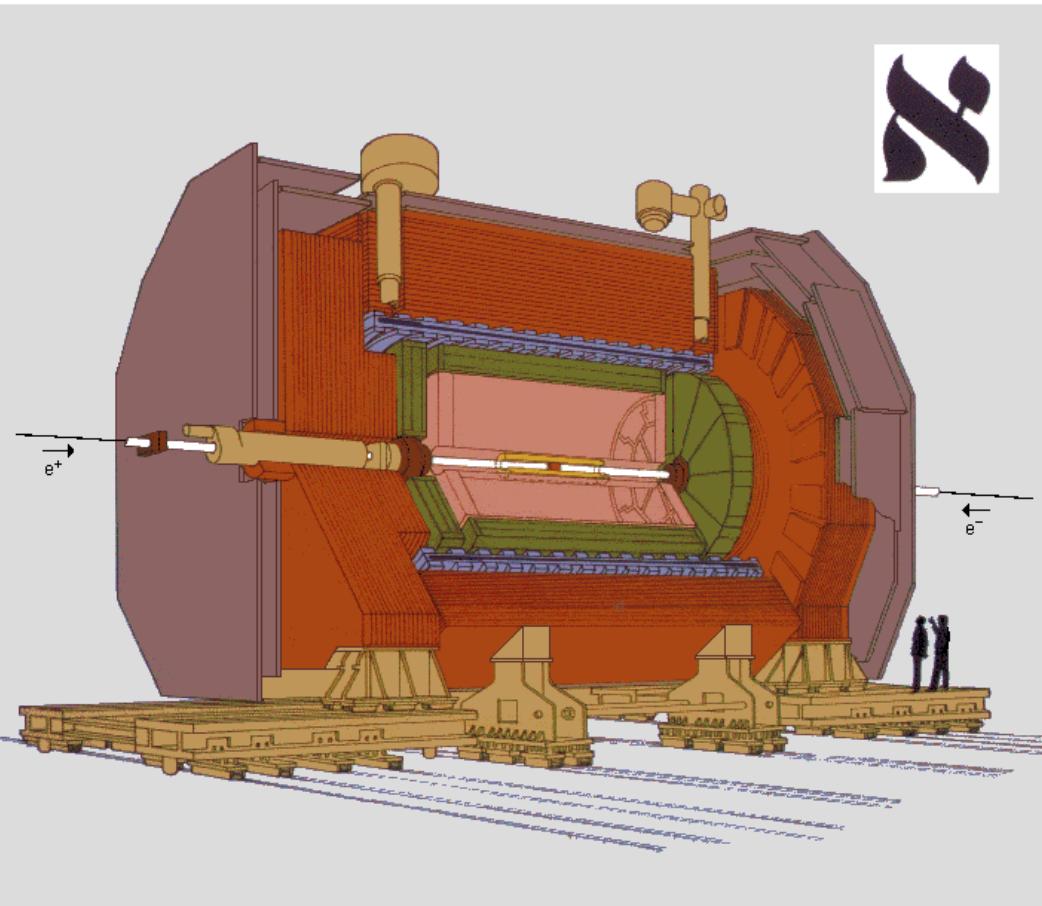


ω

Accelerator	Location	Process	CM Energy	Dates	Some Expts.	Major results
SPEAR	SLAC	e^-e^+	3-6 GeV	72-90	Mark I, Crystal Ball	Charm, τ , jets
Petra	DESY	e^-e^+	14-46 GeV	78-86	JADE, Tasso, Argus ...	gluon jets, b mixing
PEP	SLAC	e^-e^+	29 GeV	80-90	Mark II, TPC, MAC, ASP	b-lifetime
SppS	CERN	$p\bar{p}$	540 GeV	81-90	UA1, UA2, UA5	W/Z
Tristan	KEK	e^-e^+	50-64 GeV	87-95	Amy, Topaz, Venus	top has very high mass
SLC	SLAC	e^-e^+	91 GeV	90's	SLC	polarized Z prod. (A_{LR})
LEP	CERN	e^-e^+	91 GeV	89-96	Aleph, Opal, L3, Delphi	high statistics EW
Hera	DESY	ep	30GeV on 900 GeV	92-now	H1, Zeus, Hermes, HeraB	Proton structure, diffraction
Tevatron I	Fermilab	$p\bar{p}$	900 GeV	87-96	CDF, D0	top and W mass
LEP II	CERN	e^-e^+	91-210 GeV	96-00	Aleph, Opal, L3, Delphi	WW production, W mass
Tevatron II	Fermilab	$p\bar{p}$	980 GeV	01 - 09?	CDF, D0	Higgs? Supersymmetry?
LHC	CERN	$p\bar{p}$	14 TeV	late 00's	Atlas, CMS, LHCb	Higgs? Supersymmetry?
ILC	??	e^-e^+	500 GeV	late 10's	??	Higgs ? Supersymmetry?

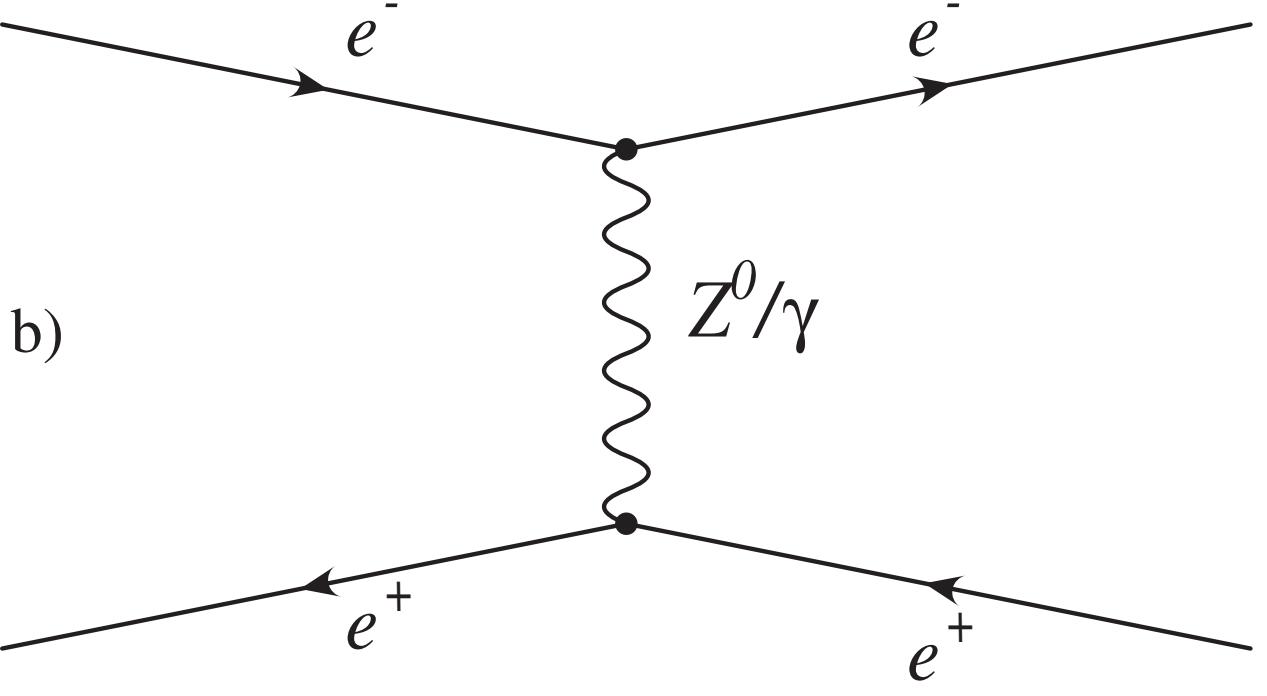
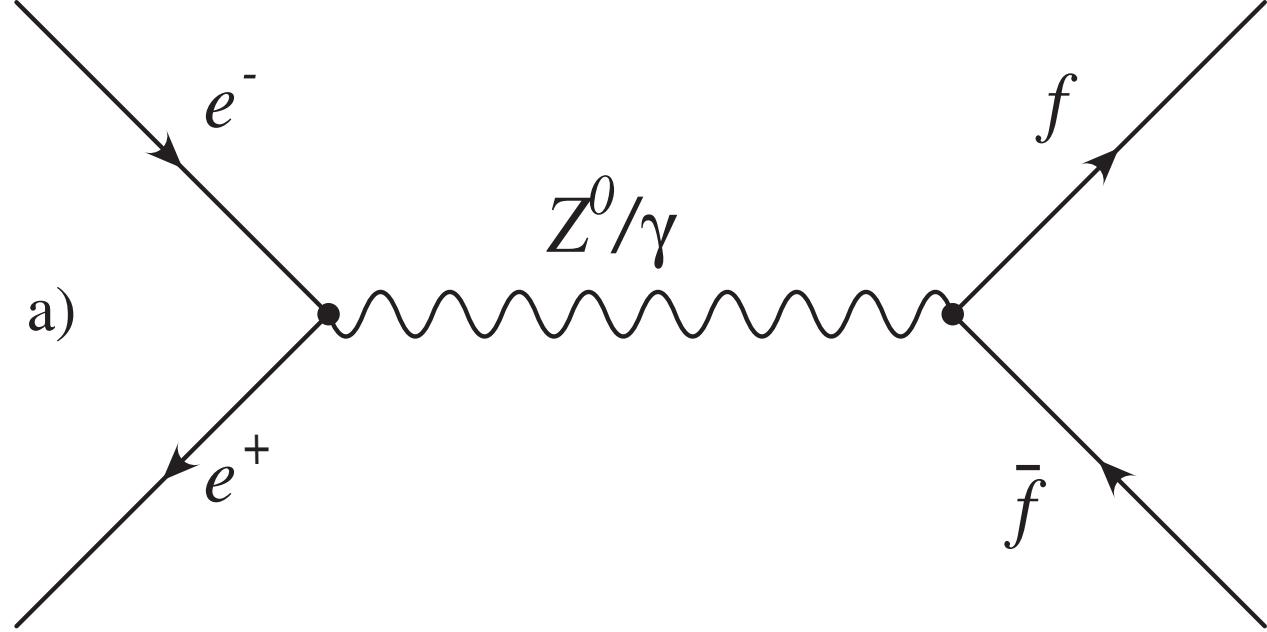
Table 1: Collider experiments at the energy frontier (DORIS, CESR, BES, Belle, Pep II not included)

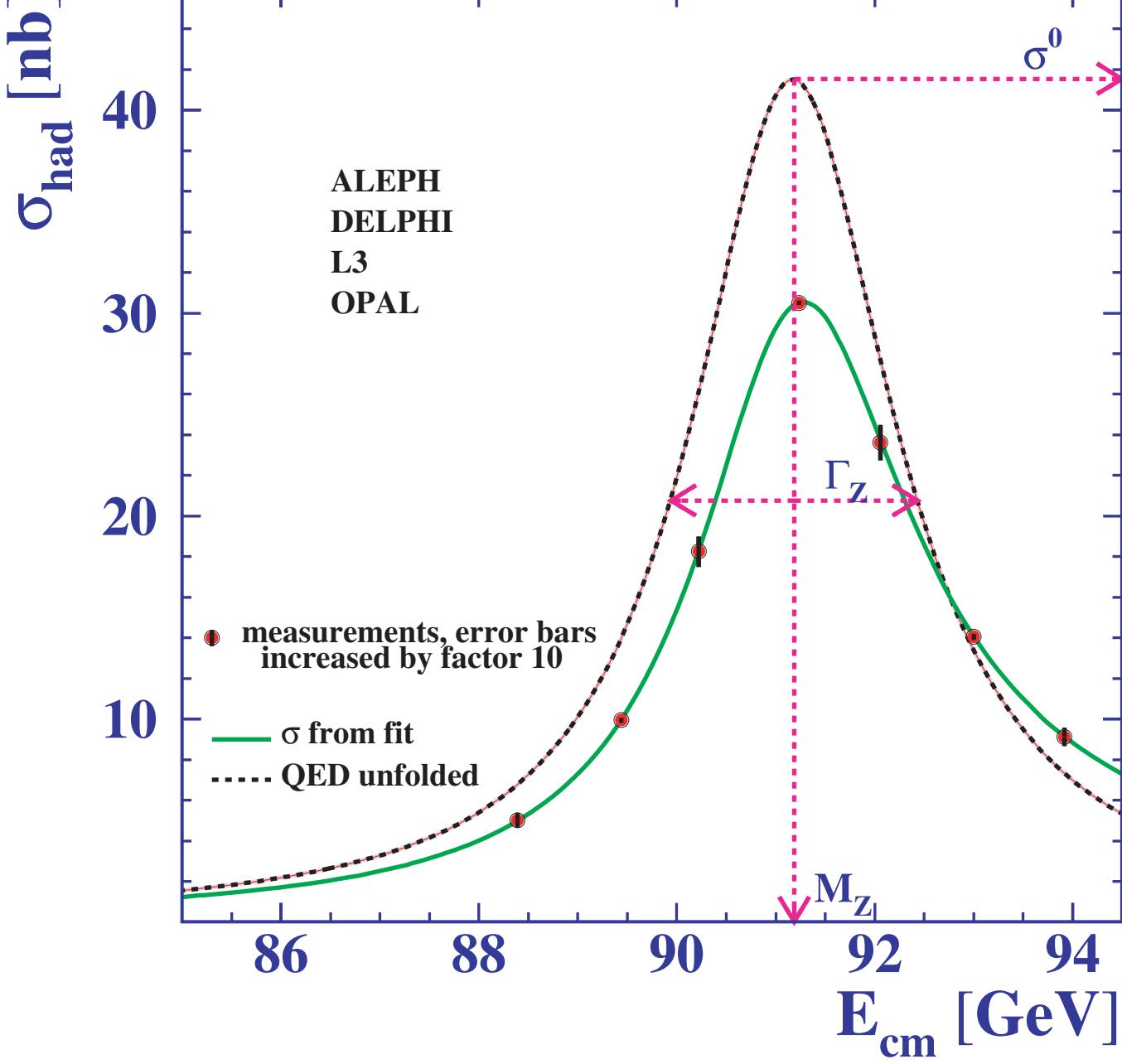


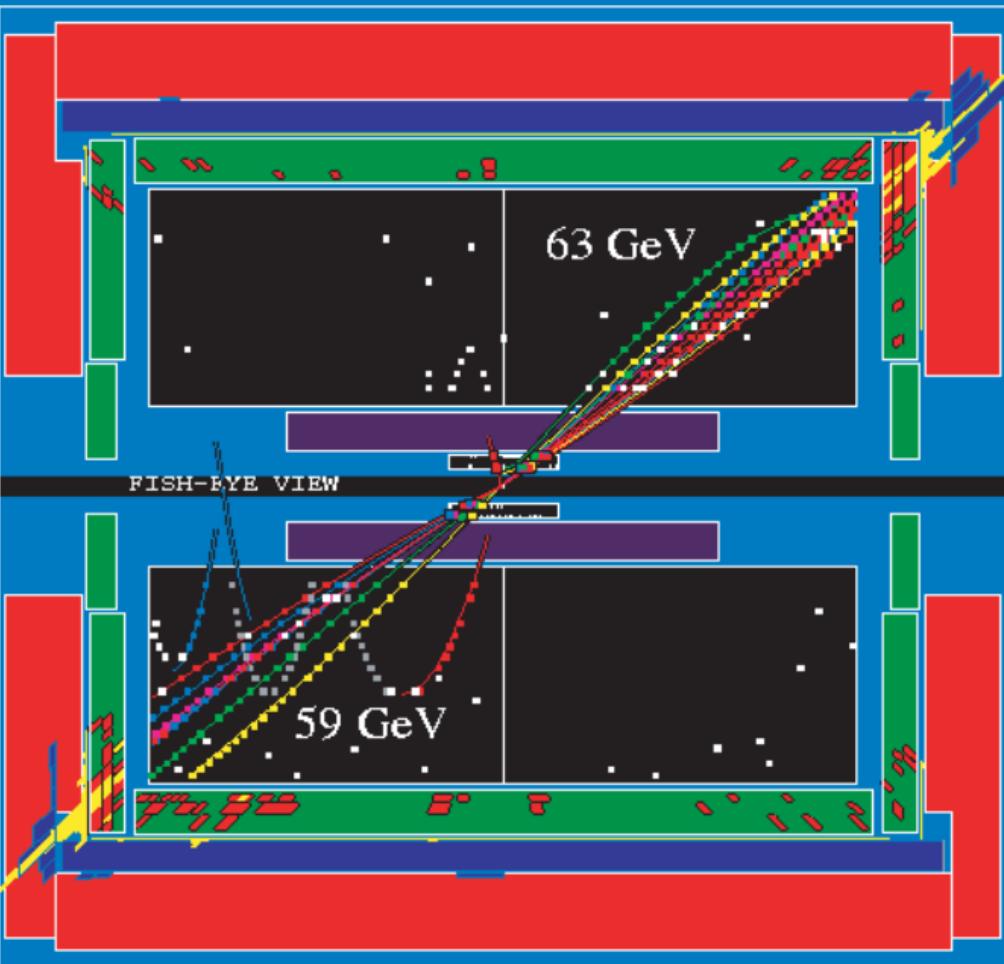
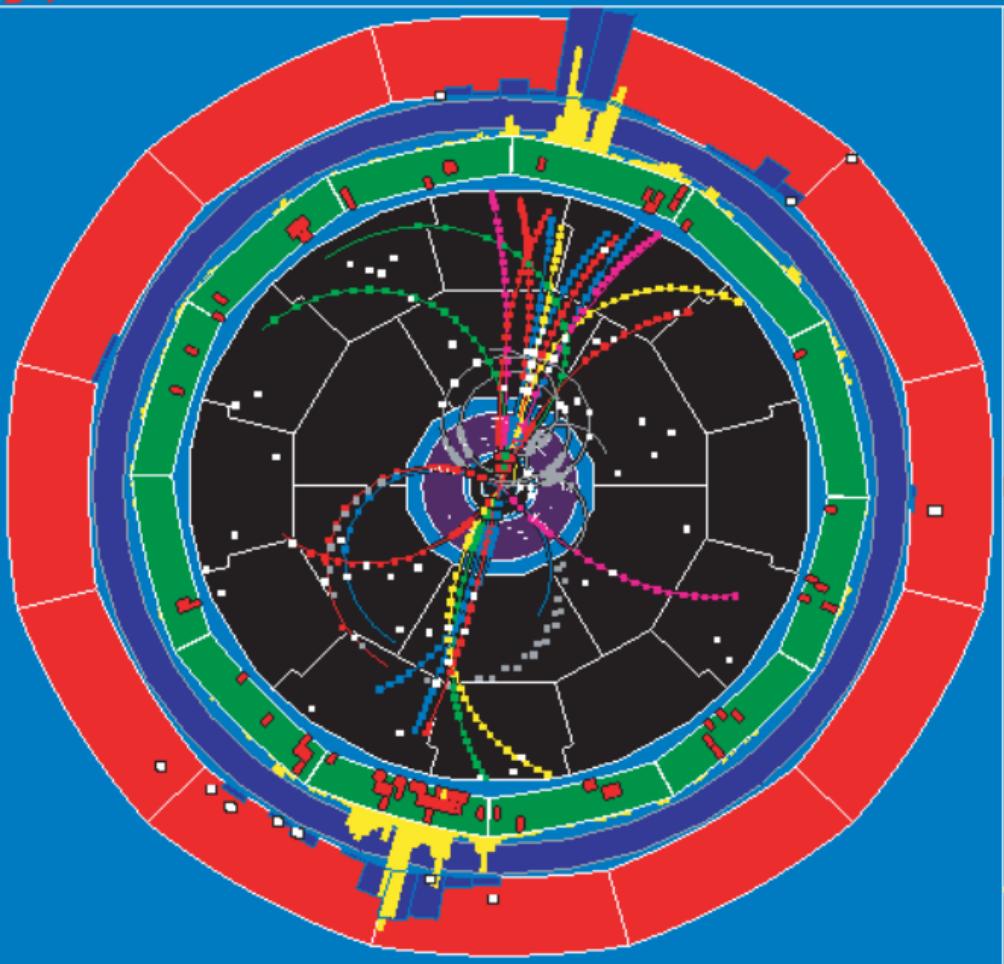
- Vertex Detector
- Inner Tracking Chamber
- Time Projection Chamber
- Electromagnetic Calorimeter
- Superconducting Magnet Coil
- Hadron Calorimeter
- Muon Chambers
- Luminosity Monitors

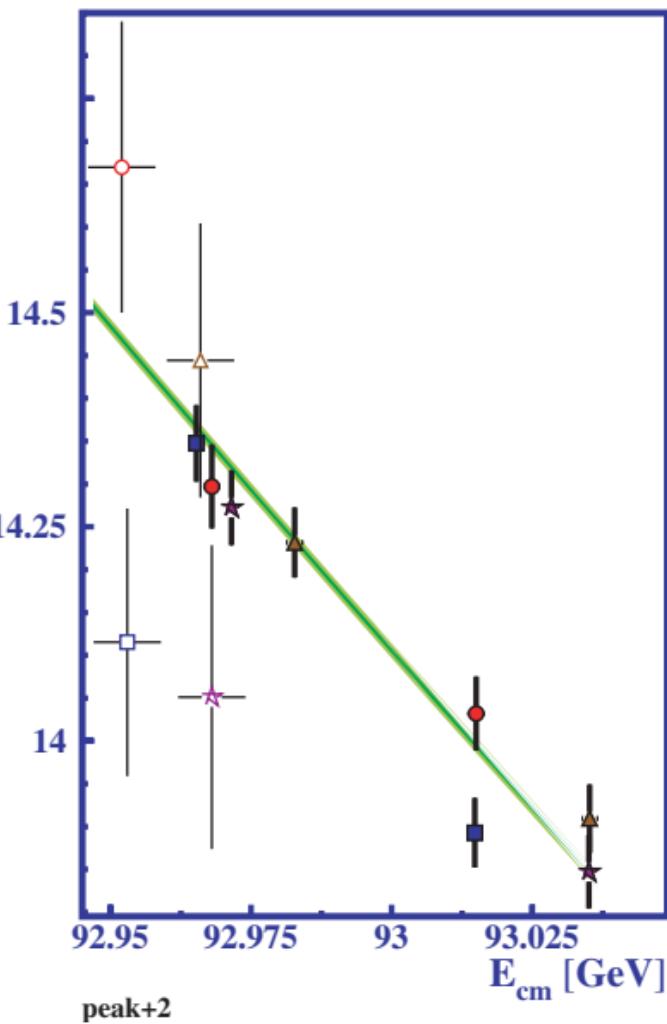
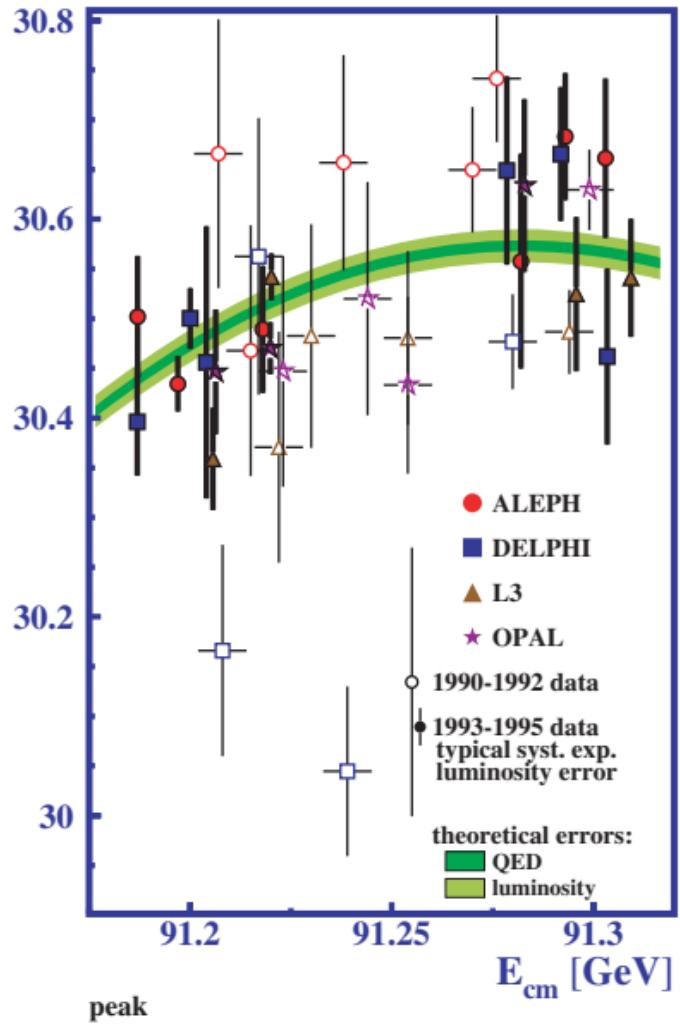
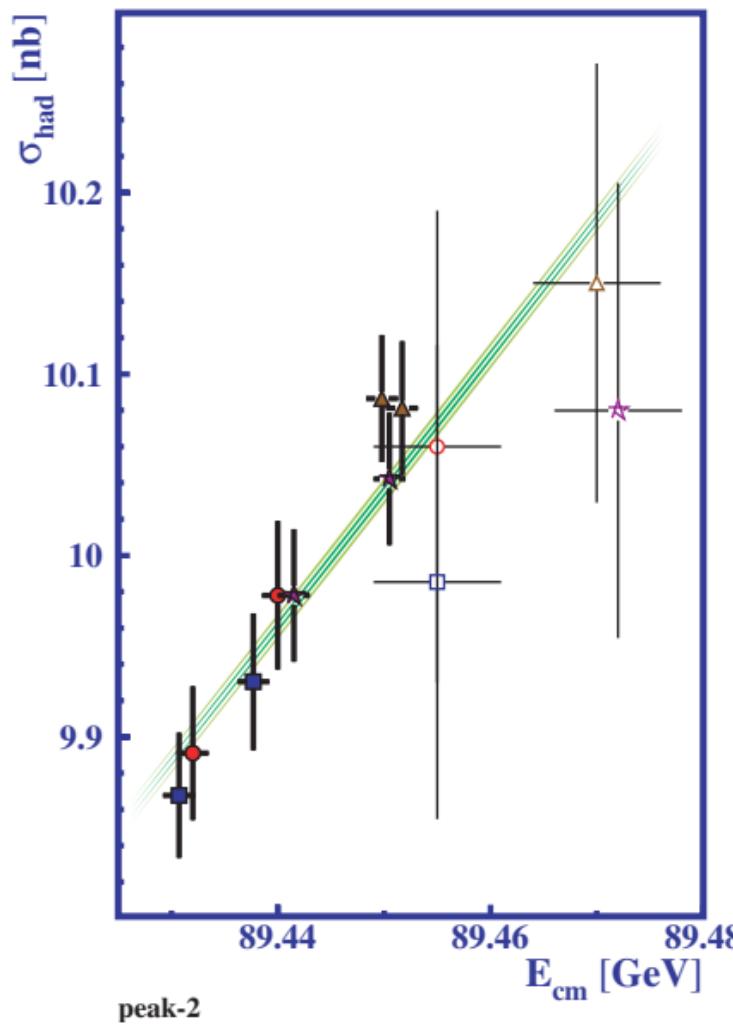
The ALEPH Detector

