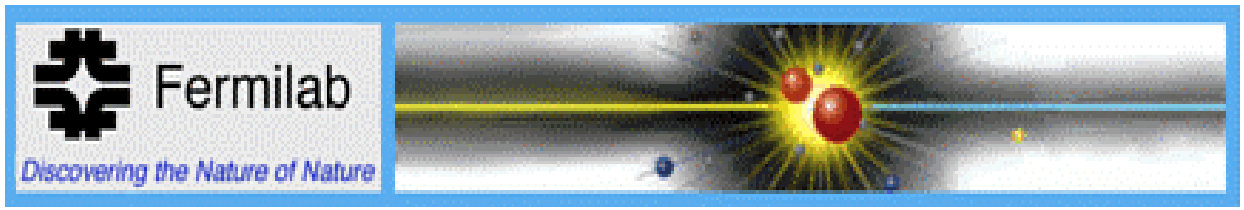
Report on the Tevatron Collider Program



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Istituto Nazionale di Fisica Nucleare
Sezione di Pisa
with the help of many colleagues
from

Outline of this talk

Tevatron status and near (2003) future

- current performances and future improvements

D0 and CDF status

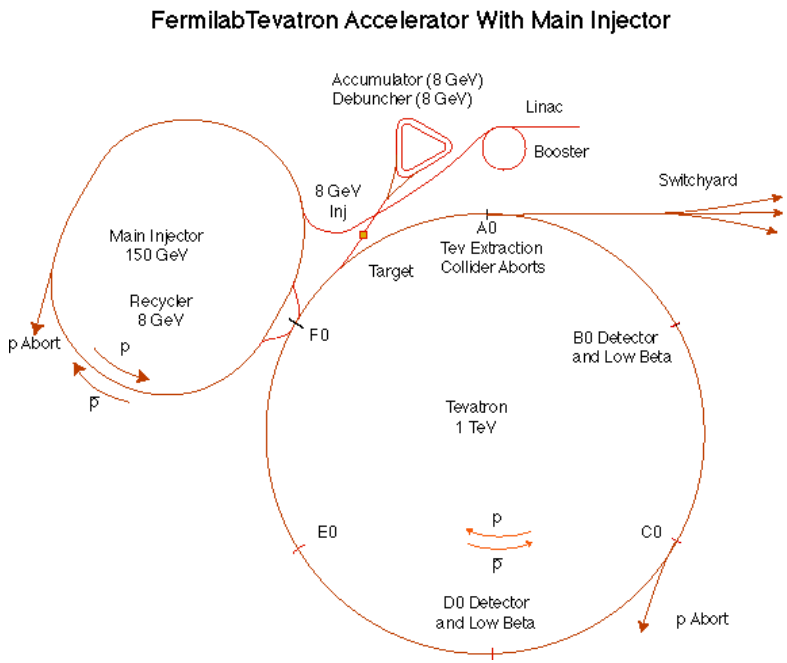
- detectors
  - selected parts
- analysis
  - selected topics

Future perspectives

Tevatron- Introduction

The Tevatron collider is an ensemble of accelerators.

- Luminosity goals for Run2a
  - $L=8 \times 10^{31}\ cm^{-2}s^{-1}$ (without Recycler)
  - $L=1 \div 2 \times 10^{32}\ cm^{-2}s^{-1}$ (with Recycler)
  - total integrated luminosity: $2 fb^{-1}$

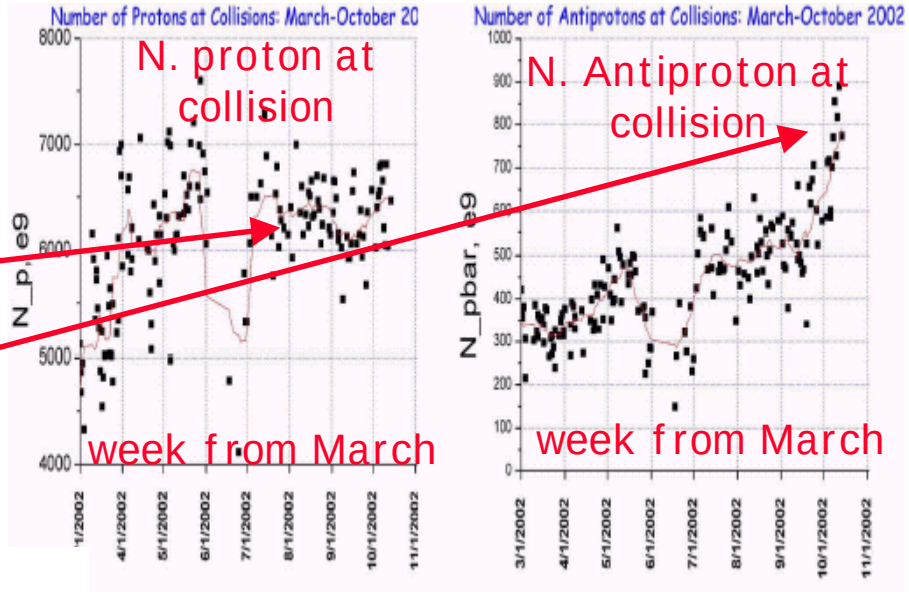


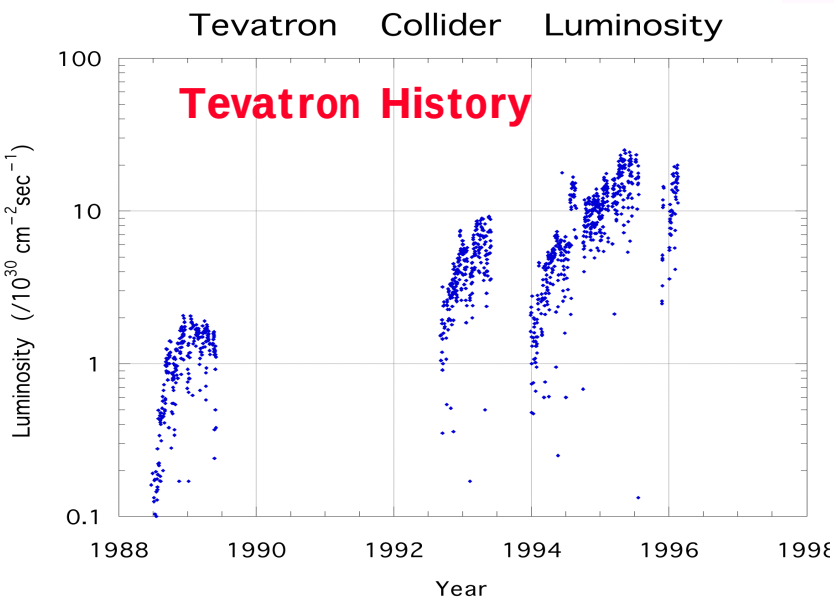
- Recycler Ring is designed to collect and recycle pbars at the end of a store

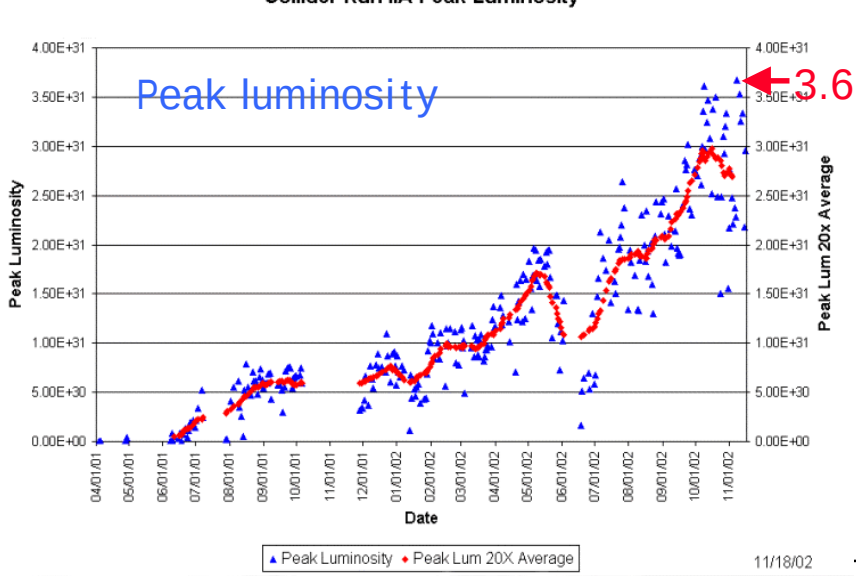
Tevatron Performance- Run2a

Startup was slow
Progress steady:

- ☞since March 02
  - ⇨Np x 1.4
  - ⇨Npbar x 2.5







Goals and current performance

$$L = \frac{10^{-6} f B N_p N_{pb} (6\beta_r \gamma_r)}{2\pi\beta^* (\varepsilon_p + \varepsilon_{pb})} H(\sigma_l / \beta^*)(10^{31} cm^{-2} s^{-1})$$

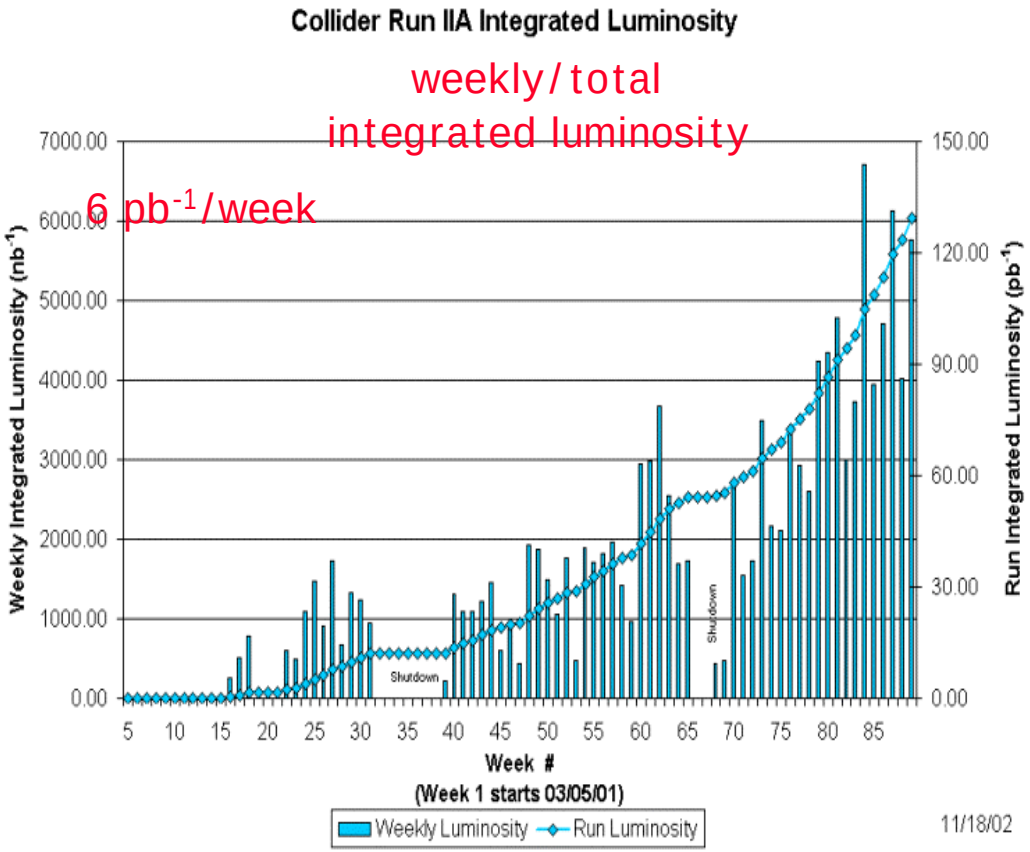
	Now	Run 2a goals	units
Protons/bunch	200	270	10^9
Pbar/bunch	26	30	10^9
Total Pbar	900	1080	10^9
Peak Pbar prod. rate	130	200	10^9/hour
Pbar:AA→ low β	0.60	0.81	
P emittance	20	20	π mm-mr
Pbar emittance	18	15	π mm-mr
Bunch length (p, rms)	0.61	0.37	m
Bunch length (pbar, rms)	0.54	0.37	m
Typical lum.	3.2	8.1	$10^{31}cm^{-2}s^{-1}$
Integrated L	5-6.7	16	pb^{-1}/week

Running with 36x36 bunches

Present and near future

A number of improvements in 2002

- change ramp to low β
- new injection helix
- change lattice in AA
- improve AP emittance
- improve APcoalescing
- ...



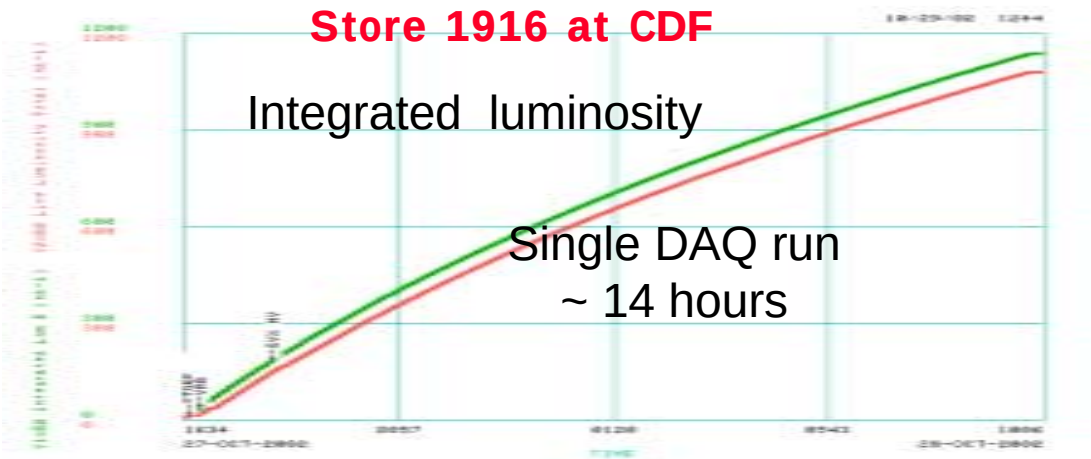
increased luminosity *and* better beam

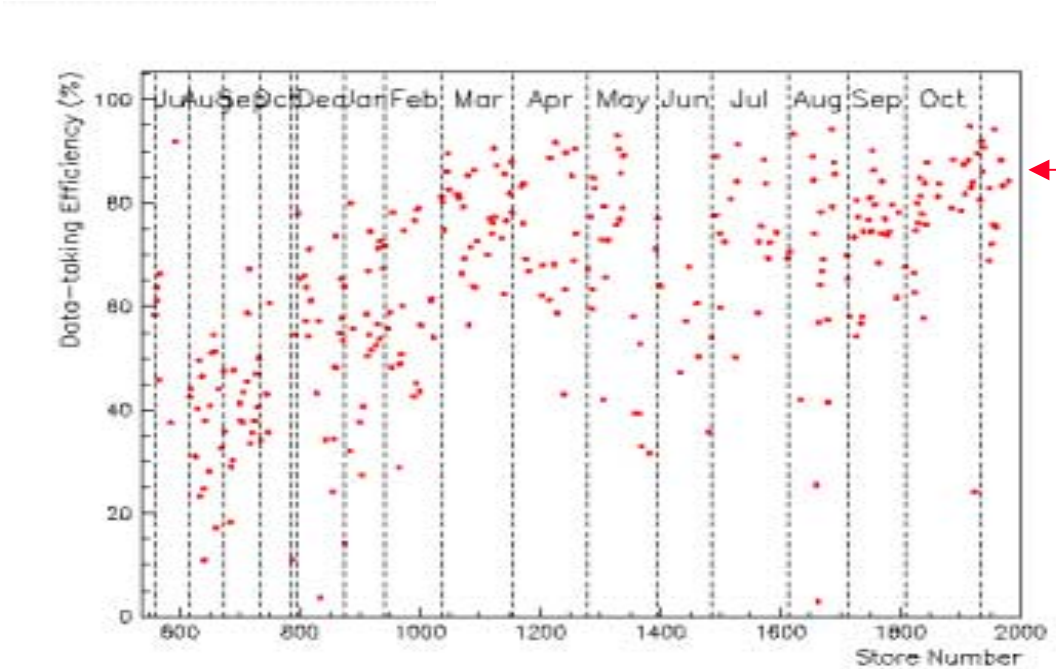
Effect on the experiments...

