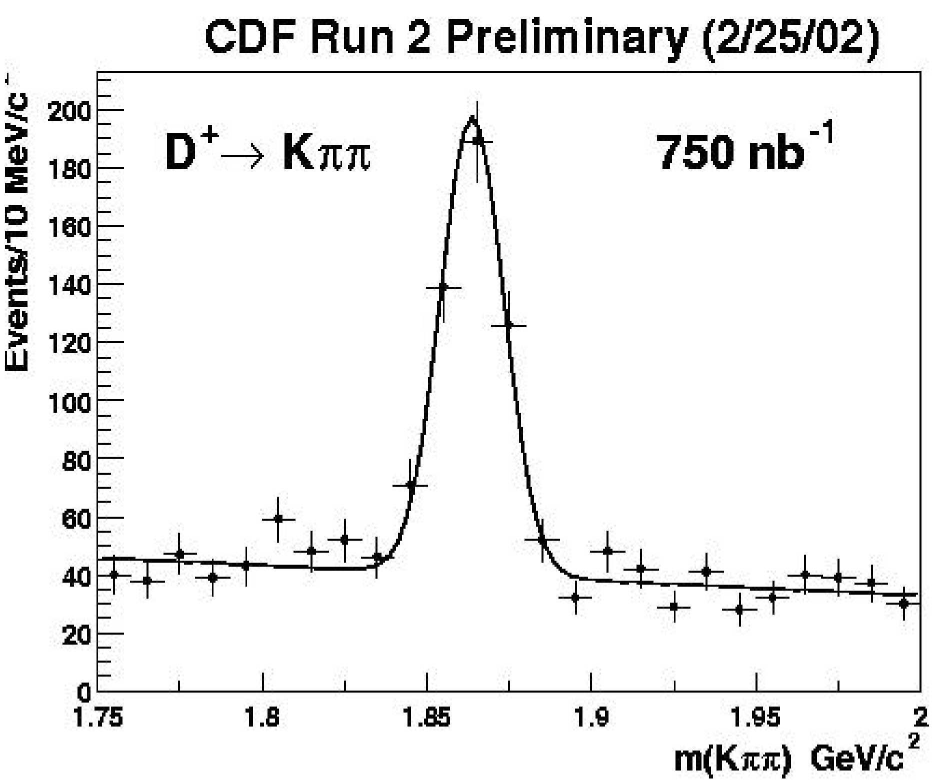
Same cuts as before



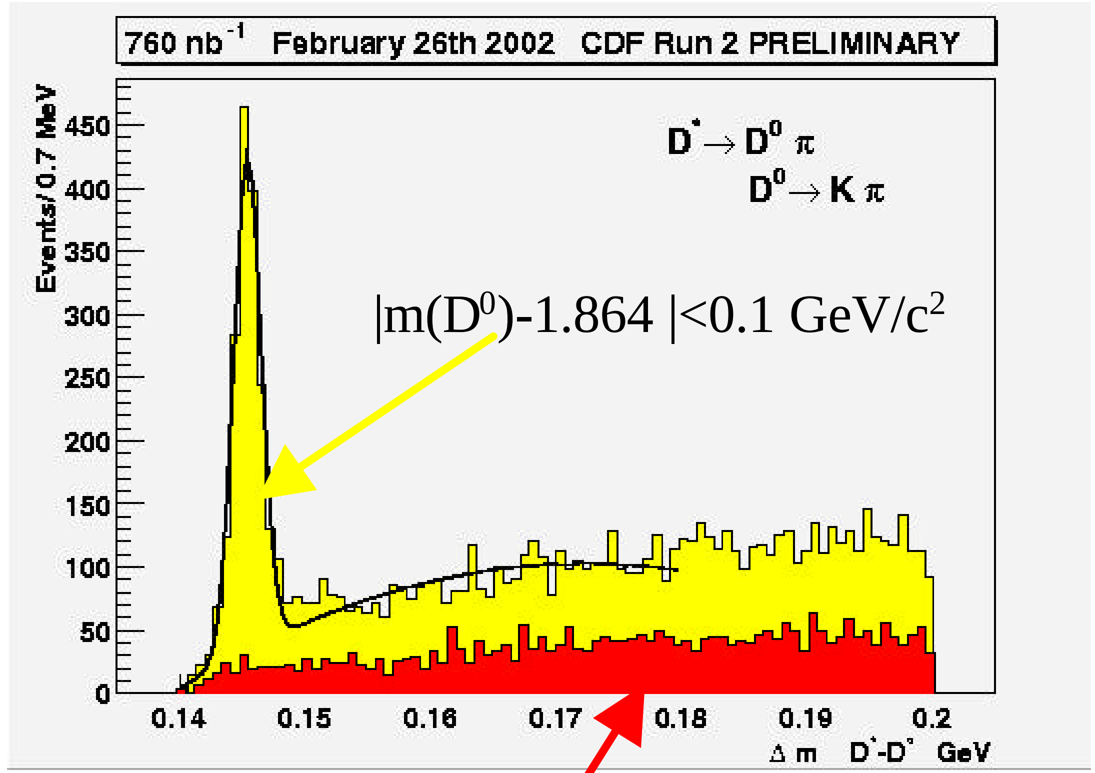


Charm reconstruction: Three prongs

Two tracks: same D^0 cuts
 3^{rd} track: loose cuts
$\Delta R<1$



Almost D^0 standard reconstruction
opposite-charge K and bachelor π



$|m(D^0)-1.864| < 0.1$ GeV/c^2

$|m(D^0)-2.064| < 0.1$ GeV/c^2

A beautiful surprise!

In 50 pb^{-1} we expect:

- ~ 0.5M $D^0 \to K^- \pi^+$
- ~ 44K $D^0 \to KK$
- ~ 16K $D^0 \to \pi\pi$
- ~ 150 $D^0 \to K^+ \pi^-$

To be compared with:

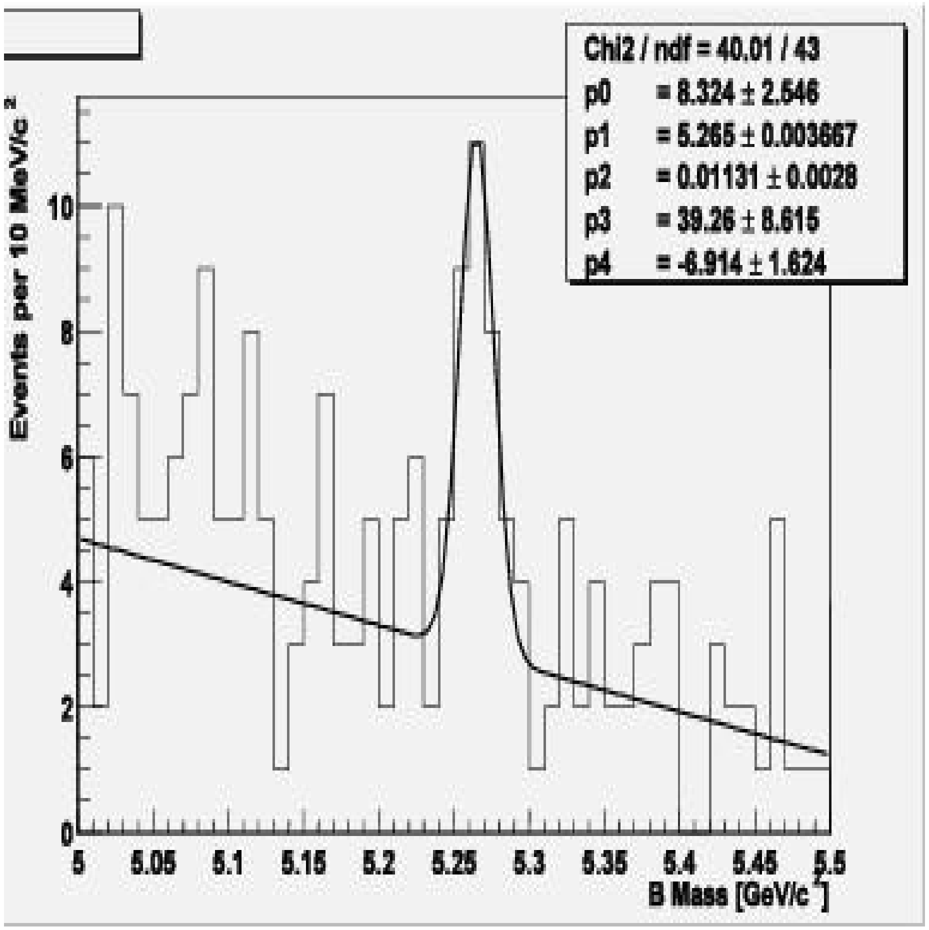
- Fixed target experiments:
  - E791 200K fully reconstr. D
  - FOCUS 1M
  - SELEX almost barions
- CLEO (similar statistic to FOCUS)
- Belle and Babar (better statistic)