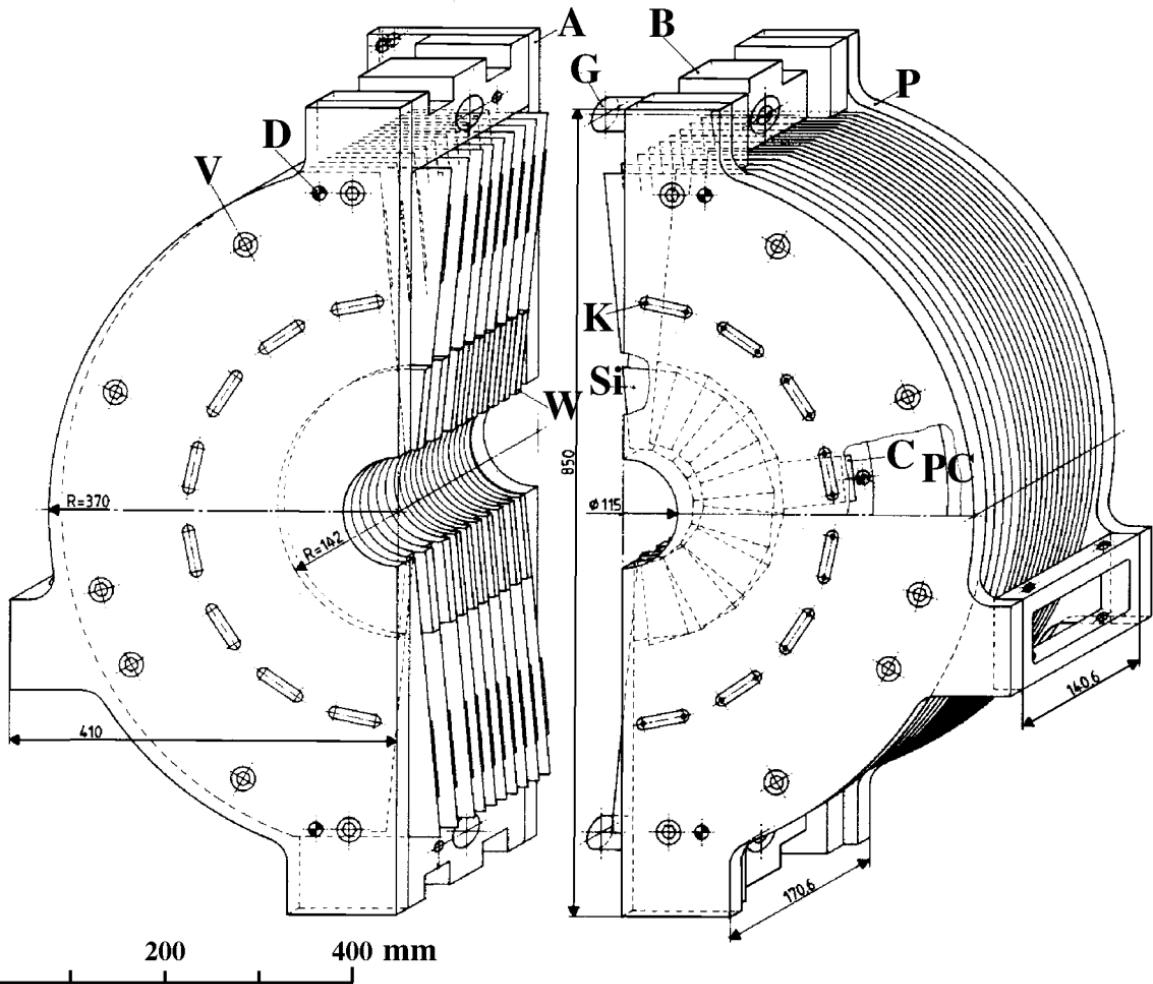






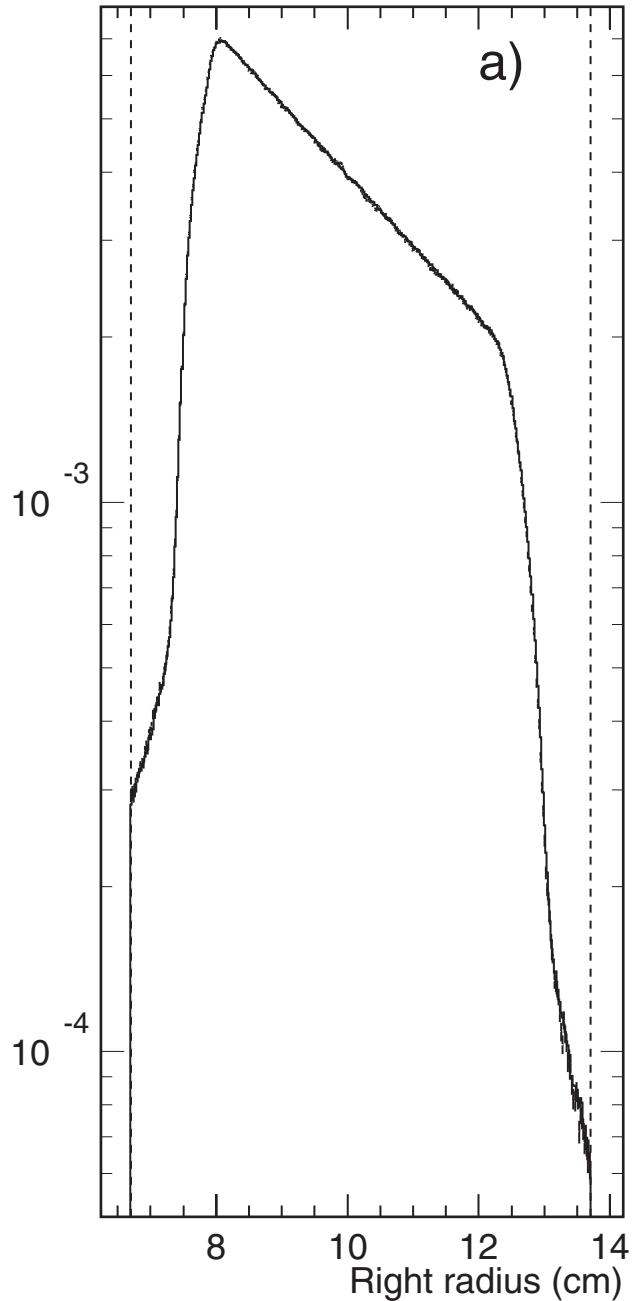




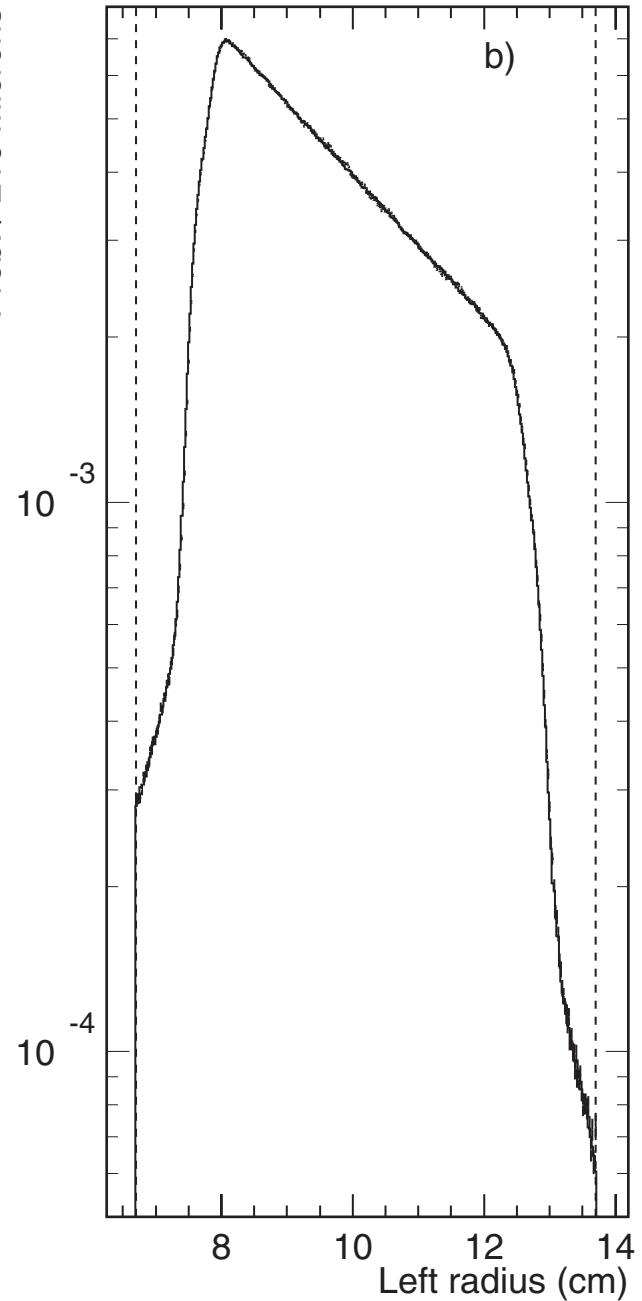


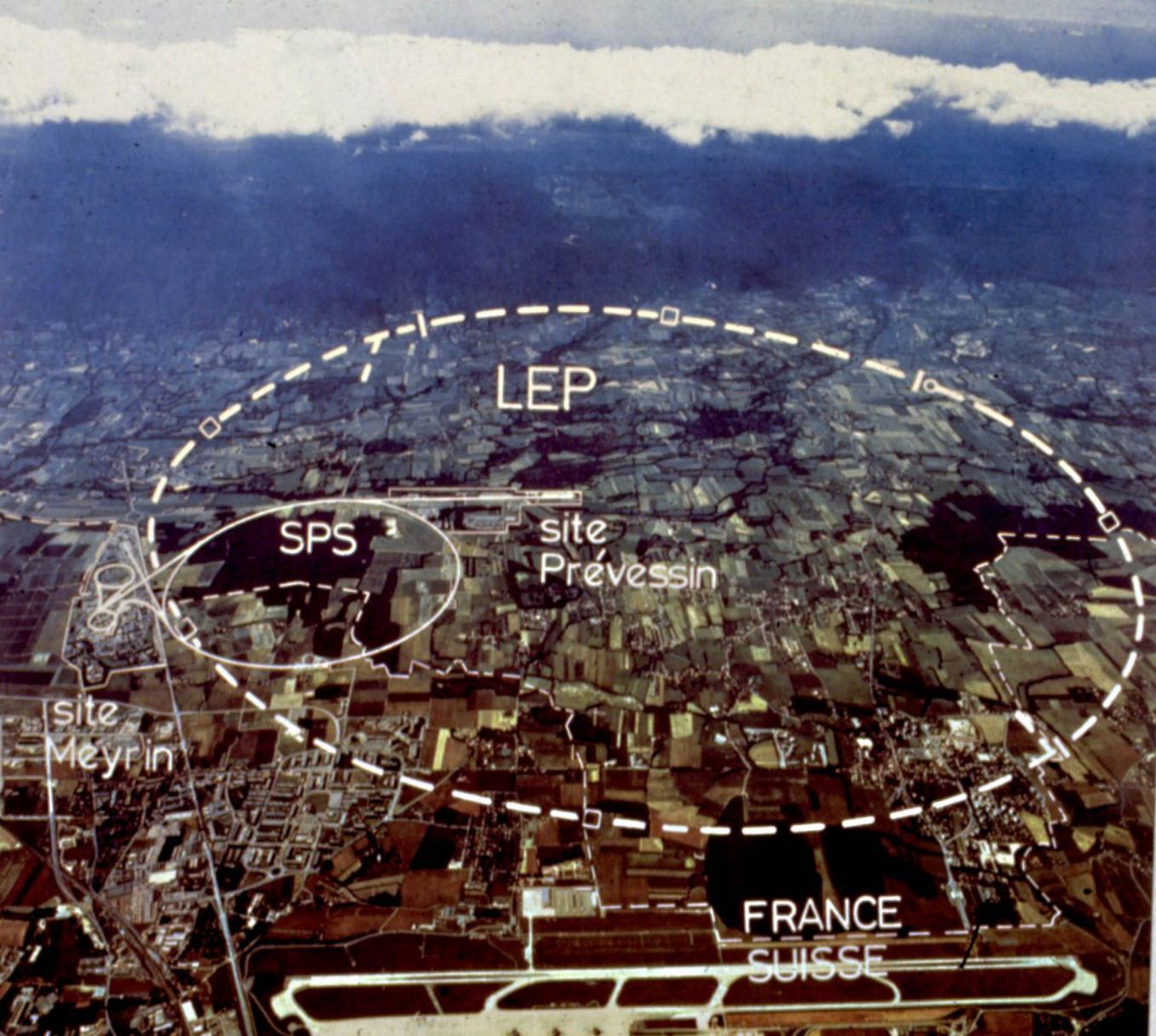
OPAL

Prob. / 210 microns



Prob. / 210 microns





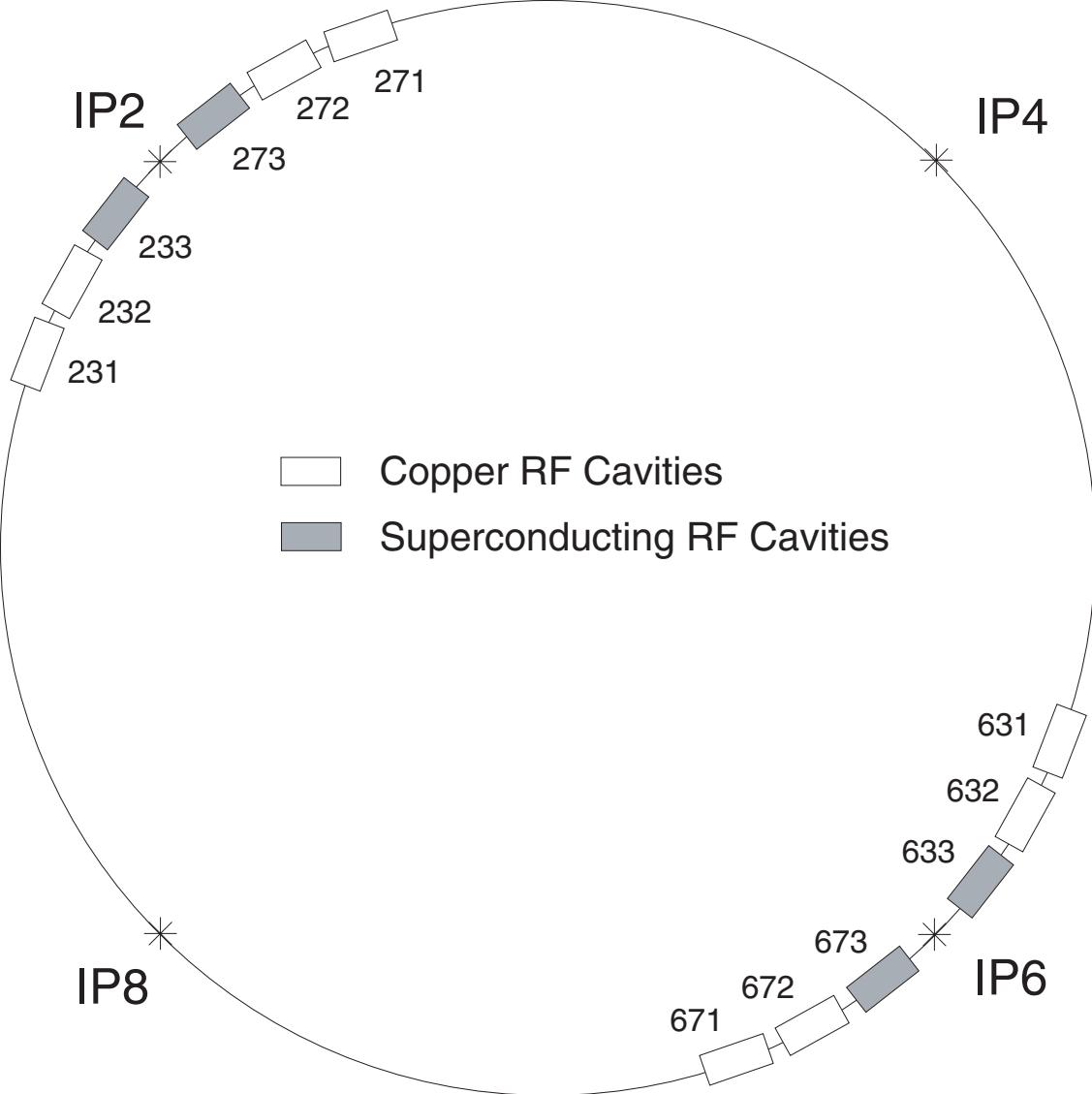
site
Meyrin

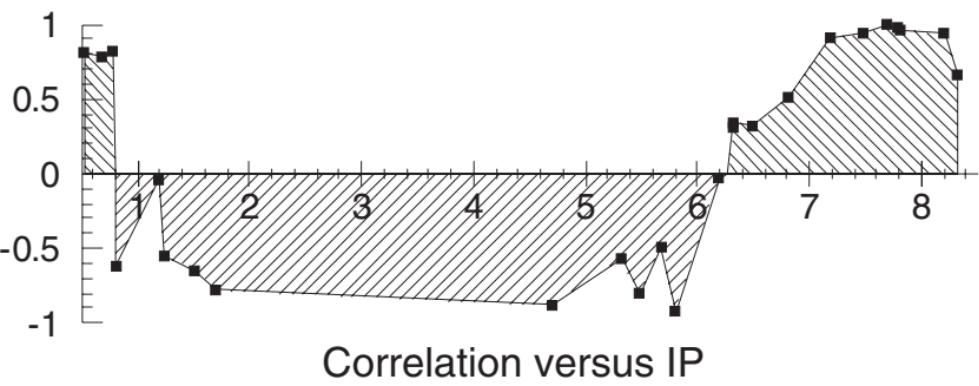
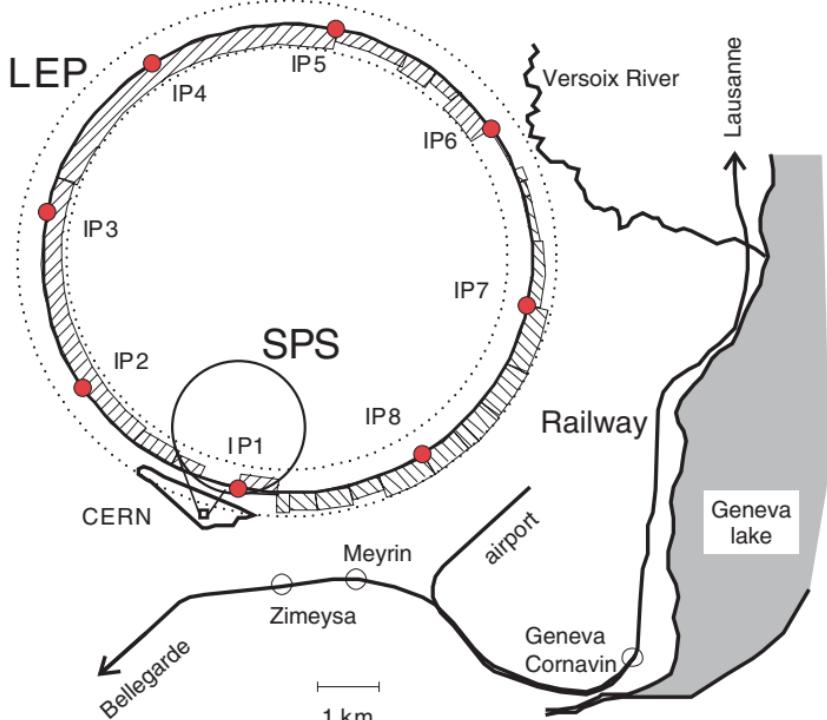
SPS

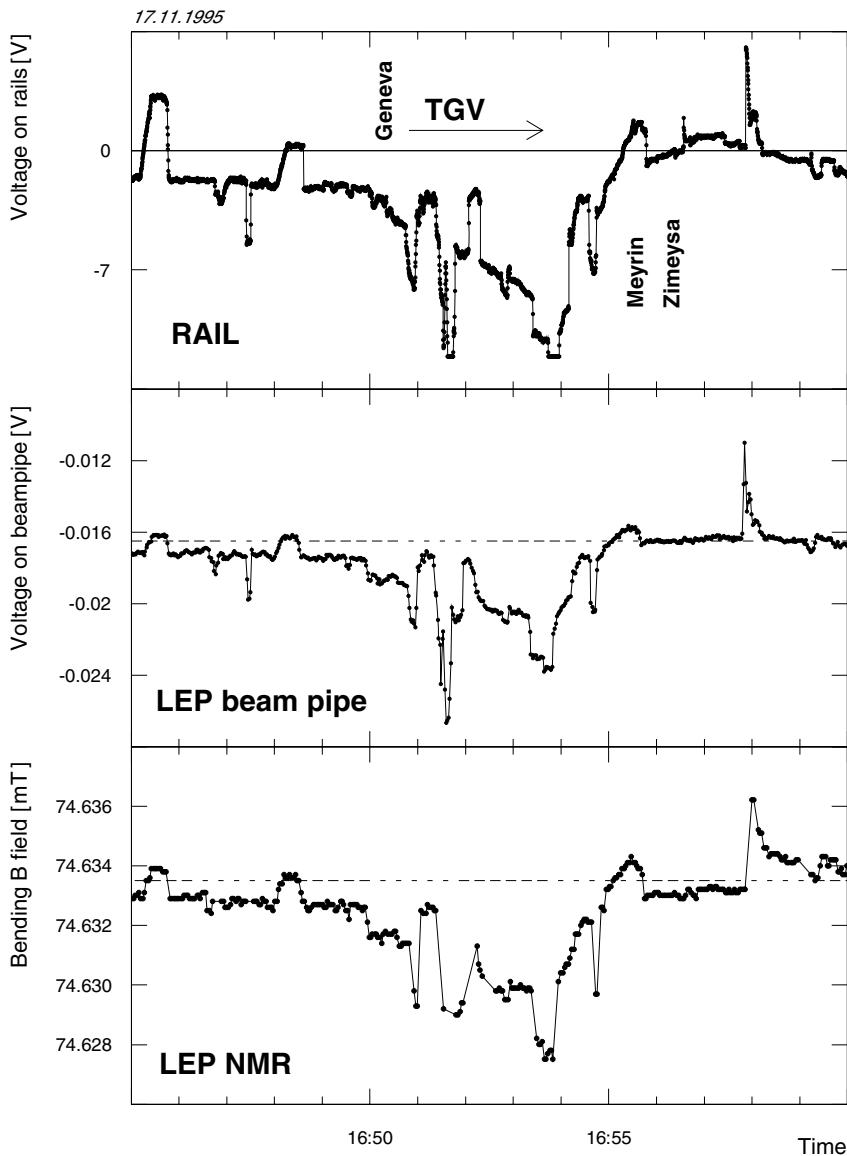
site
Prévessin

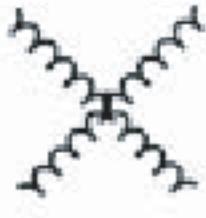
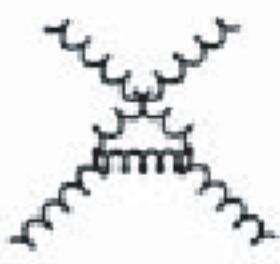
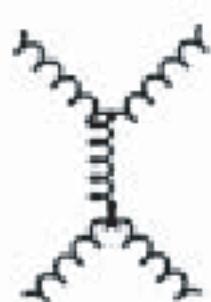
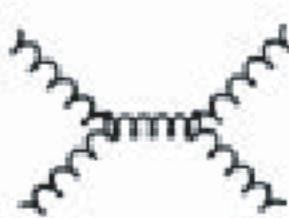
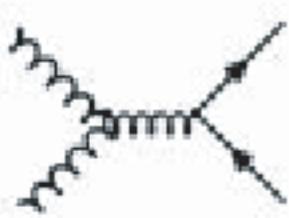
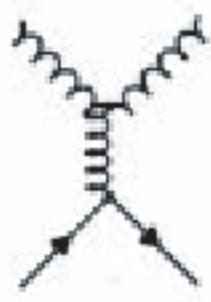
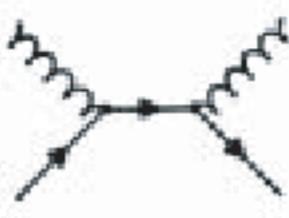
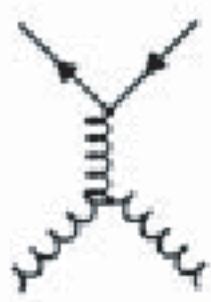
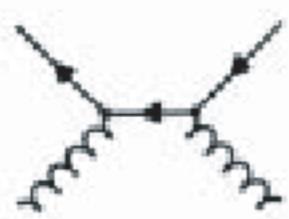
FRANCE
SUISSE