an excellent CDF run:
1.14 pb^{-1} delivered

1.08 pb^{-1} written to tape

94.5% eff. for store





85%

Less losses, more stable operations: more luminosity to tape

Short term plans

Deliver 100-130 pb^{-1} in 2002

Short (~3 weeks) shutdown in early 2003

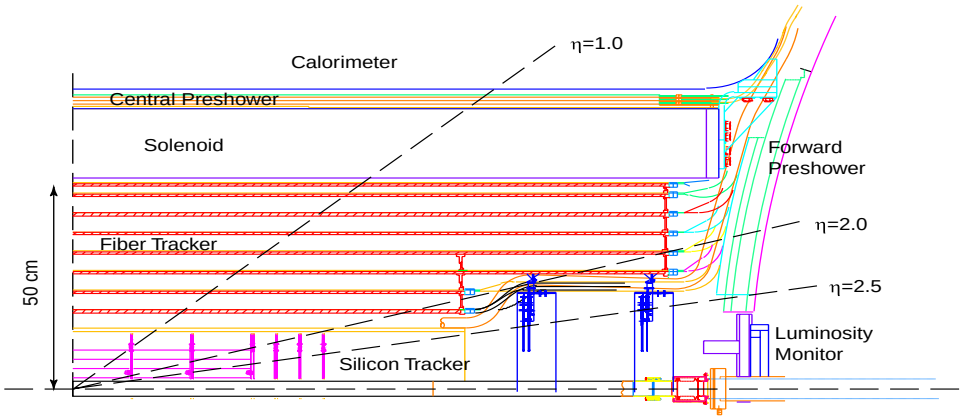
- remove obstruction to aperture in C0
- others (dampers, TEL, etc)

During 2003

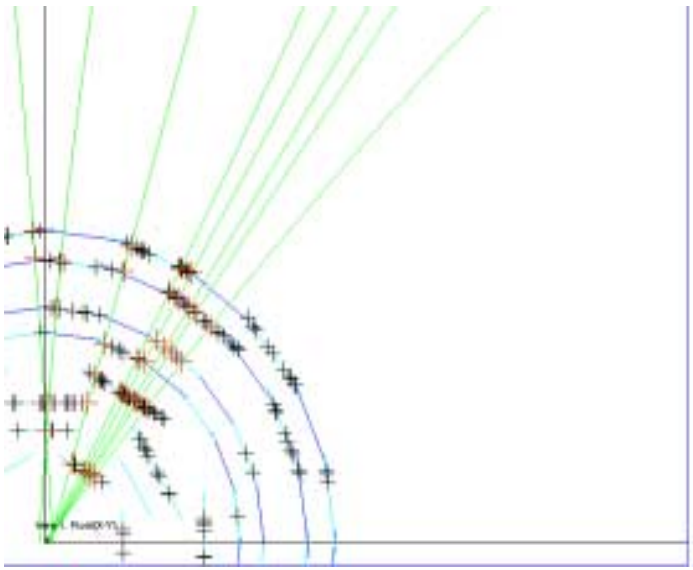
- Work on Recycler
- improvements to the Tevatron

By September 2003:
expect 200/320 pb^{-1} (base/stretch) delivered (per experiment)

D0 upgrades for Run I I

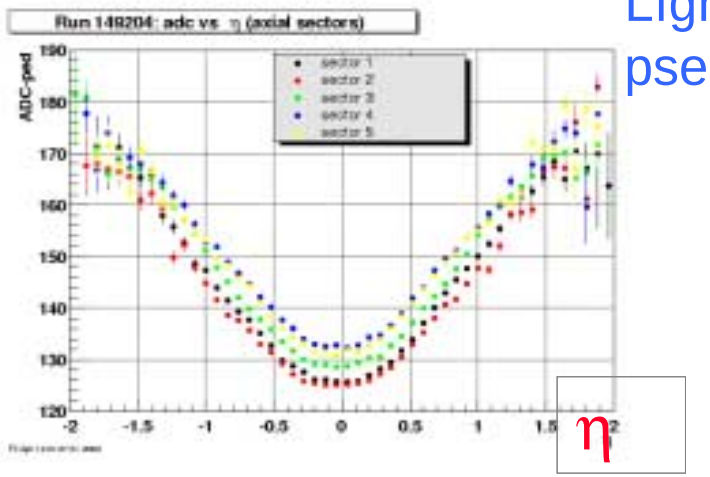


- new trigger and DAQ
- new tracking system
  - 2T magnetic field
  - silicon vertex detector
  - 8 layers fiber tracker
  - preshower
- improved muon spectrometer



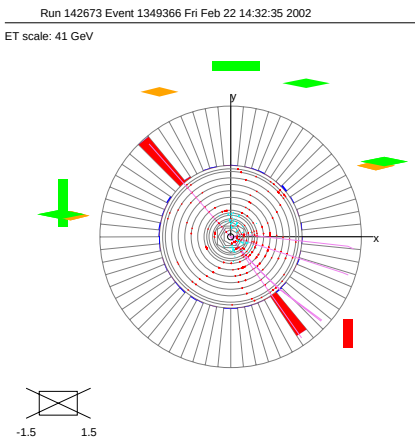
Scintillating fiber tracker

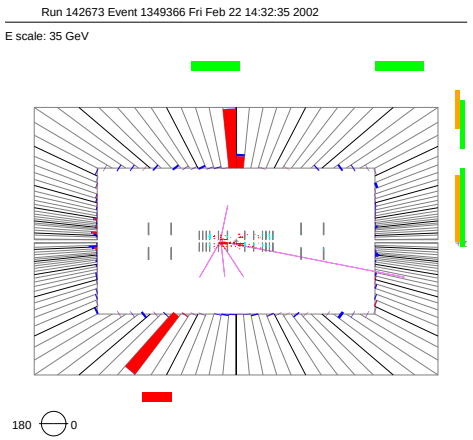
D0 Fiber Tracker is operational:



Light yield as a function of pseudorapidity

Z→ee candidate
Mass 93.2 GeV/c^2





8 axial, 8 stereo layers
fully instrumented
VLPC readout

Performing well:

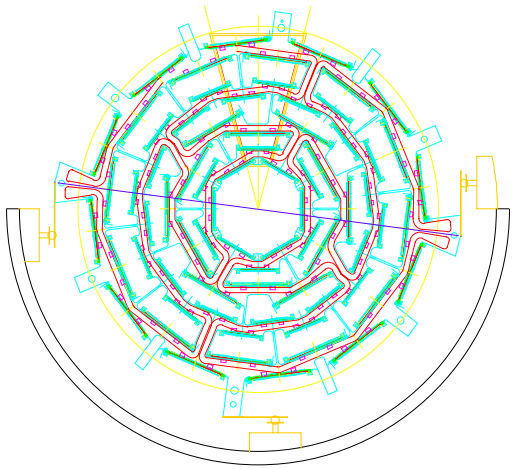
good light yield

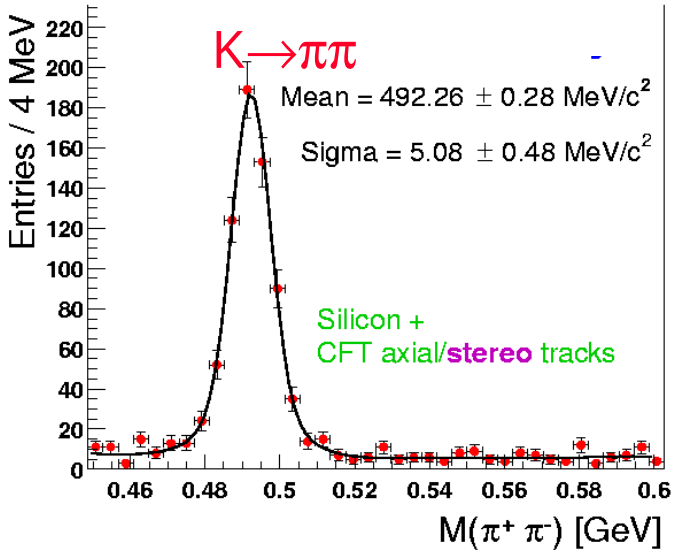
layer ε > 98%

L1 tracking trigger (using this tracker) being commissioned

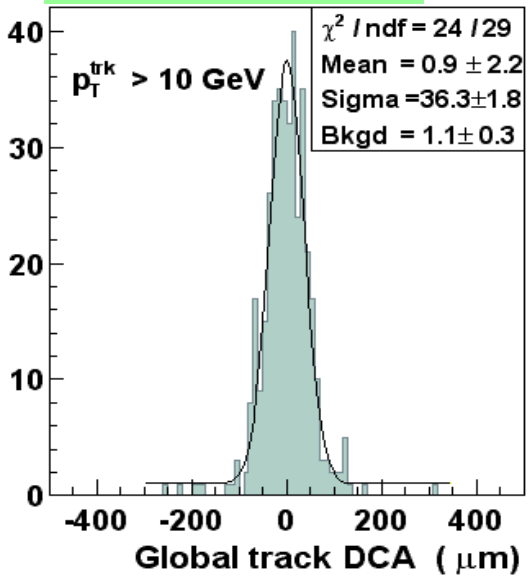
Tracking using silicon

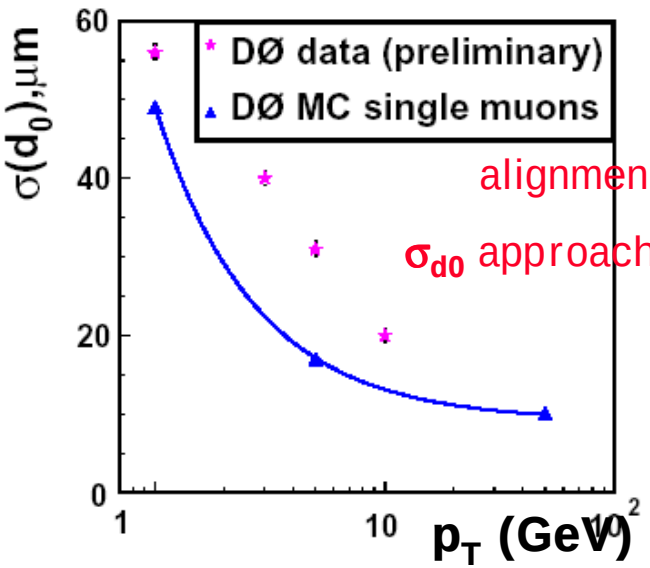
R-φ view of si tracker





width = 36 μm
σ(beam) = 30 μm
→ σ = 20 μm



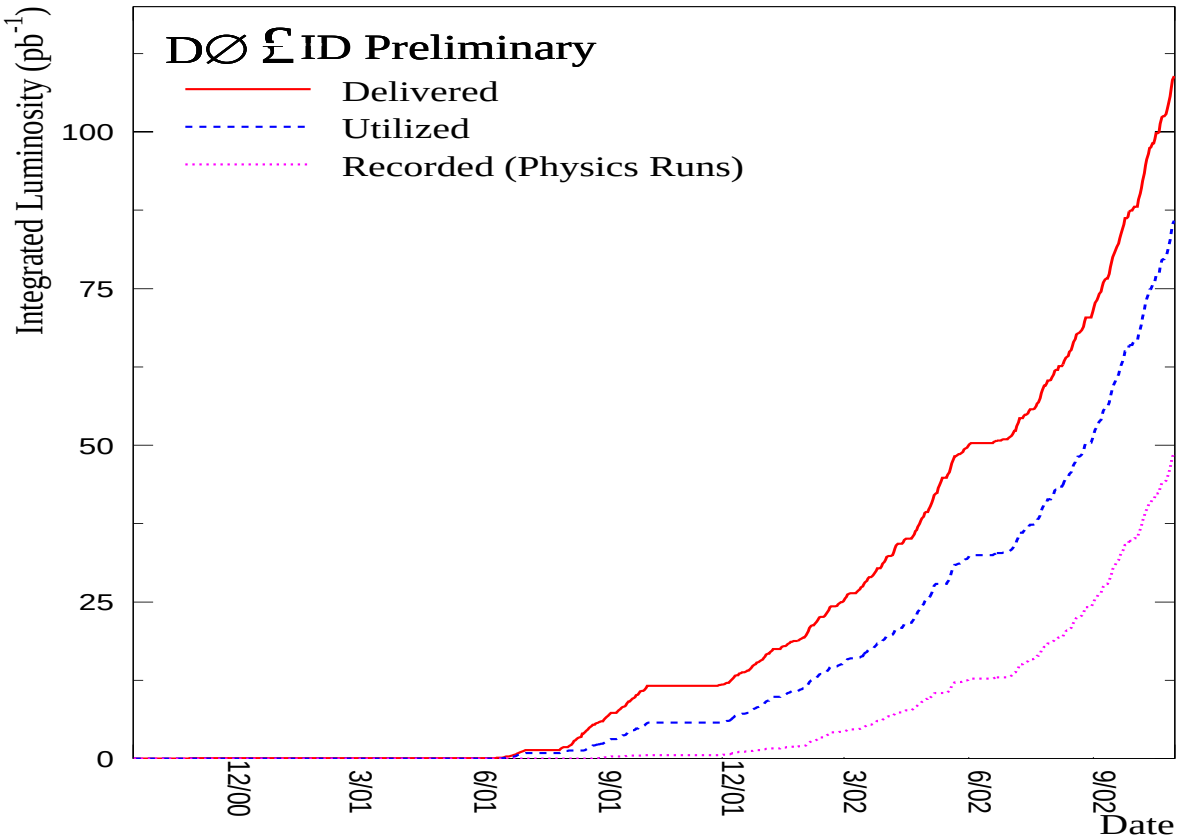


alignment in progress

σ_{d0} approaching design value

Physics results

Presented at ICHEP02 (Amsterdam), updated at HCP (Karlsruhe)
Luminosity situation:



Most of the results shown later based on

~5-10 pb^{-1}

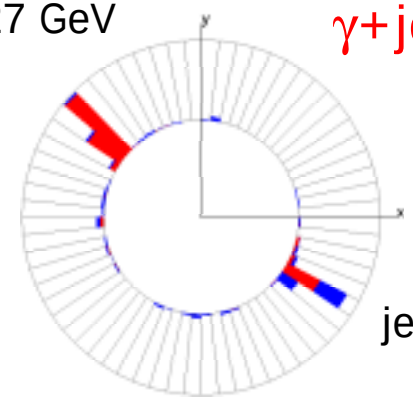
Jet Physics

Corrections in progress

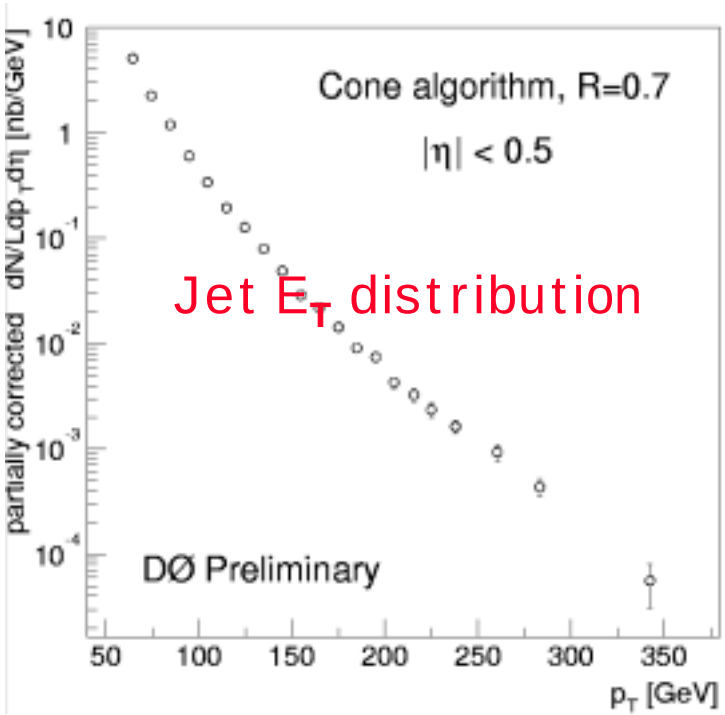
- preliminary Energy scale from γ-jet and Z→ee
- resolution and trigger effects to come