Even with a VERY low luminosity we can measure:

- charm meson cross section
- $c\bar{c}$ cross section
- D^0-$\bar{D}^0$ mixing
- $c\bar{c}/b\bar{b}$ cross section

Beauty reconstruction:

$B^{\pm} \rightarrow D^0 \pi^{\pm}$ $D^0 \rightarrow K^- \pi^+$



S=24±5 events

B=19±4 events

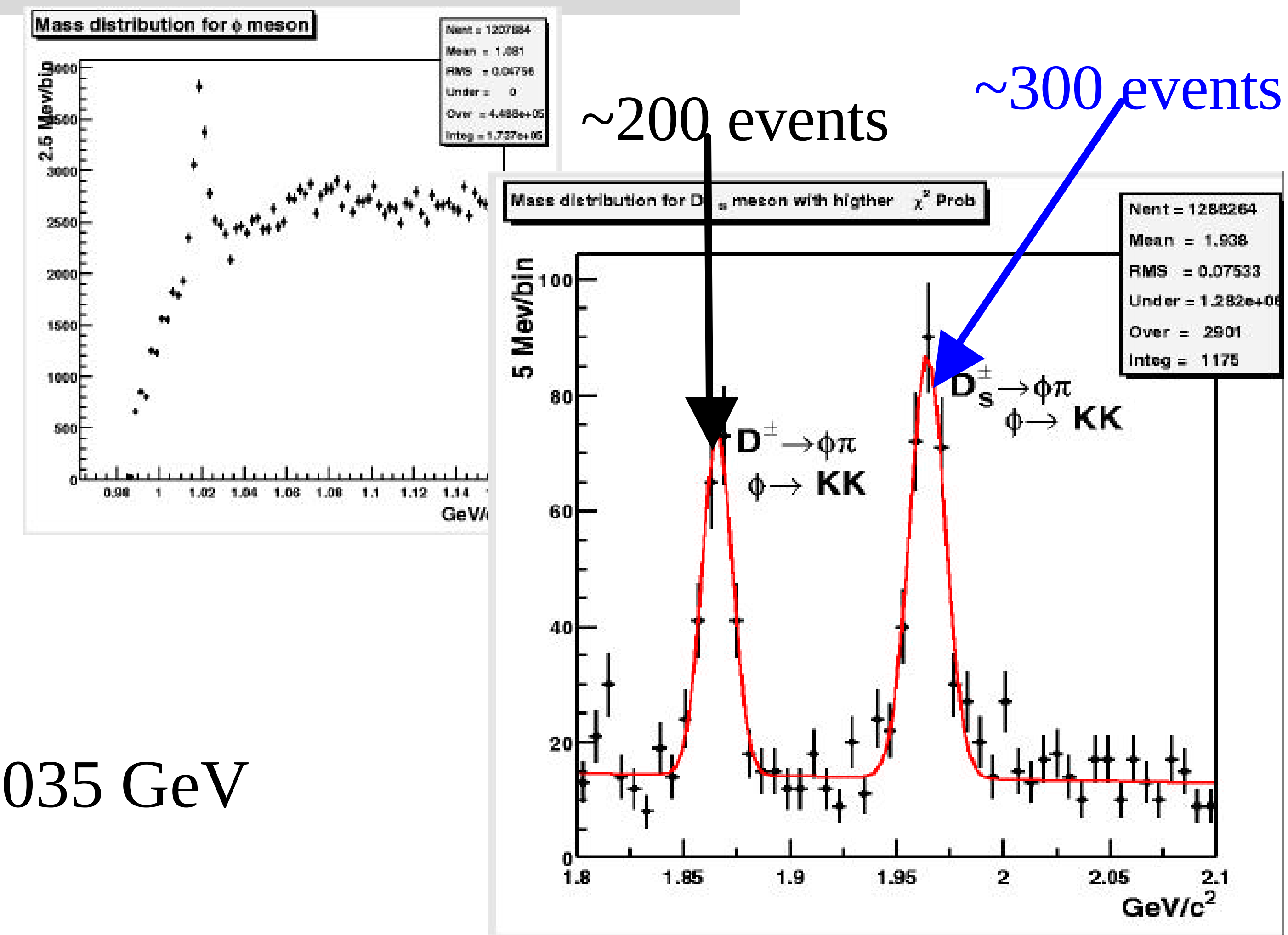
S/B~1.3

σ=11±3 MeV/c^2

Signal compatible with expectations
- SVT efficiency 0.70 instead 0.95
- SVXII coverage from 0.30 to 0.60
- Reconstruction efficiency 0.50

We may expect improvements on all this sources of inefficiency by now

Towards B_s: $D_s^{\pm}\rightarrow\phi\pi^{\pm}$ reconstruction



Cleanest decay:

$D_s^{\pm}\rightarrow\phi\pi^{\pm}$ $\phi\rightarrow K^{+}K^{-}$

2 tracks Pt>2 GeV

|d|>100 mm

3^{rd} track Pt>0.5 GeV

Lxy>0

1.01GeV<m(KK)<1.035 GeV

Here in Padova we are working on it and also

$D_s^{\pm}\rightarrow f^{0}(980)\pi^{\pm}$

Towards B_s: $D_s^{\pm} \rightarrow K^{*0}K^{\pm}$ reconstruction

Less clean but with higher Branching fraction

2 tracks Pt>2 GeV

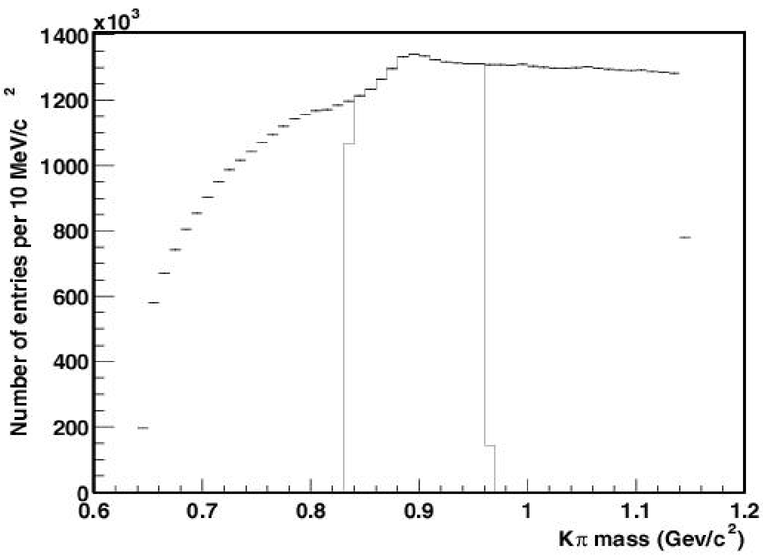
|d|>100 μm

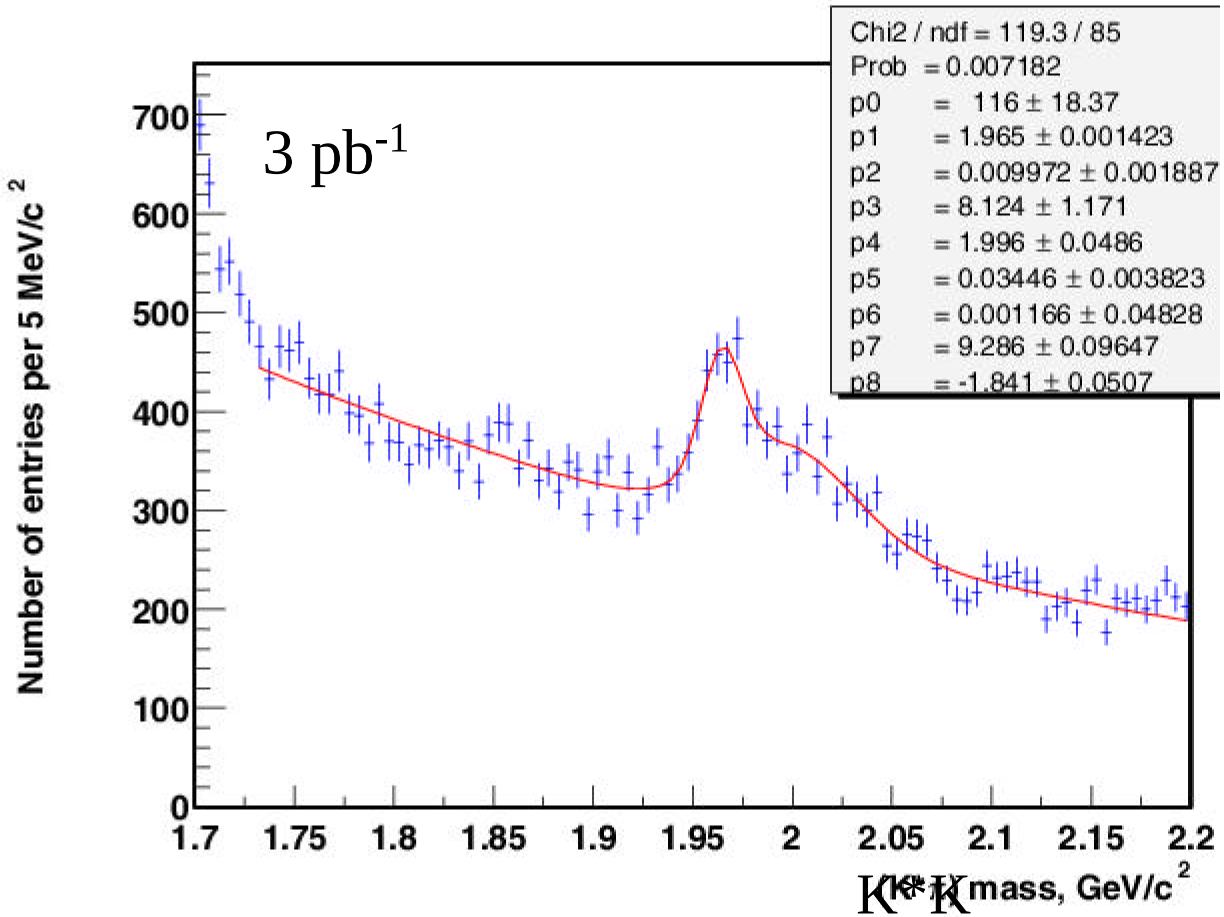
3rd track Pt>0.4 GeV

Lxy>50 μm

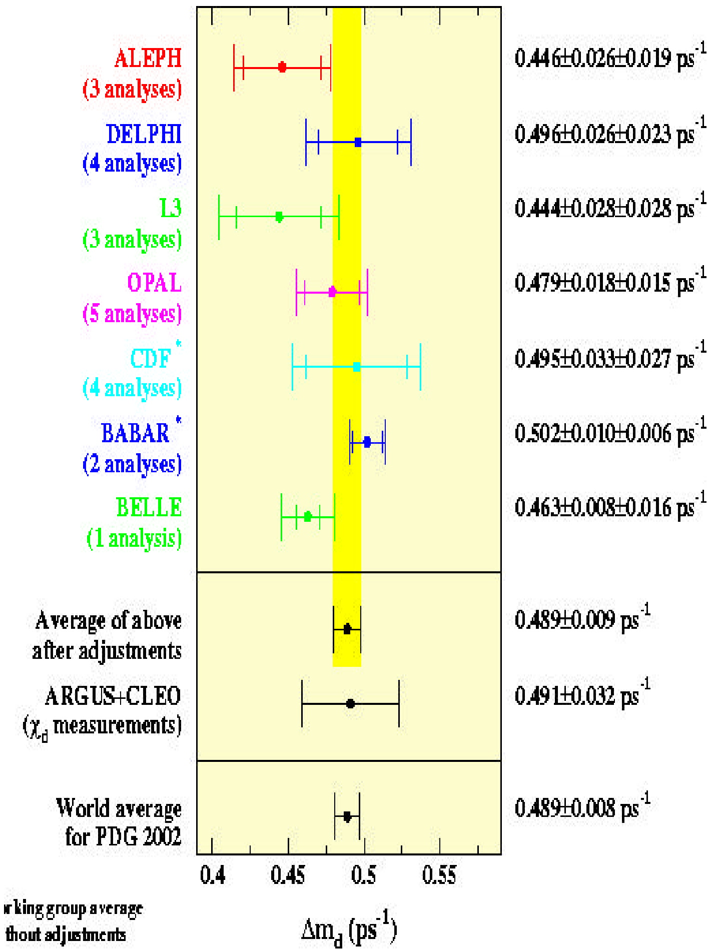
831<m(Kπ)<961 MeV

several angular cuts





The future: $B_{s,d}$ mixing



By measuring both: $\frac{V_{td}}{V_{ts}}$] $\frac{\cap m_d}{\cap m_s}$

Basic ingredients:

1 Reconstruct decay time

1 Tag B flavor at production and decay time

$Sig(\Delta m_s)=\sqrt{(N\varepsilon D^2/2)}\,e^{-(\Delta m_s \sigma_t)^2/2}\sqrt{(S/S+B)}$

Proper time resolution:45 fs achiavable with fully reconstructed decay

Hadronic decay

$\Delta m_s > 13.1\ ps^{-1}$

$X_s > 19.0$

95% C.L

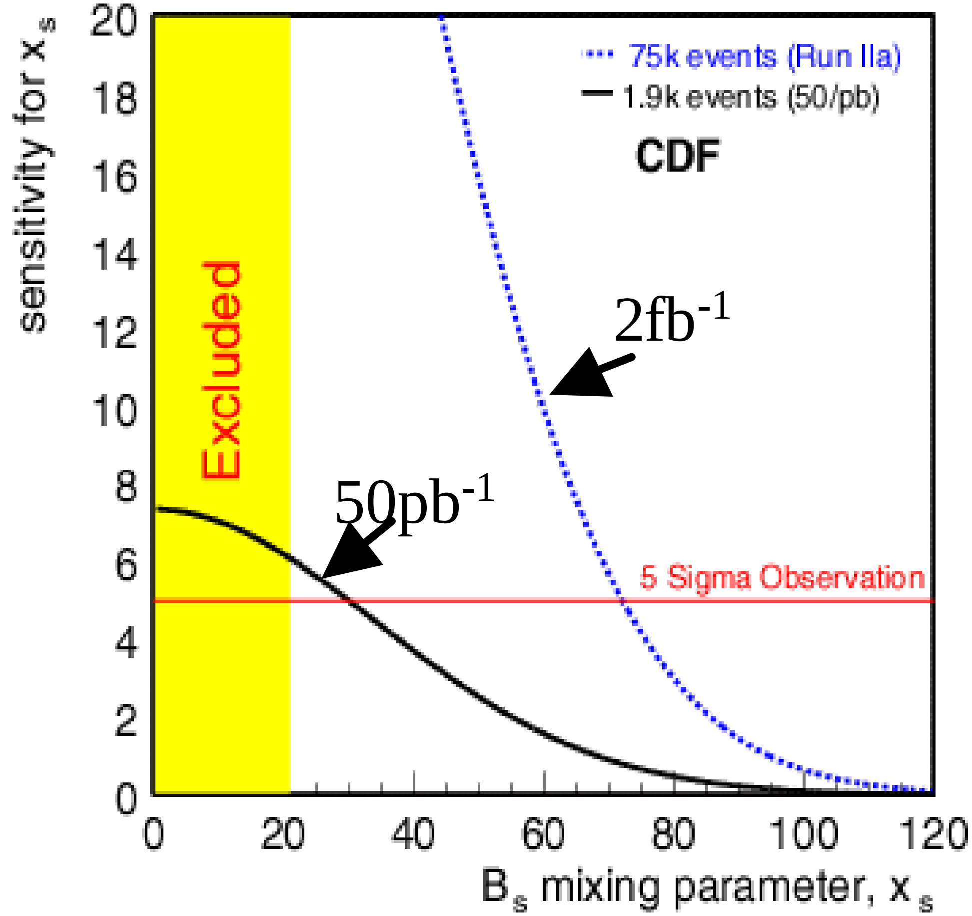
The future: $B_{s,d}$ mixing

Tagging figure of merit: εD^2

Method	Run I	RunII
SLT	1.7%	1.7%
JQT	3.0%	3.0%
SST	1.0%	4.2%
OSK	-	2.4%
Total	5.7%	11.3%