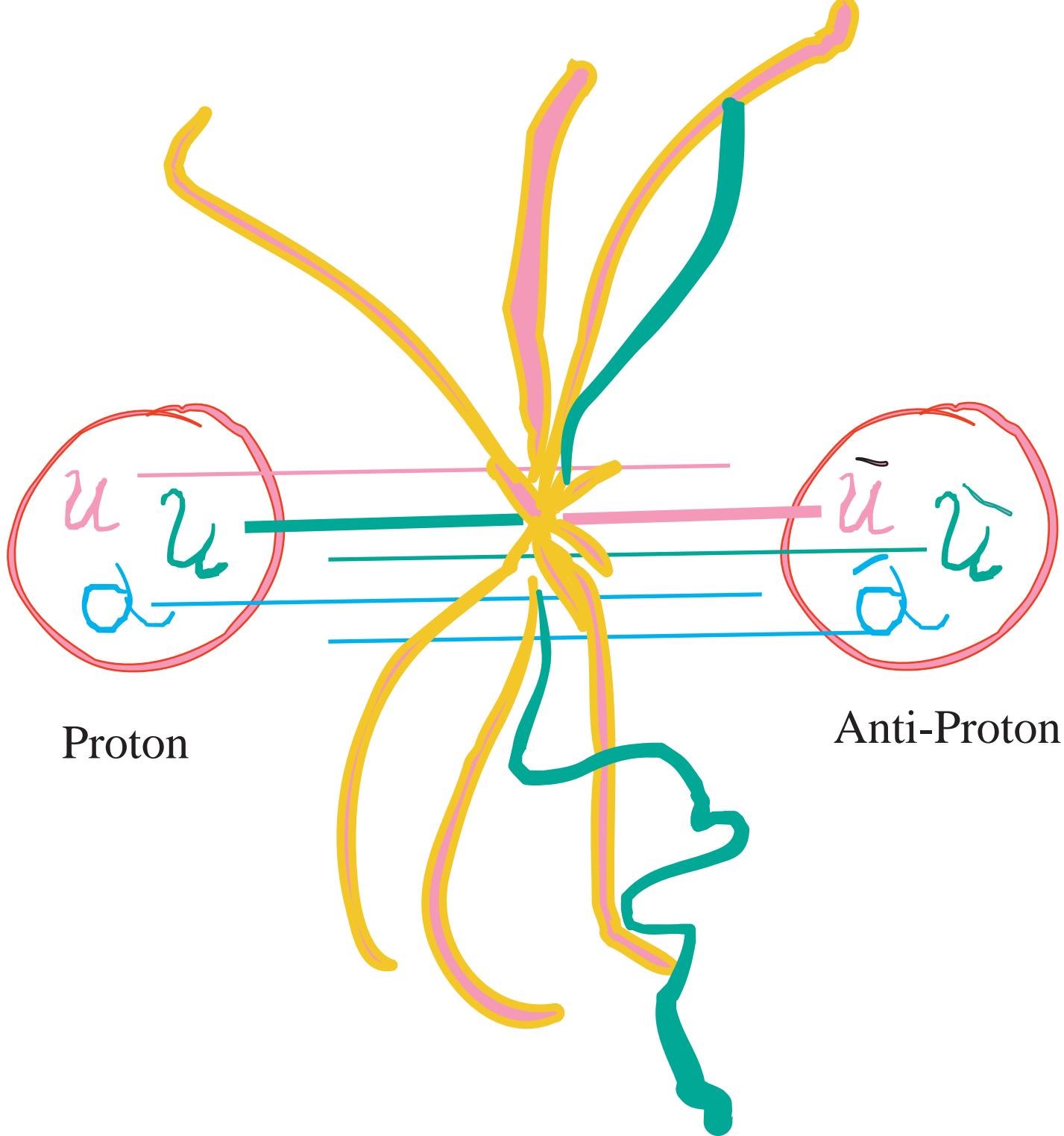
LEP

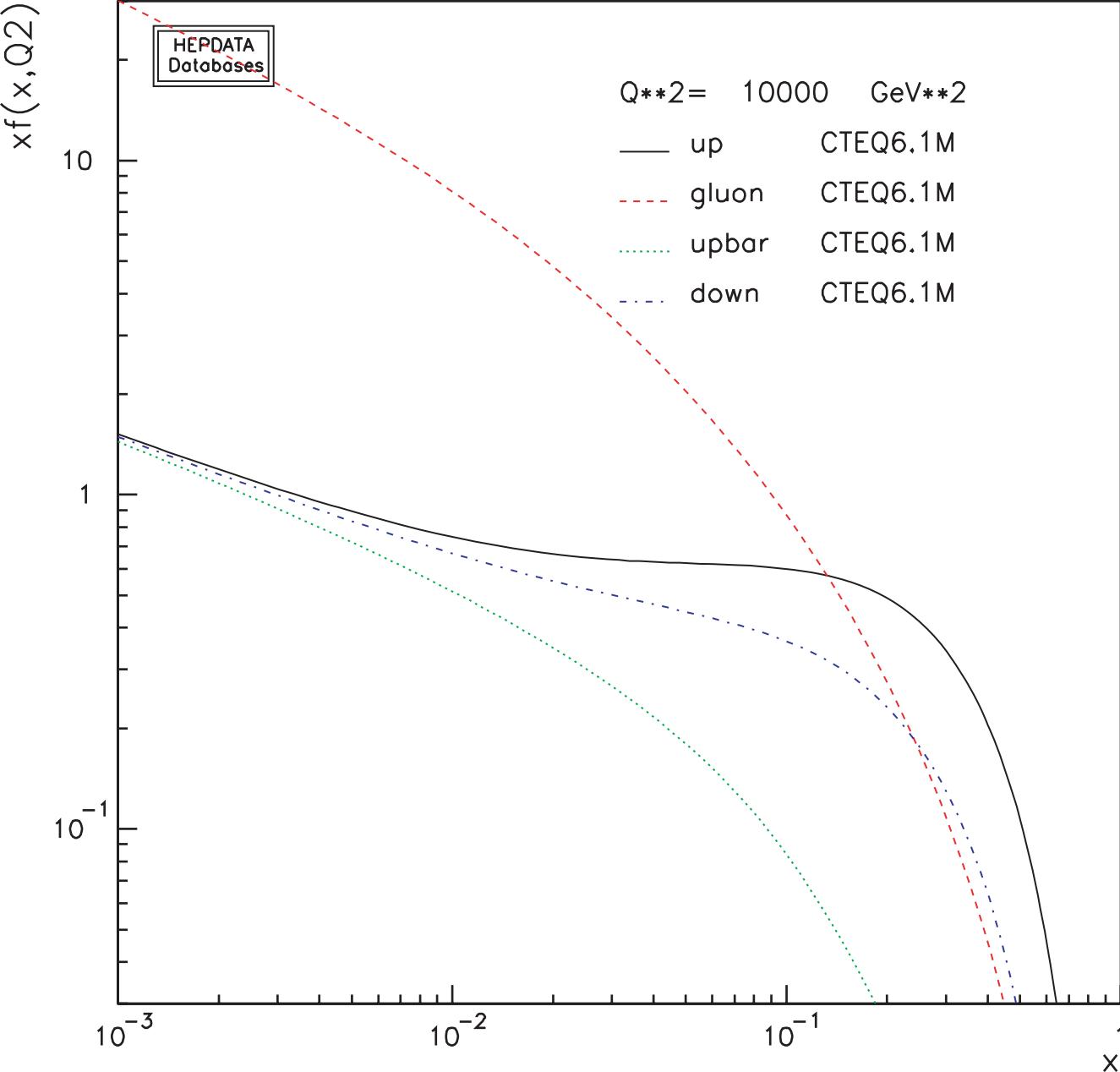


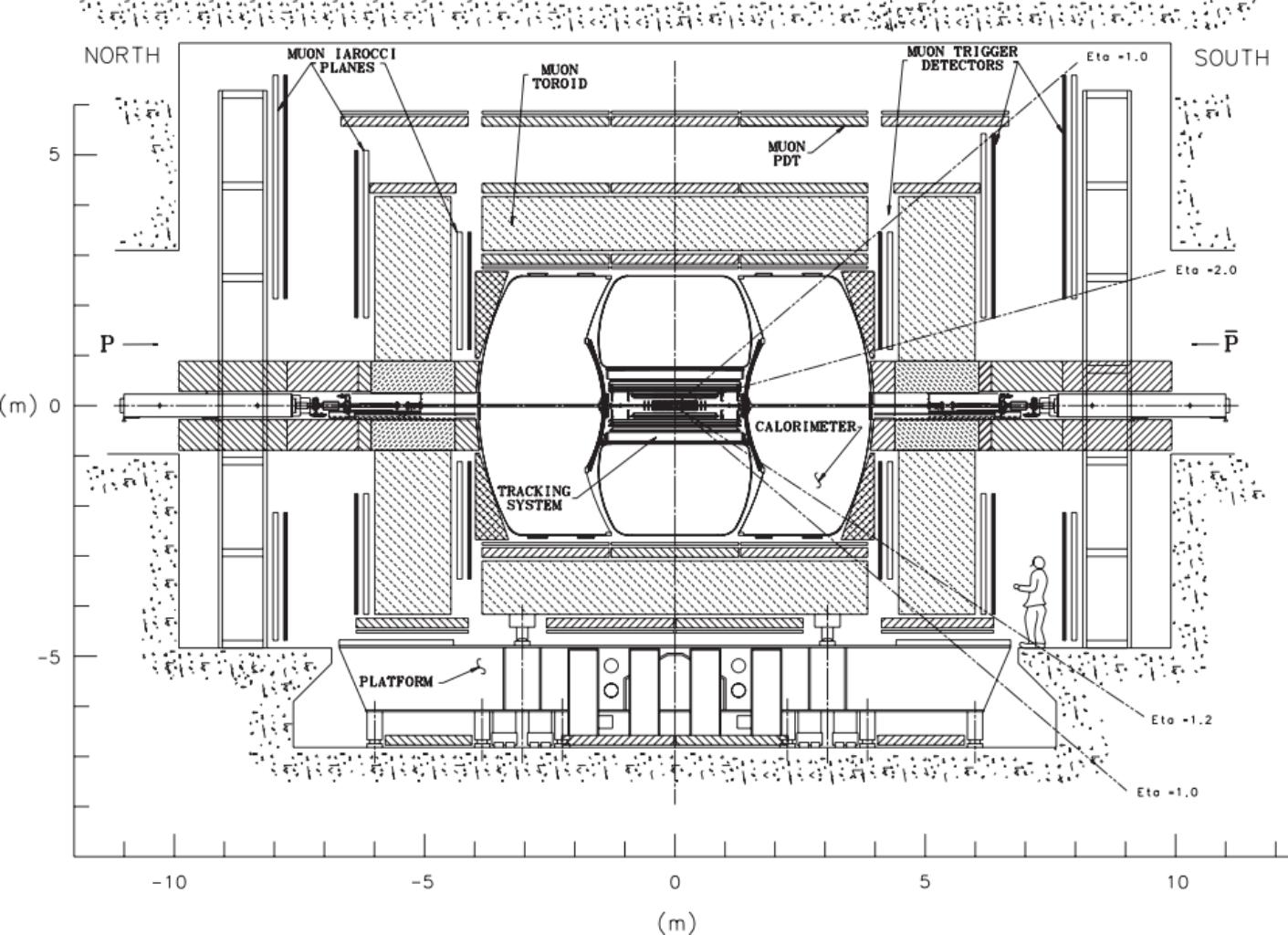


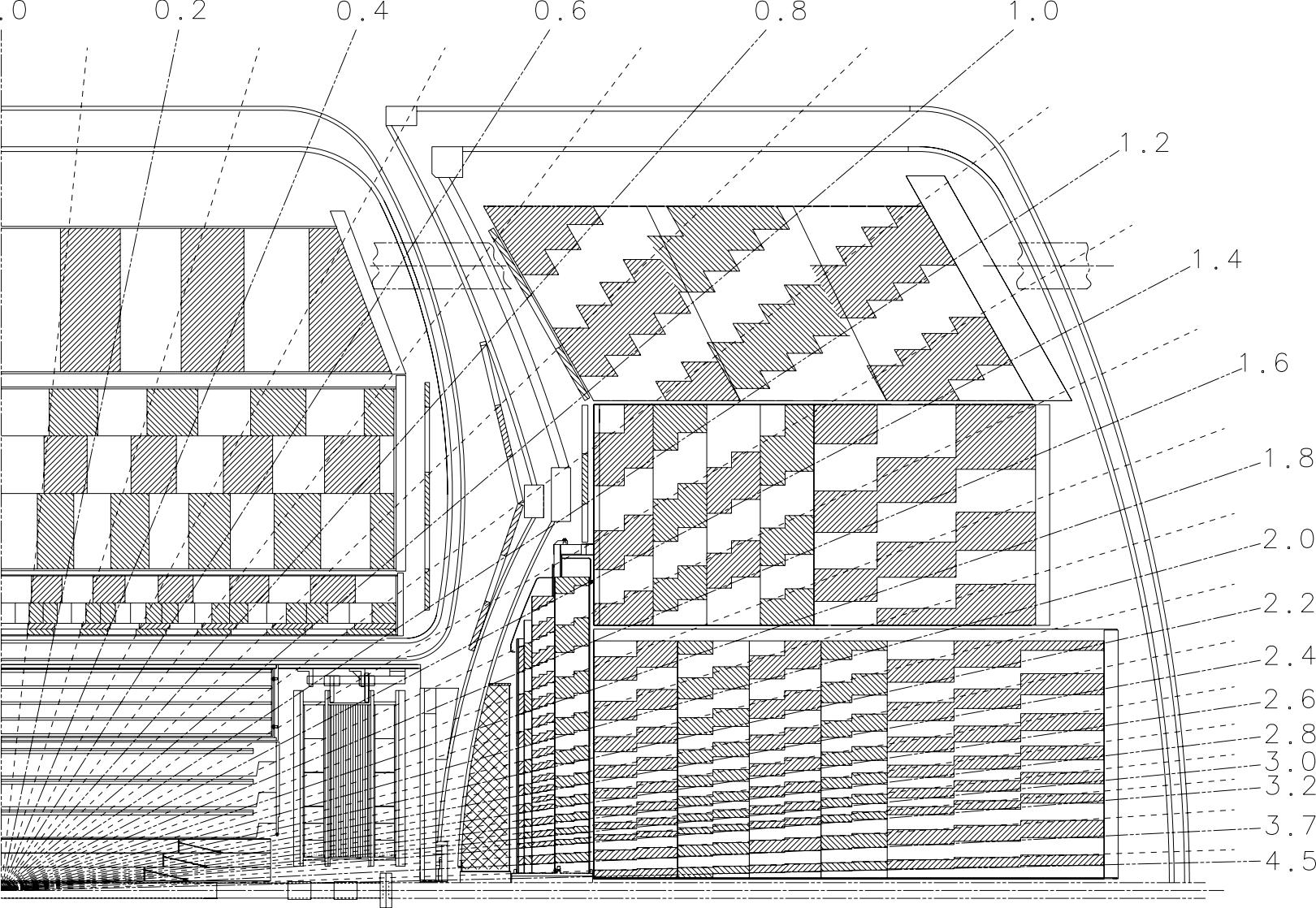


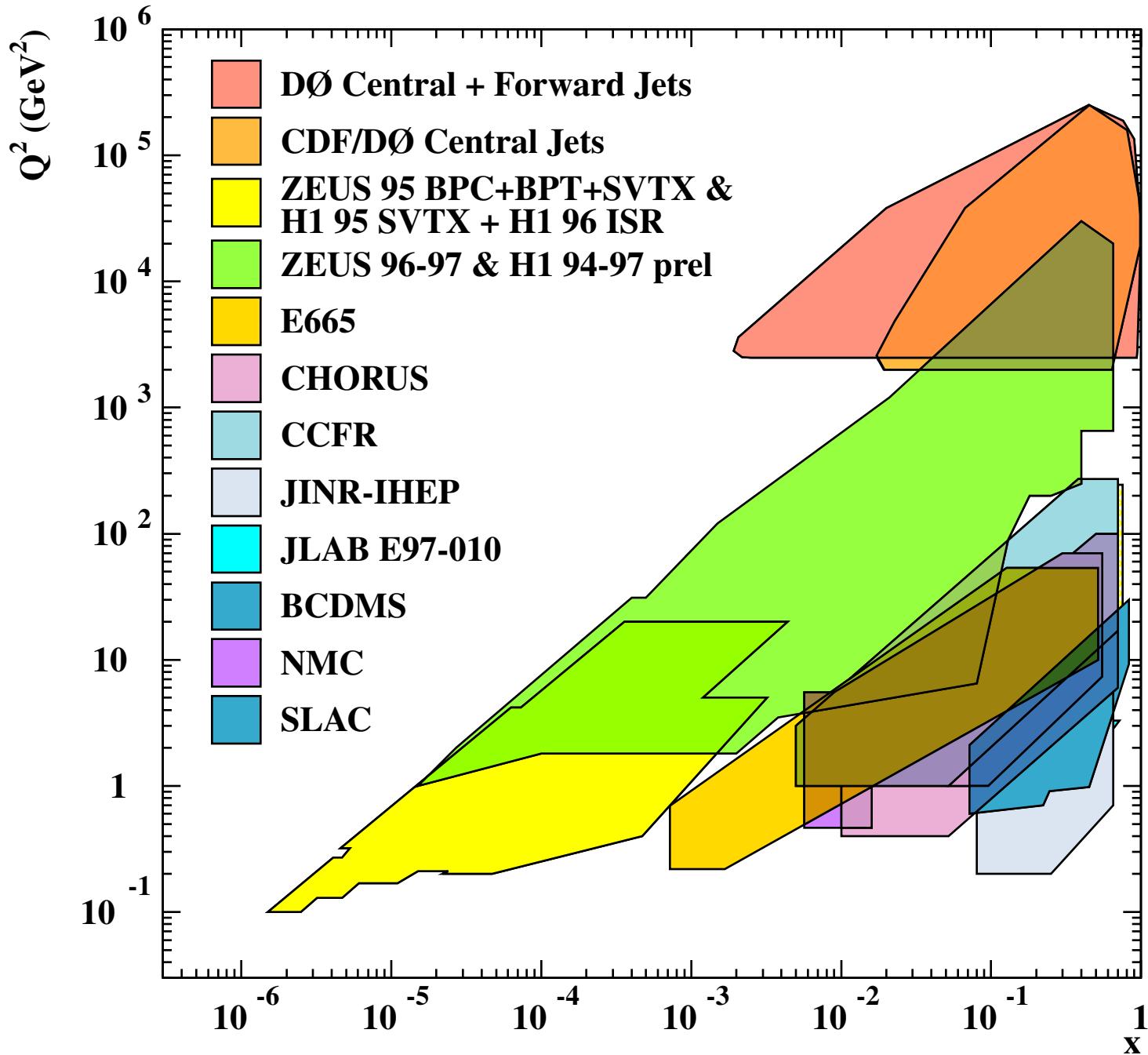


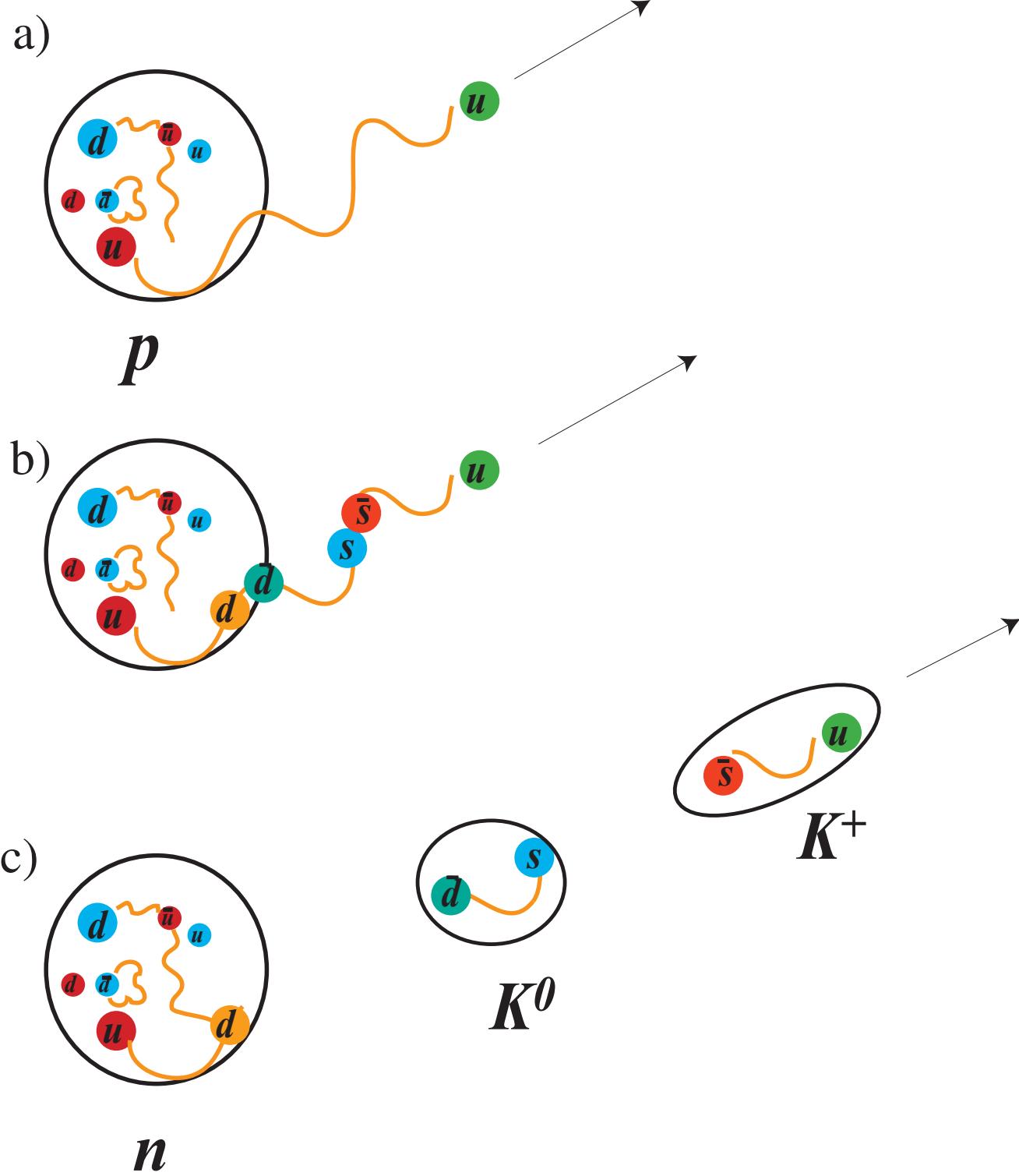




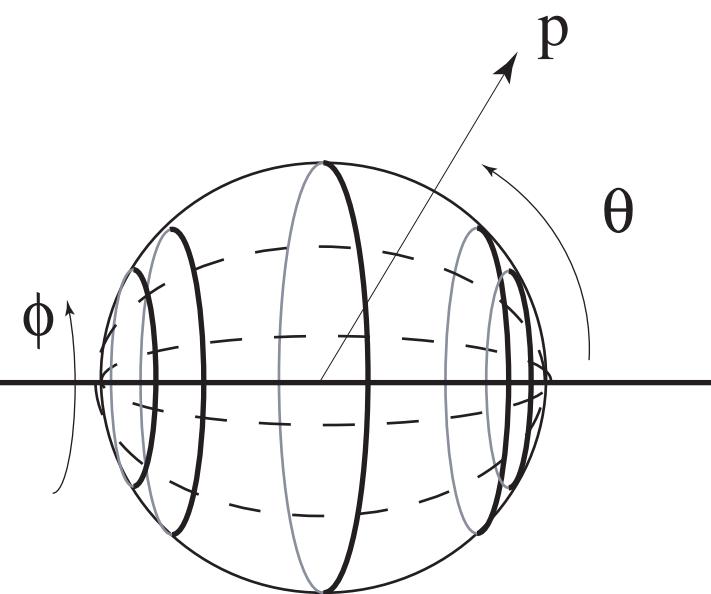






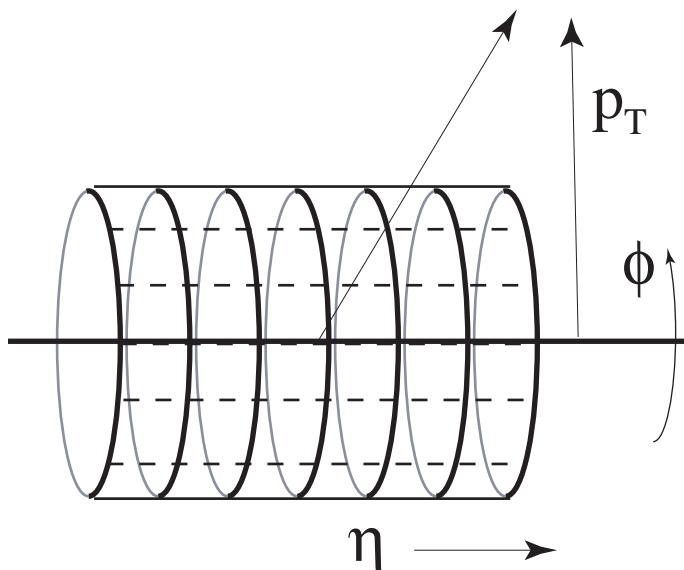


Spherical Coordinates



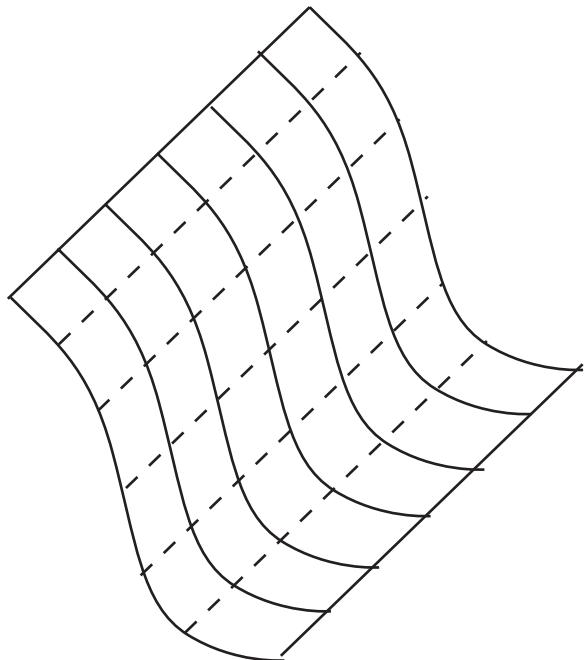
$p \theta \phi$

Collider Coordinates

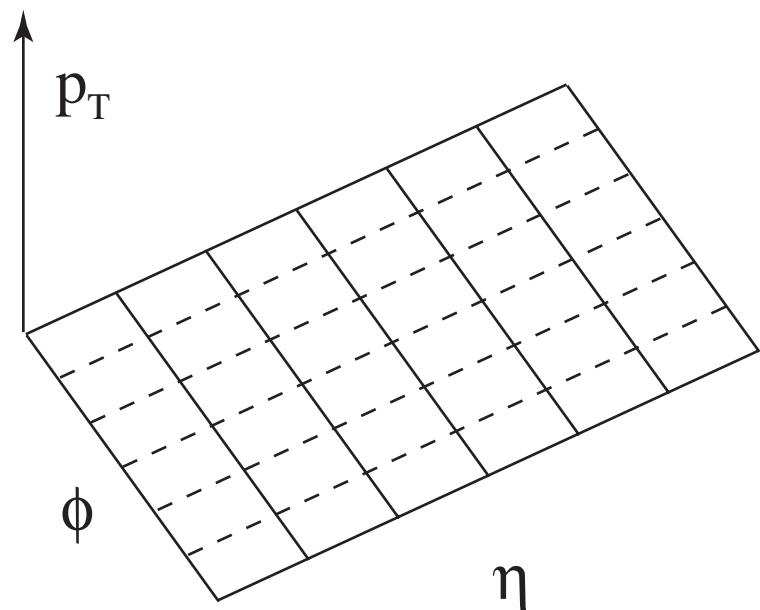


$$\eta = \ln \tan \theta / 2$$

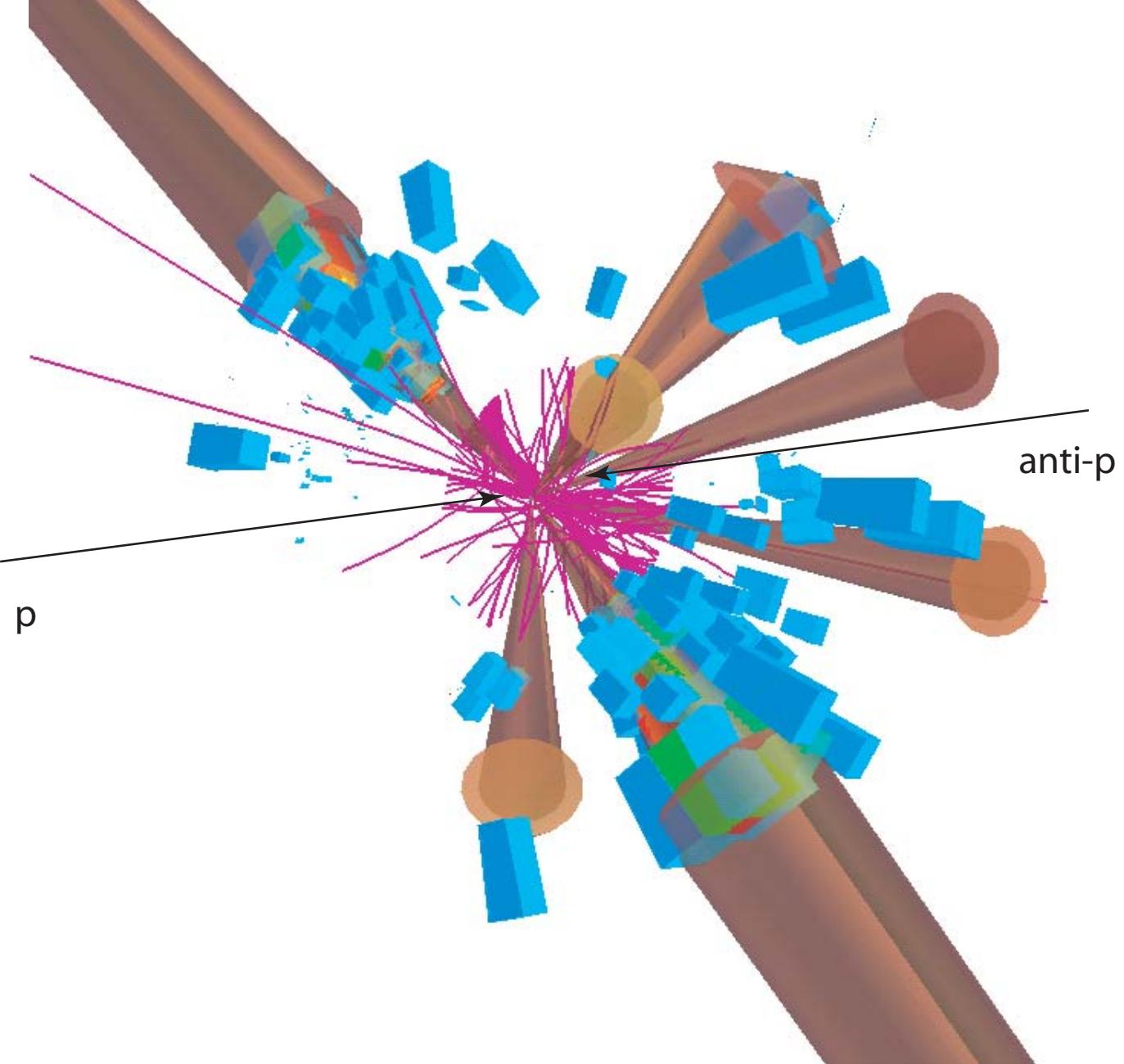
$p_T \eta \phi$

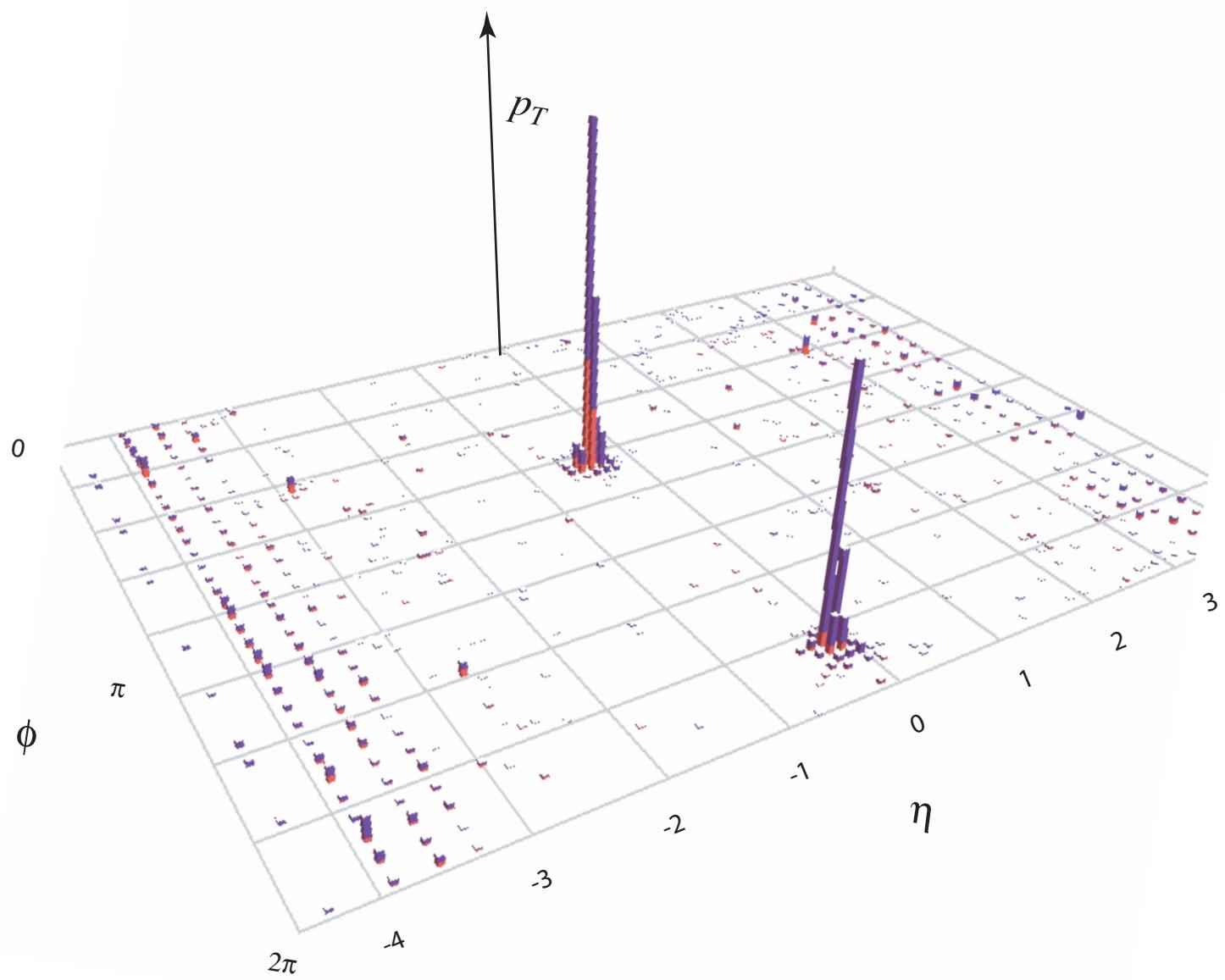


Unroll in ϕ



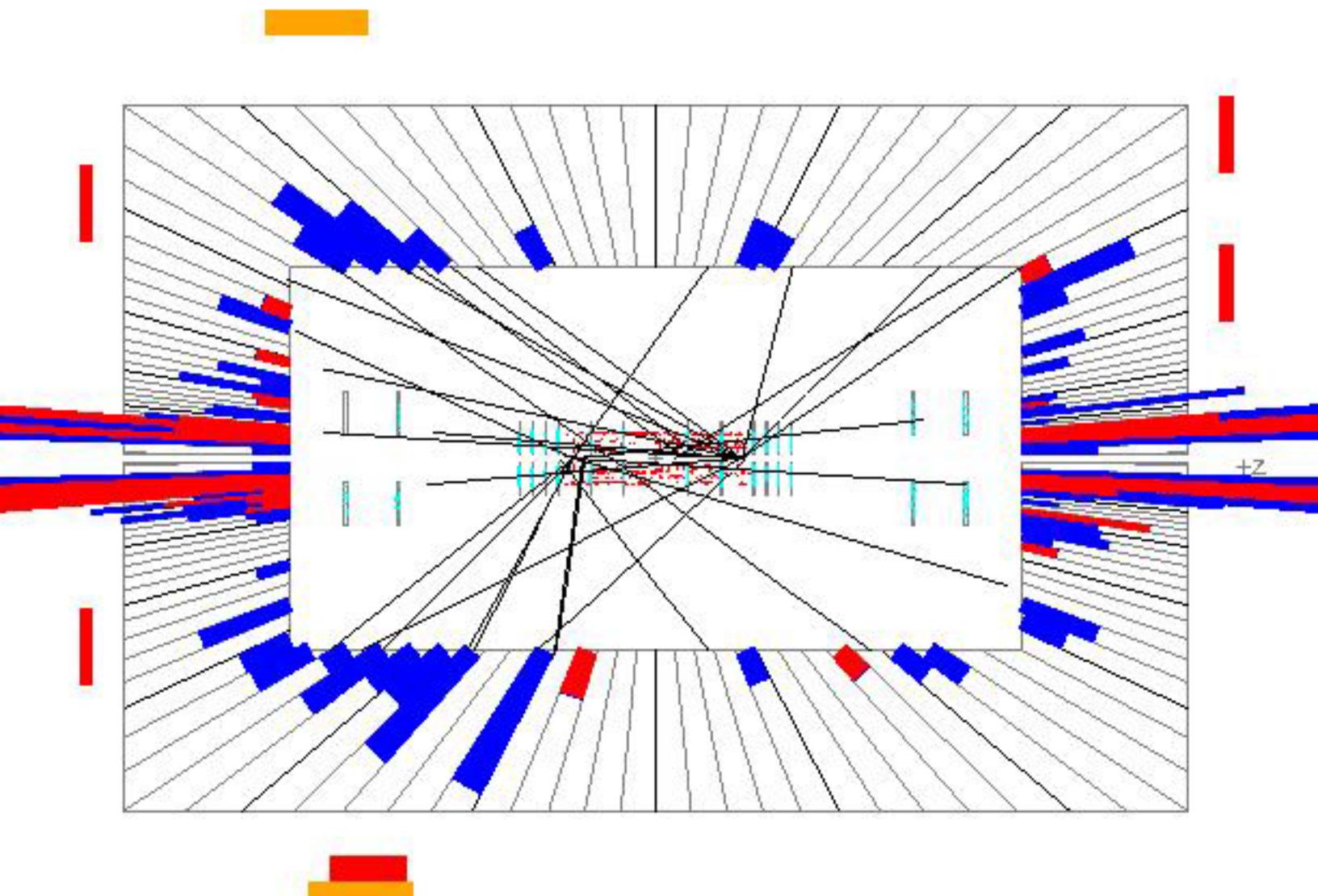
Lego Plot





Run 208433 Evt 45794747 Tue Jul 19 06:10:39 2005

E scale: 3 GeV



Event : 10198473 Run : 201133 EventType : DATA | Unpresc: 32,33,37,53,23,55,60,62 Presc: 33,60,62