γ E_T=27 GeV

γ+jet Event

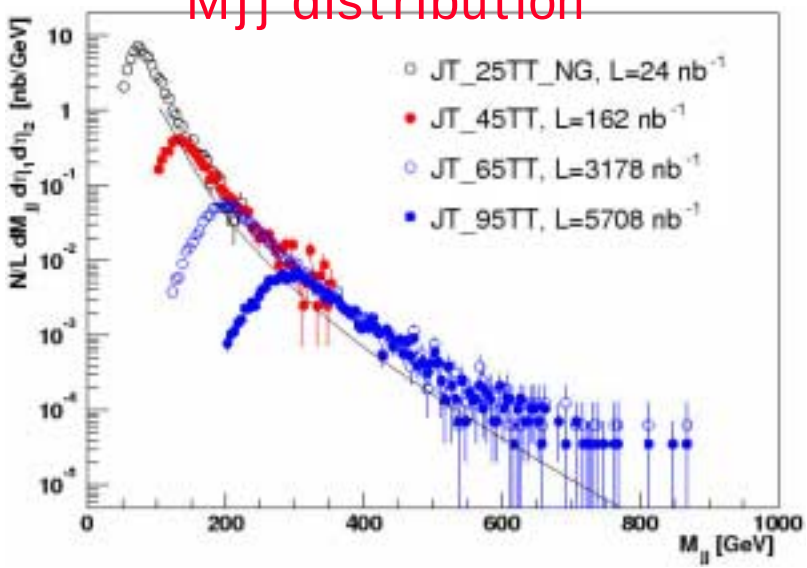


jet E_T=24 GeV



Jet E_T distribution

Mjj distribution



Searches for New Physics

Run 2 limits on ED from $\bar{p}p \rightarrow ee, \gamma\gamma, \mu\mu$

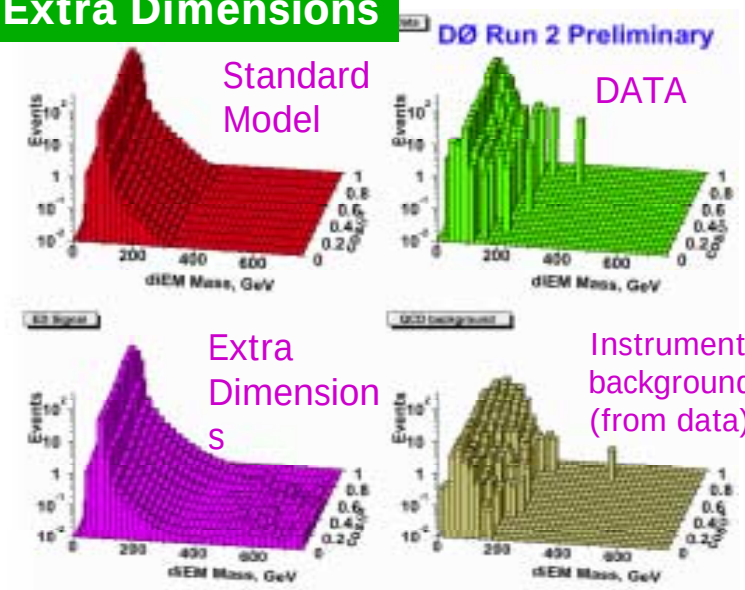
- M_s(GRW)>0.92 TeV(e,γ)
- M_s(GRW)>0.50 TeV($\mu\mu$)
  - ⇨Run 1: 1.2 TeV (e,γ)

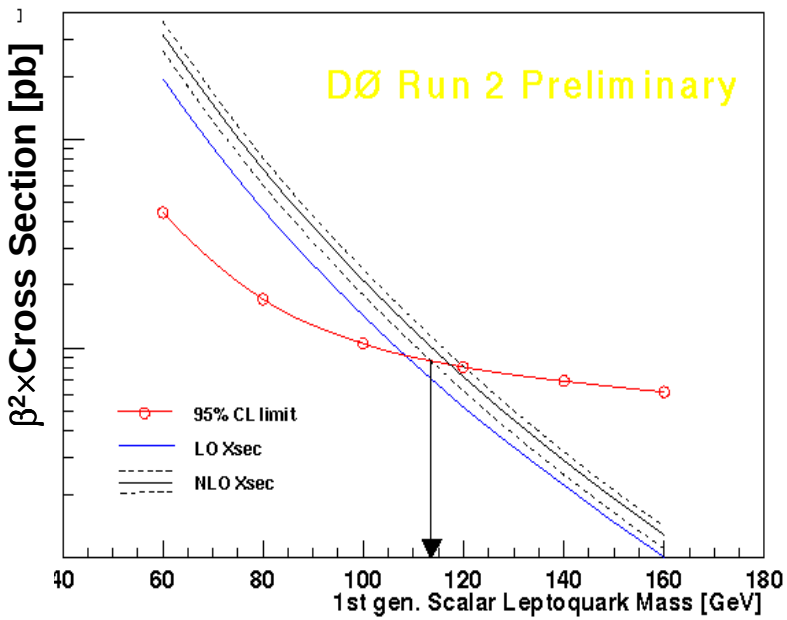
Limits on 1st generation LQ from $\bar{p}p \rightarrow eejj$

- M_{lq} > 113 GeV assuming $\beta(LQ \rightarrow ej)=1$
- Run 1: 225 GeV

Plot M_{ee} vs $\cos(\theta^*)$

Extra Dimensions



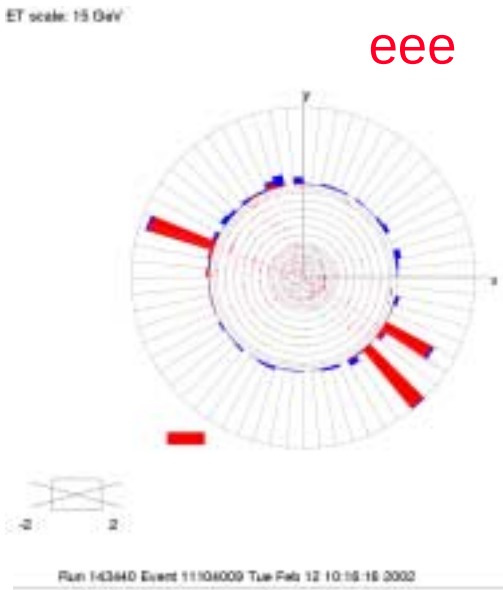


SUSY Searches in progress

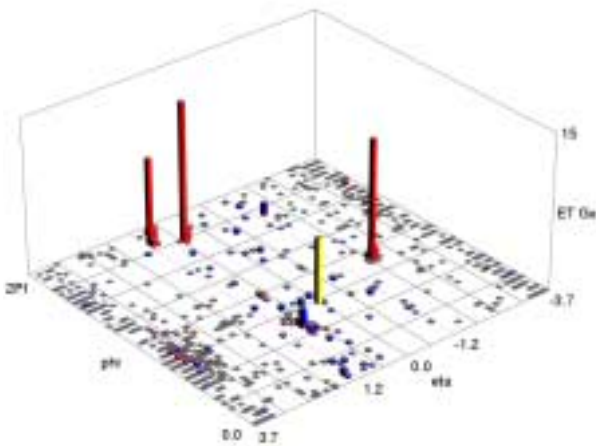
Tri-lepton search (SUSY)

	eee	*eeμ*
SM Background	0.9 +- 0.2	0.13 +- 0.08
EM Fakes	1.0 +- 0.3	0.6 +- 0.2
Cosmics	---	0.145 +- 0.014
Total	1.9 +- 0.4	0.9 +- 0.2
Data	2	1

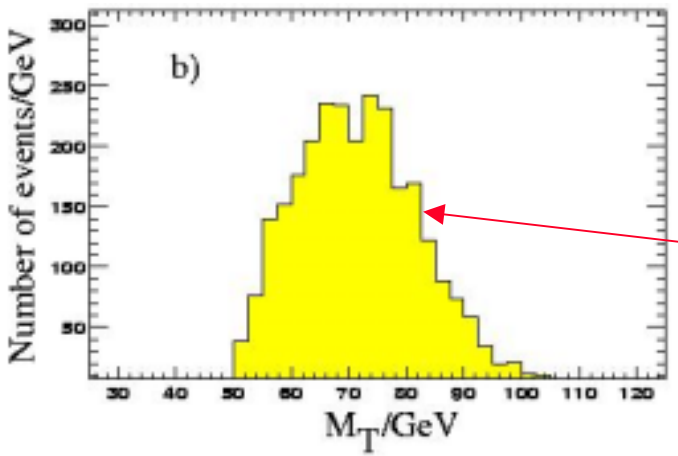
eee



e1	e2	e3
p_T = 15.9 η = 0.43 φ = 5.42	p_T = 12.5 η = -1.97 φ = 2.8	p_T = 11.9 η = 1.06 φ = 5.72
m_{e1e2} = 51.1	m_{e1e3} = 9.74	m_{e2e3} = 57.8



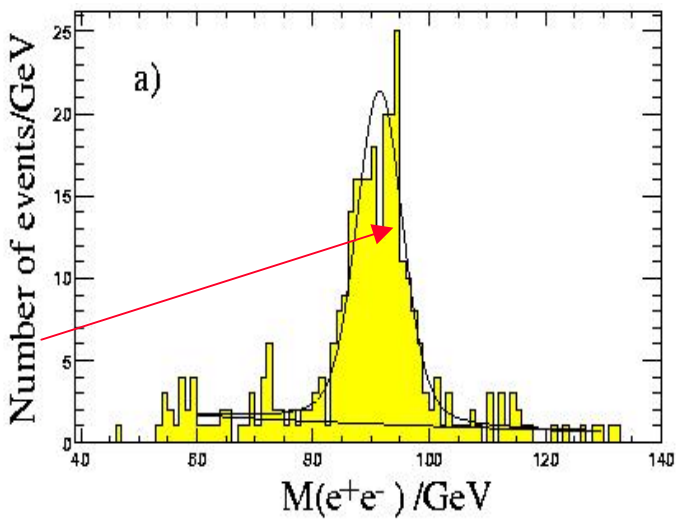
EWK Physics in progress

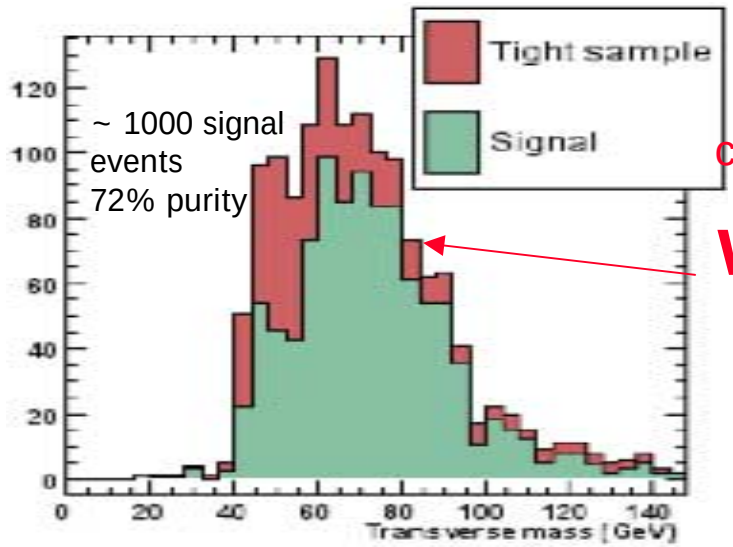


central electron(s)

W

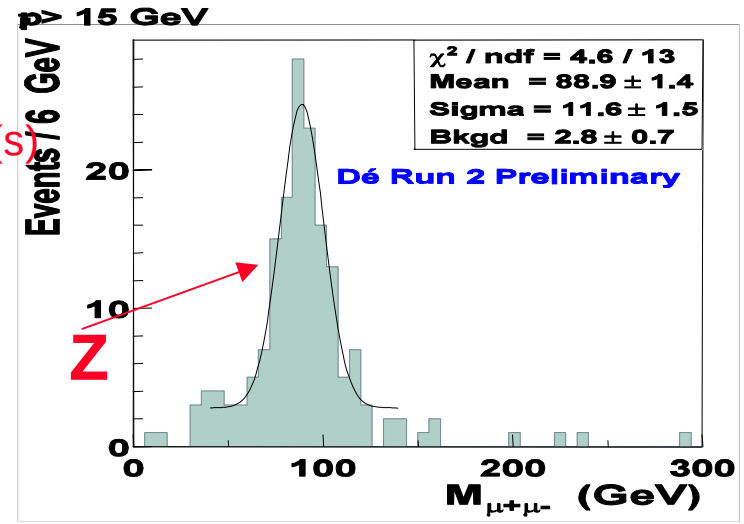
Z





central muon(s)

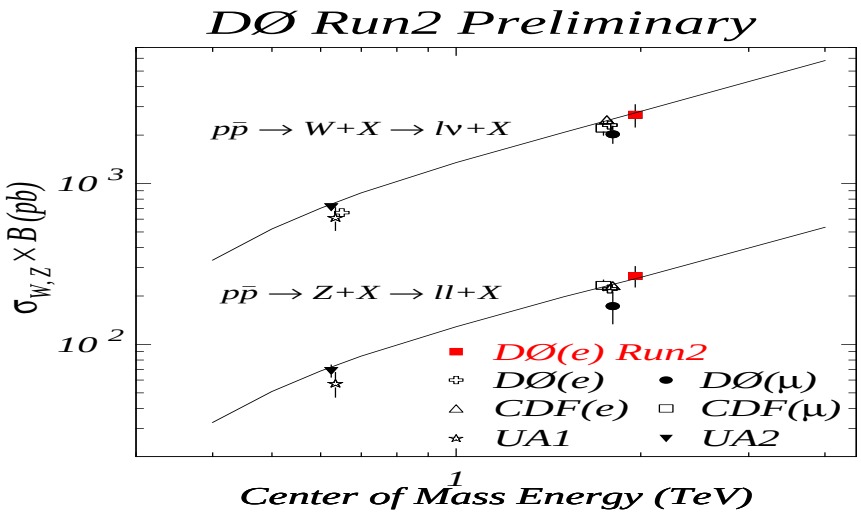
W



Z

First EWK physics results

σxBr(W→eν)	2.67±0.06(stat)±0.33(syst)±0.27(lum) nb
σxBr(Z→ee)	266±20(stat)±20(syst)±27(lum) pb



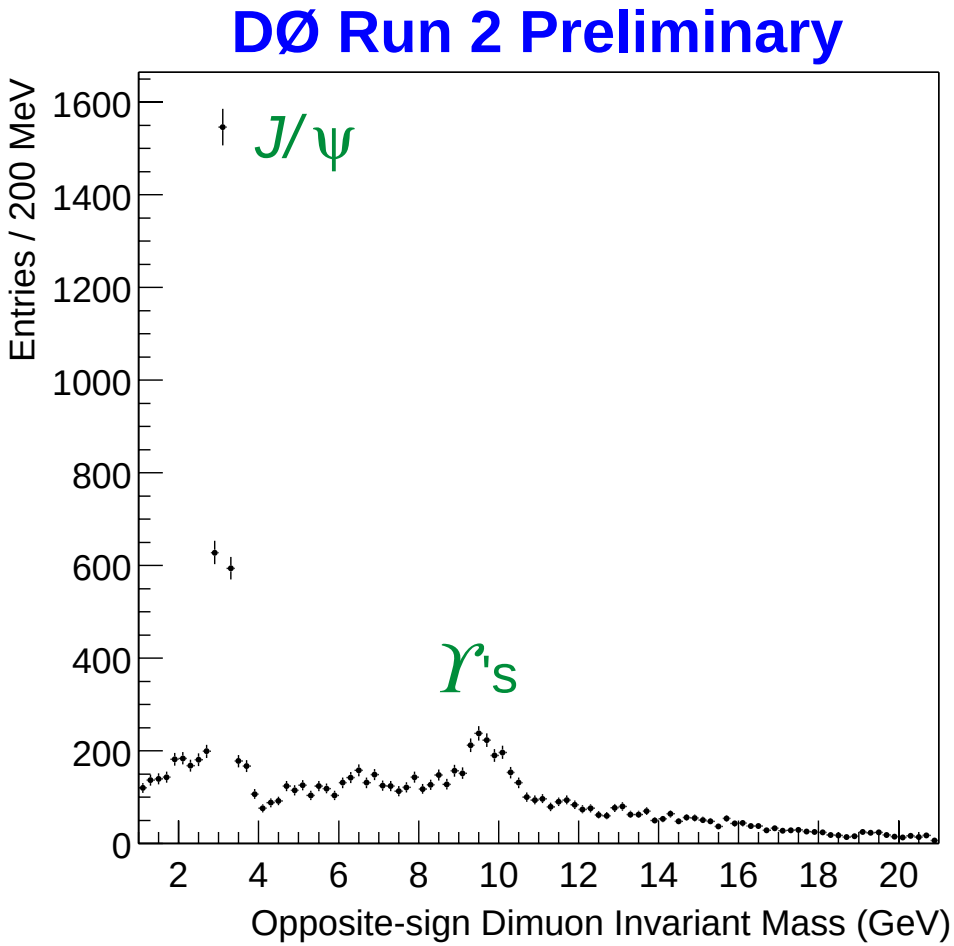
and ratio of cross sections times BF:

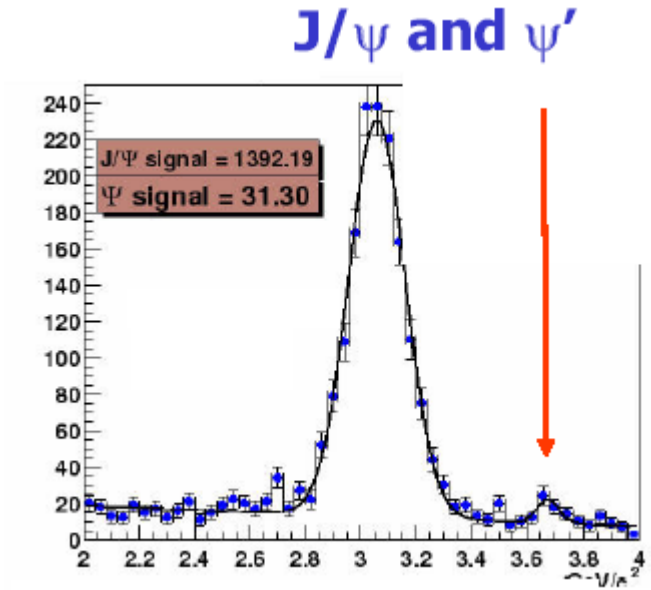
$$R = \frac{\sigma_W \times B(W \rightarrow e\nu)}{\sigma_Z \times B(Z \rightarrow ee)} = 10.0 \pm 0.8_{stat} \pm 1.3_{syst}$$

☞ taking σ_W/σ_Z from theory and $\Gamma_Z(ee)/\Gamma_Z$ from LEP:

$$\Gamma_W = 2.26 \pm 0.18_{stat} \pm 0.29_{syst} \pm 0.04_{theory}\ \text{GeV}$$

Basics for B Physics



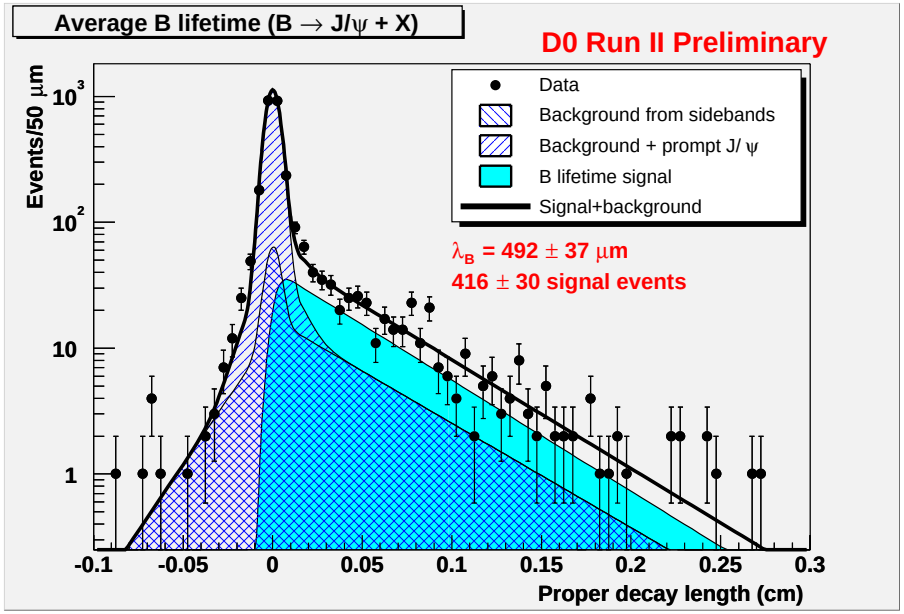


σ(J/ψ)=88±3 MeV

MC expectation: 63 MeV

B Physics

B physics with silicon vertex detector



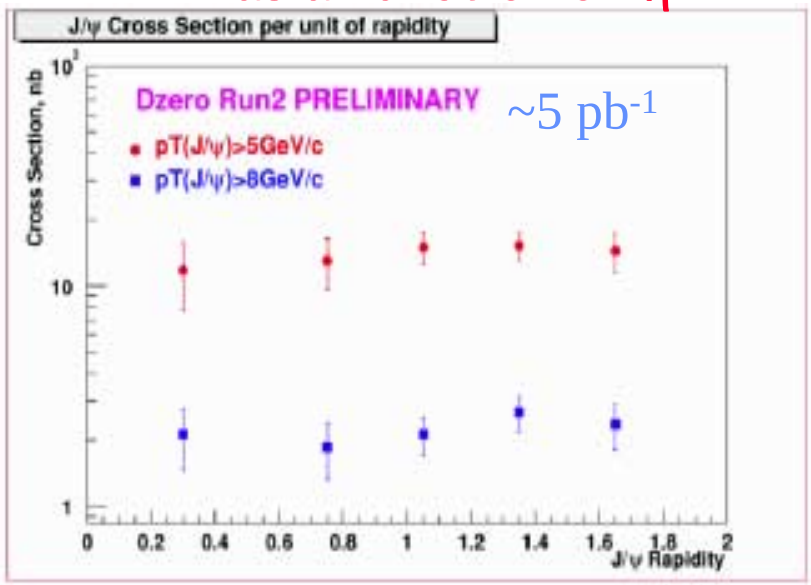
416 ± 30 signal events

2184 ± 47 prompt J/Ψ's

cτ(B) = 492 ± 37 μm (stat)

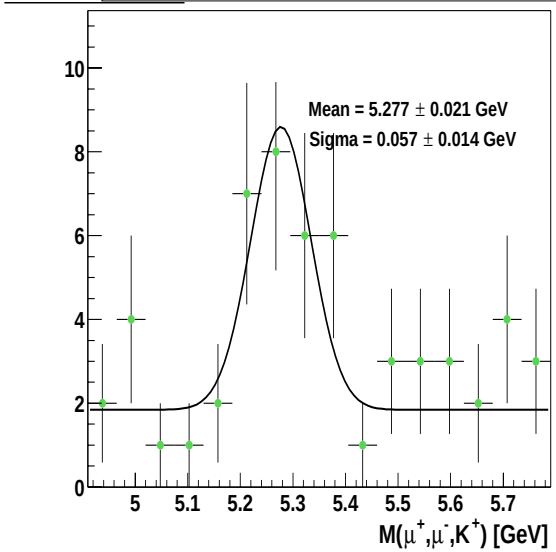
PDG: cτ(B) = 469 ± 4 μm

J/ψ cross section as a function of η



Exclusive B Physics started

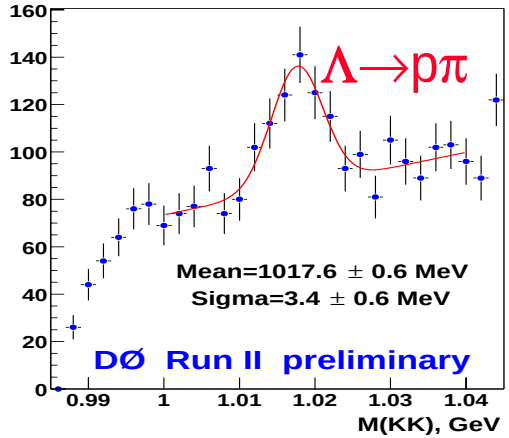
First B mesons at D0:
$B \rightarrow J/\psi\, K^{\pm}$

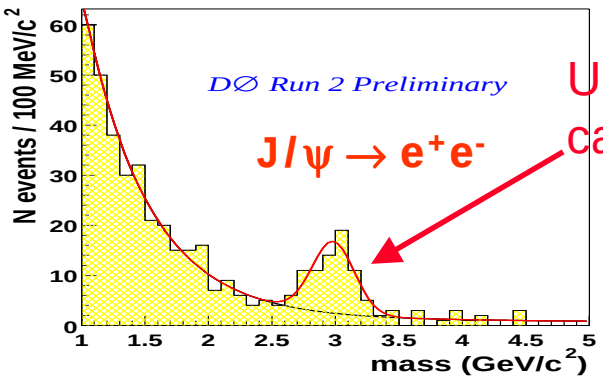


Getting ready for

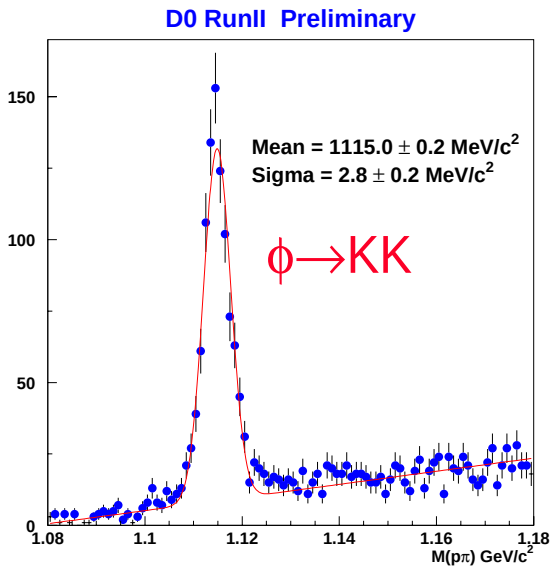
$\Lambda_b \rightarrow J/\psi\Lambda$

$B_s \rightarrow J/\psi\phi$





Using calorimeter



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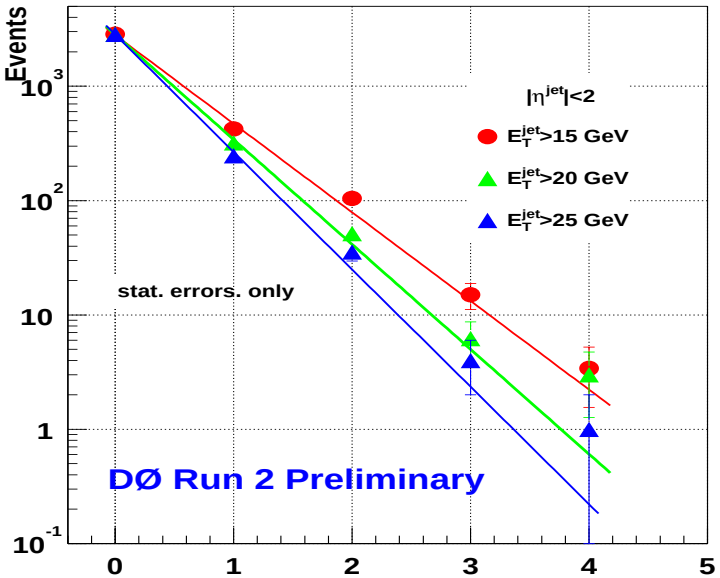
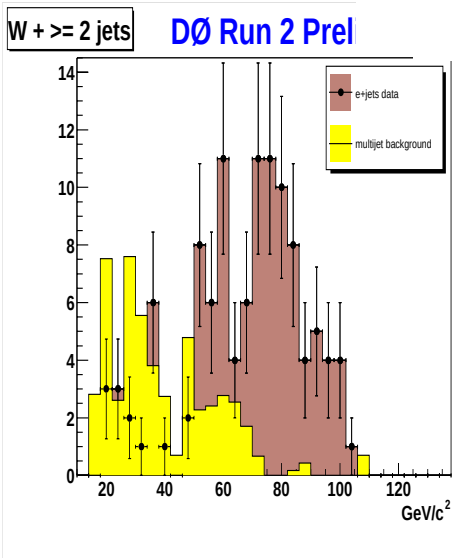
W→eν + n jets

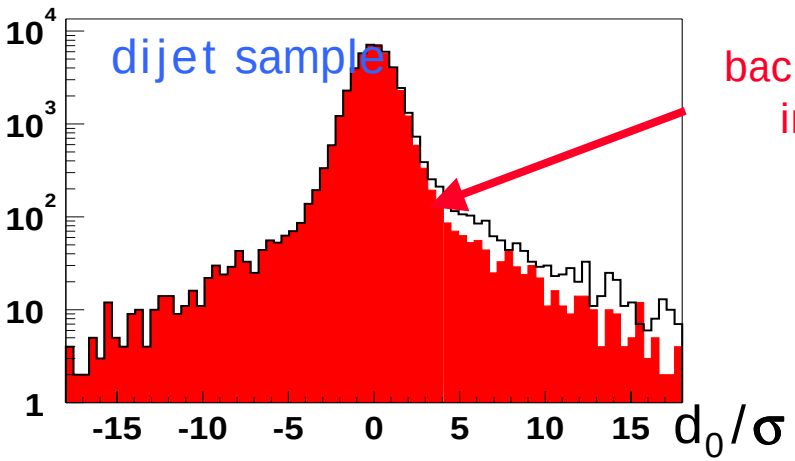


M_T, W candidates in W+≥2 jets

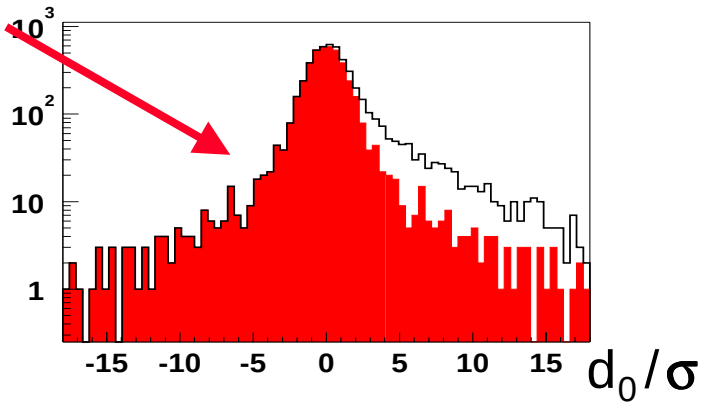


with more tools

μ+jet sample
→ enhanced b-jet content

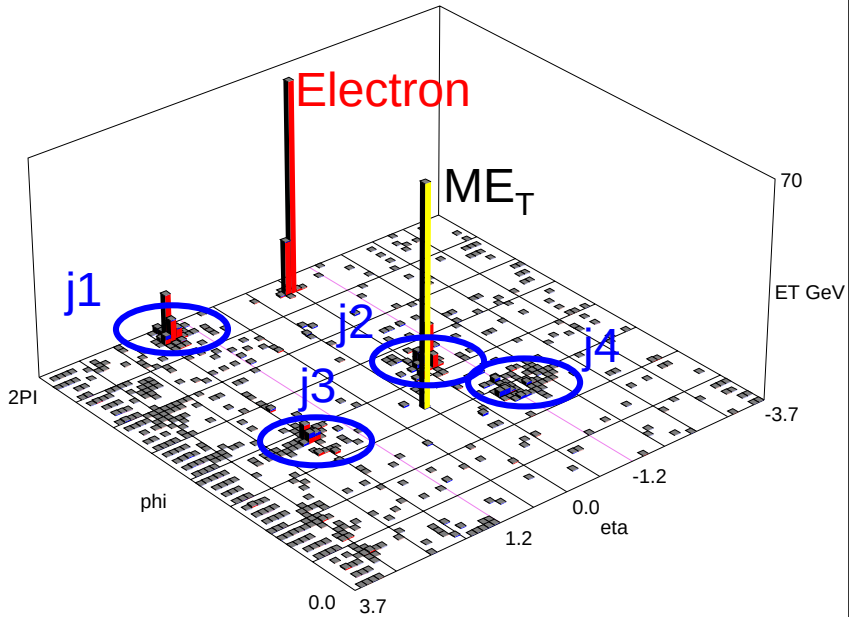


background in red



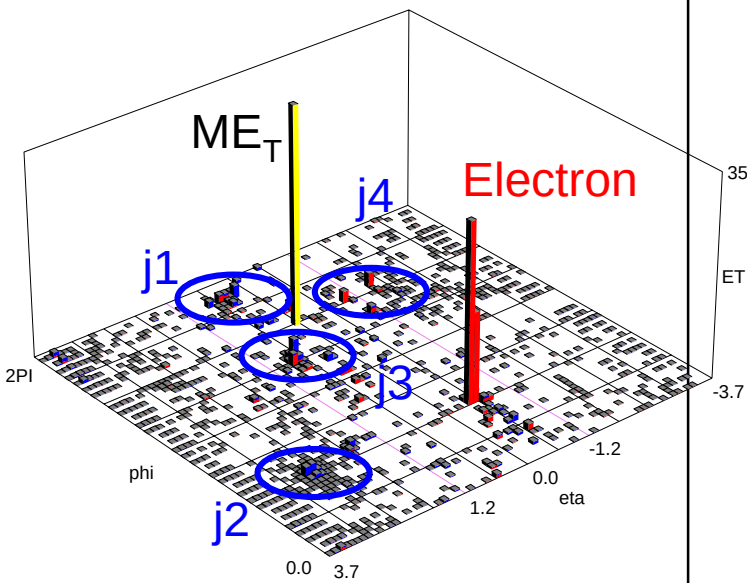
l+jets candidate events

Run 141155 Event 154798 Thu Feb 28 01:44:52 2002



e1	j1	j2	j3	j4
E_T = 52 GeV η = -0.51 φ = 1.63 Low-p_T track match	E_T = 28 GeV η = 0.73 φ = 3.82	E_T = 24 GeV η = 2.41 φ = 1.62	E_T = 21 GeV η = 0.52 φ = 5.80	E_T = 20 GeV η = -1.43 φ = 4.60
ME$_T$ = 30 GeV, M$_T$(EM-ME$_T$) = 79 GeV				