Ongoing calibration on lepton+SVT track

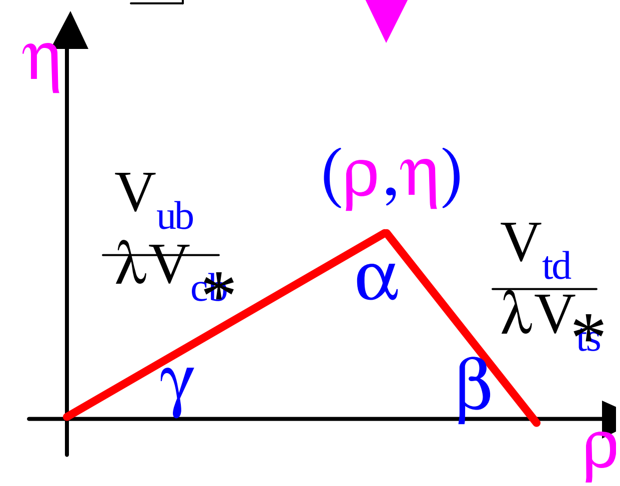
Decay Channel	$N(2fb^{-1})$
$B_s \rightarrow D_s \pi$	37K
$B_s \rightarrow D_s \pi\pi\pi$	38K
$B_s \rightarrow D_s D_s$	2,5K
$B_s \rightarrow D_s^* D_s$	5,7K
$B_s \rightarrow D_s^* D_s^*$	5,2K



Which ~~CP~~ measurement in B hadronic decays?

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

unitarity



1
γ

1. $B^0_s \to D_s^- K^+$
2. $B^- \to D^0 K^-$
3. $B^0 \to h^+ h^-$

$B^0 \to \pi^+\pi^- \Rightarrow \mathit{sin}2(\beta+\gamma)$ $(=\mathit{sin}2(\alpha)$ if $\alpha+\beta+\gamma=\pi)$

but "penguin pollution" can be large

$B^0_s \to D_s^- K^+$

R. Aleksan, et al. Z Phys. C54 653 (1992) proposal:

$B^0_s \to D_s^- K^+$ $B^0_s \to D_s^+ K^-$ time dependent decay rate

$$\Gamma(B_s^0 \to D_s^- K^+) = \frac{|A_f|^2 e^{-\Gamma_s t}}{2}\Big\{(1+|\lambda_f|^2)\cosh(\Delta\Gamma_s t/2) + (1-|\lambda_f|^2)\cos(\Delta m_s t) - 2|\lambda_f|\cos(\delta+\gamma)\sinh(\Delta\Gamma_s t/2) - 2|\lambda_f|\sin(\delta+\gamma)\sin(\Delta m_s t)\Big\},$$

$$\Gamma(B_s^0 \to D_s^+ K^-) = \frac{|A_f|^2 e^{-\Gamma_s t}}{2}\Big\{(1+|\lambda_f|^2)\cosh(\Delta\Gamma_s t/2) - (1-|\lambda_f|^2)\cos(\Delta m_s t) - 2|\lambda_f|\cos(\delta-\gamma)\sinh(\Delta\Gamma_s t/2) + 2|\lambda_f|\sin(\delta-\gamma)\sin(\Delta m_s t)\Big\},$$

$$\Gamma(\bar{B}_s^0 \to D_s^- K^+) = \frac{|A_f|^2 e^{-\Gamma_s t}}{2}\Big\{(1+|\lambda_f|^2)\cosh(\Delta\Gamma_s t/2) - (1-|\lambda_f|^2)\cos(\Delta m_s t) - 2|\lambda_f|\cos(\delta+\gamma)\sinh(\Delta\Gamma_s t/2) + 2|\lambda_f|\sin(\delta+\gamma)\sin(\Delta m_s t)\Big\},$$

$$\Gamma(\bar{B}_s^0 \to D_s^+ K^-) = \frac{|A_f|^2 e^{-\Gamma_s t}}{2}\Big\{(1+|\lambda_f|^2)\cosh(\Delta\Gamma_s t/2) + (1-|\lambda_f|^2)\cos(\Delta m_s t) - 2|\lambda_f|\cos(\delta-\gamma)\sinh(\Delta\Gamma_s t/2) - 2|\lambda_f|\sin(\delta-\gamma)\sin(\Delta m_s t)\Big\}.$$

Best case:
2-fold ambiguity

Δm_s too large
4-fold ambiguity

$\Delta\Gamma/\Gamma$ too small
8-fold ambiguity

Theoretically clean

Reasonable Branching Ratio(0.2,0.1x10^{-3})

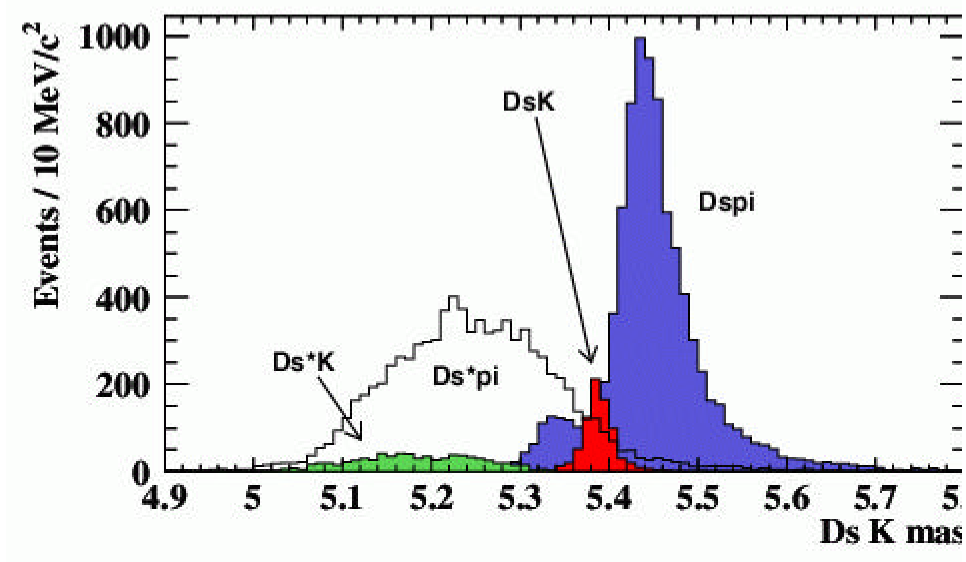
$B^0_s \rightarrow D_s^- K^+$

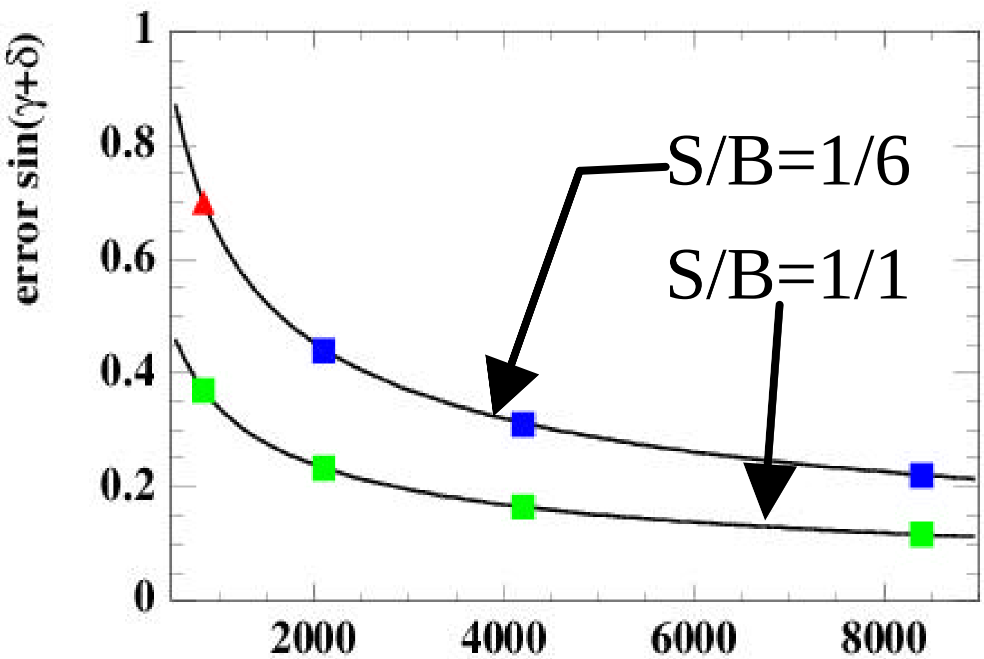
Two track trigger: N~850 events/2fb^{-1}