Missing Et
Et= 0.3 phi=3.2

List of Tracks

Id	pt	phi	eta
----	----	-----	-----

Cdf Tracks: first 5

294	-4.4	-1.5	-0.2
295	3.0	-2.0	-0.1
342	1.9	1.4	-1.8
296	1.6	0.4	-0.6
316	-1.6	-1.5	-0.7

To select track type

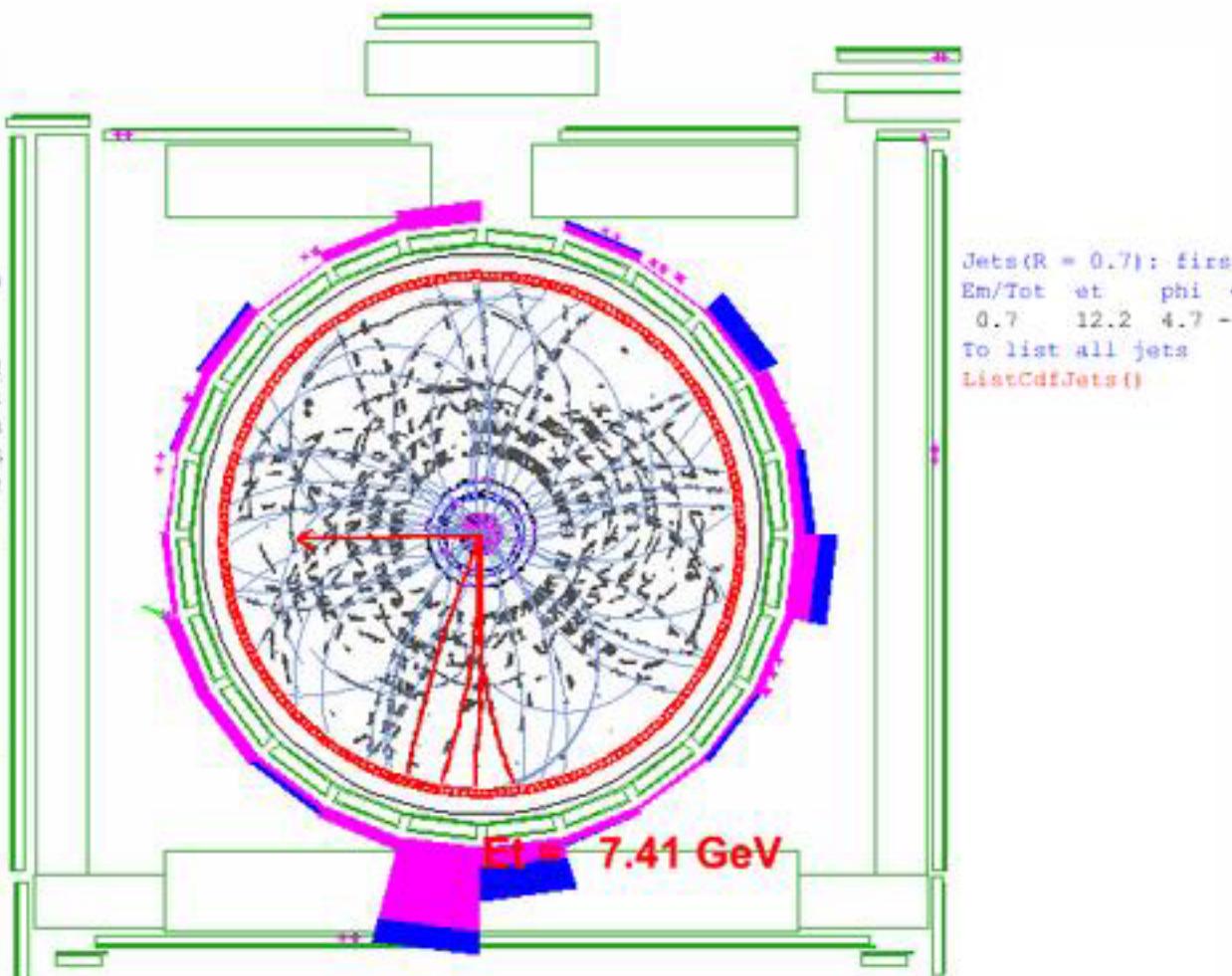
SelectCdfTrack(Id)

Svt Tracks: first 5

1	-4.3	4.8
0	3.0	4.3

To select track type

SelectSvtTrack(Id)



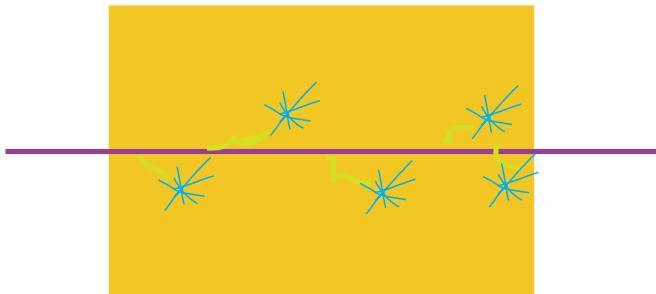
Jets(R = 0.7): fire
Em/Tot et phi
0.7 12.2 4.7 -
To list all jets
ListCdfJets()

Detection of charged particles

When a relativistic charged particle passes through matter, it knocks electron out of atoms as it passes by. This is what we call 'Energy Loss' and it is reasonably independent of the particle or material type.

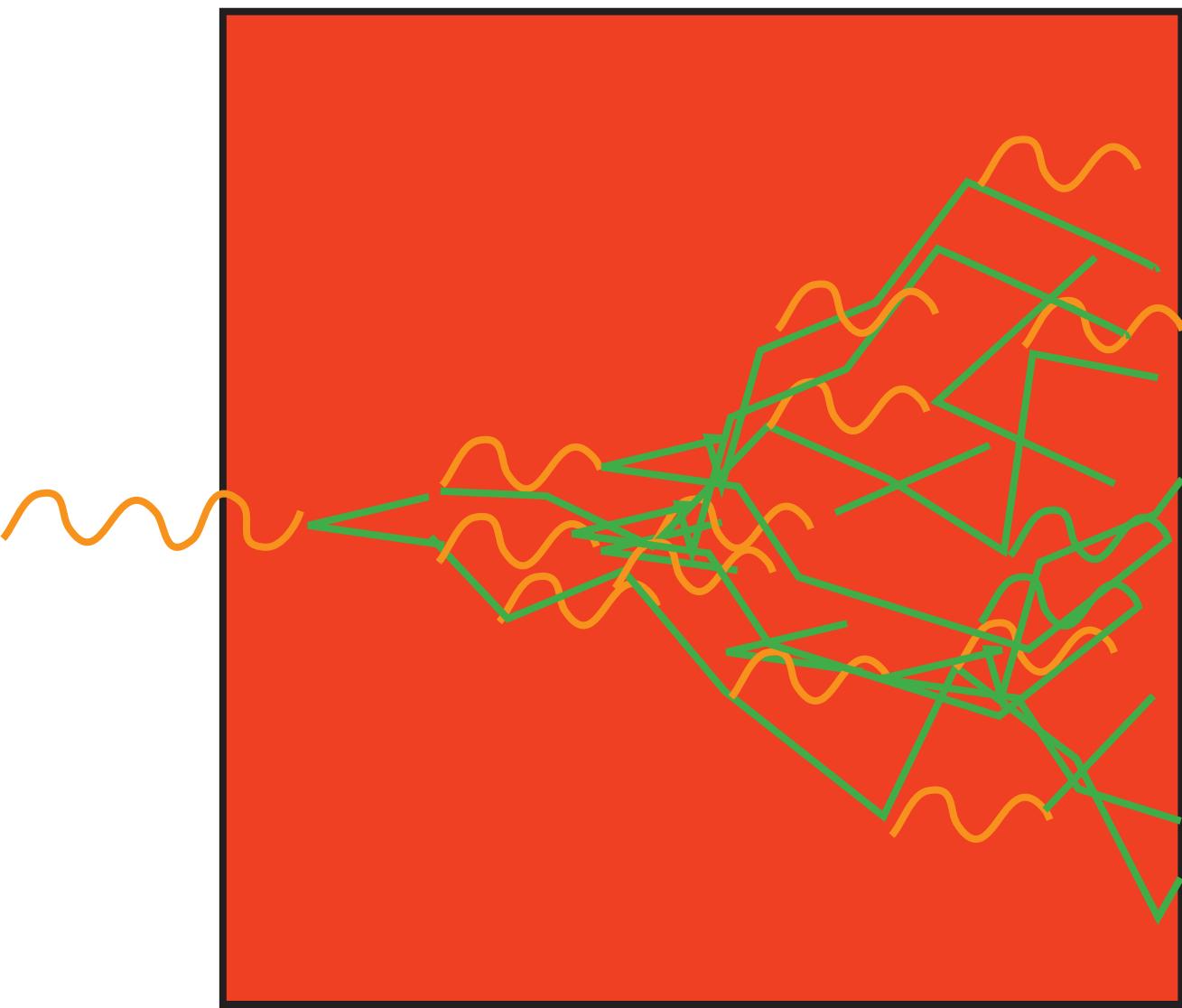
$$dE/dx \sim 2 \text{ MeV/cm} \times \rho \text{ [gr/cm}^3\text{]}$$

this energy shows up as low energy electrons and photons and can be detected optically or electronically.



Scintillator

Electromagnetic showers



6.0.1 Basics of electromagnetic calorimetry

High energy photons and electrons interact two ways in high Z materials.

- Electrons can scatter from atomic electrons and ionize the material - we can detect this ionization but the electron energy does not change much. This is an incoherent process and scales as Z/atom or $Z/A/\text{gram}$ of material.
- Both Electrons and photons can scatter off of the atomic nucleus. This is a coherent scatter and scales as Z^2/atom or Z^2/A atom. The electron scatter is bremsstrahlung and the photon is pair-production of an e^-e^+ pair. The cross section for these interaction is approximately independent of energy once the energy of the particles is $\gg m_e c^2$.

The mean free path for both processes is

$$X_0 \sim \frac{1}{4\alpha r_e^2 Z^2 \frac{N_A}{A}} \quad (21)$$

What happens when a high energy photon or electron hits some high Z material is illustrated in Figure

After the first interaction 1 particle becomes 2, after the next, 2 particles become 4 etc. asymptotically there are slightly more electrons than photons.

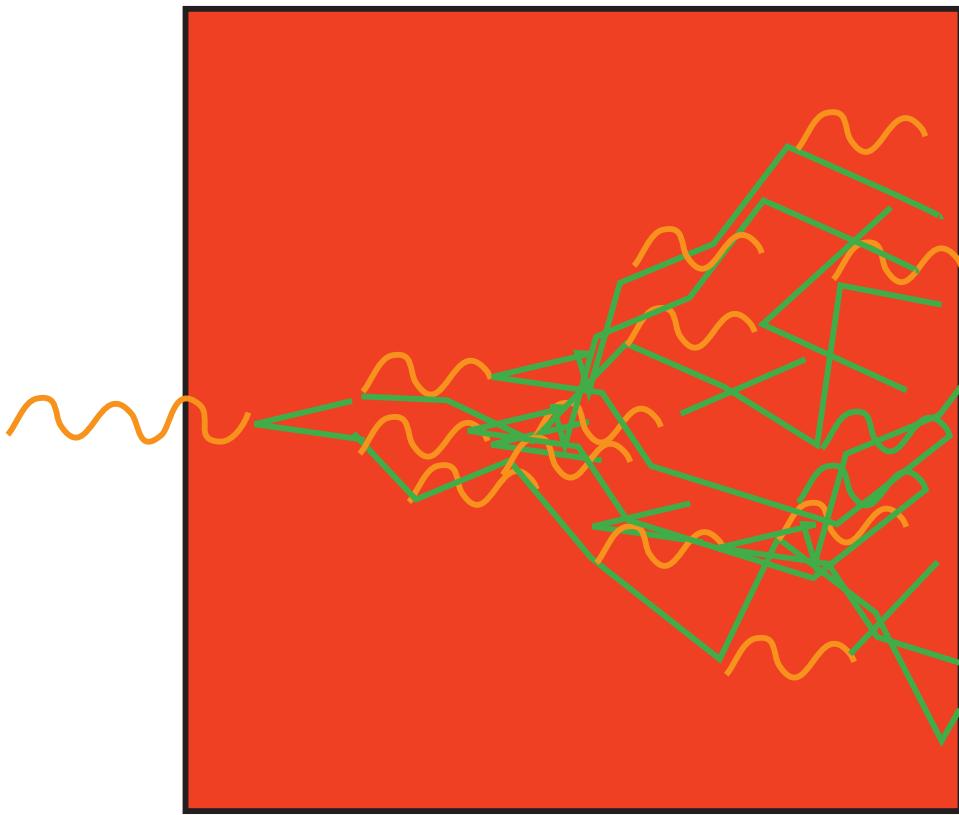


Figure 19: A photon showers in material. One can expect a hard interaction (bremsstrahlung or pair production) every X_0 .

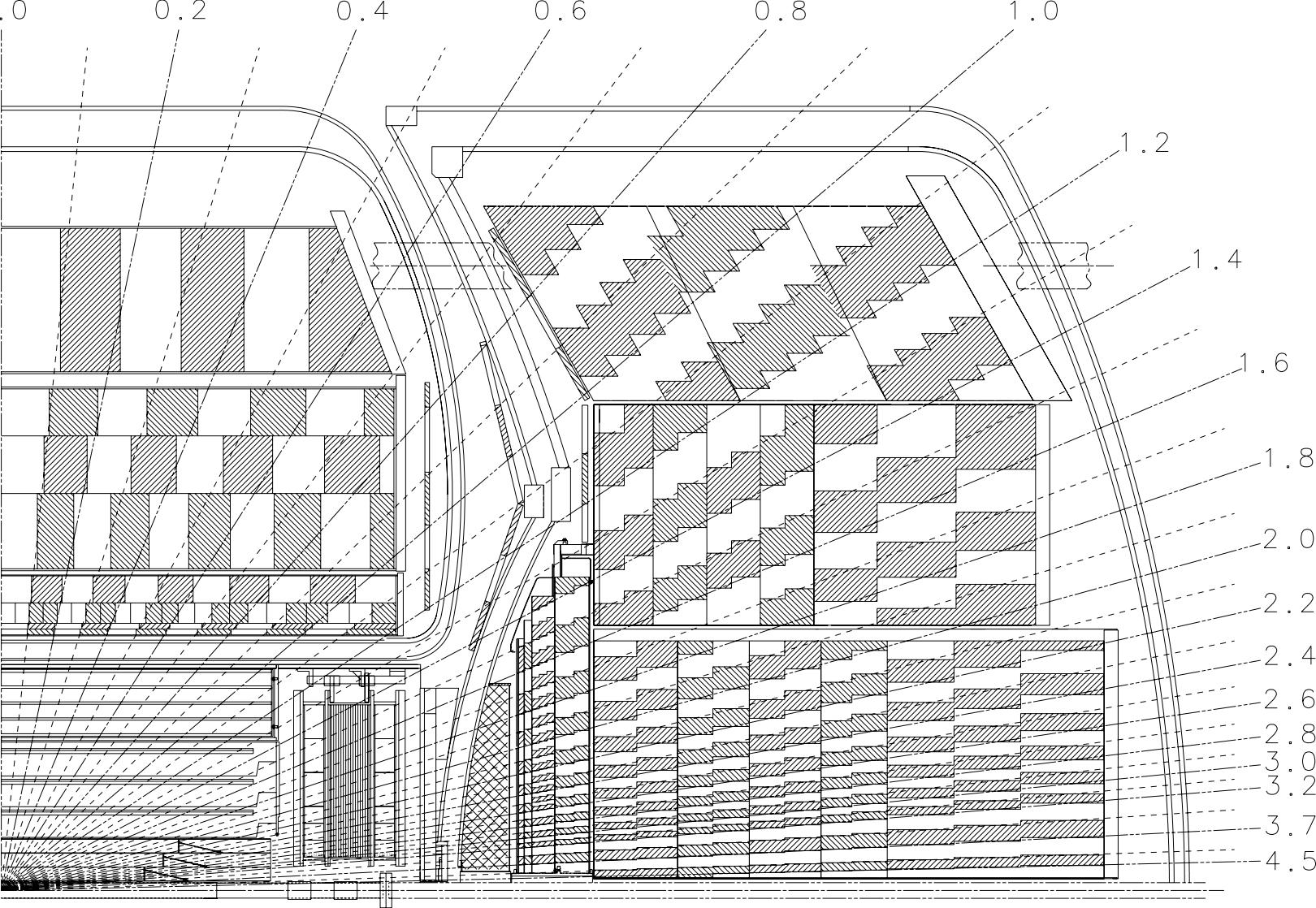
The number of particles/layer grows as 2^i where i is the number of X_0 you have traversed and the energy/particle drops by a factor of 2 each layer. At some point the energy/particle ($E_0/2^i$) becomes close to $m_e c^2$ and the hard scatters stop. The critical energy is called E_c and is actually more like 10 MeV. You can use this to solve for the maximum number of radiation lengths N .

$$2^N = E_0/E_c \quad (22)$$

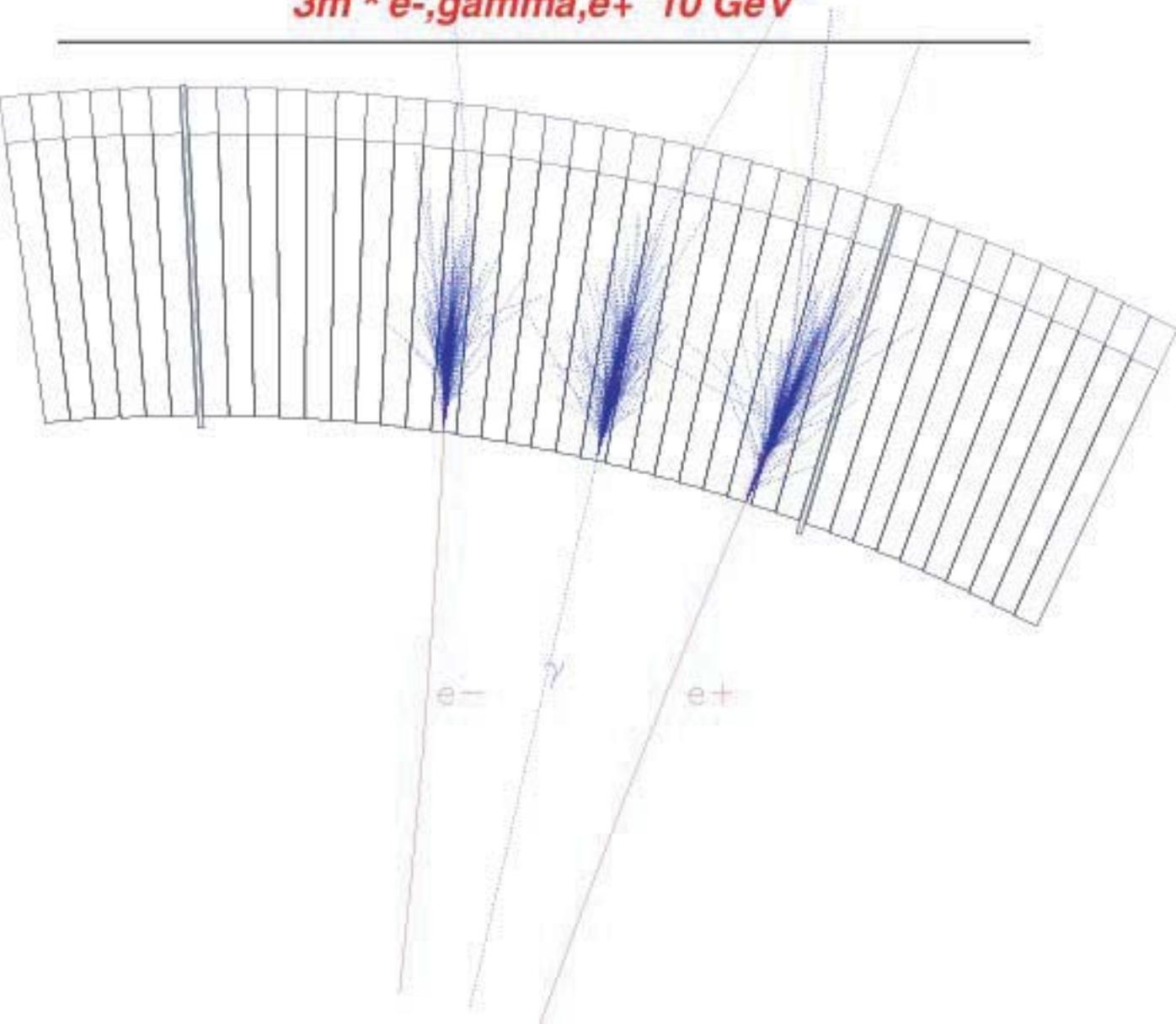
What we detect is the ionization caused by the particles, which is proportional to the total path length.

$$L = \sum_{i=1}^N (2^i f_e X_0) = f_e X_0 (2^N - 1) \sim f_e X_0 E_0 / E_c \quad (23)$$

where f_e is the electron fraction in the shower $\sim 5/8$. So the ionization observed is proportional to the incident energy. This is a nice linear detector.