Run 142344 Event 1669603 Thu Feb 28 01:42:39 2002

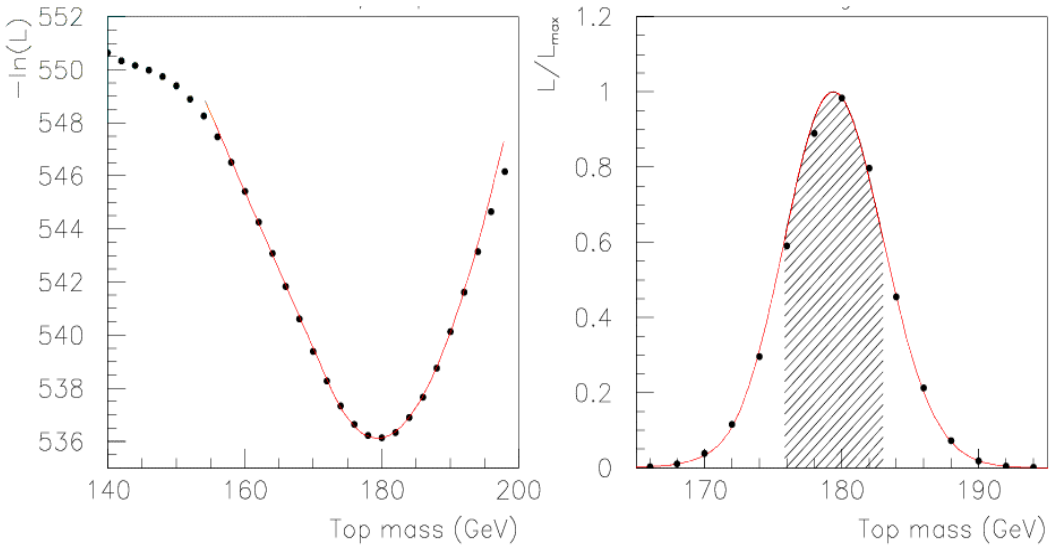


e1	j1	j2	j3	j4
E_T = 99 GeV η = -0.53 φ = 5.94 Low-p_T track match	E_T = 68 GeV η = 1.62 φ = 6.03	E_T = 57 GeV η = 0.69 φ = 3.38	E_T = 35 GeV η = 1.27 φ = 2.29	E_T = 26 GeV η = 1.83 φ = 2.90
ME$_T$ = 62 GeV, M$_T$(EM-ME$_T$) = 156 GeV				

Top mass new result from Run 1

Idea behind the measurement:

- exploits the available information on top physics
  Use for the l+jets channel the same strategy followed in the dilepton events:
  - each event has its own probabiliy distribution to be a ttbar candidate



M_t = 179.9 ± 3.6 ± 6.0 GeV

was

173.3±5.6±5.5 GeV(D0 only)

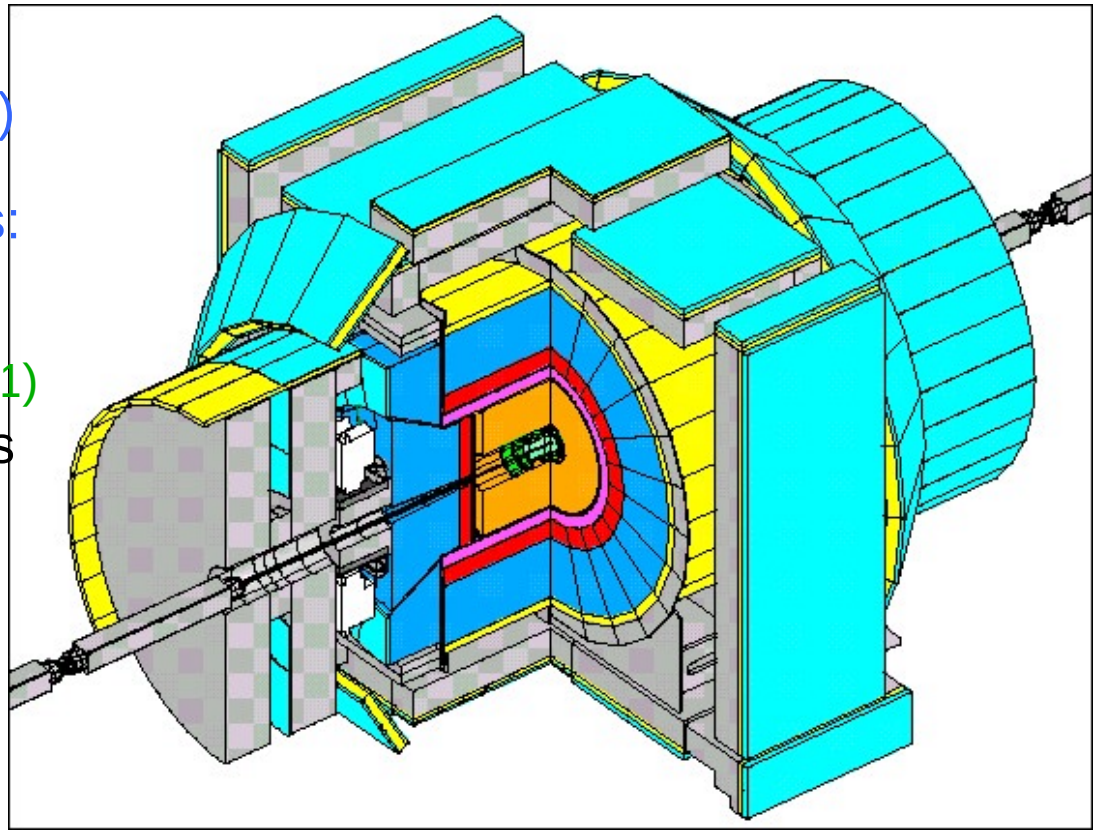
174.3±3.2± 4.0 GeV
(CDF+D0 all channels)

Improvement equivalent to running two more years in Run 1.

When you have data, ingenuity plays a big role.

CDF II

- new tracking system
  - new drift chamber (COT)
  - new silicon tracker comprising three detectors:
    - → L00 (1 SS, r-φ),
      SVXII (5 DS),
      ISL (2 DS $|\eta|>1$, 1 DS $|\eta|<1$)
- new forward calorimeters ("plug") $(1<|\eta|<3)$
- extended muon coverage
- added TOF capability

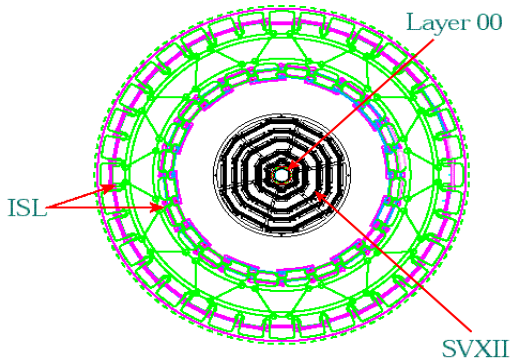


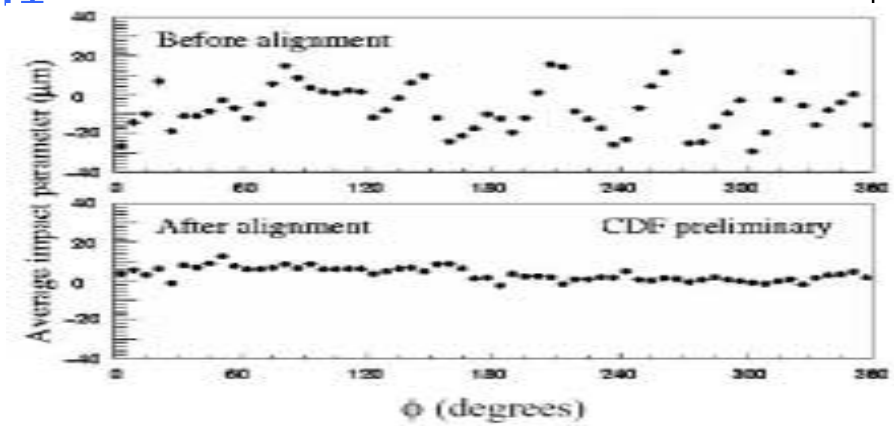
- new trigger system
  - moved track trigger to L1
  - built a Silicon Vertex Trigger (SVT) at L2 to trigger on tracks with large impact parameter

Silicon Systems: L00, SVXII, ISL

stable data taking since last shutdown (June 02)

- global ε≈ 90 % (704 ladders)
  - L00≈97%, S/N≈10:1
  - SVXII≈92%, S/N≈12:1
  - ISL≈85%, S/N≈12:1
- alignment:
  - 1st pass R-φ done
  - R-z:in progress





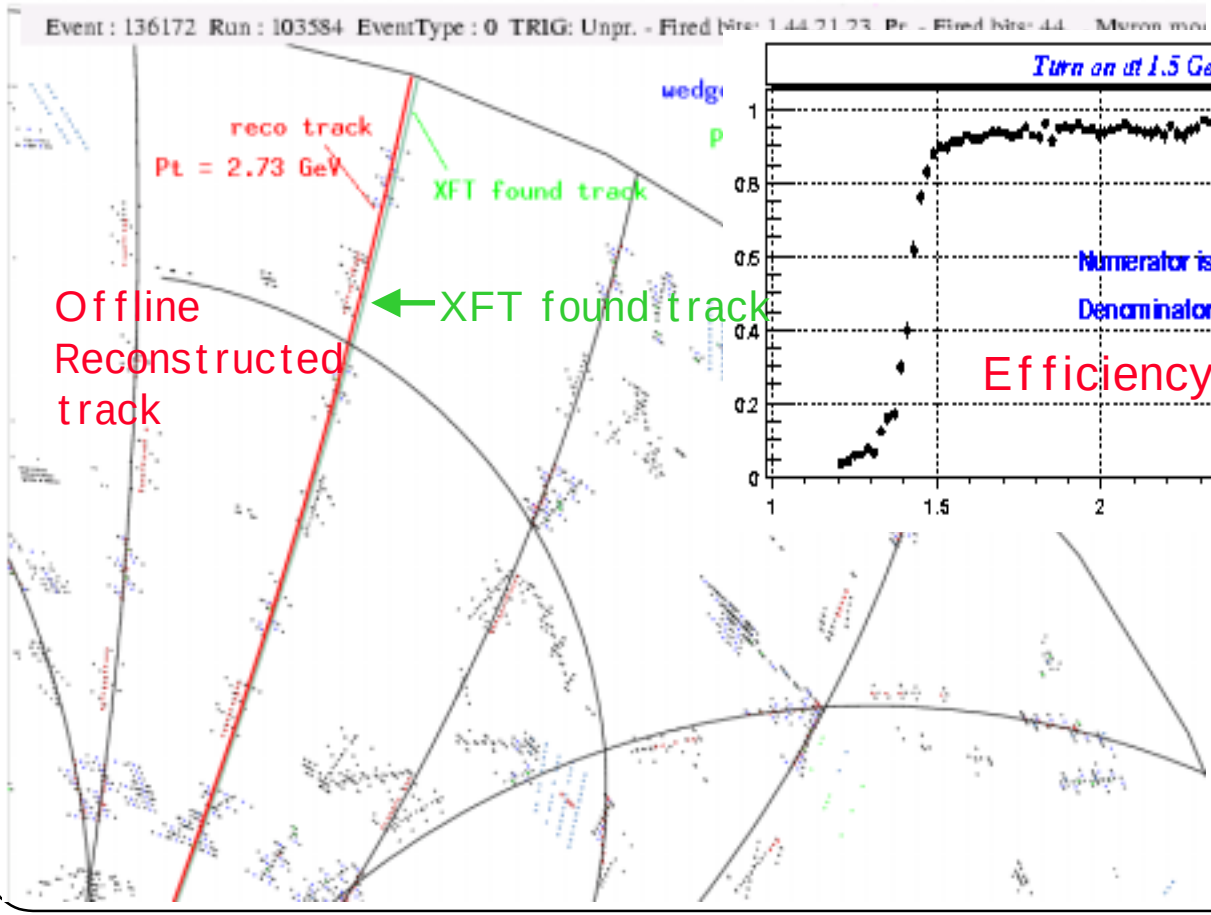
- limited number of operational failures:
  - 2 ladders are dead
  - 12: r-z side lost
  - 13: lost in part, mostly r-z side only

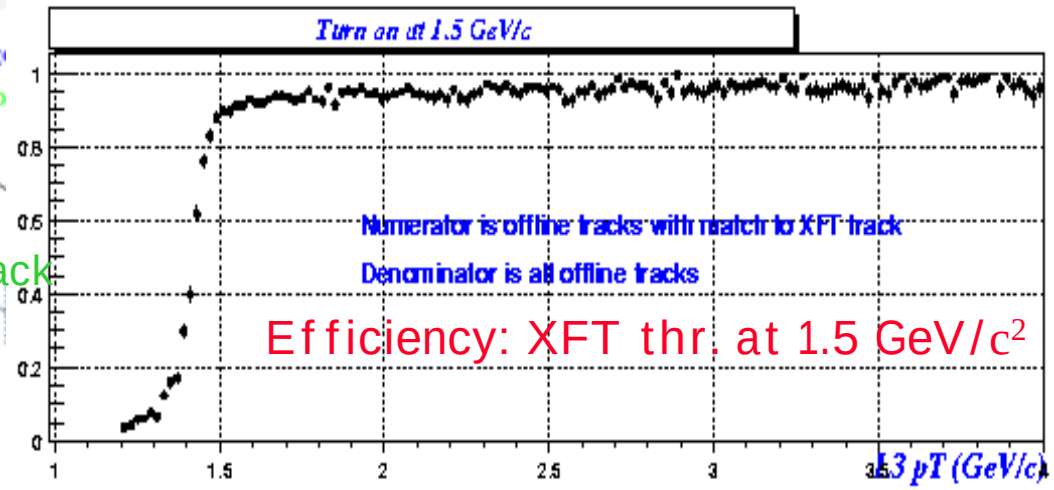
XFT

eXtremely Fast Tracker: L1 tracks

- $\Delta P_t / P_t^2$ = 1.65% (using data)
- angular resolution 5.1 mrad (using data)

better than design

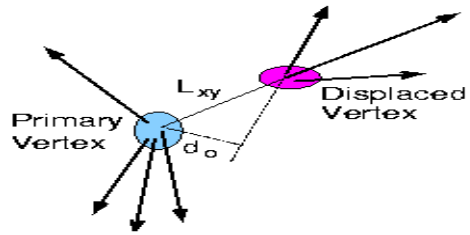




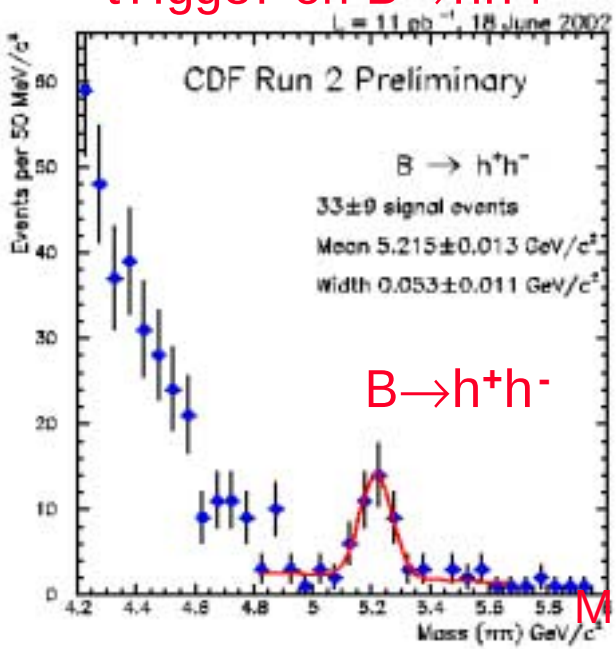
Silicon Vertex Trigger

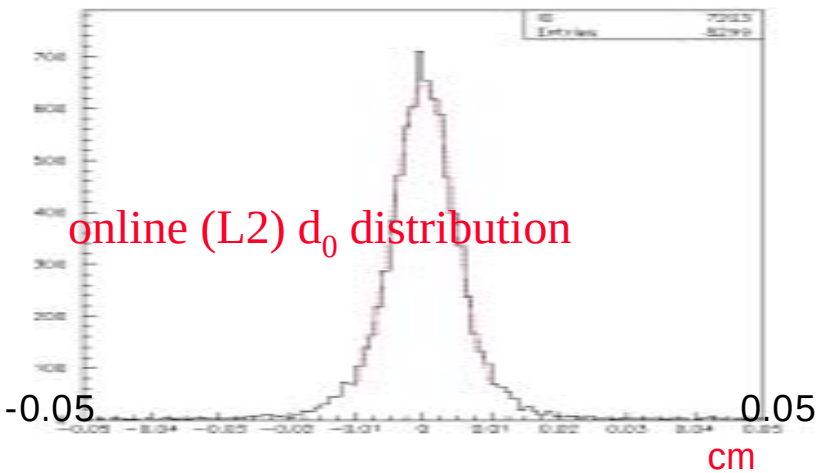
SVT, using SVX(r-φ) hits and tracks from XFT: trigger on tracks displaced from the primary:

- online primary vertex
- d_0 resolution as by design:
  - ⇨ σ ~50 μm ≅ 43(SVT)⊕~30 (beam)



trigger on B→hh !