Difficult background separation

S/B=1/1(physics)

S/B=1/3 -1/10 (combinatorial)





Need time dependent analysis

Need tagging: εD^2=11.3%

N → pre-tagged signal events

$B^- \to D^0 K^-$

Atwood,Dunietz and Soni Phys. Rev. Lett. 78, 3257 (1997)

$$a = \mathcal{B}(B^- \to K^- D^0)$$
$$b = \mathcal{B}(B^- \to K^- \bar{D}^0)$$
$$c(f_1) = \mathcal{B}(D^0 \to f_1), \qquad c(f_2) = \mathcal{B}(D^0 \to f_2)$$
$$c(\bar{f}_1) = \mathcal{B}(D^0 \to \bar{f}_1), \qquad c(\bar{f}_2) = \mathcal{B}(D^0 \to \bar{f}_2)$$
$$d(f_1) = \mathcal{B}(B^- \to K^- f_1), \qquad d(f_2) = \mathcal{B}(B^- \to K^- f_2)$$
$$\bar{d}(f_1) = \mathcal{B}(B^+ \to K^+ f_1), \qquad \bar{d}(f_2) = \mathcal{B}(B^+ \to K^+ f_2)$$

$$d(f_1) = a \times c(f_1) + b \times c(\bar{f}_1) + 2\sqrt{a \times b \times c(f_1) \times c(\bar{f}_1)}\cos(\xi_1 + \gamma)$$
$$\bar{d}(f_1) = a \times c(f_1) + b \times c(\bar{f}_1) + 2\sqrt{a \times b \times c(f_1) \times c(\bar{f}_1)}\cos(\xi_1 - \gamma)$$
$$d(f_2) = a \times c(f_2) + b \times c(\bar{f}_2) + 2\sqrt{a \times b \times c(f_2) \times c(\bar{f}_2)}\cos(\xi_2 + \gamma)$$
$$\bar{d}(f_2) = a \times c(f_2) + b \times c(\bar{f}_2) + 2\sqrt{a \times b \times c(f_2) \times c(\bar{f}_2)}\cos(\xi_2 - \gamma)$$

No time dependent analysis
No tagging
Two tracks Trigger: ~130 events/2fb^{-1}
S/B=1:9(physics)
$\delta\gamma \sim 15^o$ IF:
1. combinatorial background negligible
2. B($B^+ \to K^+ D^0$) known at 20%

$B^0 \rightarrow h^+h^-$

Four decays compete:

- Tree dominant (BR~10^{-6})
  1. $B_d \rightarrow \pi^+\pi^-$ 2. $B_s \rightarrow K^+\pi^-$
- Penguin dominant(BR~10^{-5})
  3. $B_s \rightarrow K^+K^-$ 4. $B_d \rightarrow K^+\pi^-$

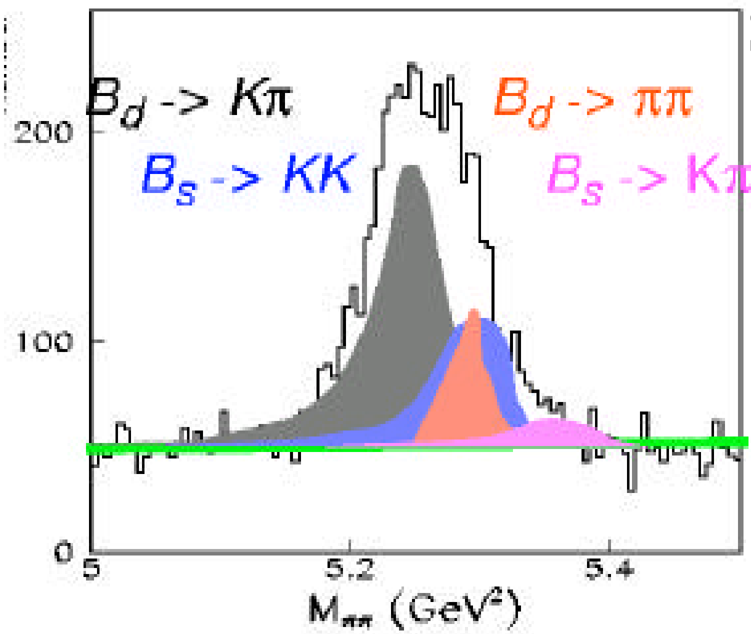
Two track trigger:

$B_d \rightarrow \pi^+\pi^-$ ~5K events

$B_s \rightarrow K^+K^-$ ~10K "

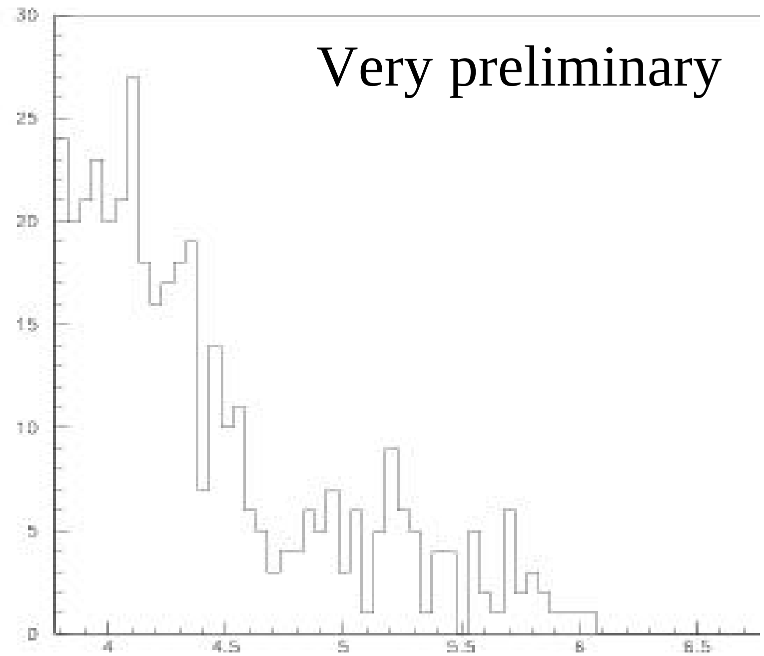
$B_s \rightarrow K^+\pi^-$ ~2,5K "

$B_d \rightarrow K^+\pi^-$ ~20K "



Separated using

1. dE/dx
   (K-π 1.3σ P_t>2)
2. kinematics



$B^0 \to h^+h^-$

R. Fleisher (PLB459, 306 (1999) suggest to use:

1. $B_d \to \pi^+\pi^-$ and 3. $B_s \to K^+K^-$

$$a_{CP}(B_d(t) \to f) \equiv \frac{\Gamma(B_d^0(t) \to f) - \Gamma(\overline{B_d^0}(t) \to f)}{\Gamma(B_d^0(t) \to f) + \Gamma(\overline{B_d^0}(t) \to f)}$$

$$= \mathcal{A}_{CP}^{dir}(B_d \to f)\cos(\Delta M_d t) + \mathcal{A}_{CP}^{mix}(B_d \to f)\sin(\Delta M_d t)$$

$$\mathcal{A}_{CP}^{dir}(B_d \to f) = -\left[\frac{2\, d \sin\theta \sin\gamma}{1 - 2\, d\cos\theta\cos\gamma + d^2}\right]$$

$$\mathcal{A}_{CP}^{mix}(B_d \to f) = \eta\left[\frac{\sin(\phi_d + 2\gamma) - 2\, d\cos\theta\, \sin(\phi_d + \gamma) + d^2 \sin\phi_d}{1 - 2\, d\cos\theta\cos\gamma + d^2}\right]$$

$$a_{CP}(B_s(t) \to f) \equiv \frac{\Gamma(B_s^0(t) \to f) - \Gamma(\overline{B_s^0}(t) \to f)}{\Gamma(B_s^0(t) \to f) + \Gamma(\overline{B_s^0}(t) \to f)}$$

$$= 2\, e^{-\Gamma_s t}\left[\frac{\mathcal{A}_{CP}^{dir}(B_s \to f)\cos(\Delta M_s t) + \mathcal{A}_{CP}^{mix}(B_s \to f)\sin(\Delta M_s t)}{e^{-\Gamma_H^{(s)} t} + e^{-\Gamma_L^{(s)} t} + \mathcal{A}_{\Delta\Gamma}(B_s \to f)(e^{-\Gamma_H^{(s)} t} - e^{-\Gamma_L^{(s)} t})}\right]$$

$$\mathcal{A}_{CP}^{dir}(B_s \to f) = +\left[\frac{2\, \tilde{d}' \sin\theta' \sin\gamma}{1 + 2\, \tilde{d}'\cos\theta'\cos\gamma + \tilde{d}'^2}\right]$$

$$\mathcal{A}_{CP}^{mix}(B_s \to f) = +\eta\left[\frac{\sin(\phi_s + 2\gamma) + 2\, \tilde{d}' \cos\theta'\, \sin(\phi_s + \gamma) + \tilde{d}'^2 \sin\phi_s}{1 + 2\, \tilde{d}'\cos\theta'\cos\gamma + \tilde{d}'^2}\right]$$

$$\mathcal{A}_{\Delta\Gamma}(B_s \to f) = -\eta\left[\frac{\cos(\phi_s + 2\gamma) + 2\, \tilde{d}' \cos\theta' \cos(\phi_s + \gamma) + \tilde{d}'^2 \cos\phi_s}{1 + 2\, \tilde{d}'\cos\theta'\cos\gamma + \tilde{d}'^2}\right].$$