*3m * e-,gamma,e+ 10 GeV*



Sampling Calorimeter

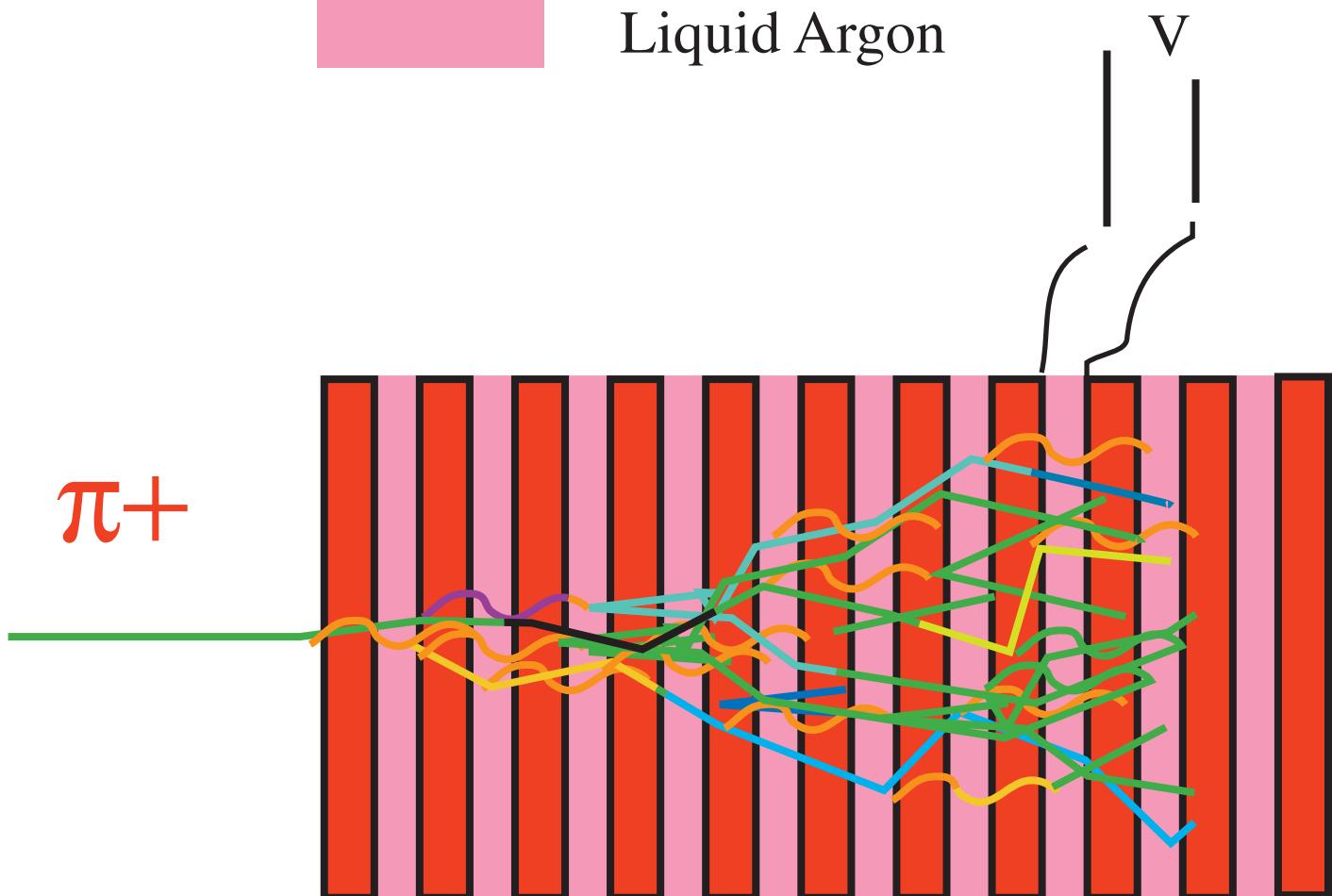


Uranium



Liquid Argon

π^+

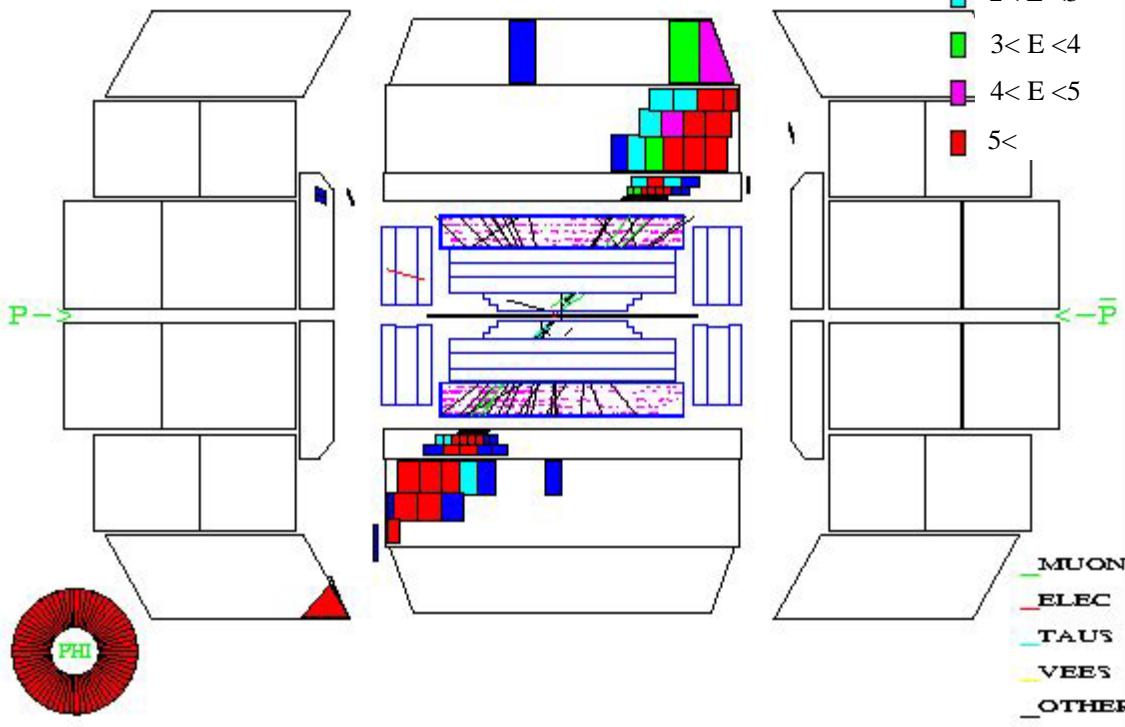


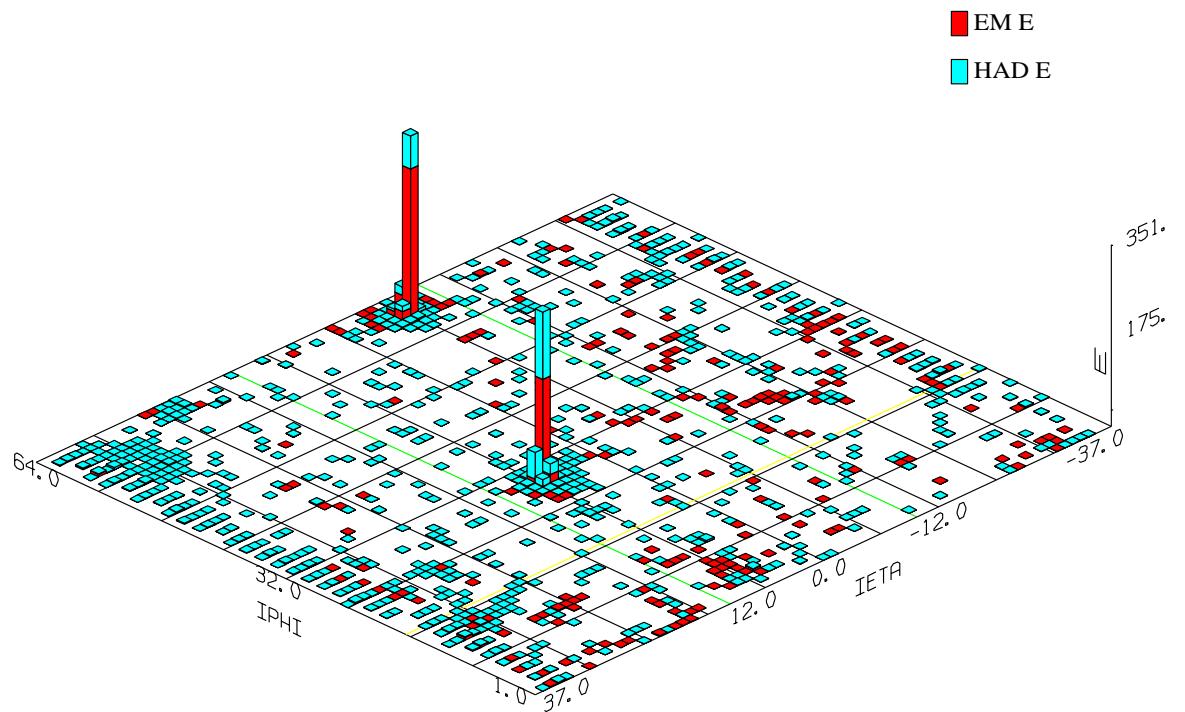
'Typical' Event in the D0 Detector

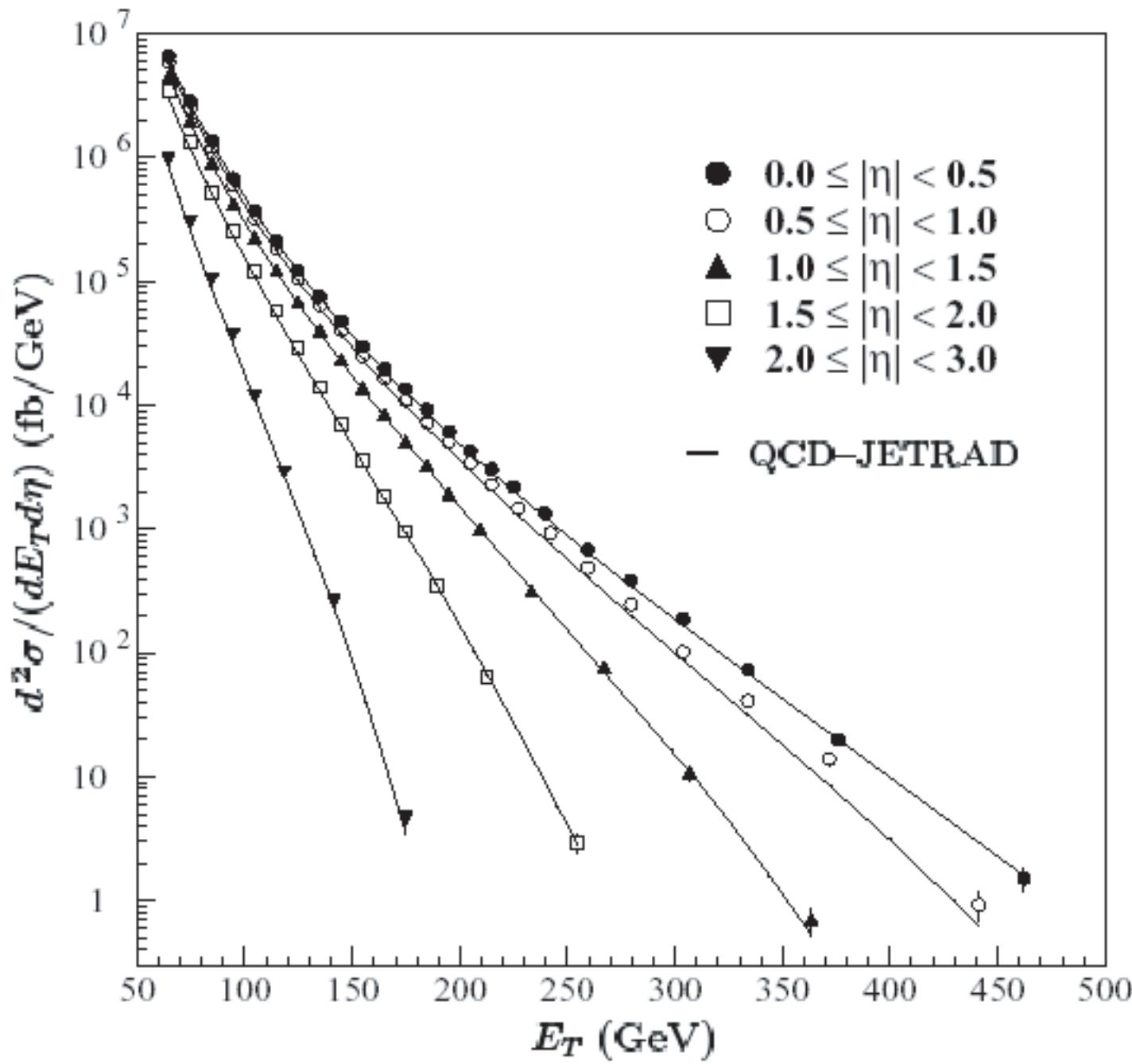
Missing ET 8.4 GeV

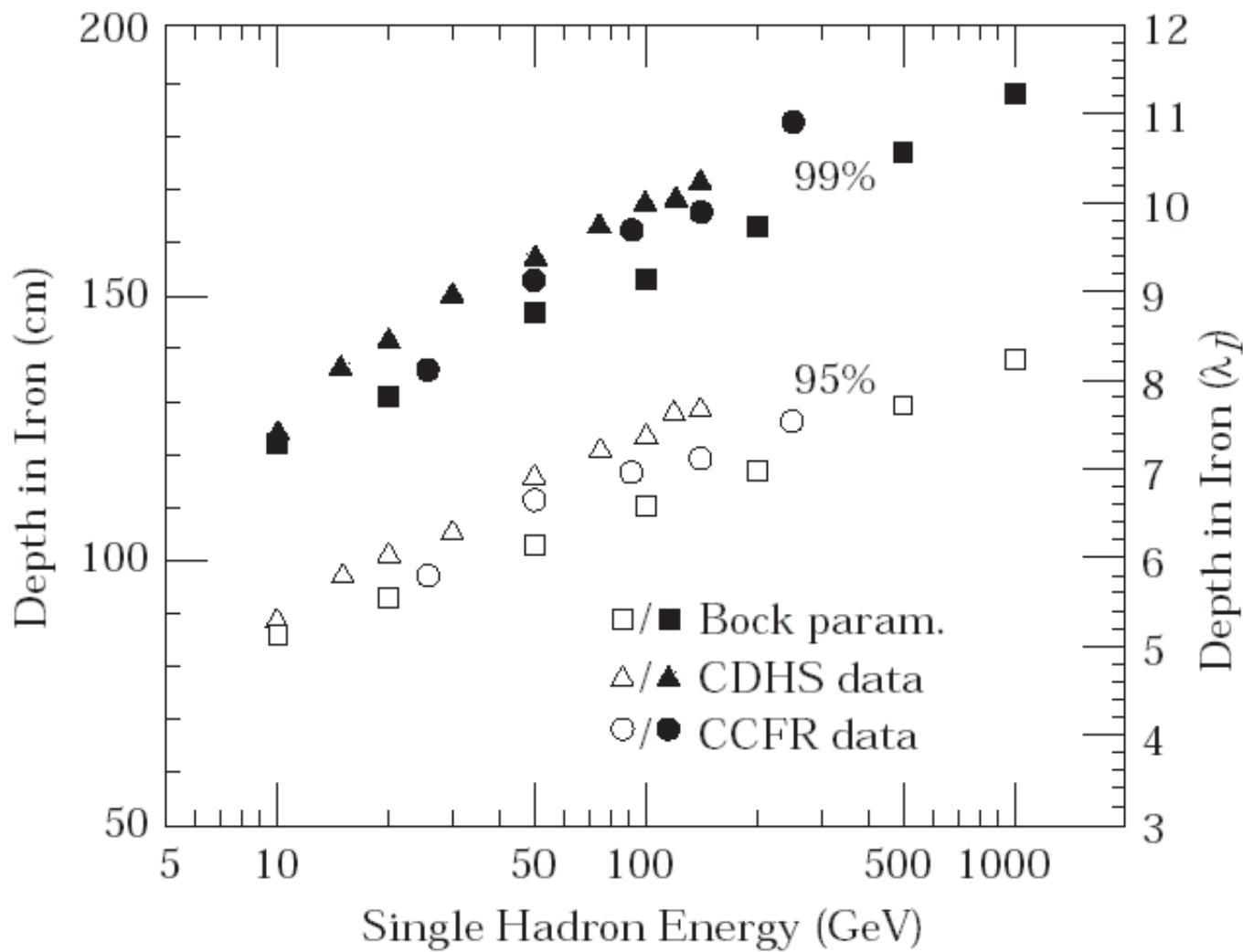
$\hat{s} = 1187 \text{ GeV}$

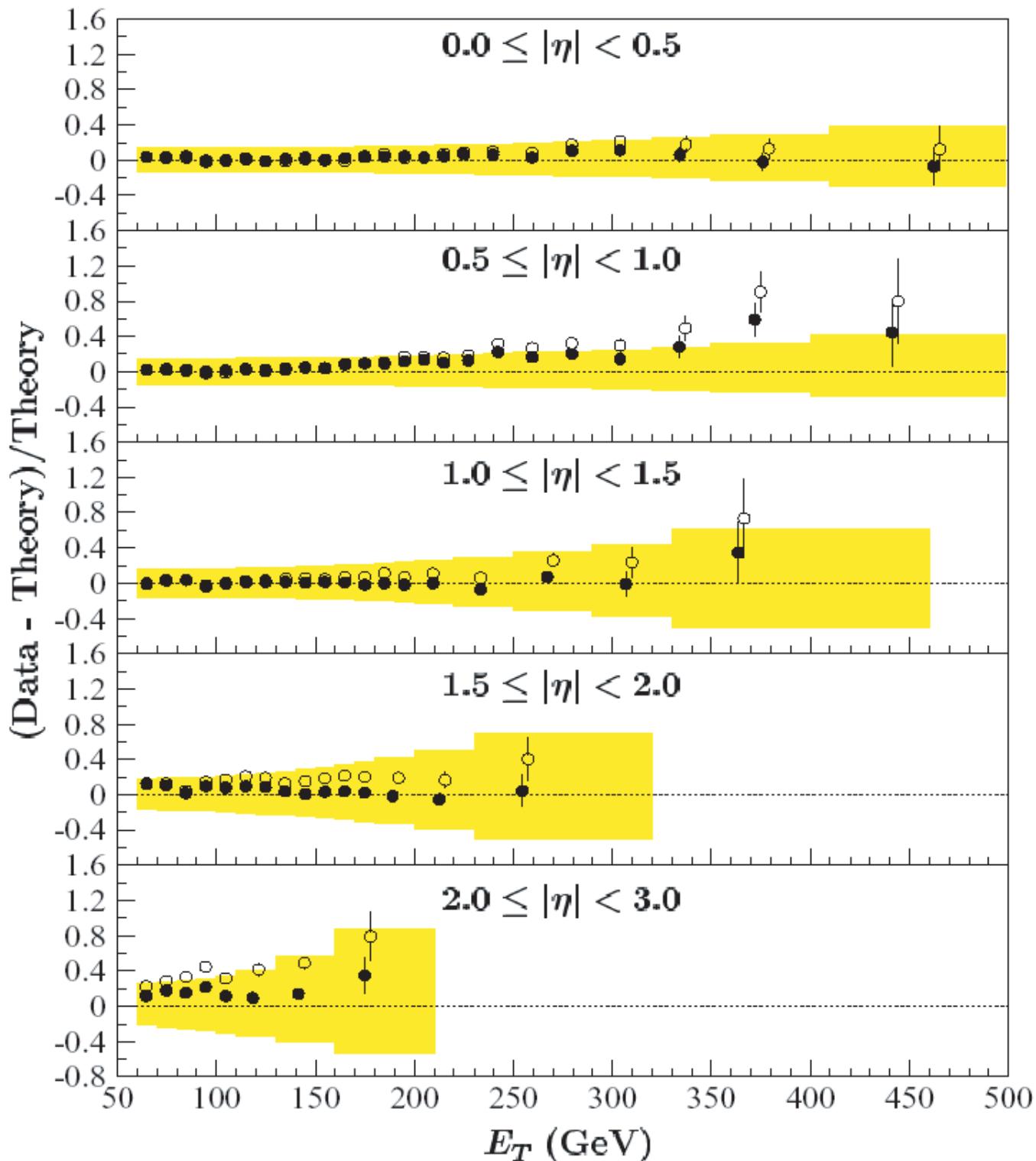
	E_T, GeV	η	ϕ	x_{parton}
Jet 1	477	-0.69	5.95	0.67
Jet 2	473	0.69	2.88	0.67