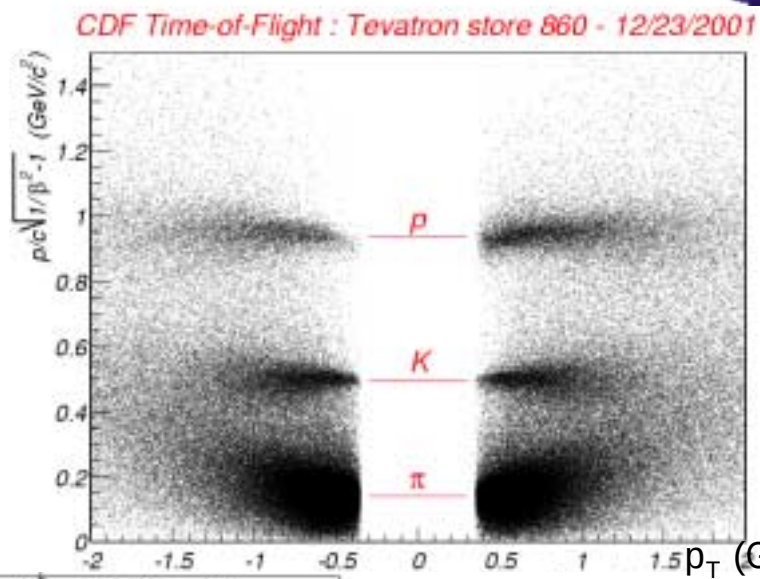




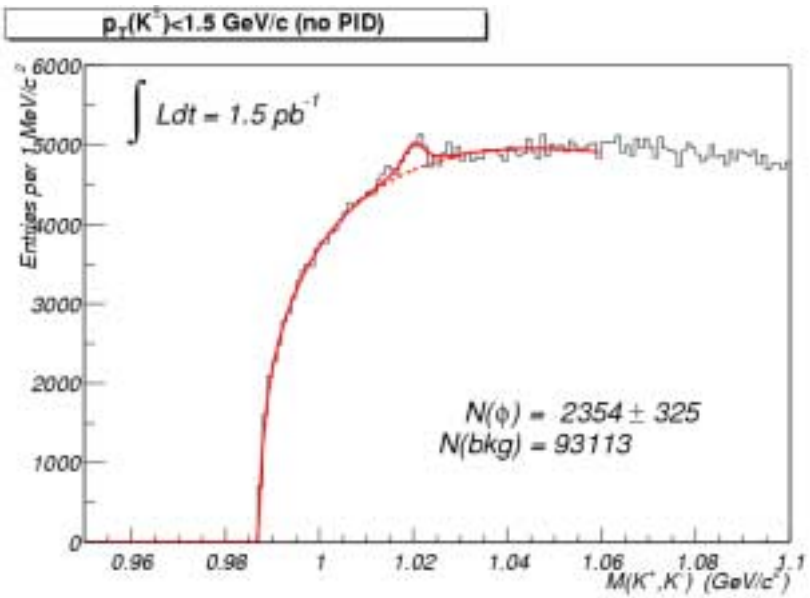
Time of Flight

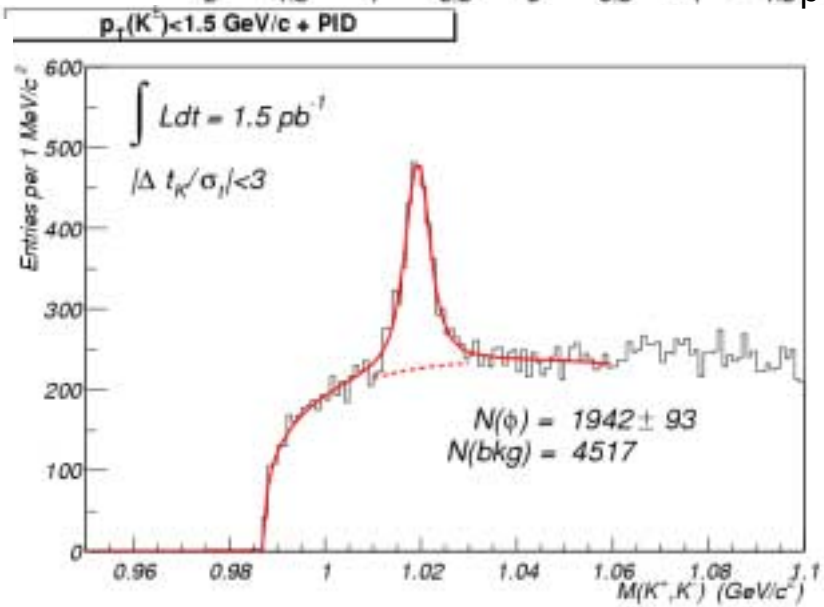
TOF still being commissioned
resolution (now 110ps)
getting close to design
(100 ps)

- ☞ improving calibrations
- ☞ developing corrections



Test looking for $\phi \rightarrow KK$





Run II Physics

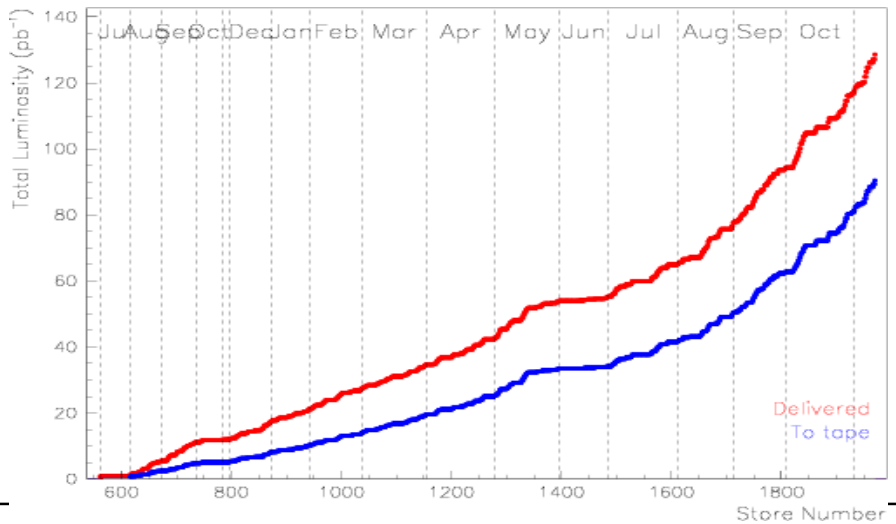
First results at ICHEP02, updated at HCP

Luminosity situation

☞≈80 pb^{-1} to tape (including part of commissioning)

- ⇨ Jets 64 pb^{-1}
- ⇨ High Et electrons 55 pb^{-1}
- ⇨ SVT with hadronic B trigger 50 pb^{-1}
- ⇨ Top l+jets+b-tagging 44 pb^{-1}

→ requires whole detector to be operational



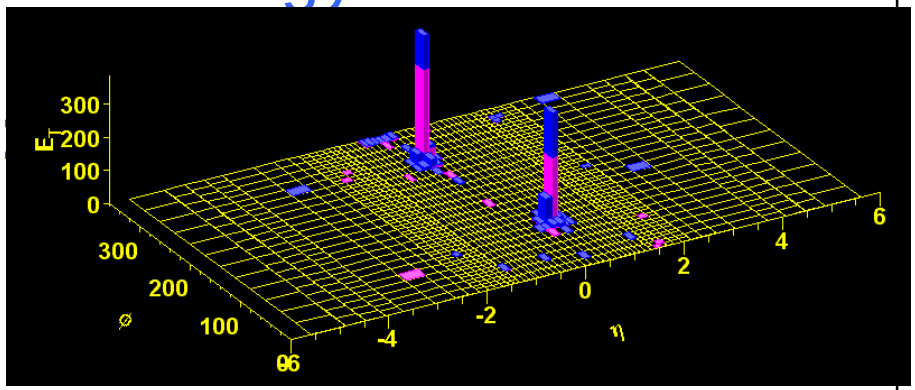
Red: delivered luminosity

Blu: recorded to tape

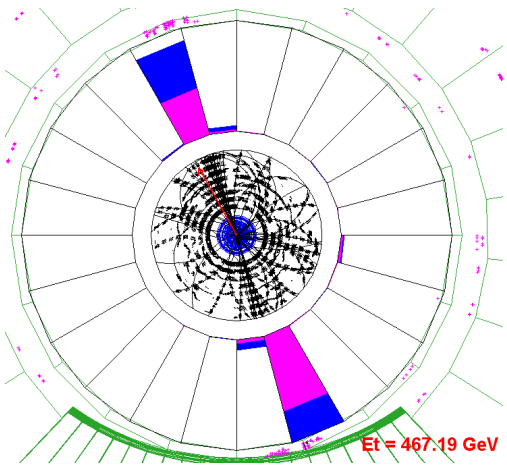
Jet Physics

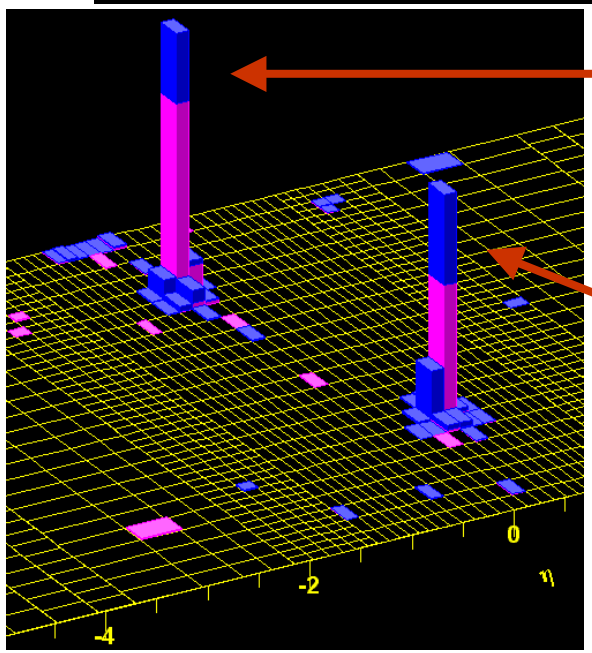
New calorimeter, work on energy scale in progress. Interesting events already on tape!

largest jet E_T recorded !



Dijet Mass = 1146 GeV (corr)



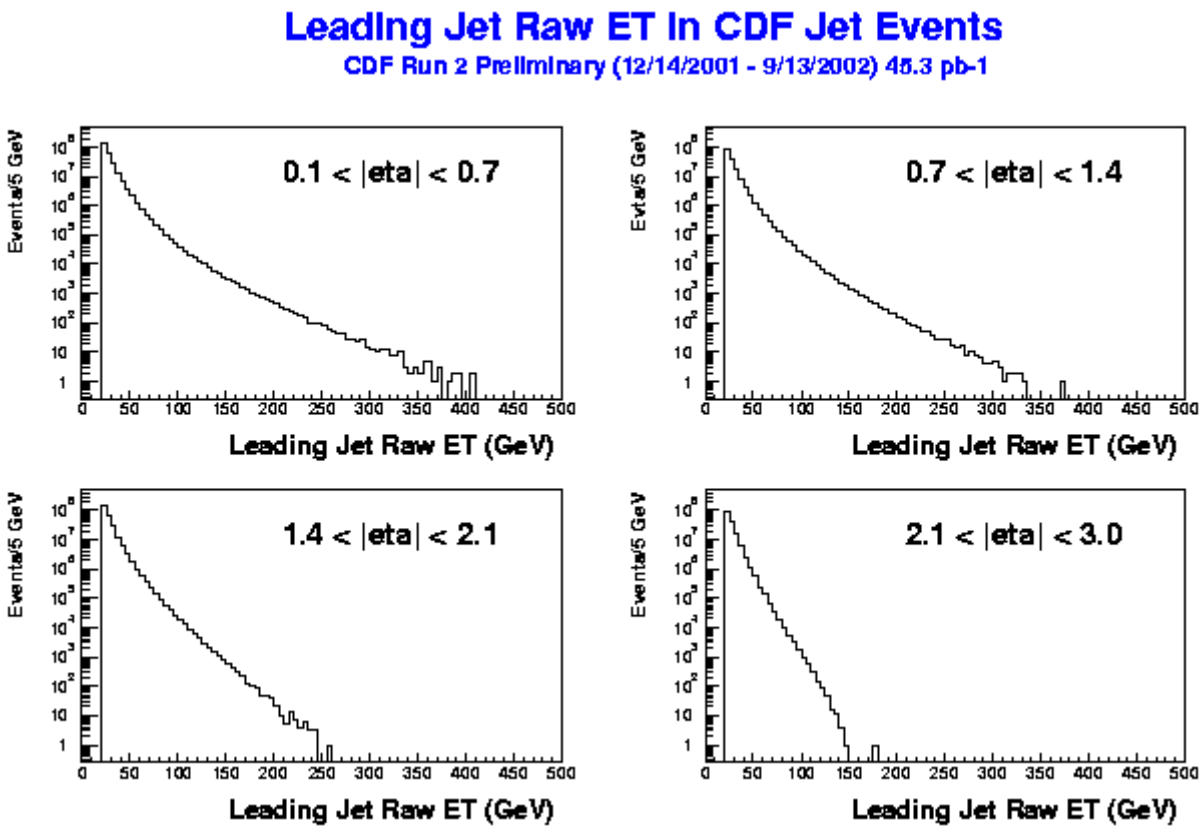


J_2 E_T = 528 GeV (corr)
J_2 η = -0.55 (correct z)

J_1 E_T = 538 GeV (corr)
J_1 η = 0.20 (correct z)

Corrected E_T and mass are preliminary

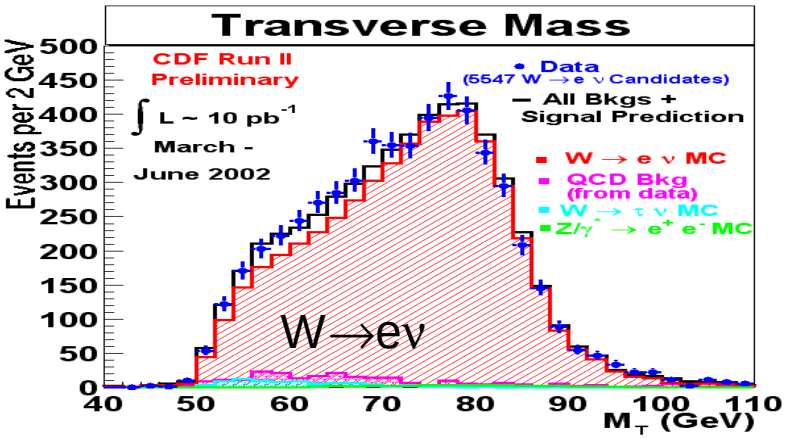
Jet Physics



new calorimeter for $|\eta| > 1$

Corrected E-scale by the 2003 Winter Conferences

First EWK Physics Results



σxBr(W→eν)	2.60±0.07(stat)±0.11(syst)±0.26(lum) nb
σxBr(W→μν)	2.70±0.04(stat)±0.19(syst)±0.27(lum) nb