$e^{i\theta}$: function of peng/tree $\phi_d = 2\beta$

$\phi_s = -2\delta\gamma$

Assuming SU(3) symmetry: $d' = d$ $\theta' = \theta$

	$\gamma = 60^o$		$\gamma = (60^{+5.4}_{-6.8})^o$
Input	$d = 0.3$, $\theta = 0$	Output	$d = 0.3^{+0.11}_{-0.07}$, $\theta = 0 \pm 10.8$
	$\beta = 22.2^0 \pm 2.0^0$		$\beta = 22.2^0 \pm 2.0^0$

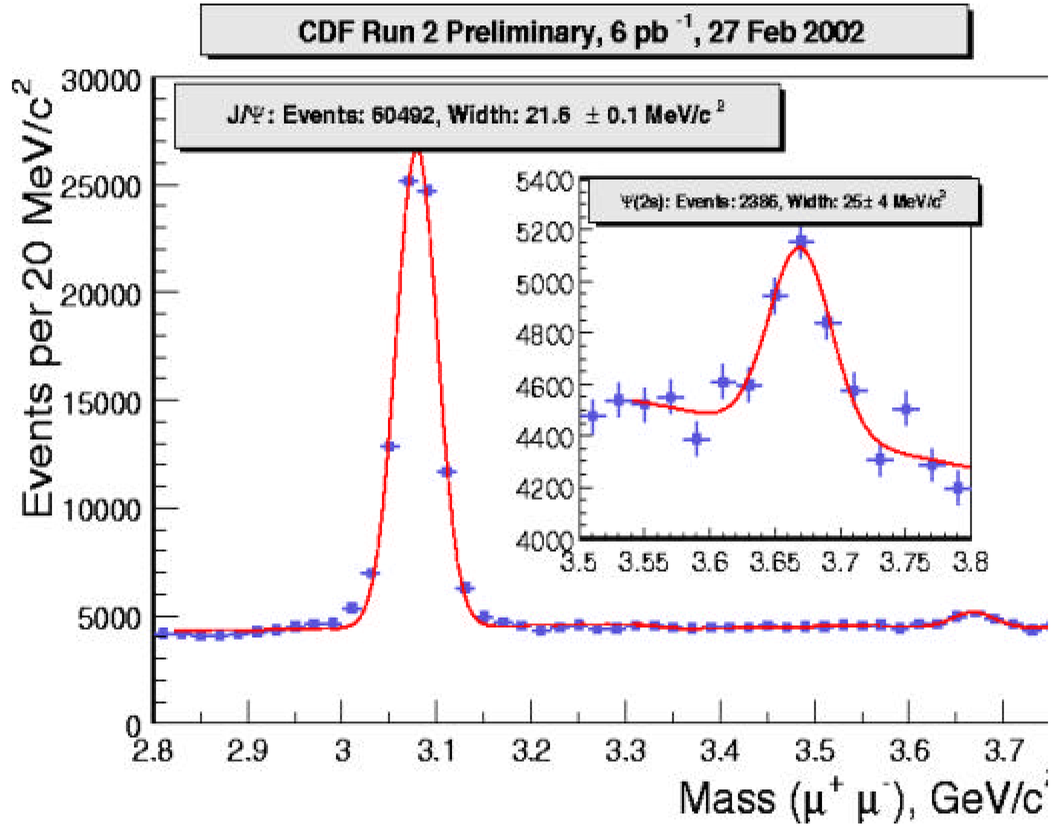
μμ Sample

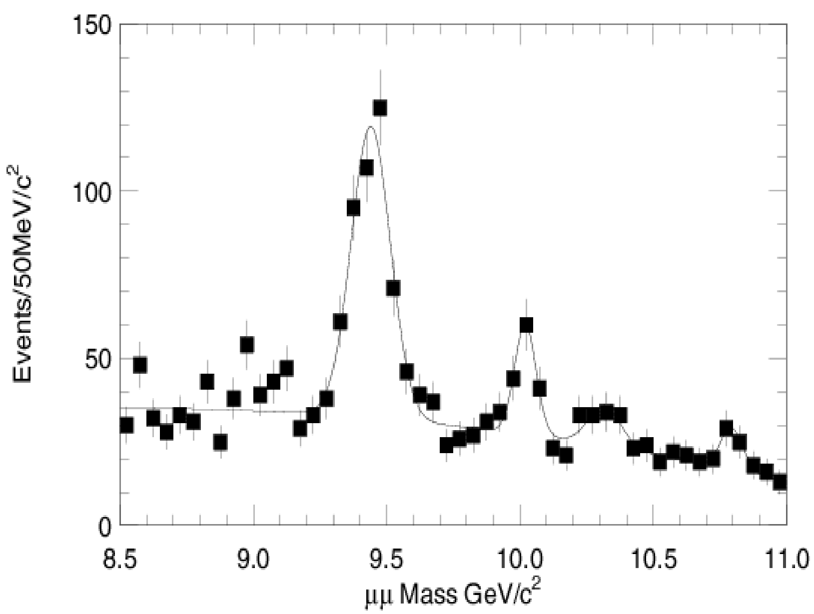
Usefull for

: Tracking

- optimization
- efficiency
- magnetic field correction

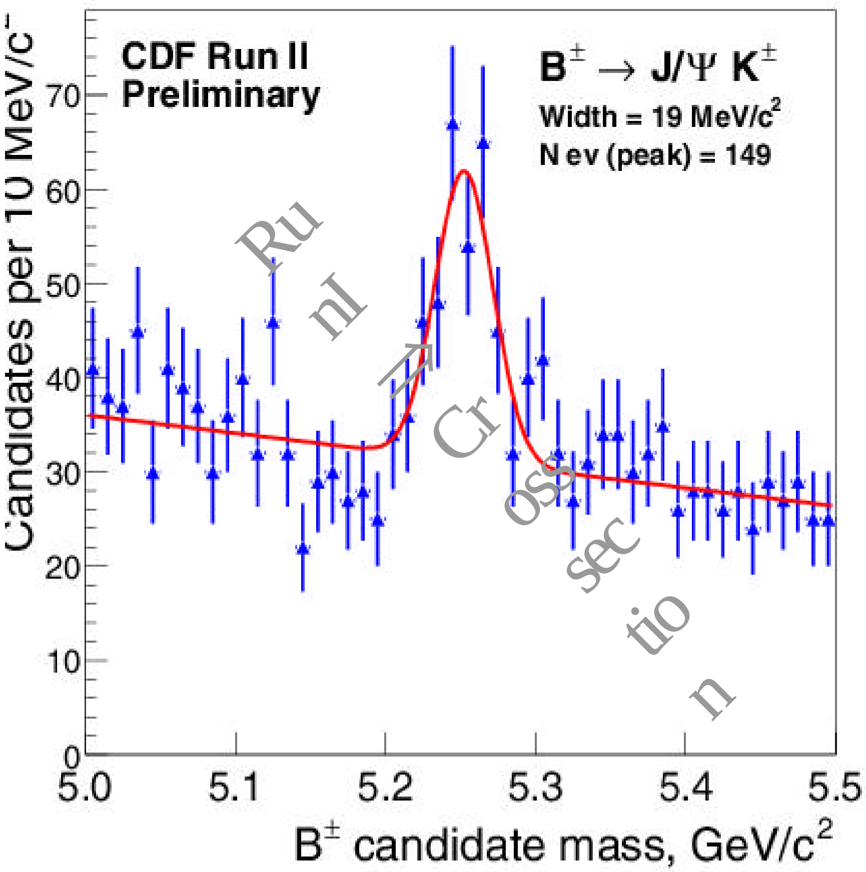
: Trigger efficiency (SVT)