Proton antiProton collision

Z

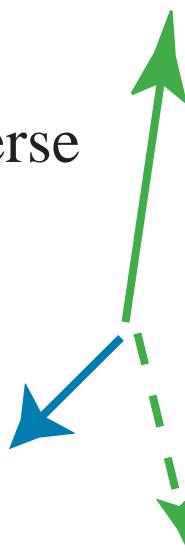
Produces $W + \text{recoil}$

Z

W decays to $e \nu$

Z

Transverse
view



Can reconstruct p_T of ν
but not $p_{||}$

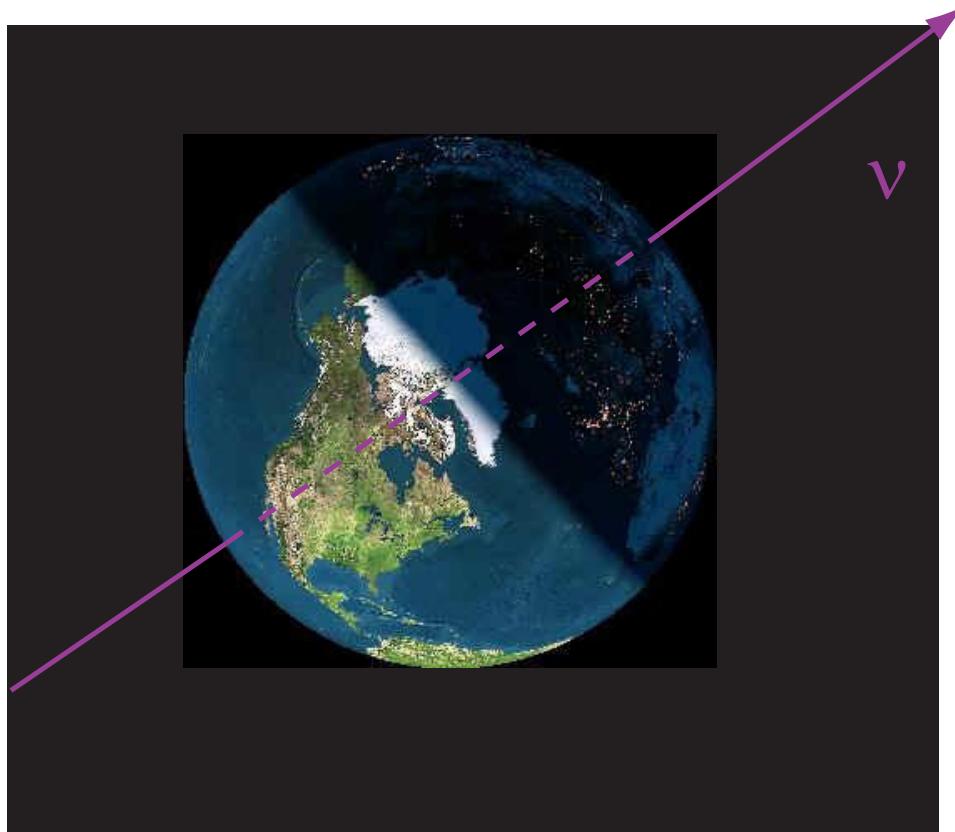
ν

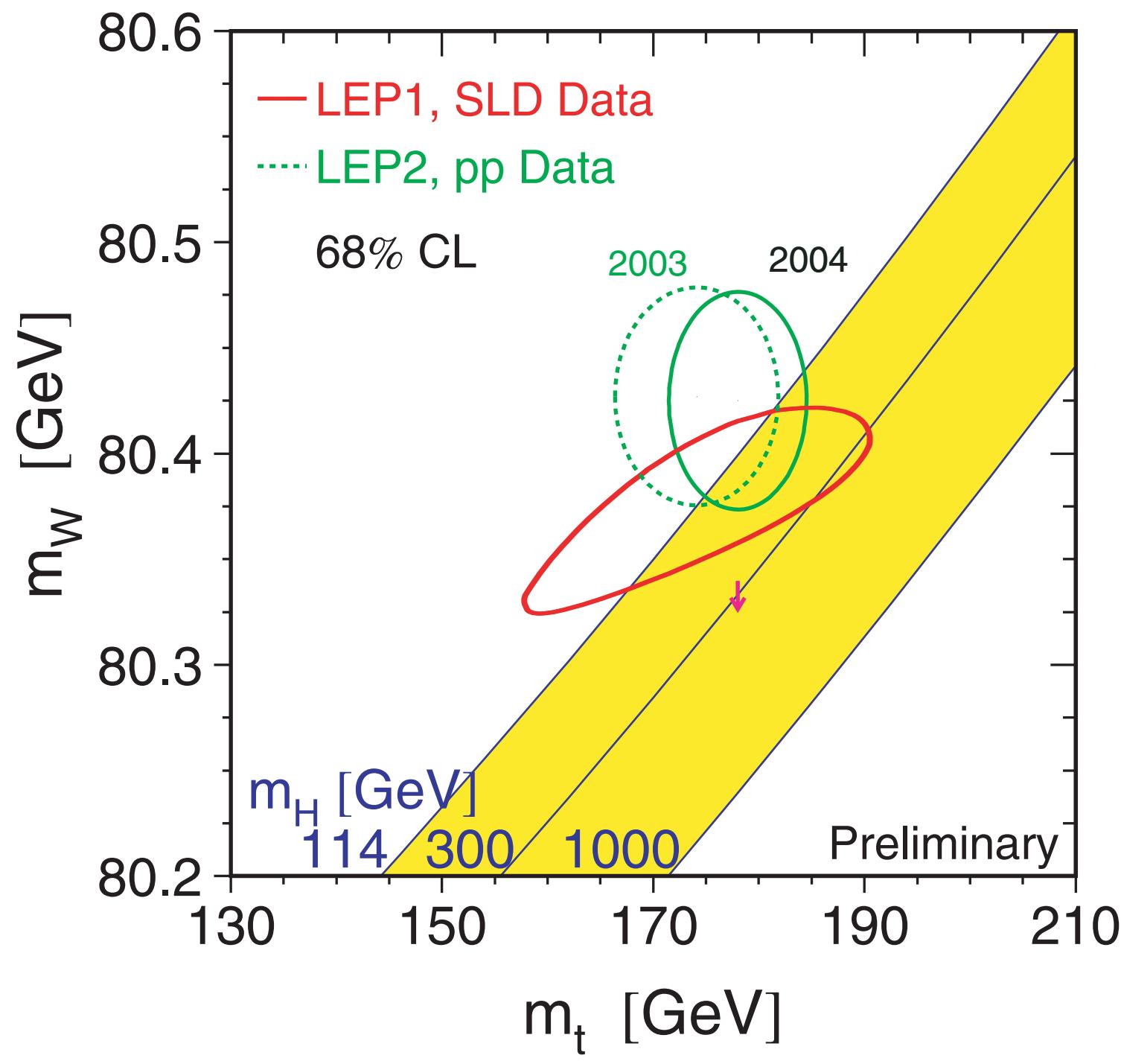
neutrinos

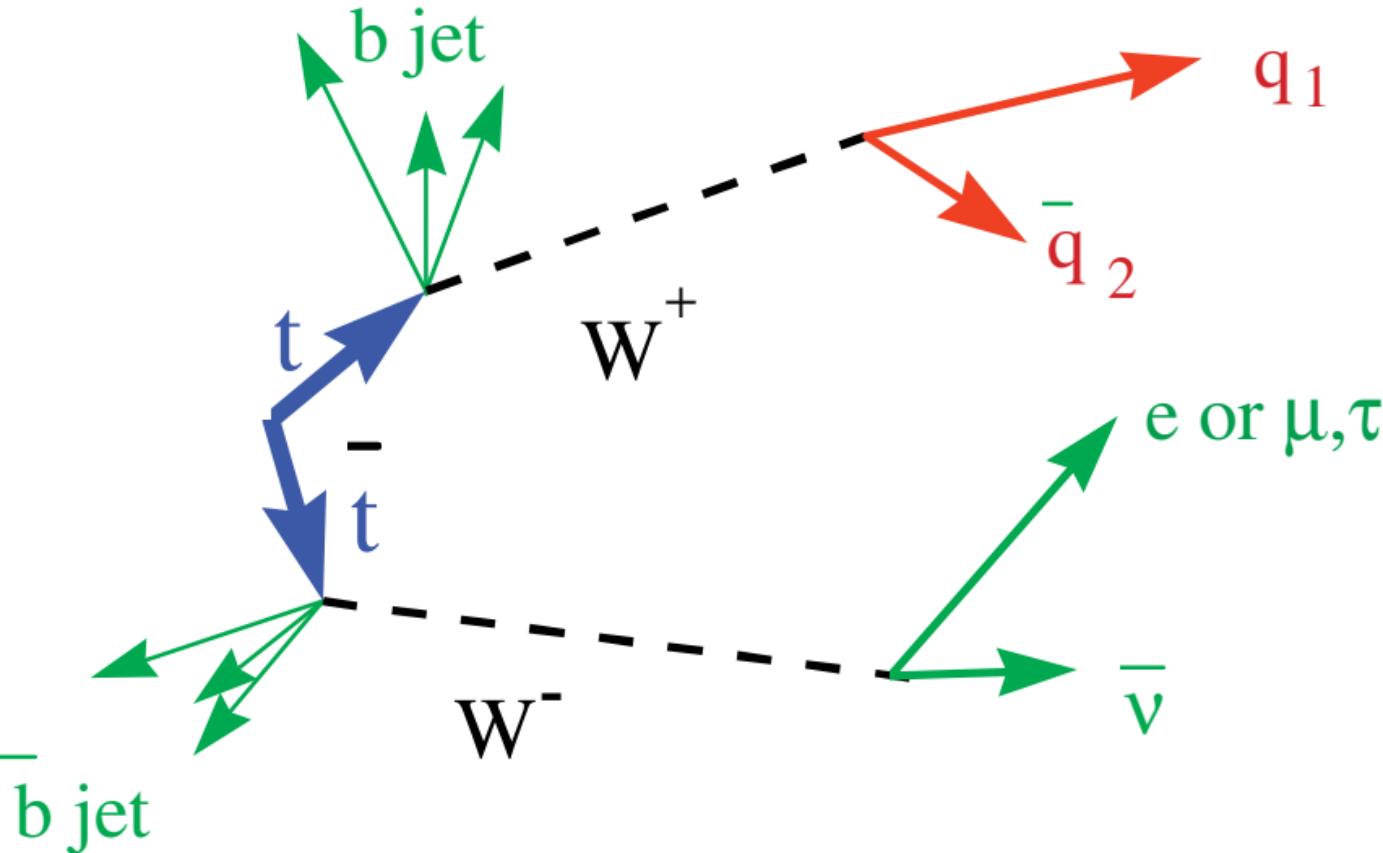
$Q = -\theta$

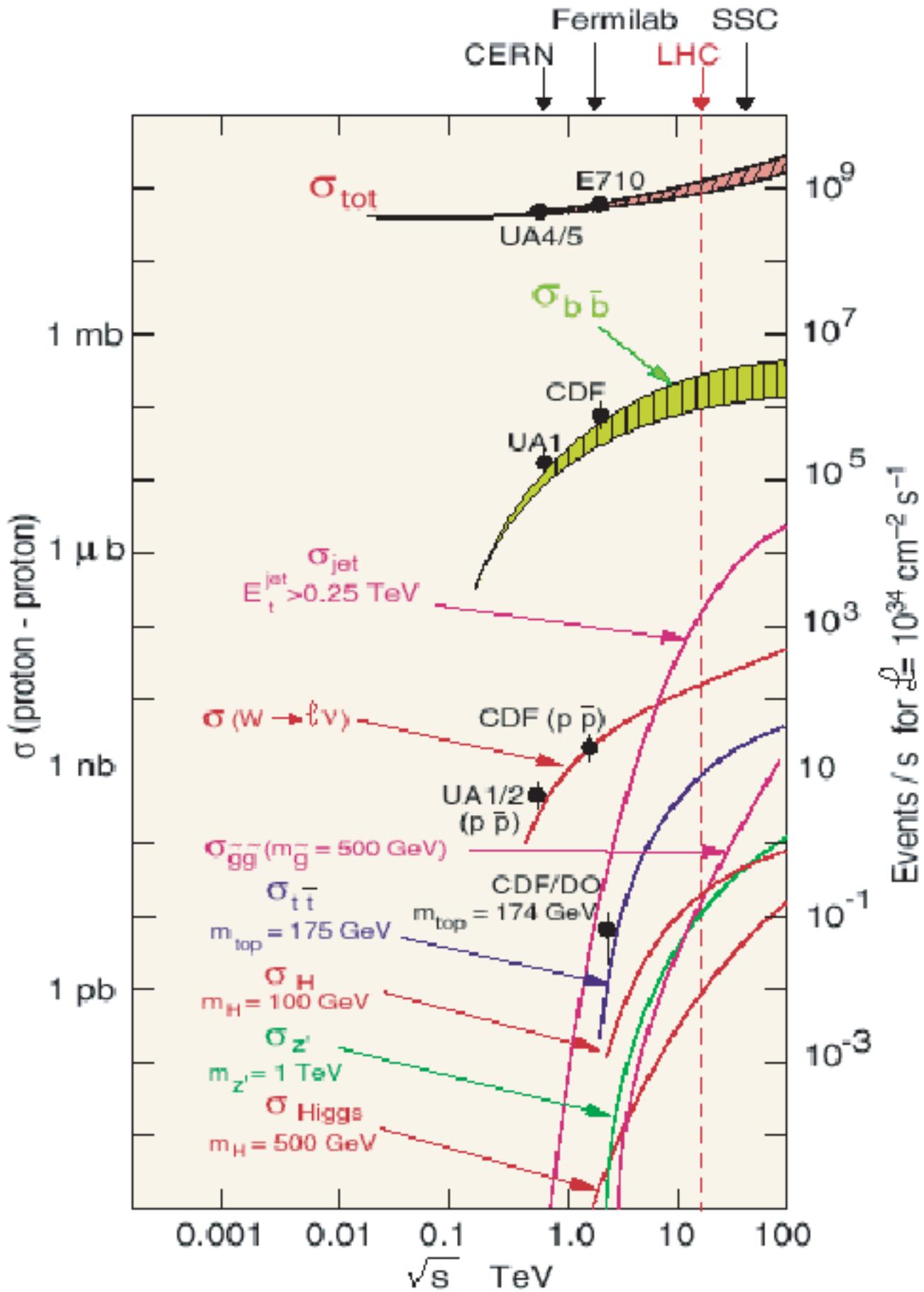
$m = 0?$

stable
couples to W, Z

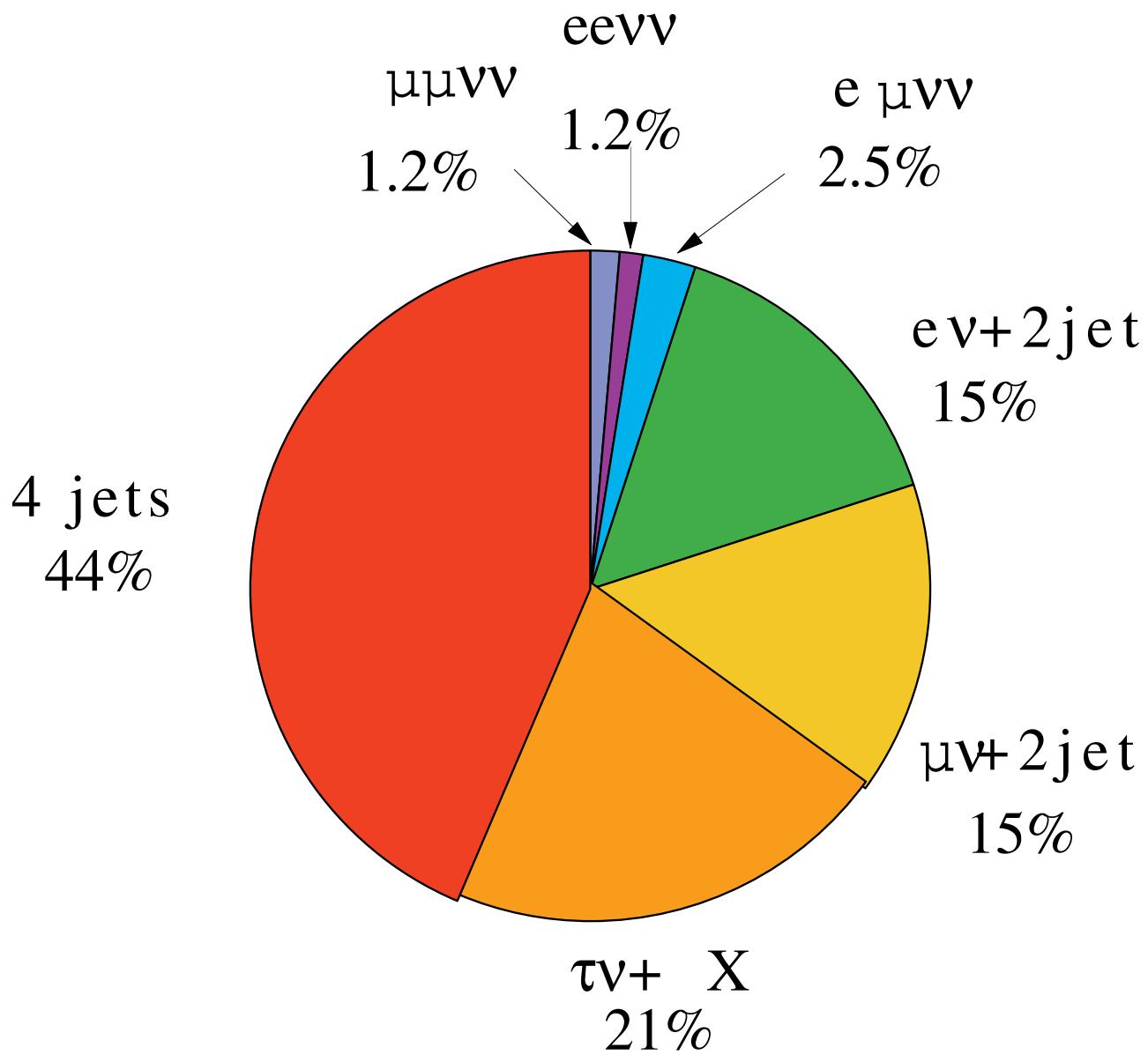


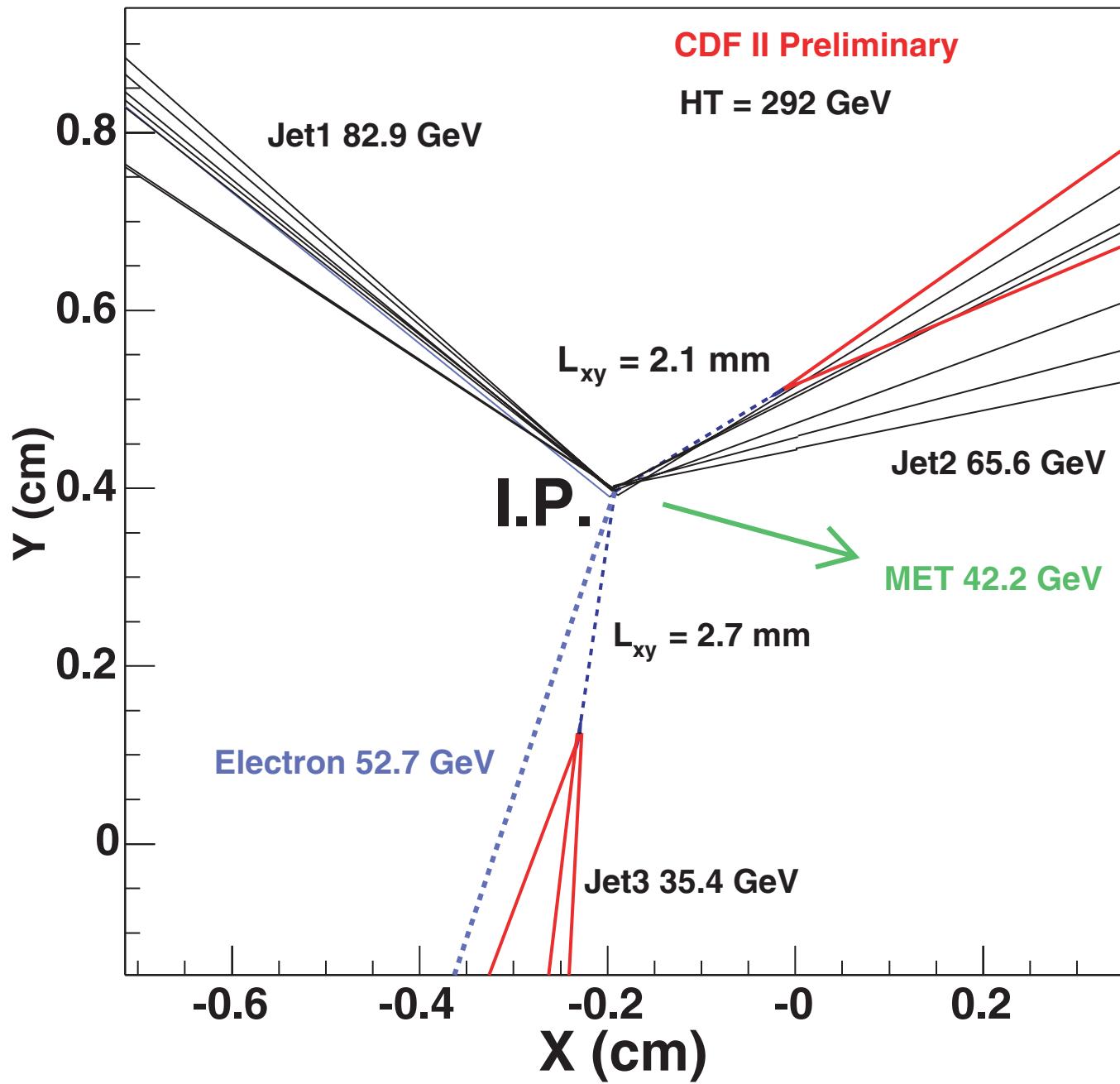




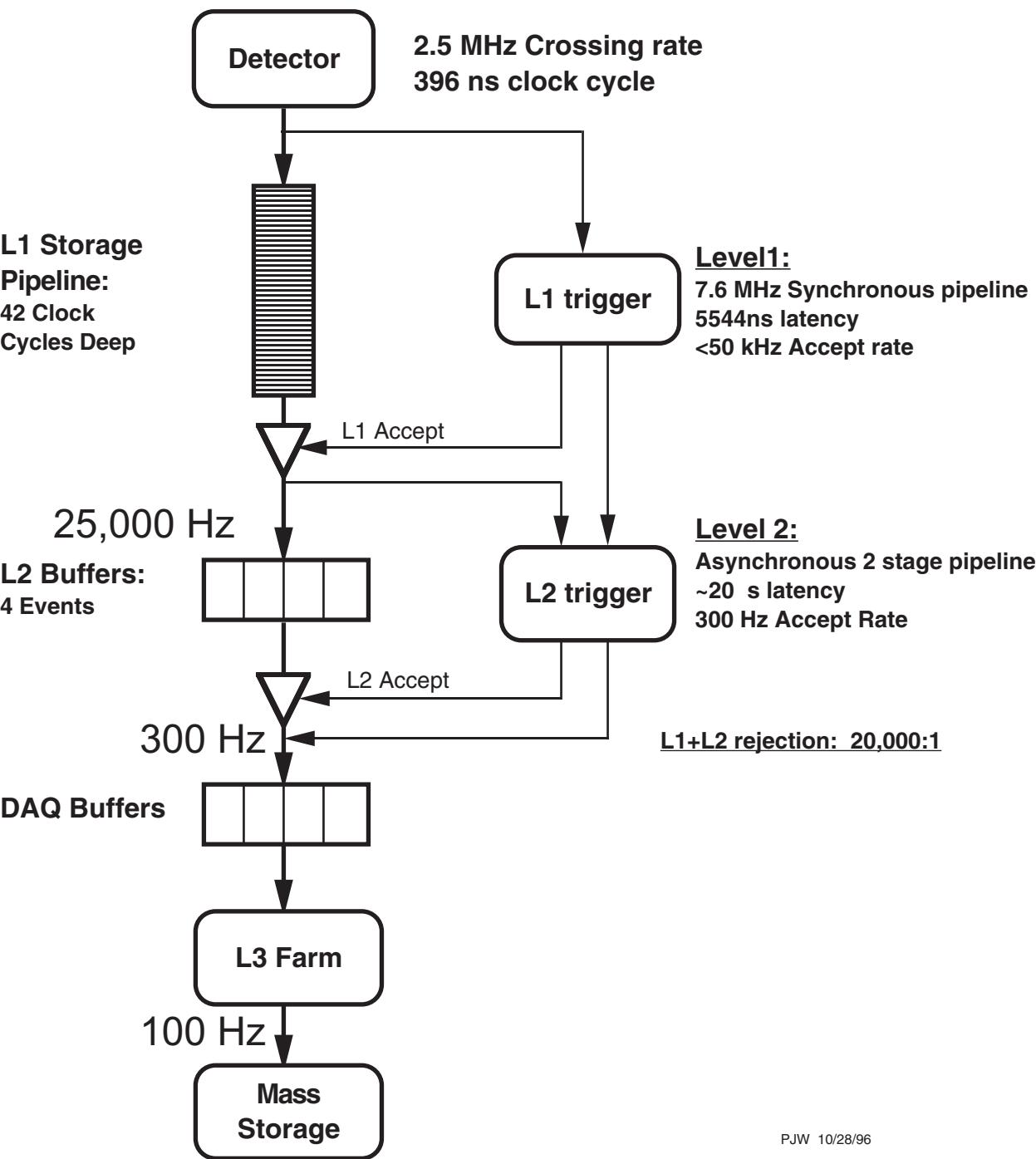


$W^+ W^-$ decay signatures in top decays



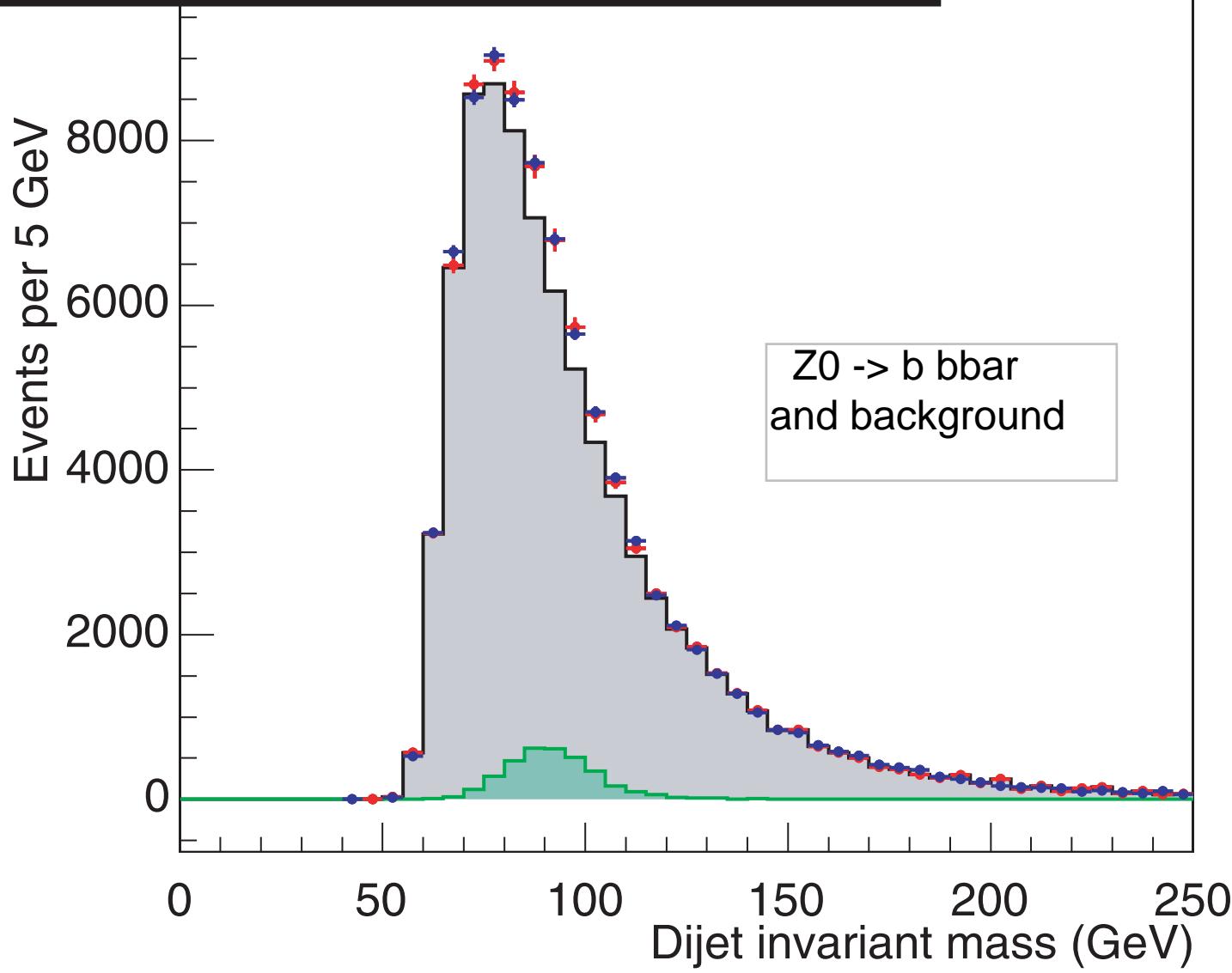


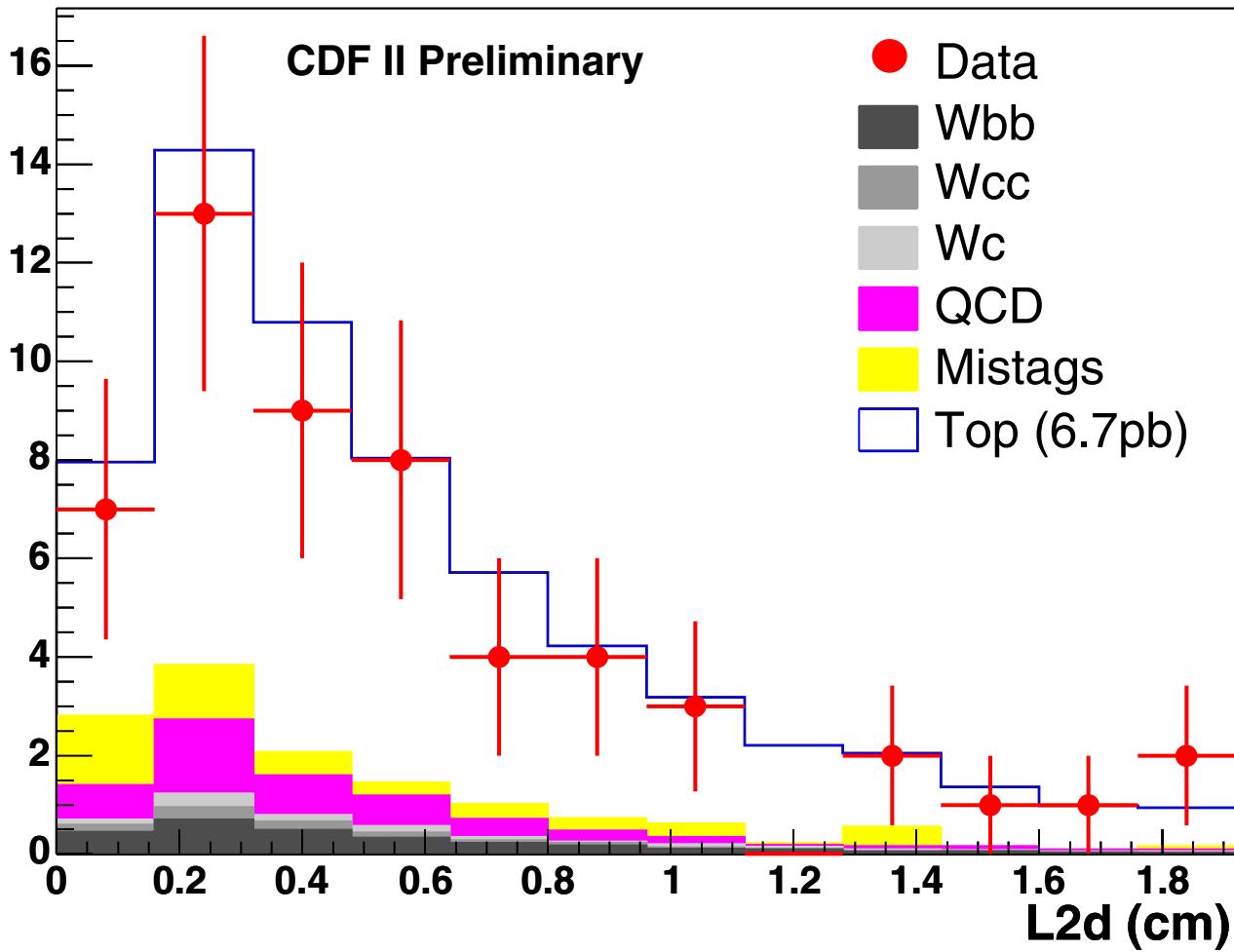
Dataflow of CDF "Deadtimeless" Trigger and DAQ



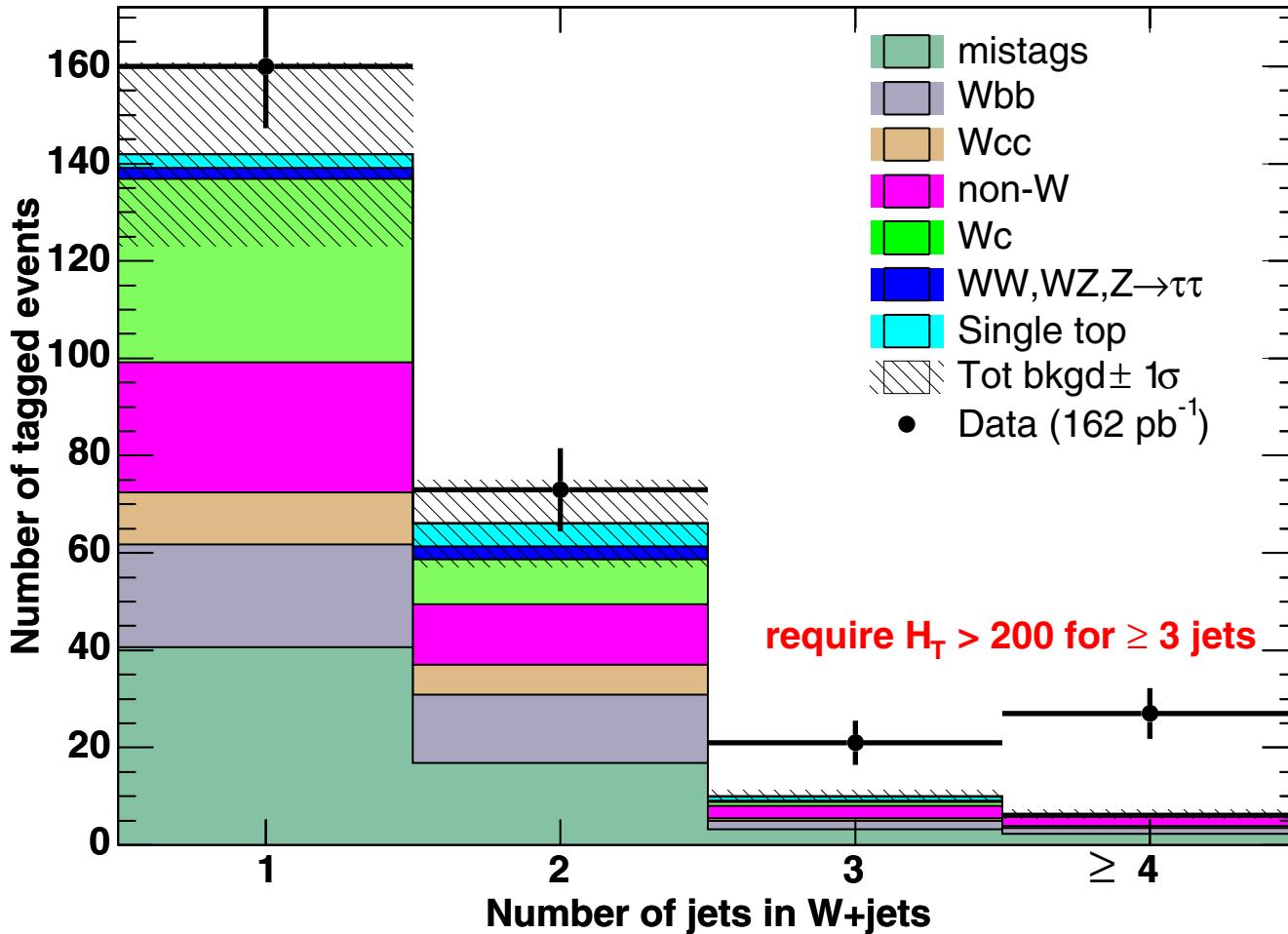
CDF Run 2 preliminary - $L=333 \text{ pb}^{-1}$

- Selected events
- Background
- Z signal: 3394 ± 515 events
- Fit result





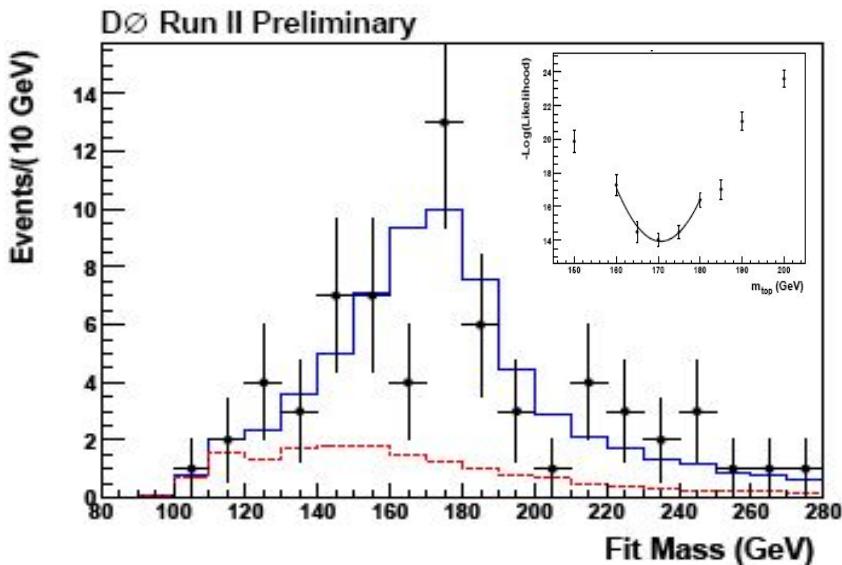
CDF II preliminary



Lepton+jets: DØ Template Method



- Lepton + jets channel with b-tag using 'SVT' secondary vertex tagger
 - similar selection
 - one or more b-tagged jets
 - ≥ 4 jets with $p_T > 15$ GeV
 - No cut on low bias discriminant D_{LB}
- 60 $t\bar{t}$ candidates selected, S/B $\sim 3/1$



Systematic Uncertainties	Δm_{top} (GeV/c ²)
Jet Energy Scale	-5.3/+4.7
Gluon Radiation	2.4
Signal Model	2.3
Jet Energy Resolution	0.9
Calibration	0.5
Background Model	0.8
b-tagging	0.7
Trigger Bias	0.5
Limited MC Statistics	0.5
Total	6.0

NEW
 $\sim 230 \text{ pb}^{-1}$

best preliminary RunII top mass result

$$M_{top} = 170.6 \pm 4.2 (\text{stat}) \pm 6.0 (\text{sys}) \text{ GeV}/c^2$$

Lepton+jets: CDF Template Method

- Lepton +jets selection:

One e or μ with $p_T > 20 \text{ GeV}/c$

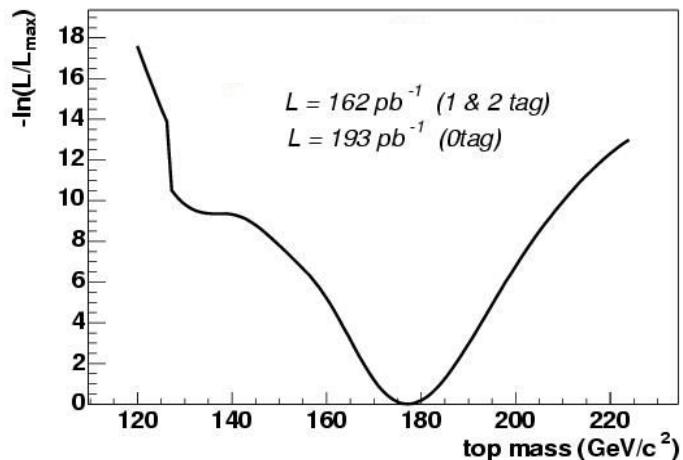
3 jets with $E_T > 15 \text{ GeV}$, 4th jet $E_T > 8 \text{ GeV}$
missing $E_T > 20 \text{ GeV}$

Kinematic Fit;
lowest χ^2
solution
compatible with
b-tags

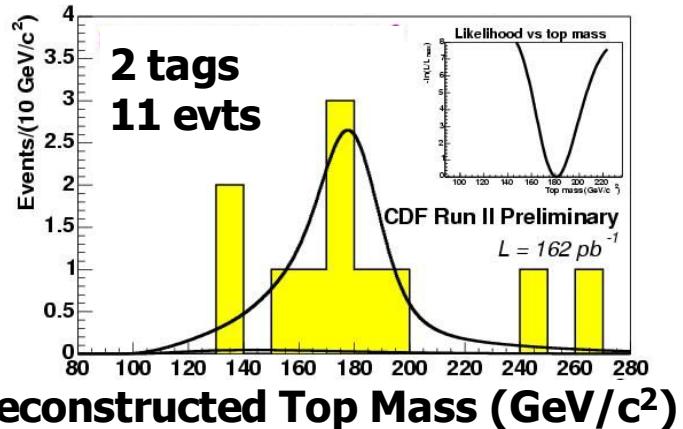
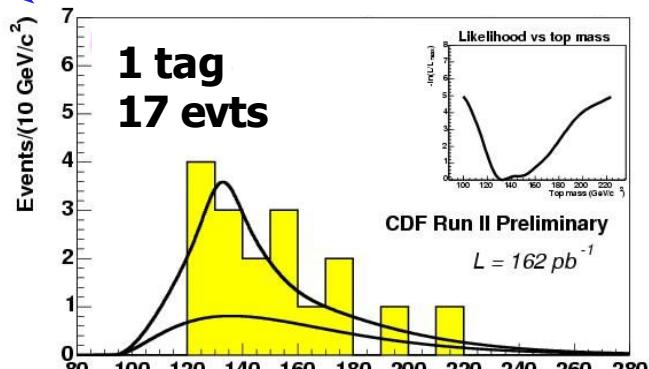
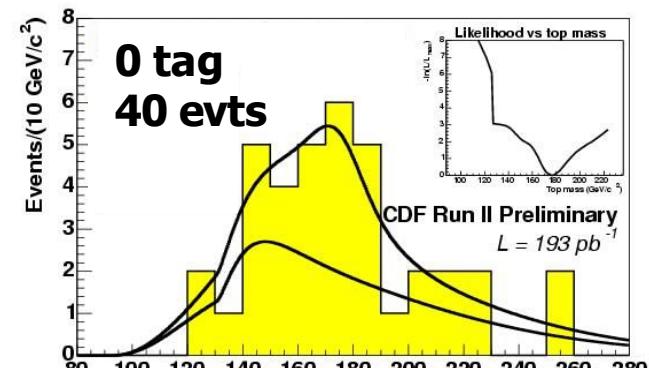
- 0 tag sample: 4th jet $E_T > 21 \text{ GeV} \rightarrow S/B \sim 2/3$

- 1 tag sample: One jet with SVX tag $\rightarrow S/B \sim 3/2$

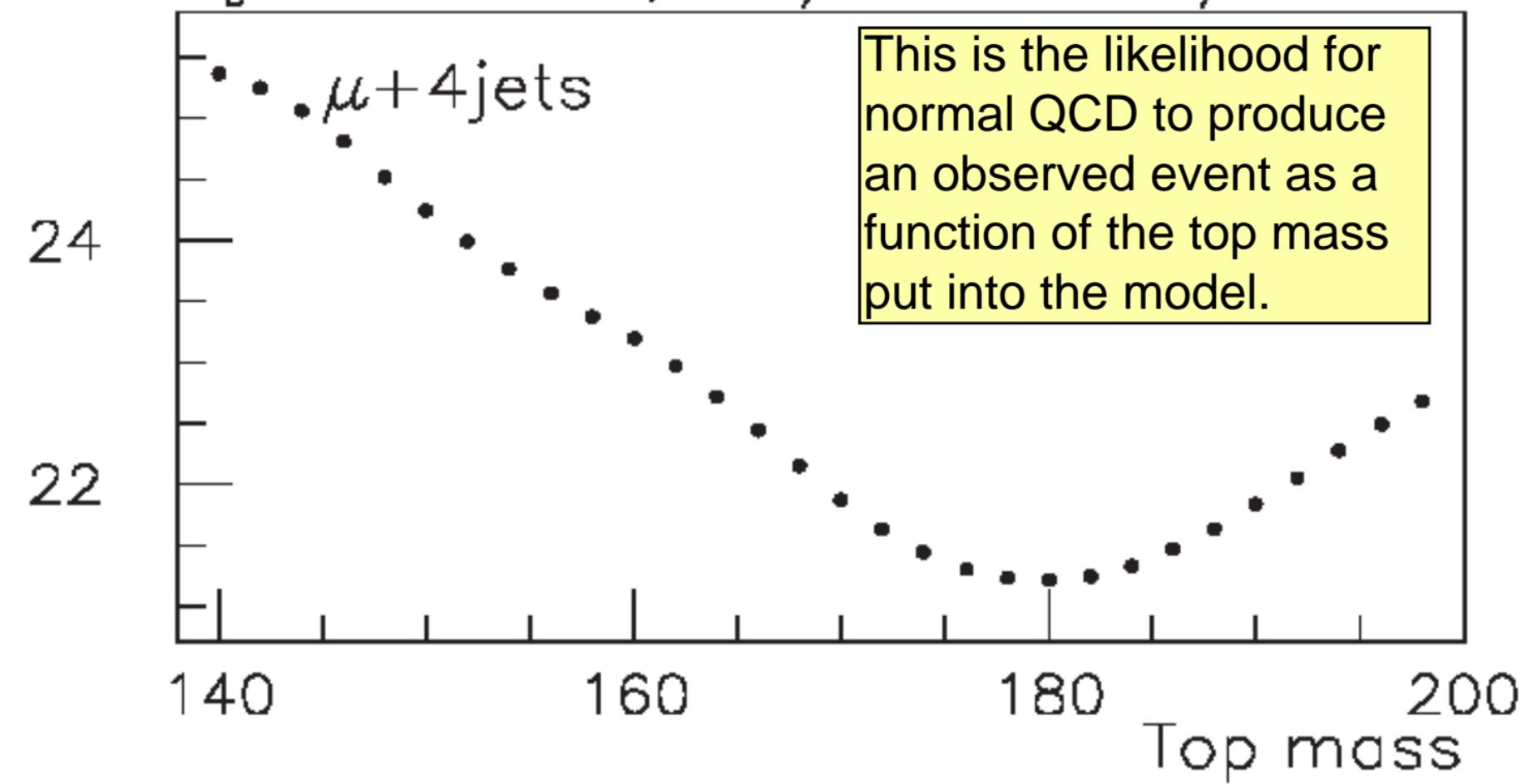
- 2 tag sample: Use more efficient Jet Probability algorithm for 2nd b-tag $\rightarrow S/B \sim 40/1$