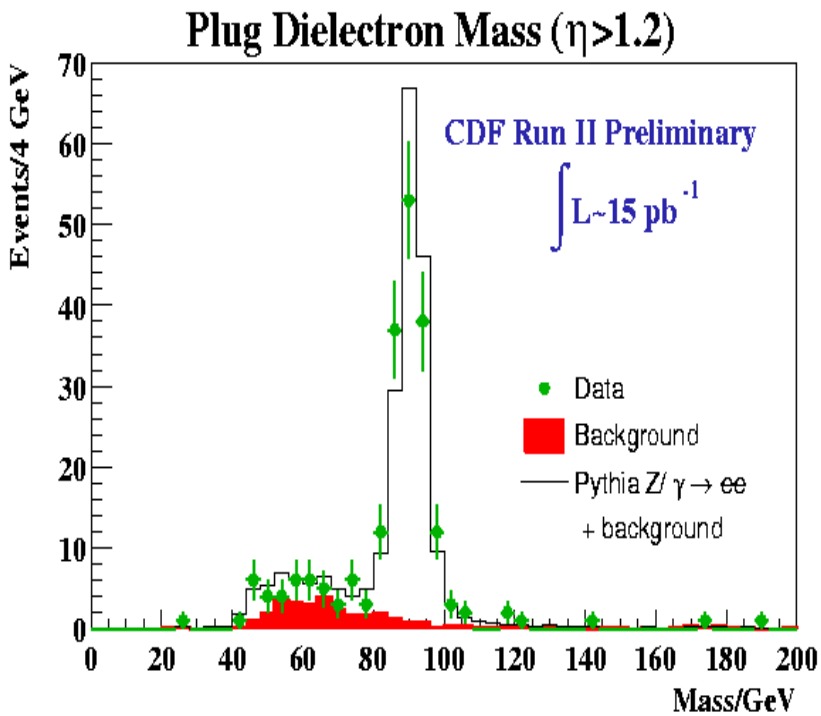
luminosity uncertainty now ±6 %

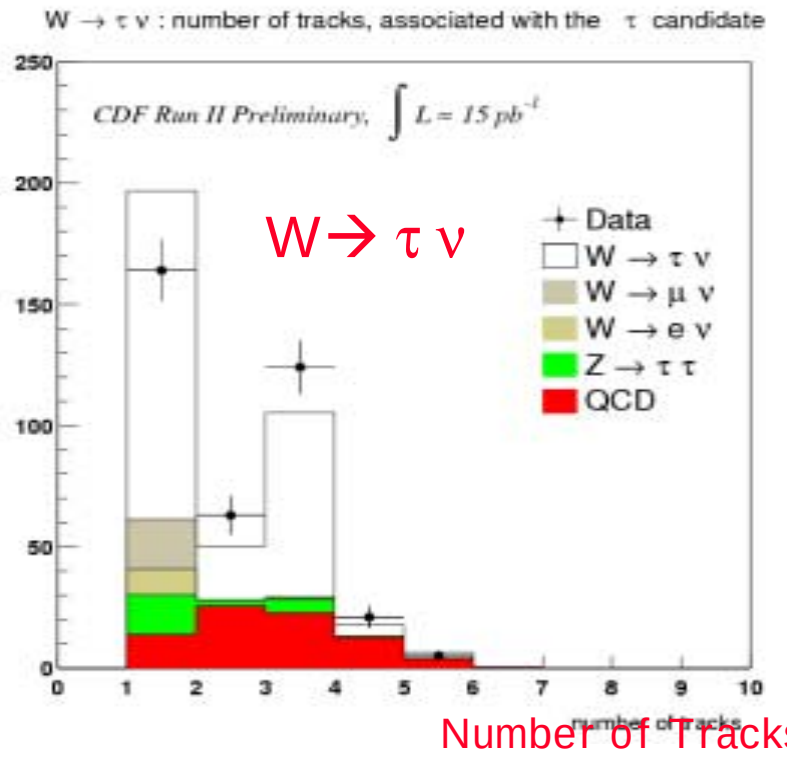
Expectation at √s= 1.96 TeV: 2.73 (Stirling,NNLO)

EWK Physics: near future

New tools for physics:

- forward electrons, using silicon tracking, clean Z signal with both candidates in "plug" calorimeters
- $W \rightarrow \tau\nu$, CDF developed a track-based trigger





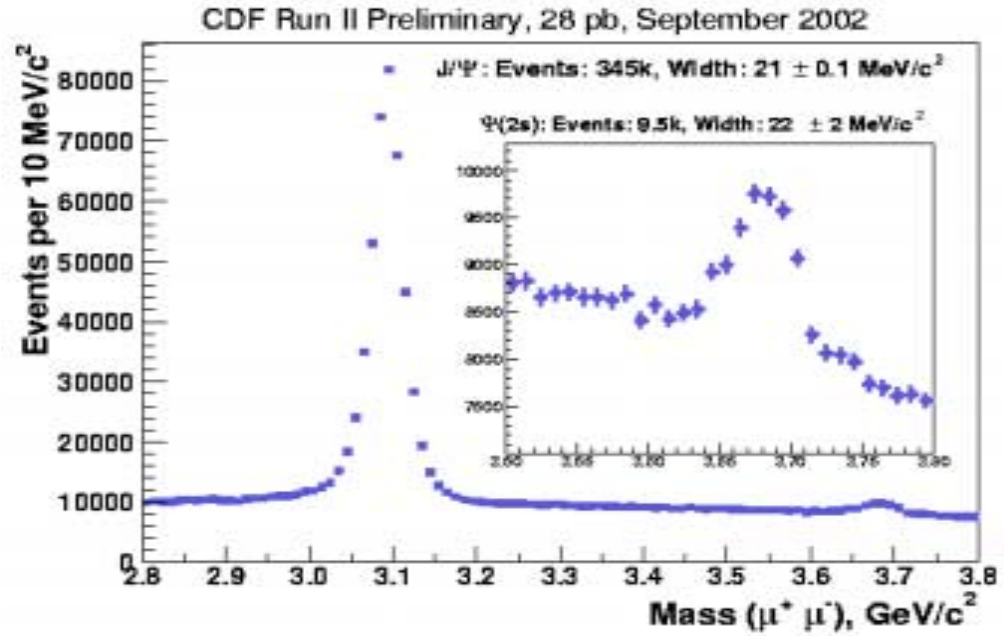
Number of Tracks

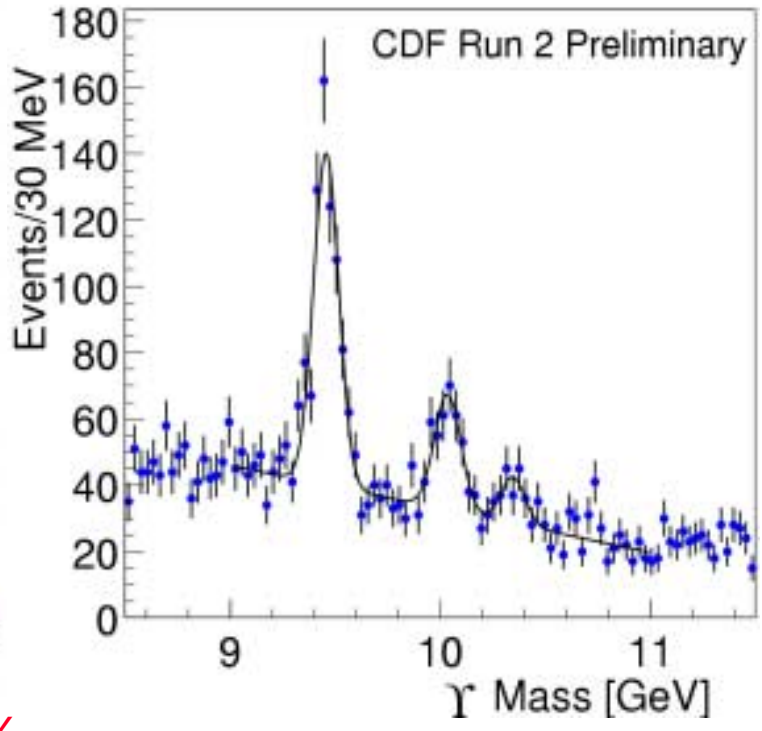
B Physics

J/Ψ is a nice tool to study detector response.

- once scale is set, use Υ, D^0, $D^{\pm}$,D_s, K_s, Λ...to check it
- also measure inclusive B lifetime:
  - $c\tau = 458 \pm 10_{stat.} \pm 11_{syst.}$ μm (PDG: 469±4 μm)

$N_{J/\Psi}$=345K

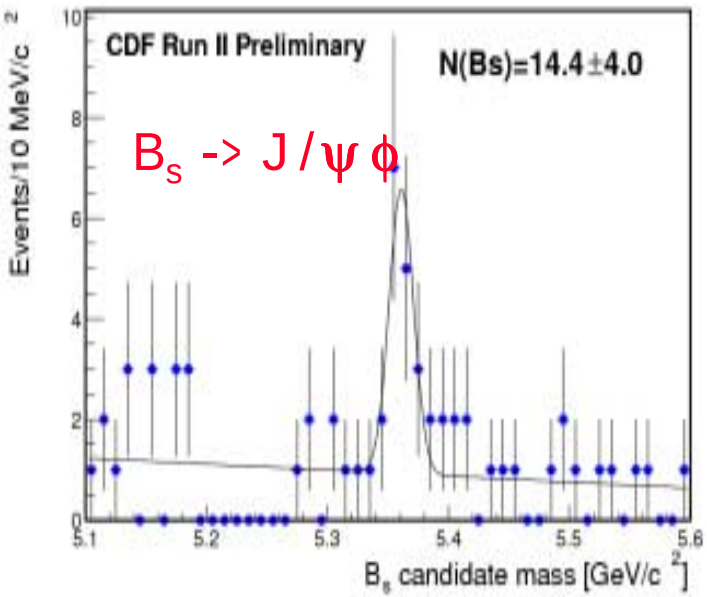


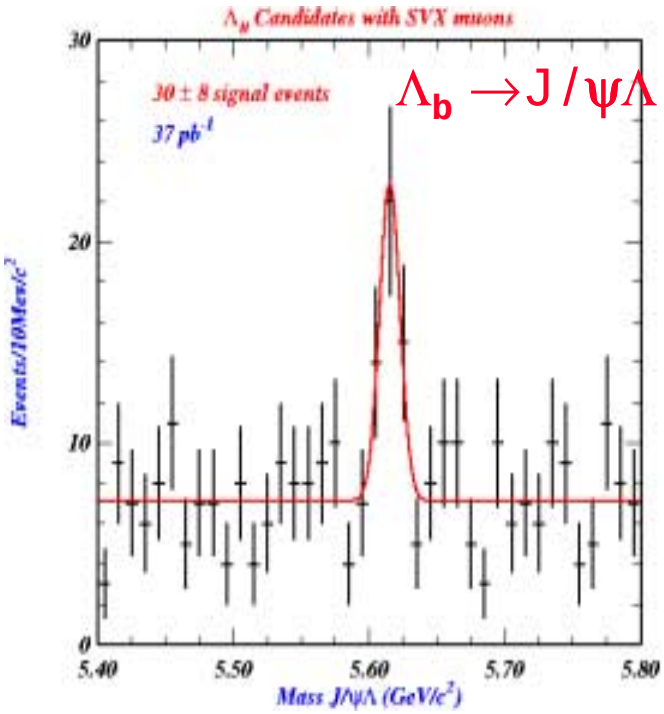


σ=22 MeV (COT only) expect 15 MeV with SVX

Mass of B states

	Mass(Mev/c^2)	(RUN 2 uncertainty)/(PDG uncertainty)
$\psi(2S)$	3686.43±0.54	6.00
B_u	5280.60±1.70±1.1	4.05
B_d	5279.80±1.90±1.4	4.72
B_s	5360.30±3.80±...	1.90



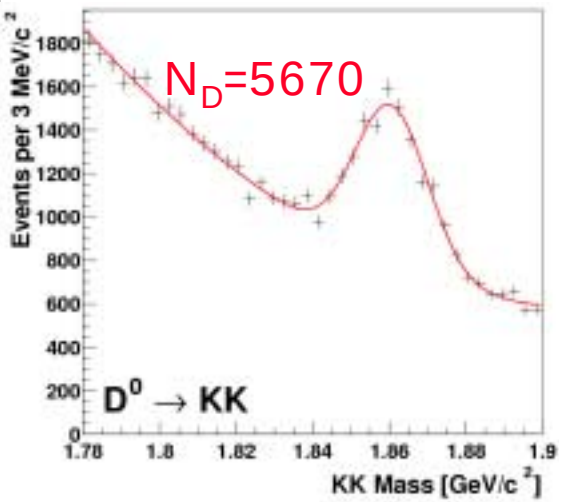


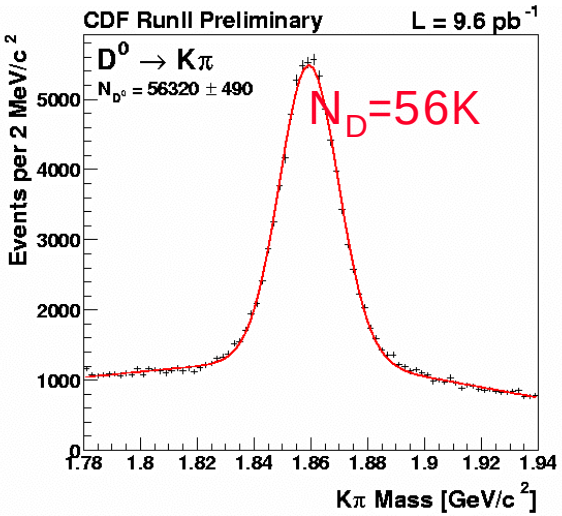
B_c...coming soon...

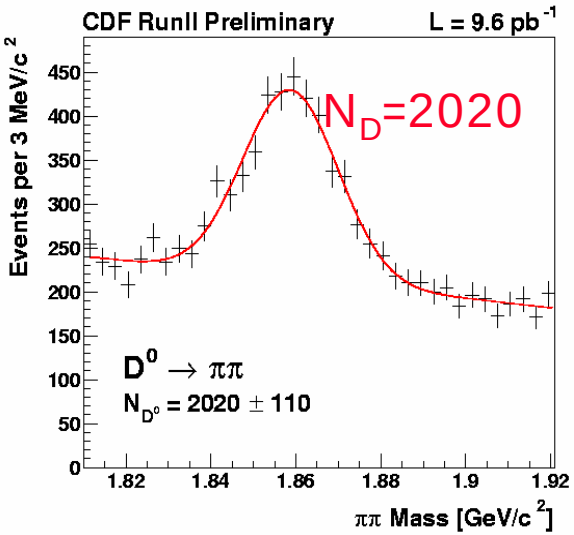
Charm Physics

Thanks to SVT we select charm events at trigger level,unforeseen nice physics possible

- ~10 Million reconstructed D mesons in 2 fb^{-1} !







Measure Cabibbo suppressed channels:

$\Gamma(D \to KK)/\Gamma(D \to K\pi)$ = (11.17±0.48±0.98)% (PDG: 10.83±0.27)

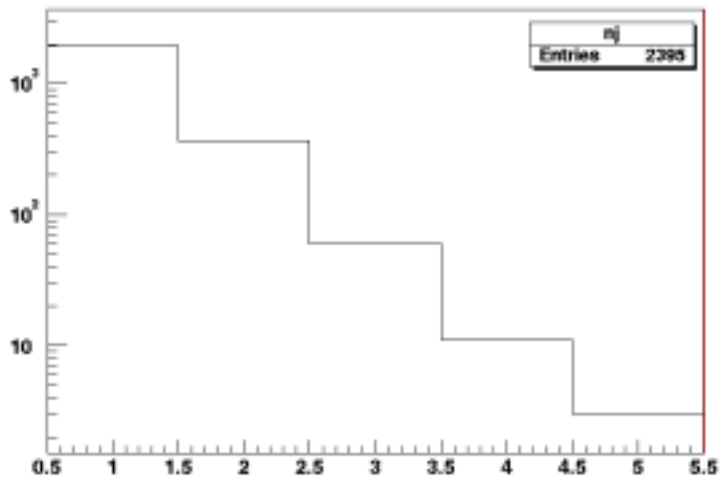
$\Gamma(D \to \pi\pi)/\Gamma(D \to K\pi)$ = (3.37±0.20±0.16)% (PDG: 3.76±0.17)

going to the Top...