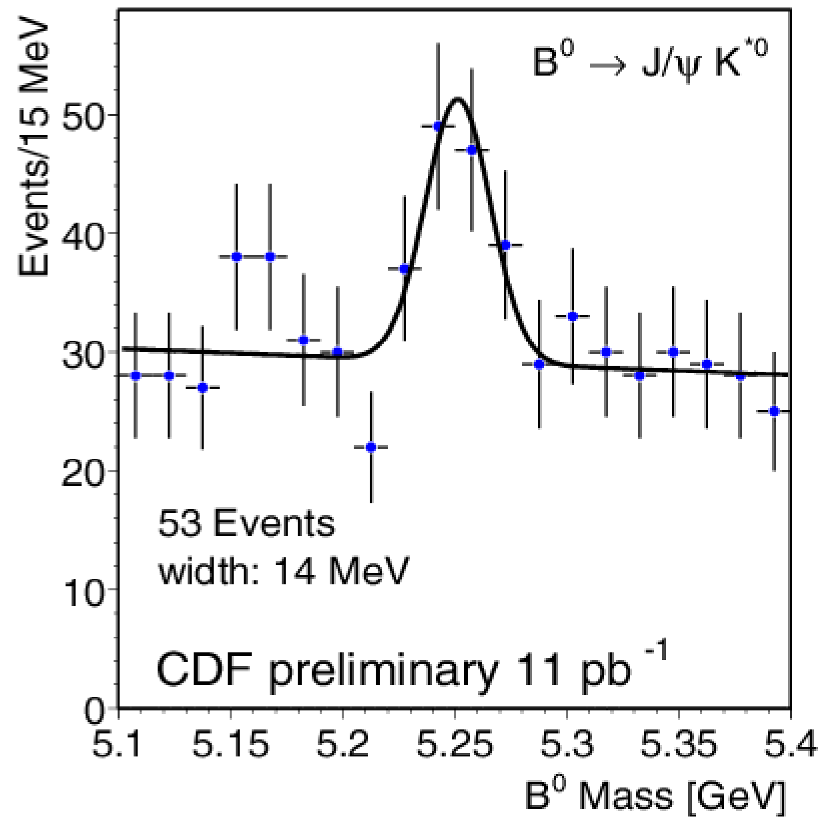
Many B→J/ψ +X Decays

$B_u \to J/\psi K$



$P_t(k)>2$ GeV
$P_t(B)>6$ GeV

$B_d \to J/\psi K^*$



$P_t(k)>3$ GeV $P_t(\pi)>0.5$ GeV
$P_t(B)>4.5$ GeV $L_{xy}>0$
810<m(K*)<970 MeV

B→J/ψ K_s Decays

Run I: sin(2β)=0.79 $^{+0.41}_{-0.44}$ stat ⊕ sys.

Scale the error for RunII: $\sigma(\sin 2\beta) = \frac{\sigma(A)}{D} \oplus \sin 2\beta \bullet \frac{\sigma(D)}{D}$

<u>Statistical error:</u>

RunI: 198±17 events

RunII: 10,000 events

x50 luminosity +

detector improvements

$\frac{\sigma(A)}{D}$ =0.067

<u>Systematic error:</u>

RunI: εD^2=(6.3±1.7)%

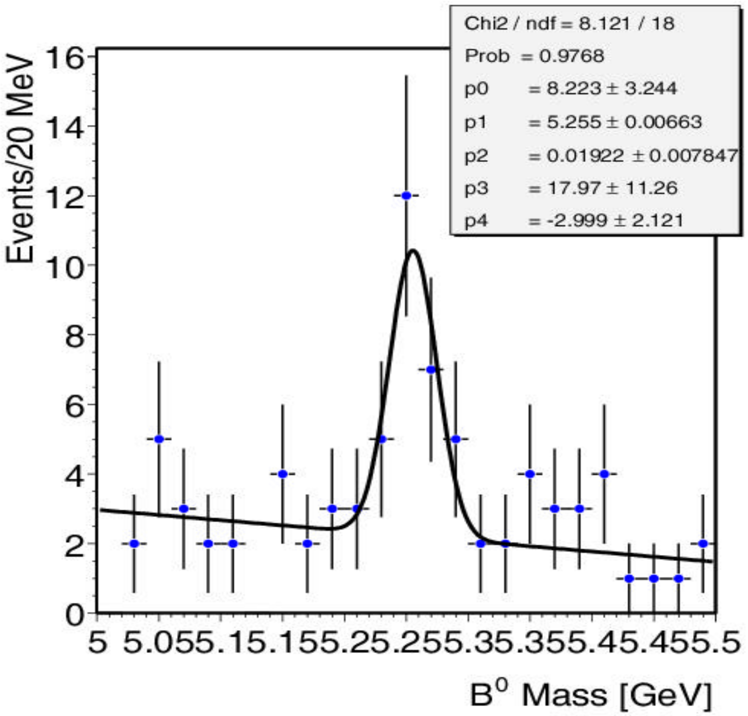
RunII:9.1% $\frac{\sigma(D)}{D}$ =0.027

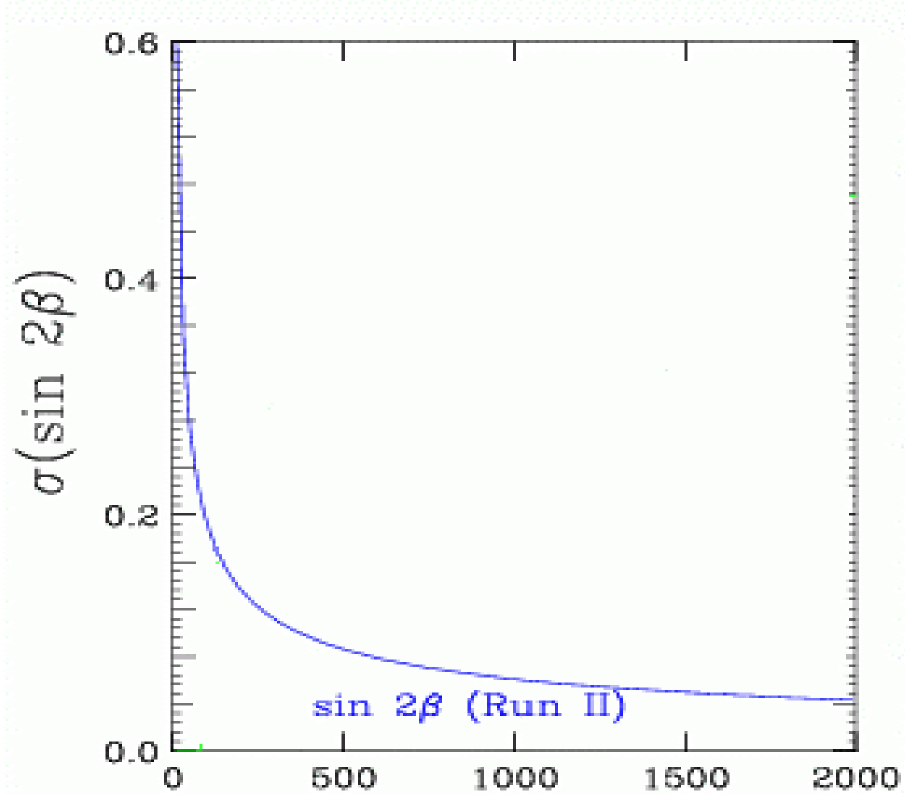
If *sin*(2β)=1 ⇒ σ(*sin*(2β))=0.072

If N~28,000 σ(*sin*(2β))=0.043

BaBar latest results: 0.75 ± 0.09(stat.) ± 0.04(syst.)