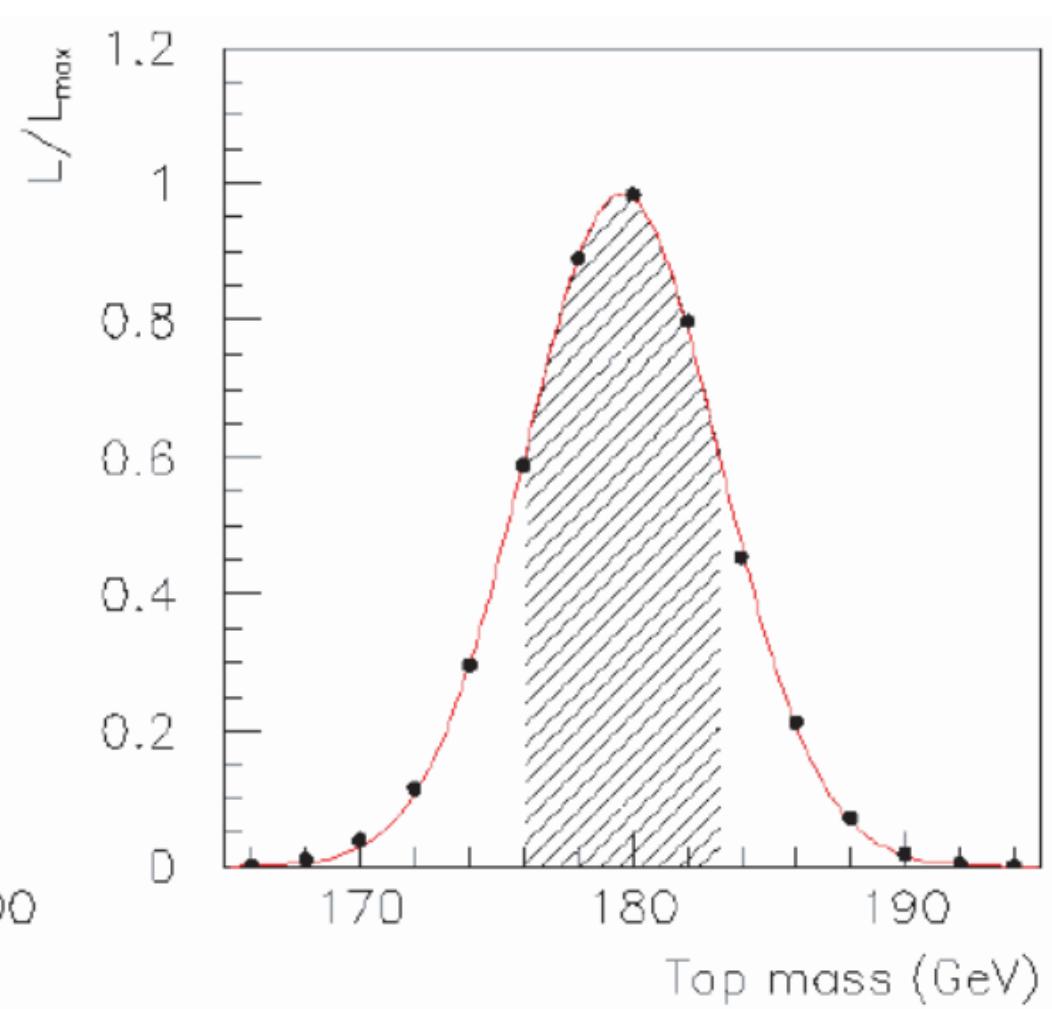
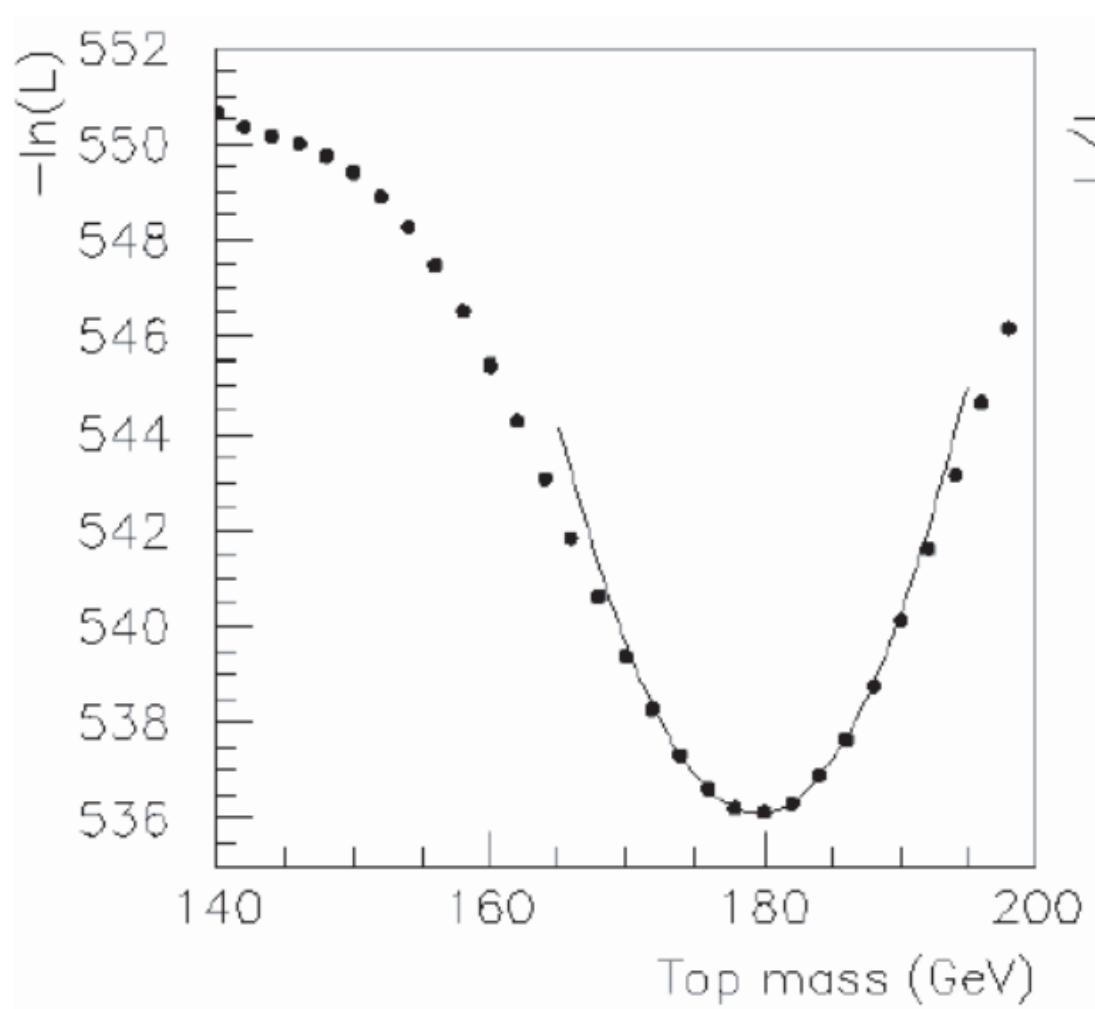


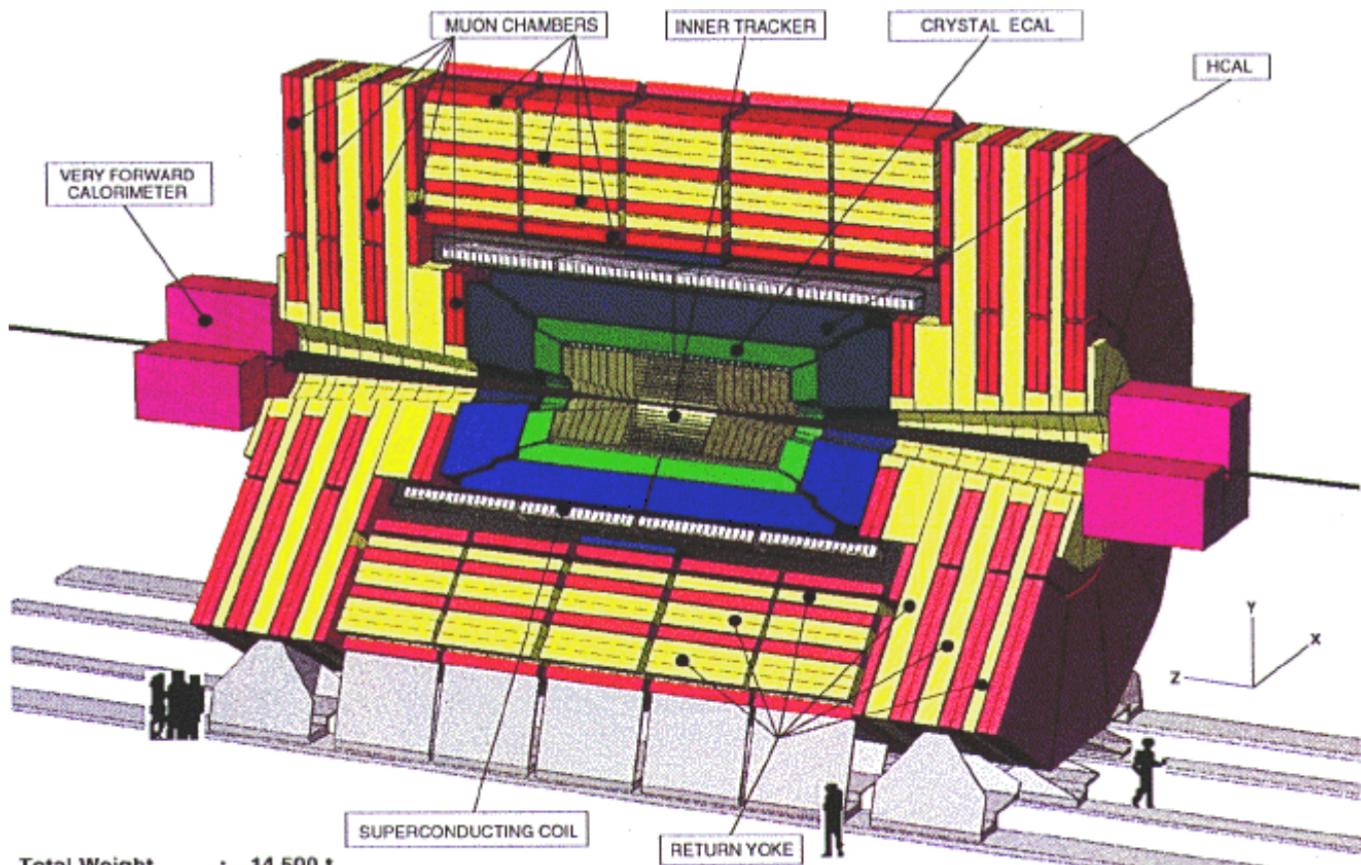
$$M_{\text{top}} = 177.2^{+4.9}_{-4.7} (\text{stat}) \pm 6.6 (\text{sys}) \text{ GeV}/c^2$$



$P_B = 1.63E-12$, run/ev=87063/14368

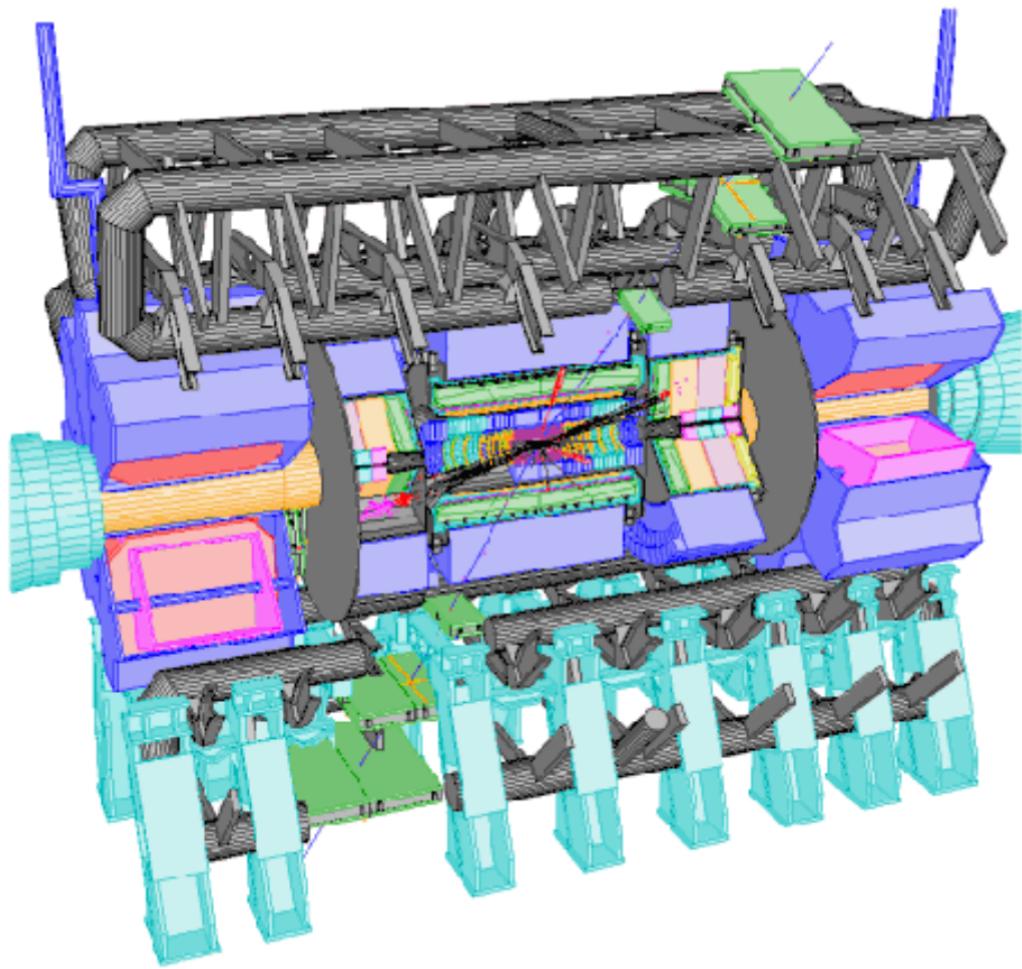






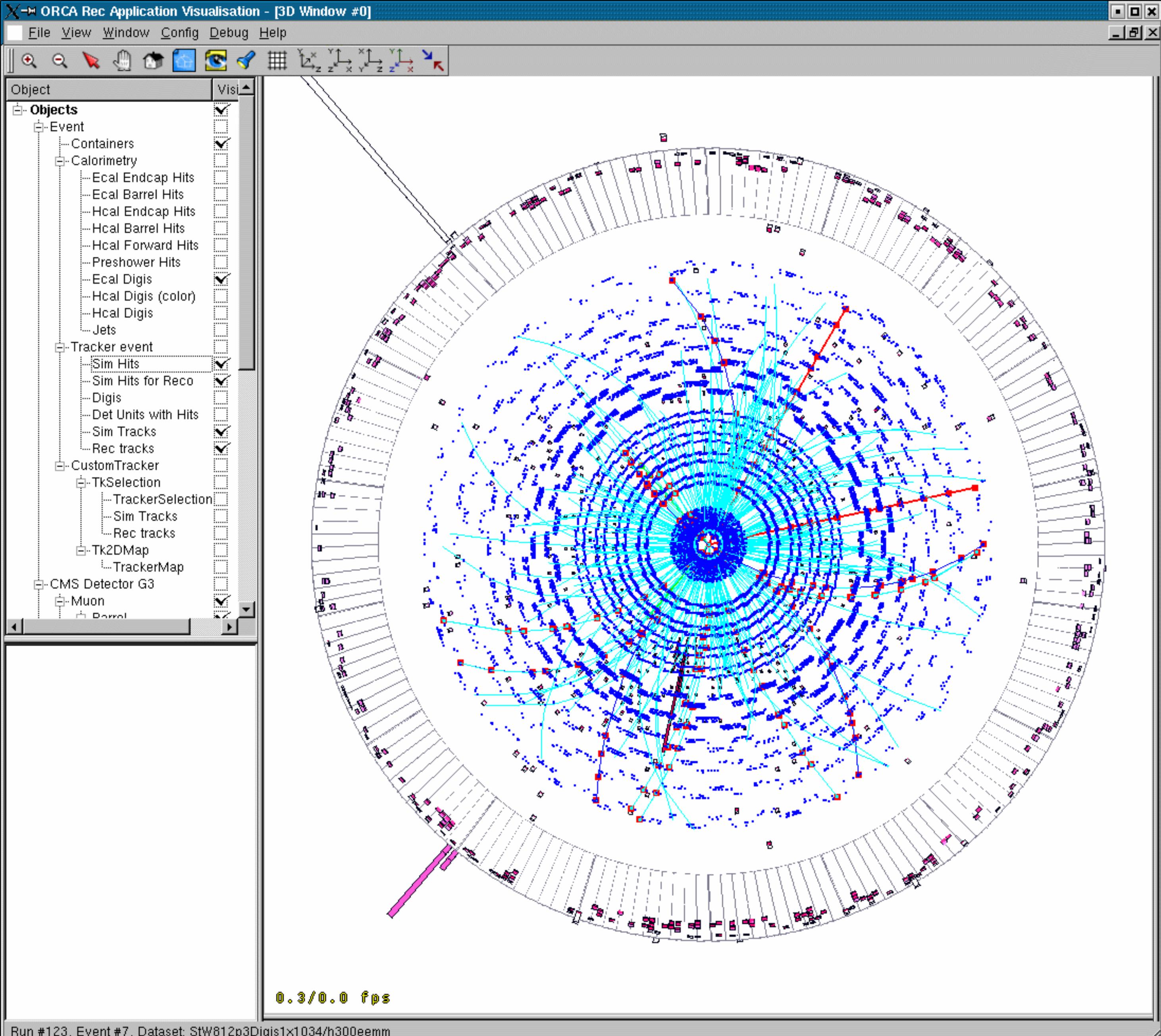
Total Weight	:	14,500 t.
Overall diameter	:	14.60 m
Overall length	:	21.60 m
Magnetic field	:	4 Tesla

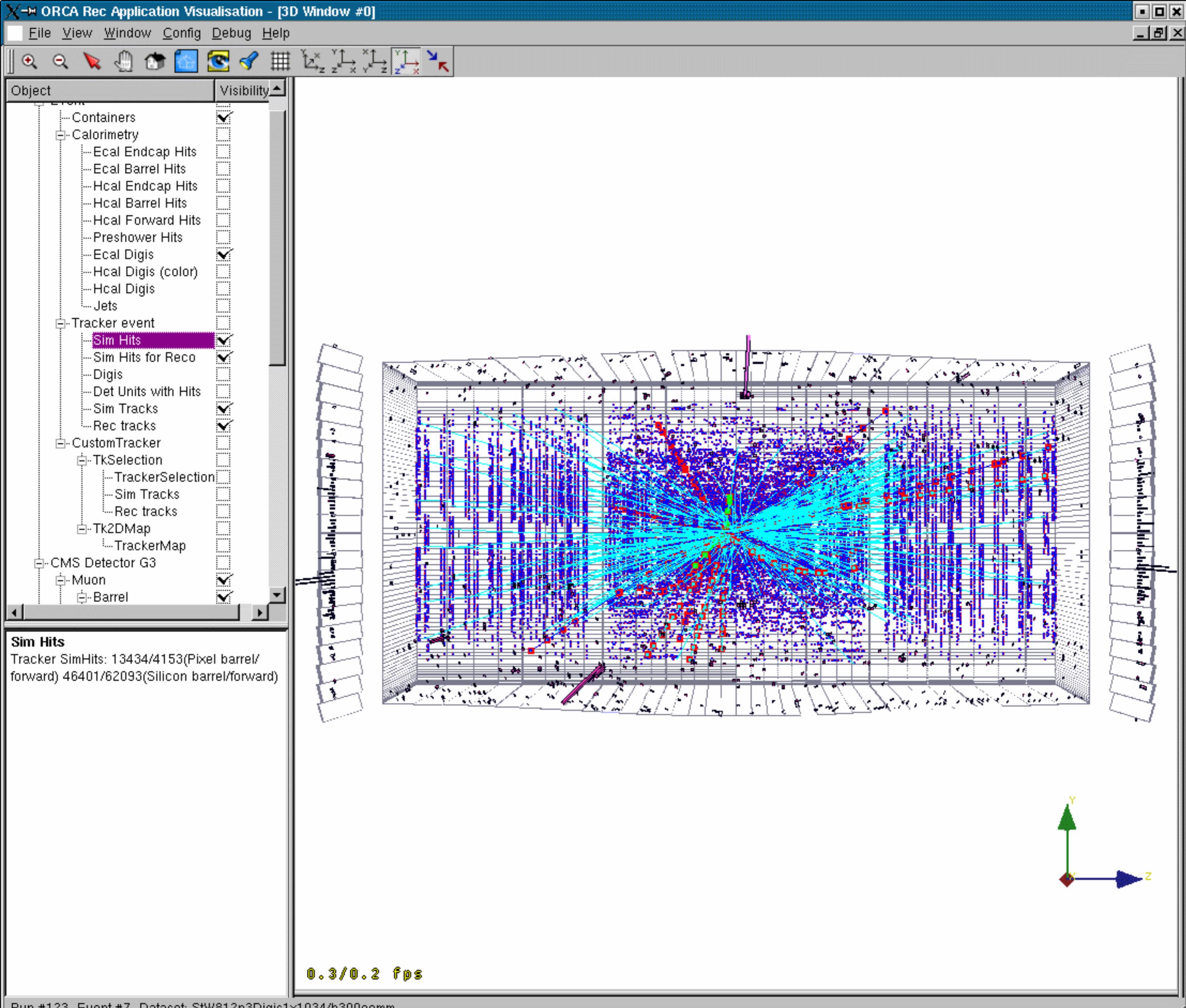




UX15 Geneva Thu Jul 21 23:00:01 2005

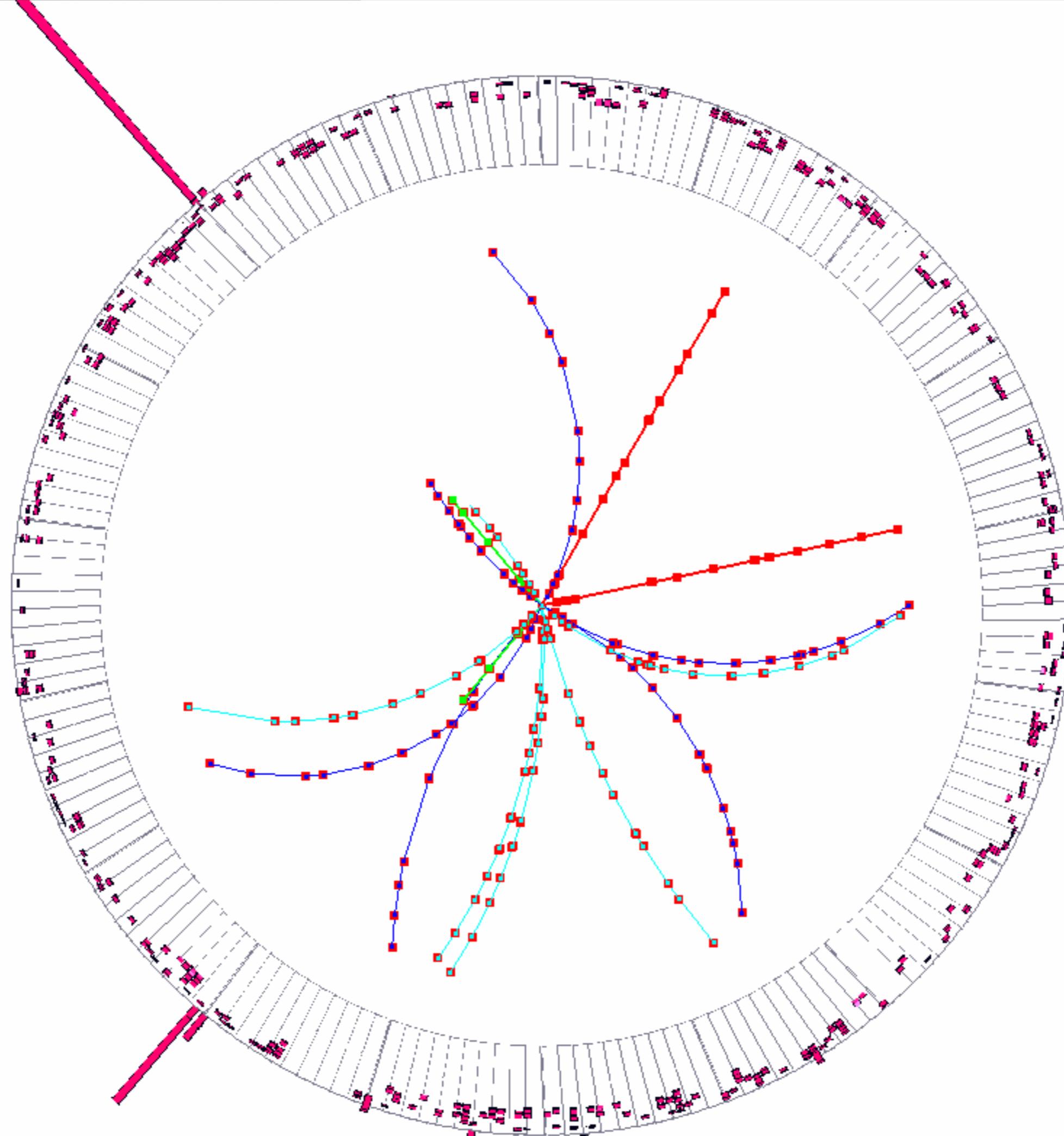






X-ORCA Rec Application Visualisation - [3D Window #0]

File View Window Config Debug Help



0.4 / 0.3 fps

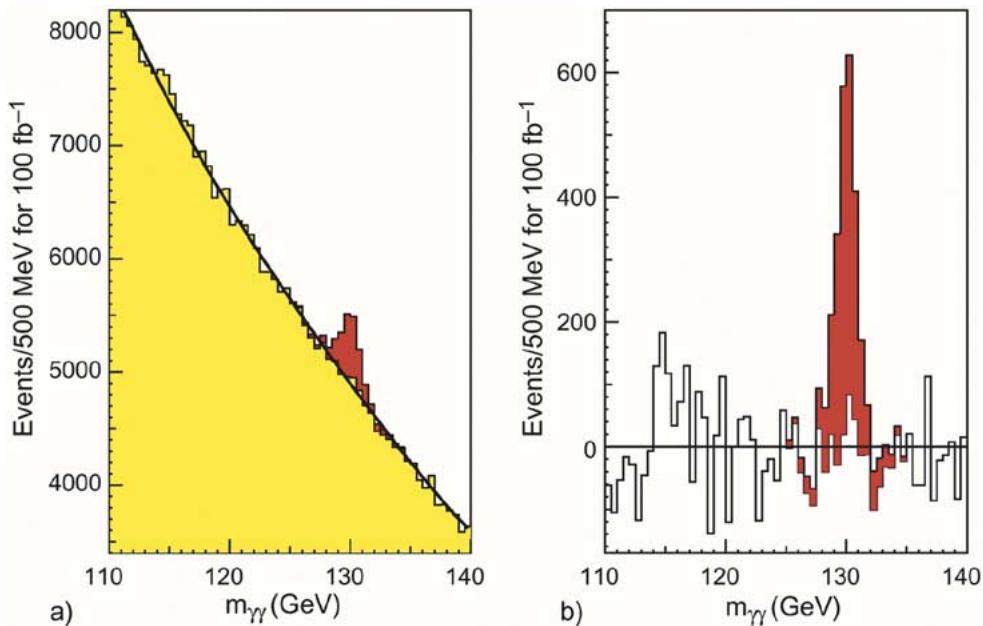


Fig. 1. A simulated 130-GeV Higgs signal, reconstructed by using an electromagnetic calorimeter with energy resolution of $2\%/\sqrt{E} \oplus 0.5\%$, for $H \rightarrow \gamma\gamma$ channel with integrated luminosity of 100 fb^{-1} before (left) and after (right) background subtraction.