Validation in progress

- 55 pb-1 for l+jets sample
- 44 pb-1 if b-tagging required
- cross section by Winter Conferences

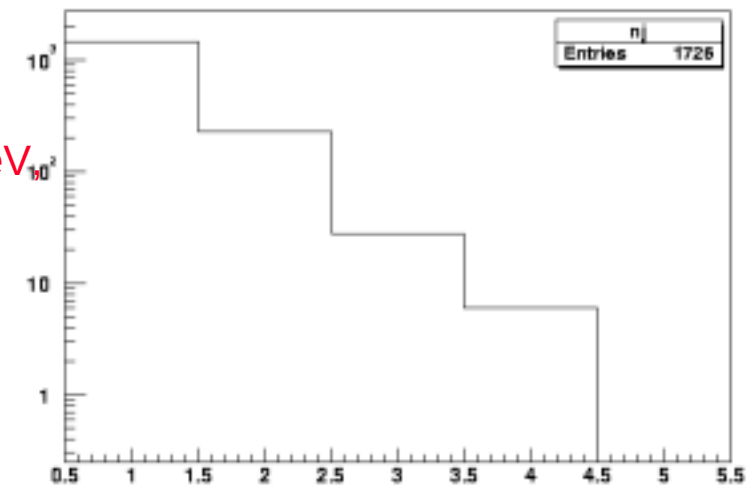
$W \rightarrow e\nu$ + n jets



number of jets

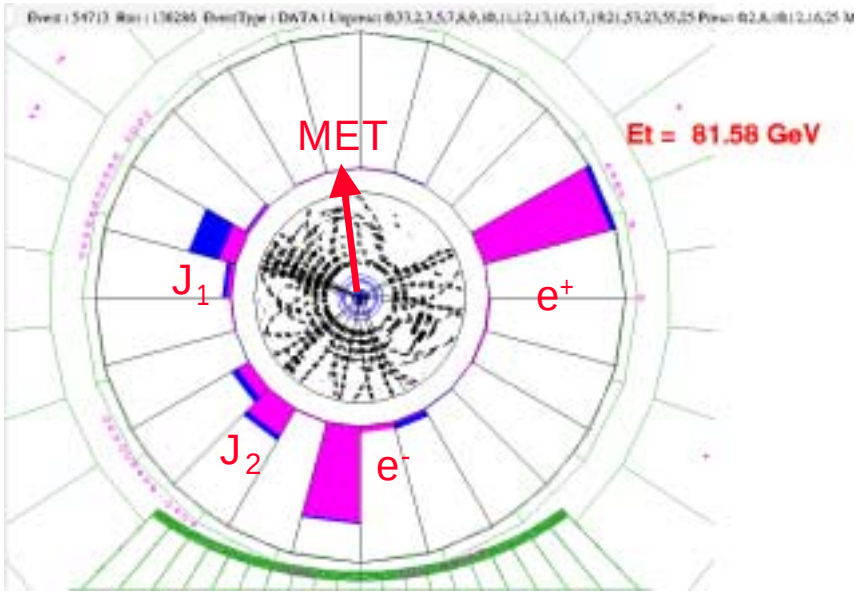
$E_T^j > 20$ GeV
$|\eta| < 2$

$W \rightarrow \mu\nu$ + n jets

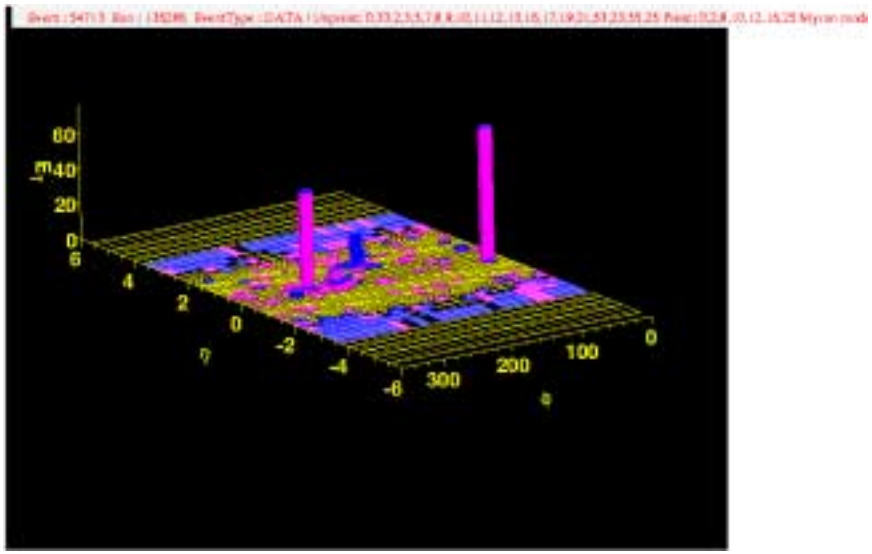


number of jets

Dilepton ttbar candidate



Et e^+ 73
Et e^- 56
Et Jet 1 35
Et Jet 2 34
Missing Et 43 GeV
M(e+e-) 118 GeV/c2



Current Status Summary

Detectors are in good shape

- physics data taking in progress
- new results for Winter Conferences 2003
  - ⇨ O(100)pb^{-1}/experiment
- more in Summer

Tevatron improved during the past year

- Expect >200 pb^{-1} by the end of 2003

a lot of physics ahead of us!

Perspectives→Beyond 2 fb^{-1}

CDF and D0 submitted proposal for upgrades of their detectors in view of a larger exposure to ppbar collisions than originally designed (2 fb^{-1})

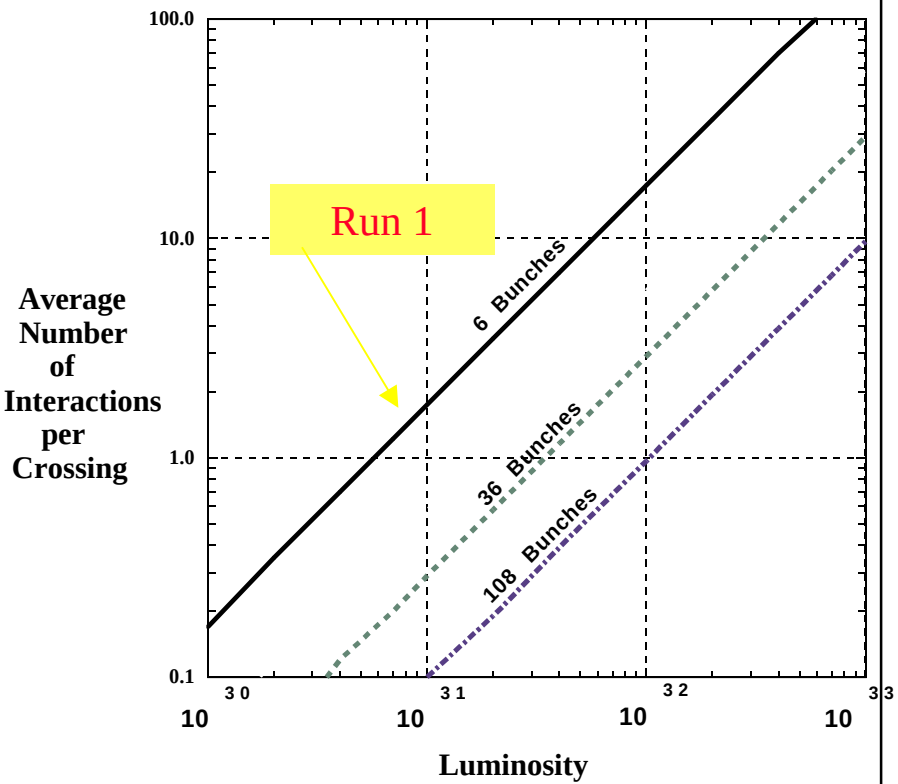
- ☞current status is:
  - ⇨Fermilab PAC has given scientific approval (stage 1)
  - ⇨DOE/HEP technical and cost review (Lehman review): Projects technically ready to be baselined
  - ⇨DOE/HEP decision to be made by the end of 2002

Information and accelerator challenges shown in the next slides were taken from public presentations (HEPAP talk by M.Witherell)

Run 2

Run 2 is the continuation of on-going Run 2a

- smooth transition to higher luminosity after $2fb^{-1}$
- interbunch, two options:
  - 132 ns interbunch
  - 396 ns interbunch (most likely)
- if 396 ns
  - our detectors were not designed to cope with large $<N_{int}>$/x-ing
  - limit this number without losing in int.lum.
    - → luminosity leveling



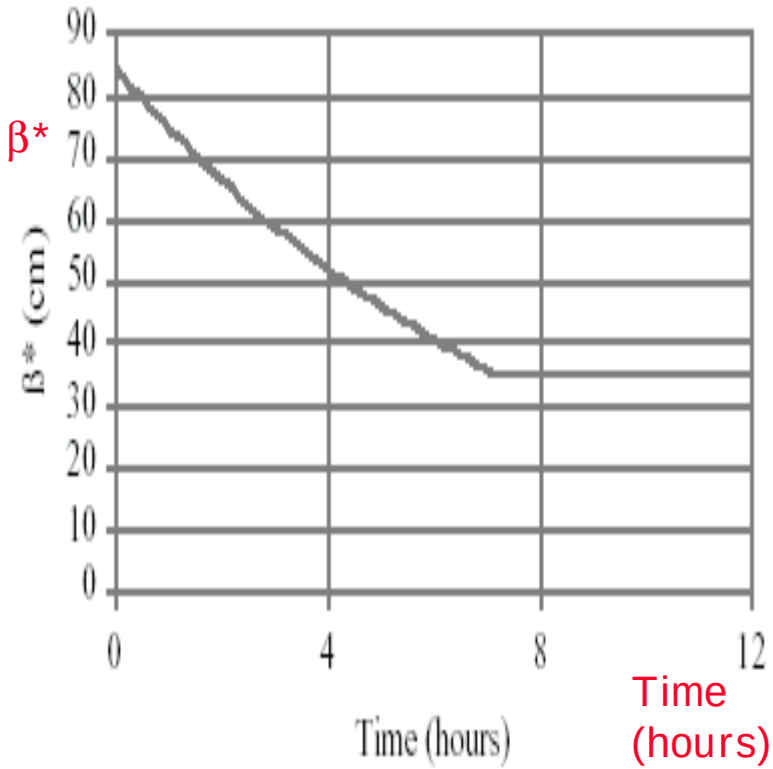
How to get lots of luminosity

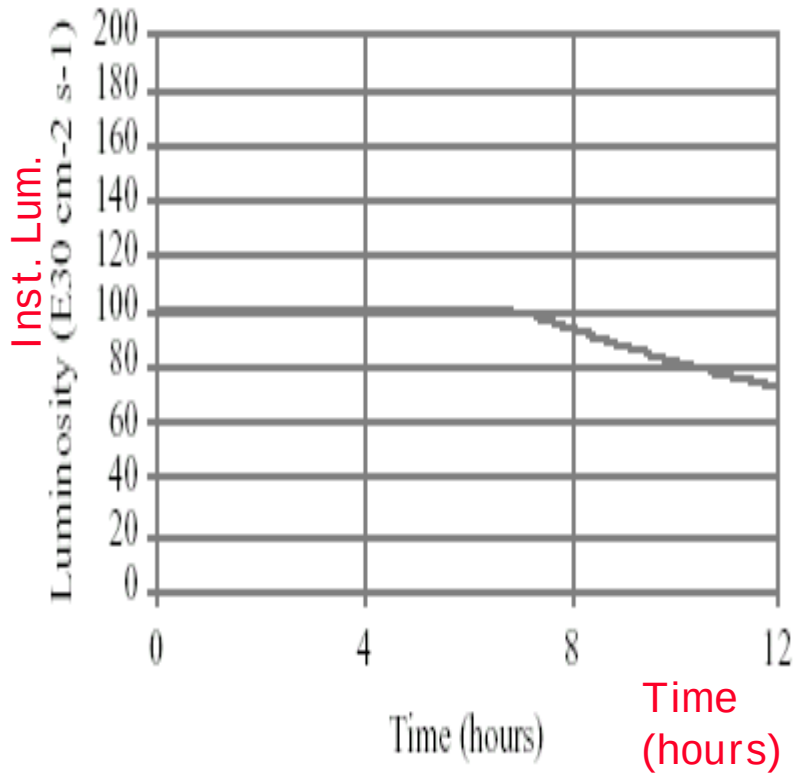
Options being considered

⇨change focusing (β*) at IP

→via change to magnetic fields (quads) or

→via change of electrostatic separators (x-ing angle)





after 2fb^{-1}, Run 2

- a number of (sub)projects to fulfill:
- strategy:
  - ⇨ increase the pbar flux (more p on target)
    - we achieved a record of 130 10^9/hour
    - → better collection ε (new lenses and better optics)
  - ⇨ cool the increased antiproton flux
    - → increase pbar flux capability of the AA
    - → electron cooling in Recycler Ring

	Run 2 now	Run 2a design	Run 2 target	units
Protons/bunch	200	270	270	10^9
AntiProtons/bunch	26	30	148	10^9
Pbar prod. rate (avg)	69	120	392	10^9/hour
Stack Size	131.1	132	625	10^{10}
Bunch separation	396	396	396	ns
Typical lum.	3.2	8.1	39.2	10^{31}cm^{-2}s^{-1}
Integrated L	5-6.7	16	87.9	pb^{-1}/week

Run 2 goal

accelerator challenge (in fb^{-1})

FY	base	stretch
2002	0.08	0.08
2003	0.2	0.32
2004	0.4	0.6
2005	1.0	1.5
2006	1.5	2.5
2007	1.5	3.0
2008	1.8	3.0
Total	6.5	11.

Hunting for the Higgs is one part of a wider physics program:

- $2\,fb^{-1}$ exclude m_H=115 GeV(*); SUSY at large tanβ
- $5\,fb^{-1}$: 3σ signal for m_H=115 GeV(*); search through most of the SUSY Higgs parameters space
- $10\,fb^{-1}$: 3σ signal for m_H=115-125, 155-175 GeV(*)

Looking for unexpected phenomena in our data

(*)Results from the Fermilab Higgs Working Group. Being reexamined by CDF and D0

Conclusion

A lot of physics ahead of us!

By Winter 2003 results on

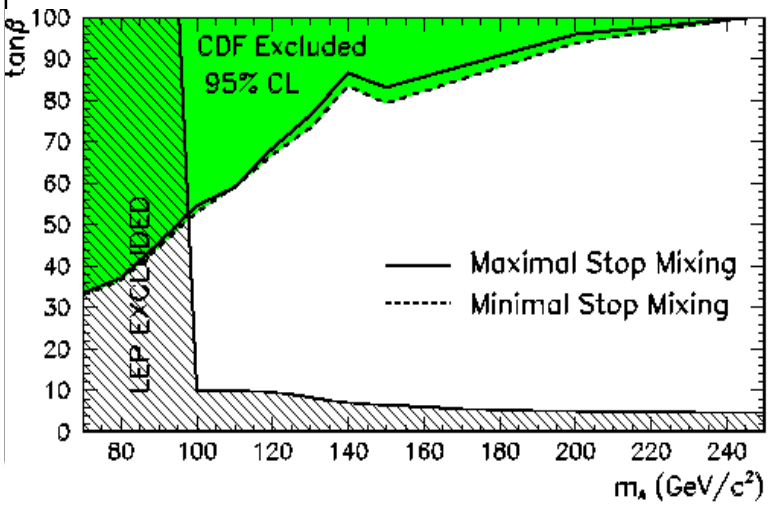
- EWK, σ_{ttbar}, charm, Λ_b and B_s, B_d mixing...

With several hundreds pb^{-1}

- B_s mixing, CPV in $J/\Psi K$,B_c...
- top physics: top production and decay B.Ratios

Longer term:

- SUSY, Higgs, searches...



$1\ fb^{-1}$
m_A =150 GeV,
tan β = 50