$B \to J/\psi\ K_s$ Decays



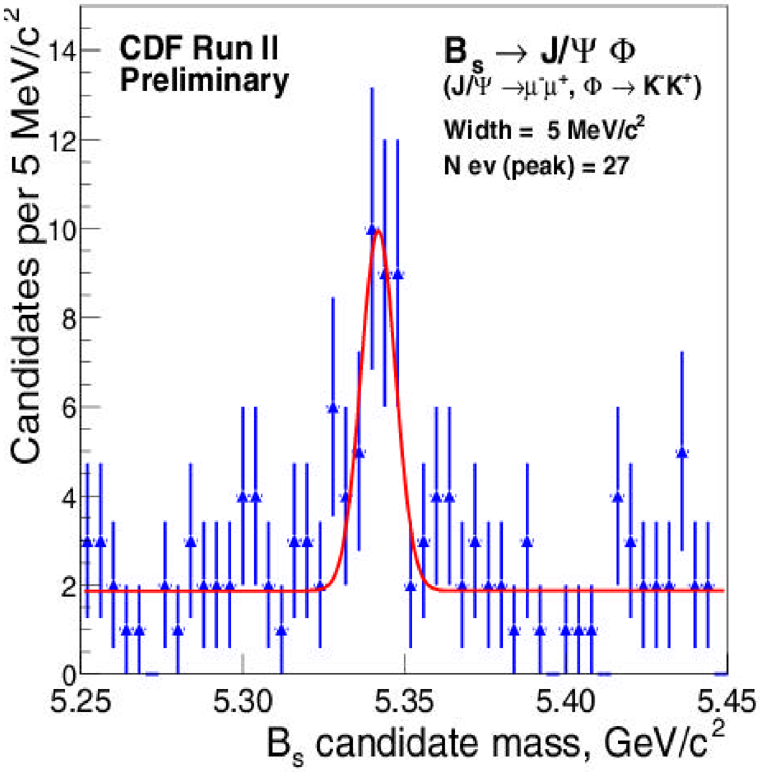


K_s: $P_t(\pi)>0.4$GeV
$479<m(\pi\pi)<512$ MeV

J/ψ: $3.0<m(\mu\mu)<3.16$ GeV

B: Angular cut

B→J/ψ φ: CP beyond S.M.

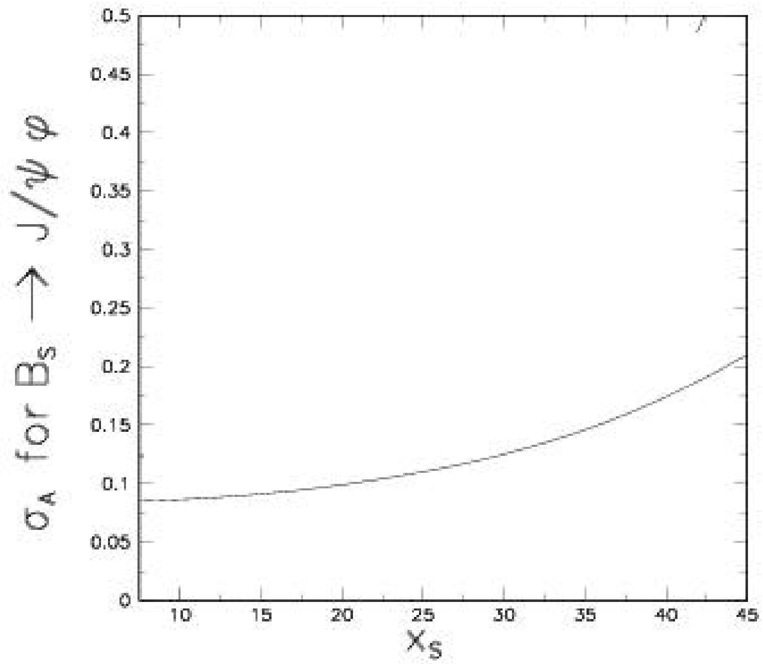


CP asymmetry

- CP asymmetry ~few %
- if larger ⇒ new physics
- measure CP asymmetry ⇒phase β_s

RunII: ~4,000 events $2fb^{-1}$

$\varepsilon D^2 = 9.7\%$



$P_t(B)>5$ GeV

$1.00964<m(\varphi)<1.02964$ MeV

$P_t(\varphi)>2$ GeV

New B_s lifetime hopefully in summer

$B \to J/\psi\ \varphi$: $\Delta\Gamma/\Gamma$

$\Delta\Gamma/\Gamma = 1/2(\Gamma_h - \Gamma_l)/(\Gamma_h + \Gamma_l)$

$\Delta\Gamma/\Gamma$ = 0.05 - 0.20 in the Standard Model

Run I: $\Delta\Gamma/\Gamma = 0.36^{+50}_{-42}$

RunII:

S/N & mass resolution=RunI $\sigma(c\tau)$=18μm

$CP_{even} = 0.77 \pm 0.19 \Rightarrow \sigma(\Delta\Gamma/\Gamma) = 0.05$

$CP_{even} = 0.5(1) \Rightarrow \sigma(\Delta\Gamma/\Gamma) = 0.08\ (0.035)$

Other decays:

$B_s \to D_s \pi \Rightarrow$ measure $1/\Gamma$

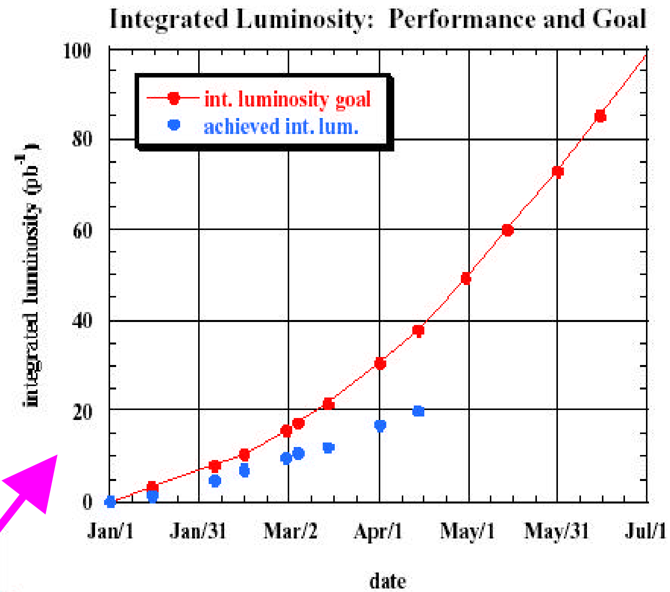
$B_s \to D_s D_s$ (CP even) $\Rightarrow \sigma(\Delta\Gamma/\Gamma) = 0.06$

I did not say anything about:

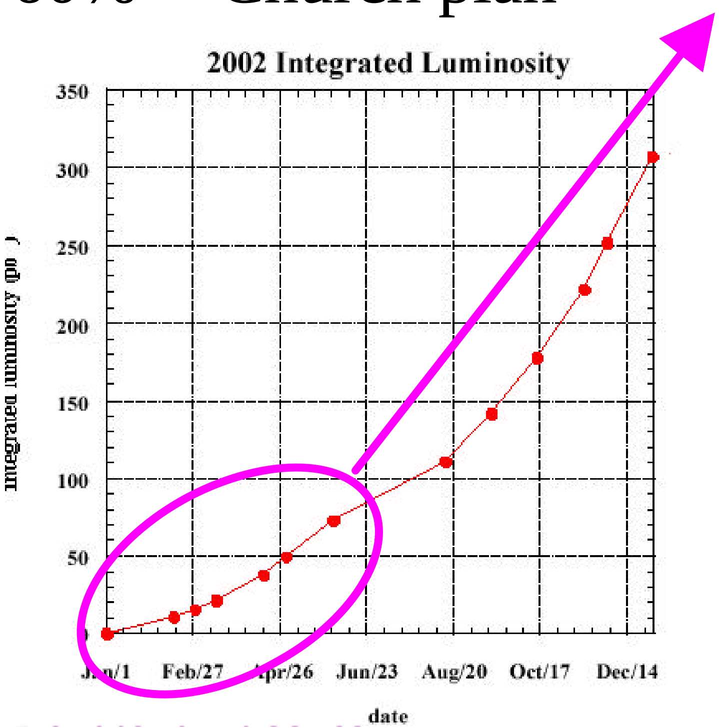
- Cross sections (B,b, D,c)
- $B_{d,s}$ Lifetimes (exclusive, inclusive)
- B_c
- Λ_b lifetime and polarizzazion
- spettroscopy
- Quarkonia production and polarization
- Rare decays: $B_{d,s} \to K^*\gamma$ $\Lambda_b \to \Lambda\gamma$ $B_d \to K^*\mu\mu$ $B \to \mu\mu$
- β_s through $B_s \to J/\psi\, \eta(\eta')$ (~1,000 events/2fb^{-1})

Conclusions

Even with very few pb^{-1} of data CDF can do a lot of B & D physics



oncerns about
uminosity:
60% ``Church plan"



but the new adventure already started

Luminosity progress in RunI
~1yr to get x10
Steady progress after that