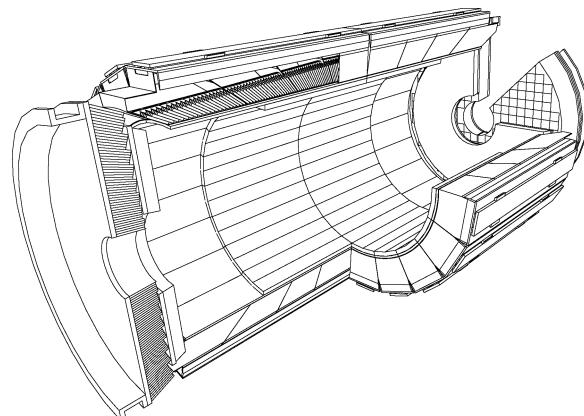
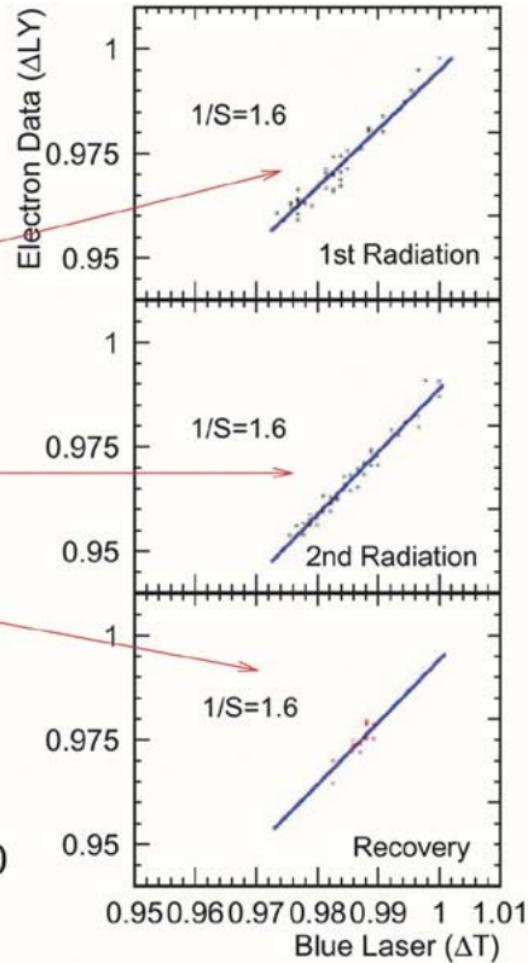
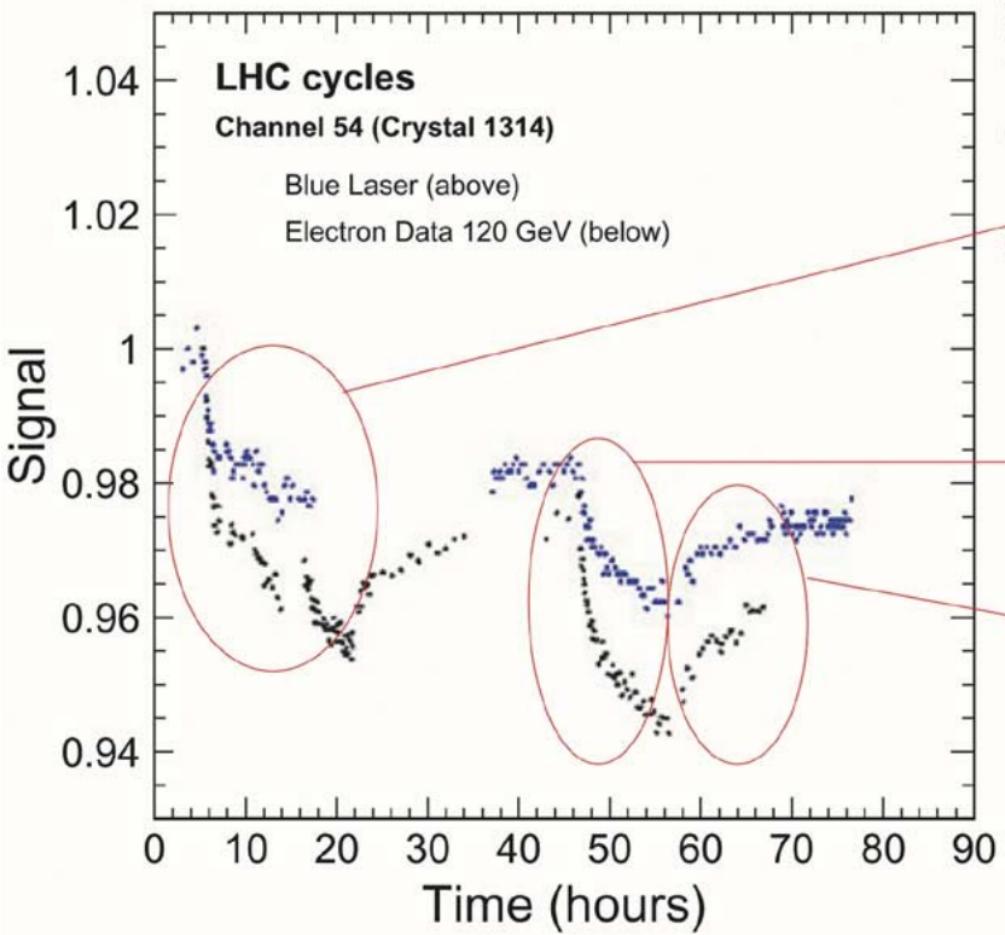


Fig. 2. A 3-D cut-away view of the CMS PWO ECAL.



Supersymmetry and R-hadrons

R-parity conserved, stable \tilde{g} hadronizes to

R-hadrons

- R-mesons: $R = \tilde{g}q\bar{q}, (\tilde{q}\bar{q}) \rightarrow R^+, R^-, R^0$
- R-baryons: $R = \tilde{g}qqq, (\tilde{q}qq) \rightarrow R^{++}, R^+, R^-, R^0$
- R-gluinoballs: $R = \tilde{g}g \rightarrow R^0$

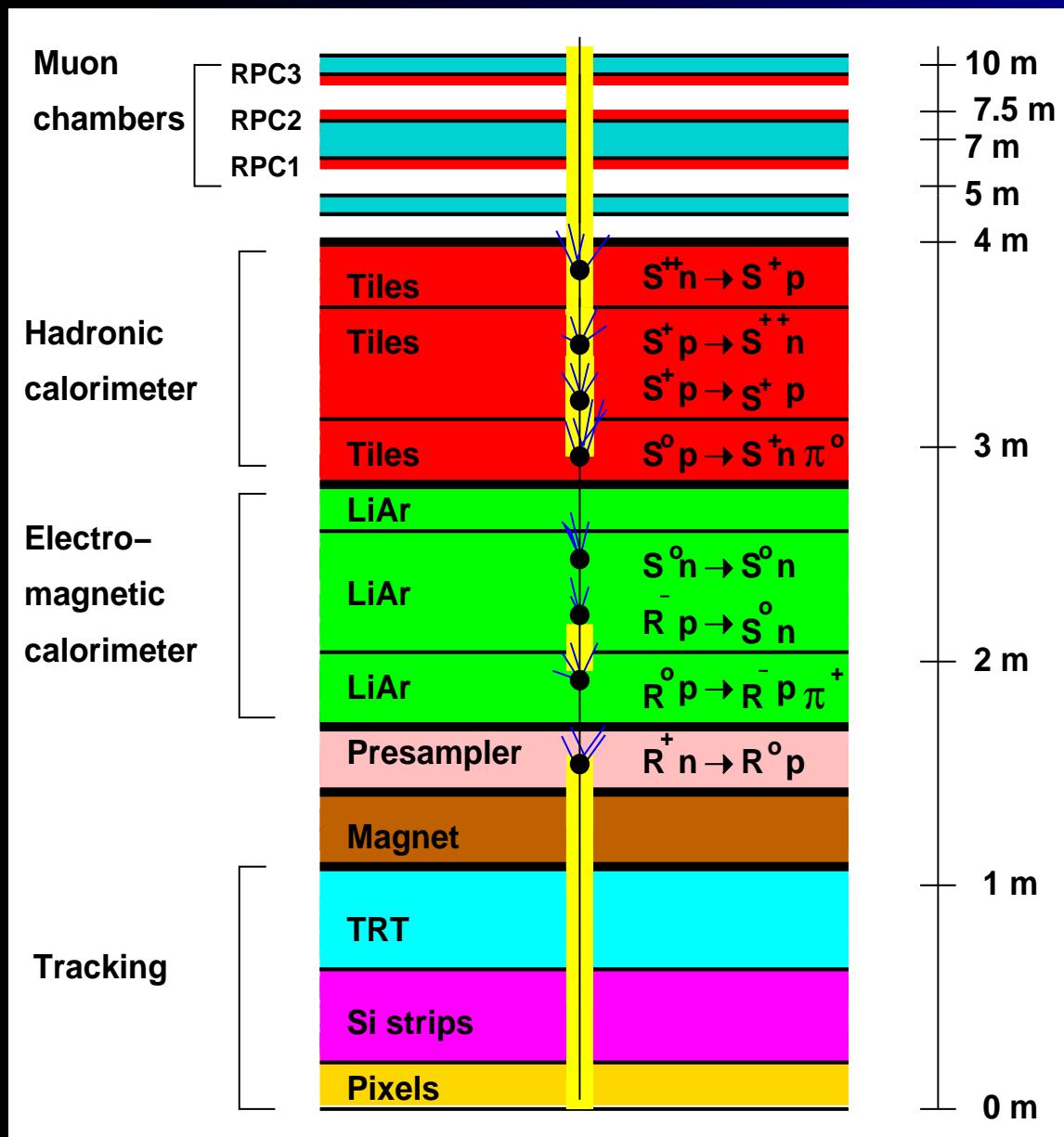
Gluino R-hadron production at LHC:

- $pp \rightarrow \tilde{g}\tilde{g}$
- $pp \rightarrow \tilde{g}\tilde{q} \rightarrow \tilde{g}\tilde{g}q$
- $pp \rightarrow \tilde{q}\tilde{q} \rightarrow \tilde{g}\tilde{g}qq$

NB1: heavy hadrons also predicted in theories with leptoquarks, extra dimensions, GUT...

NB2: Stable gluinos at LHC mass ranges not excluded by accelerator experiments or cosmology

Interactions of R-hadrons in ATLAS

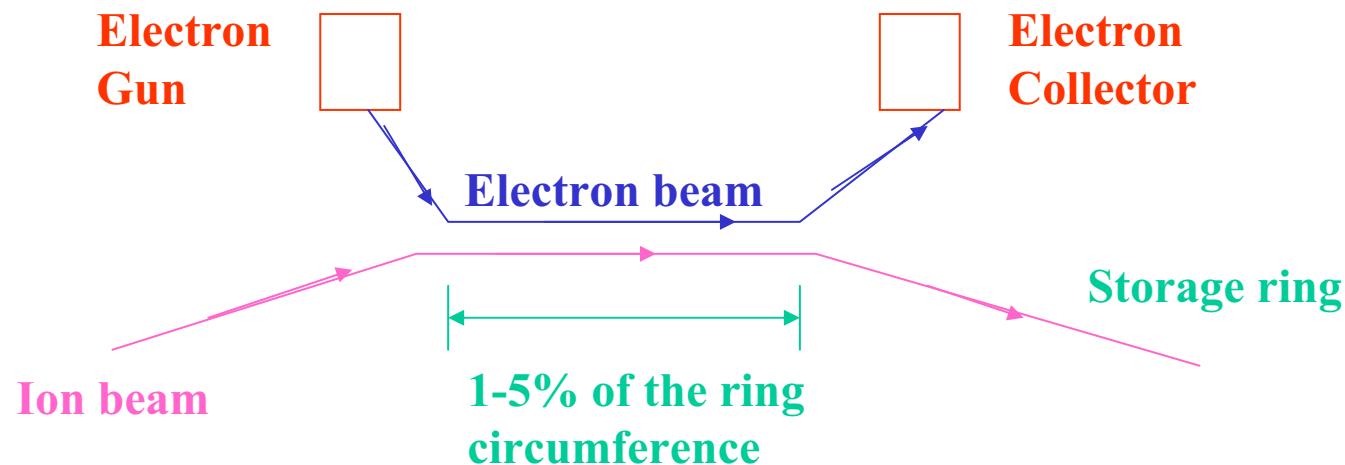


Nr of interactions:
~ 10 – 15

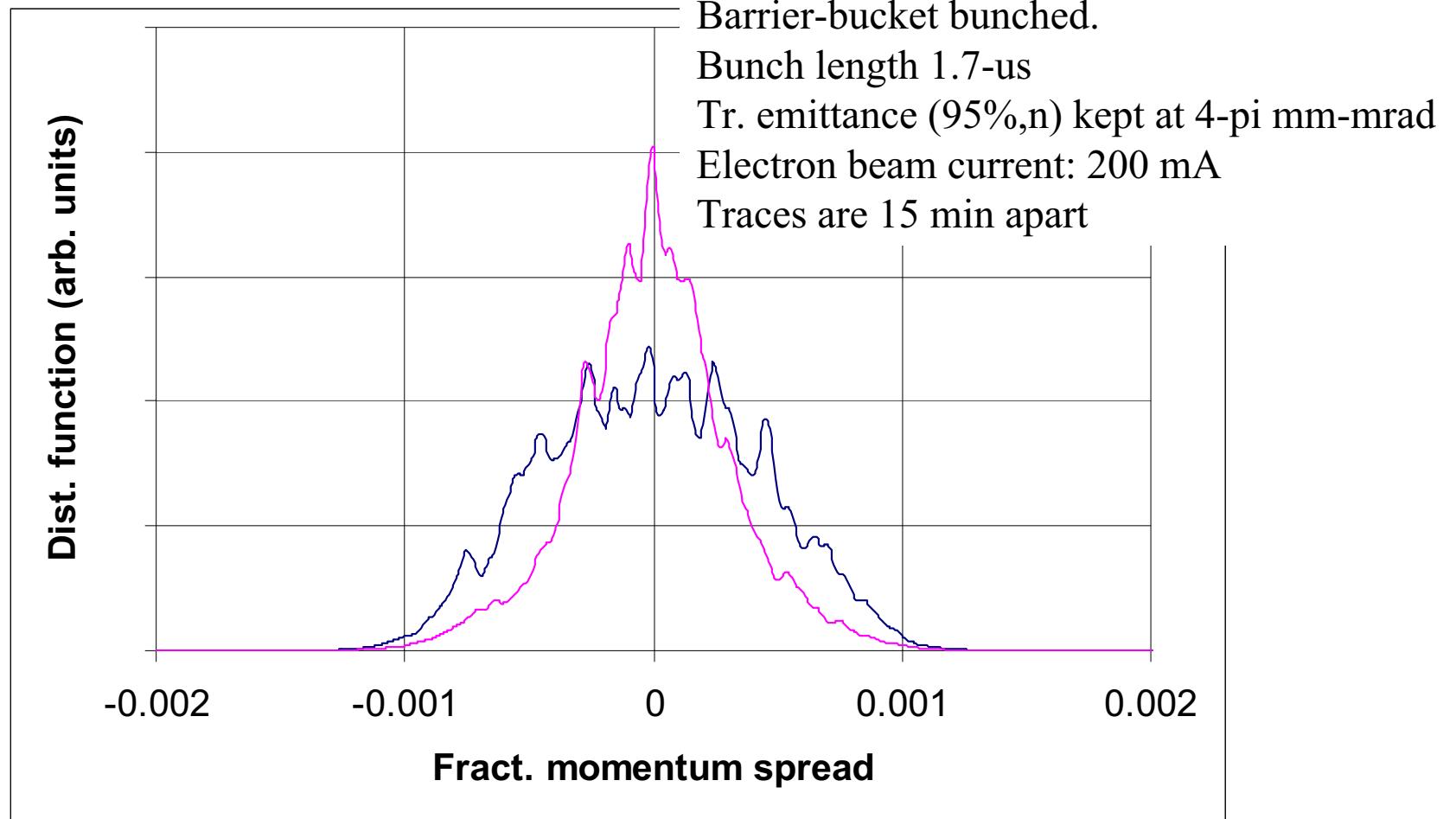
How does electron cooling work?

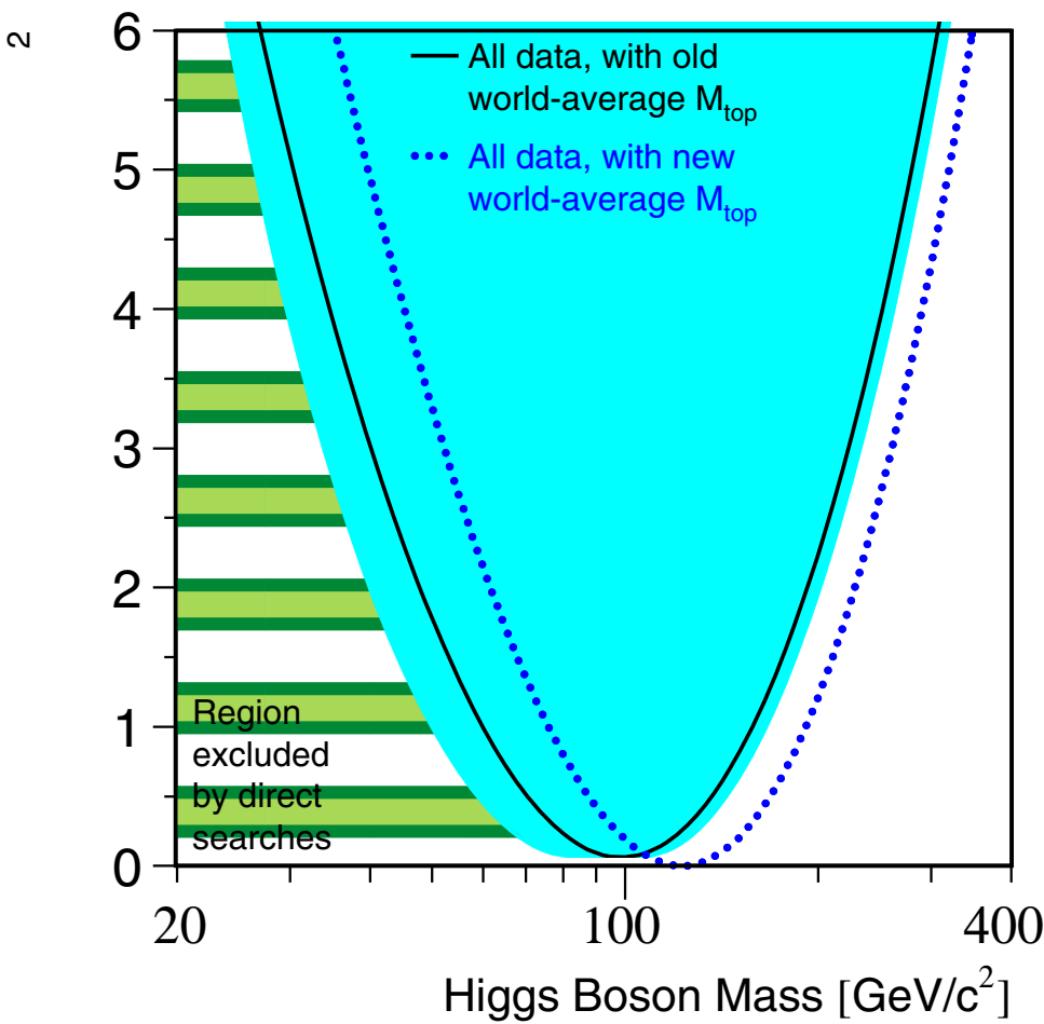
The velocity of the electrons is made equal to the average velocity of the ions.

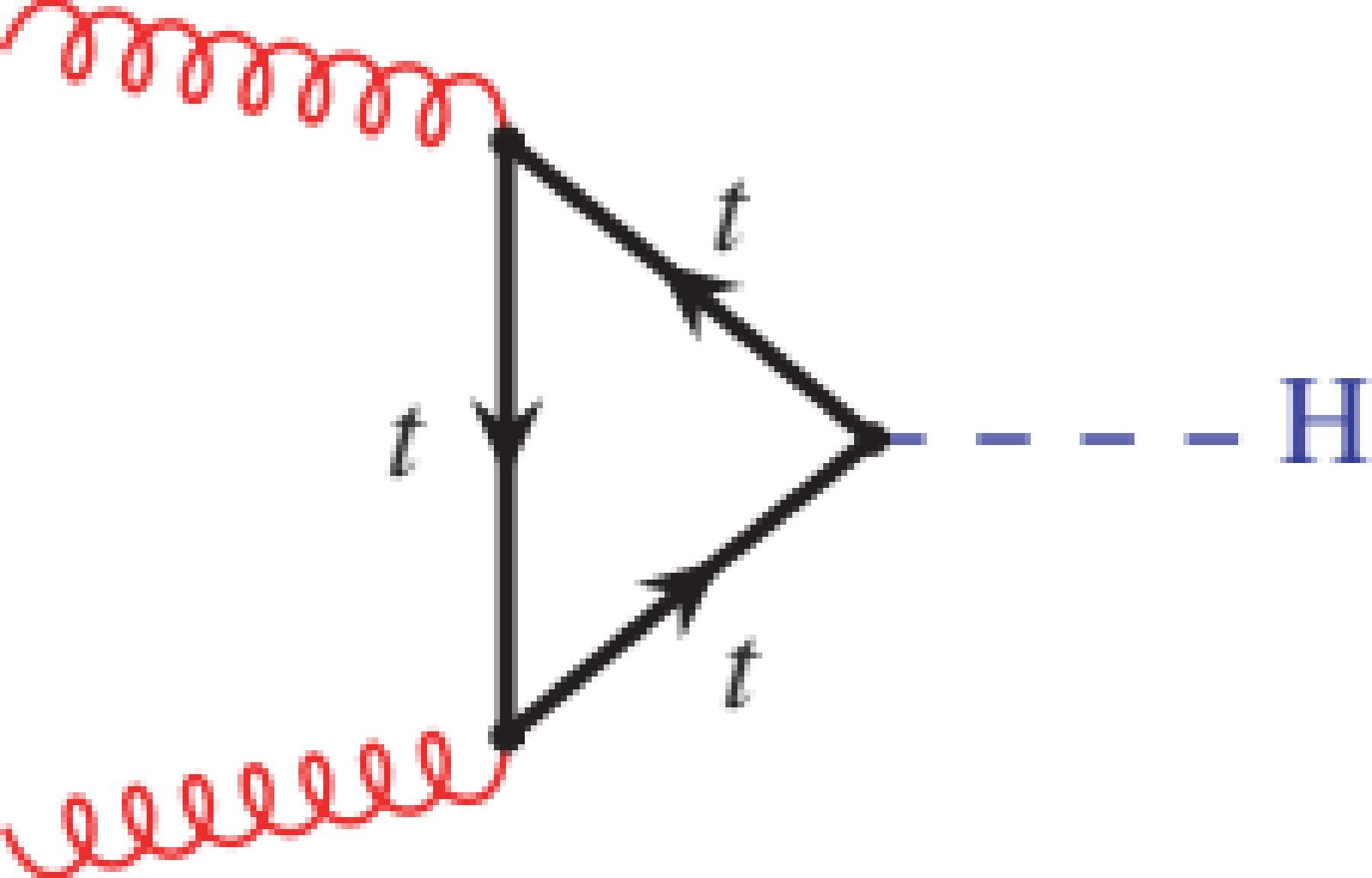
The ions undergo Coulomb scattering in the electron “gas” and lose energy, which is transferred from the ions to the co-streaming electrons until some thermal equilibrium is attained.

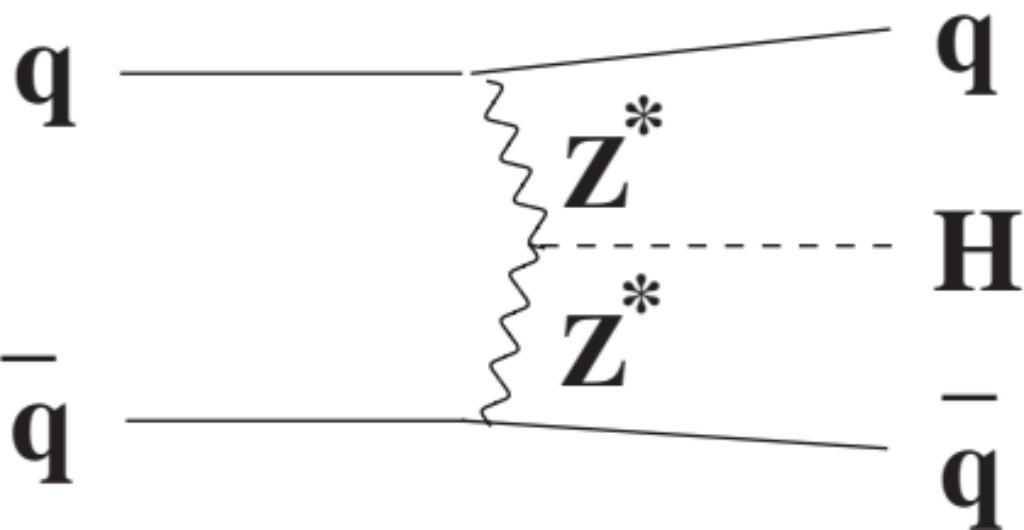
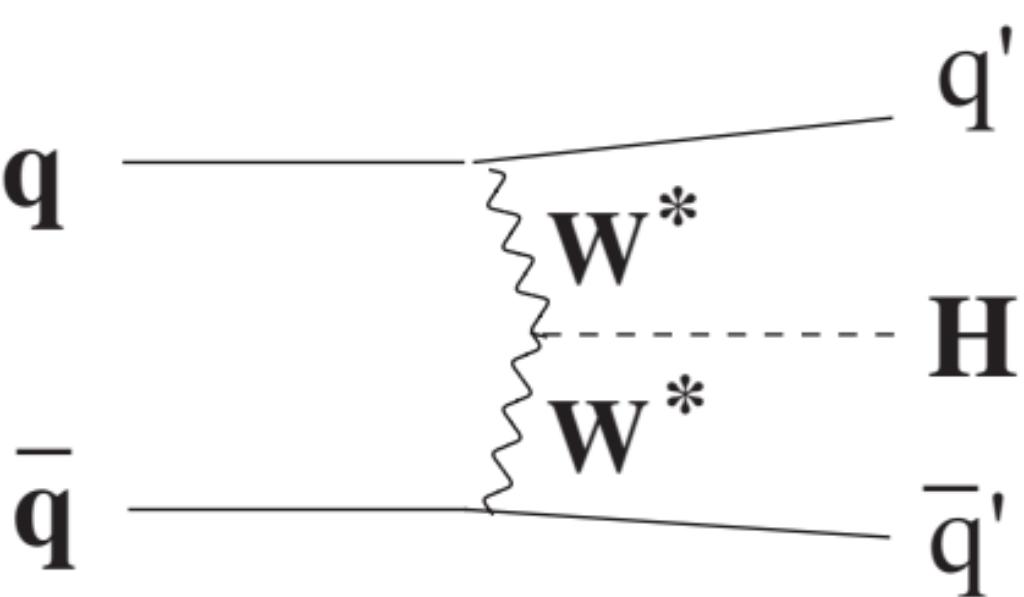


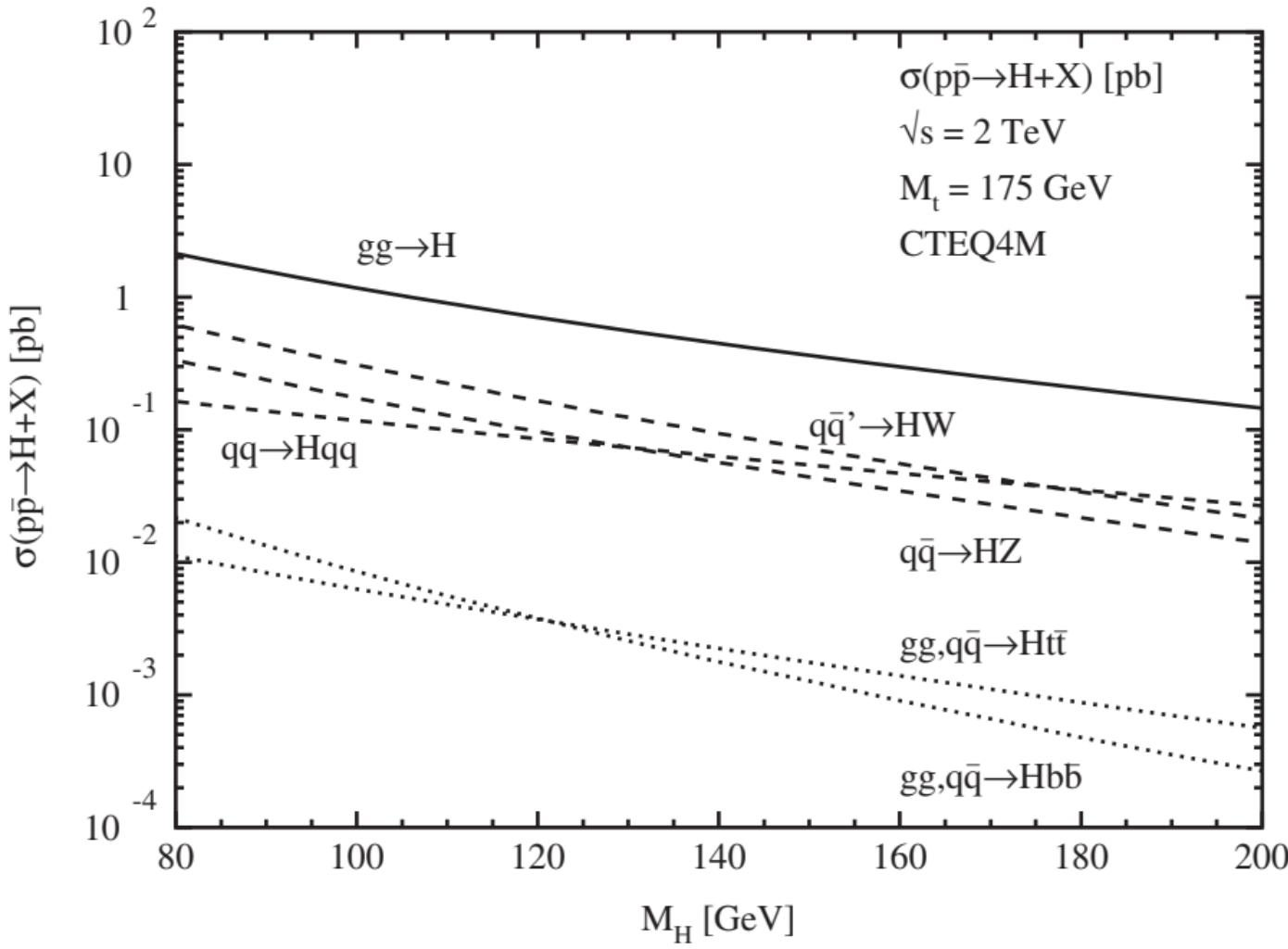
First e-cooling demonstration - 07/15/05



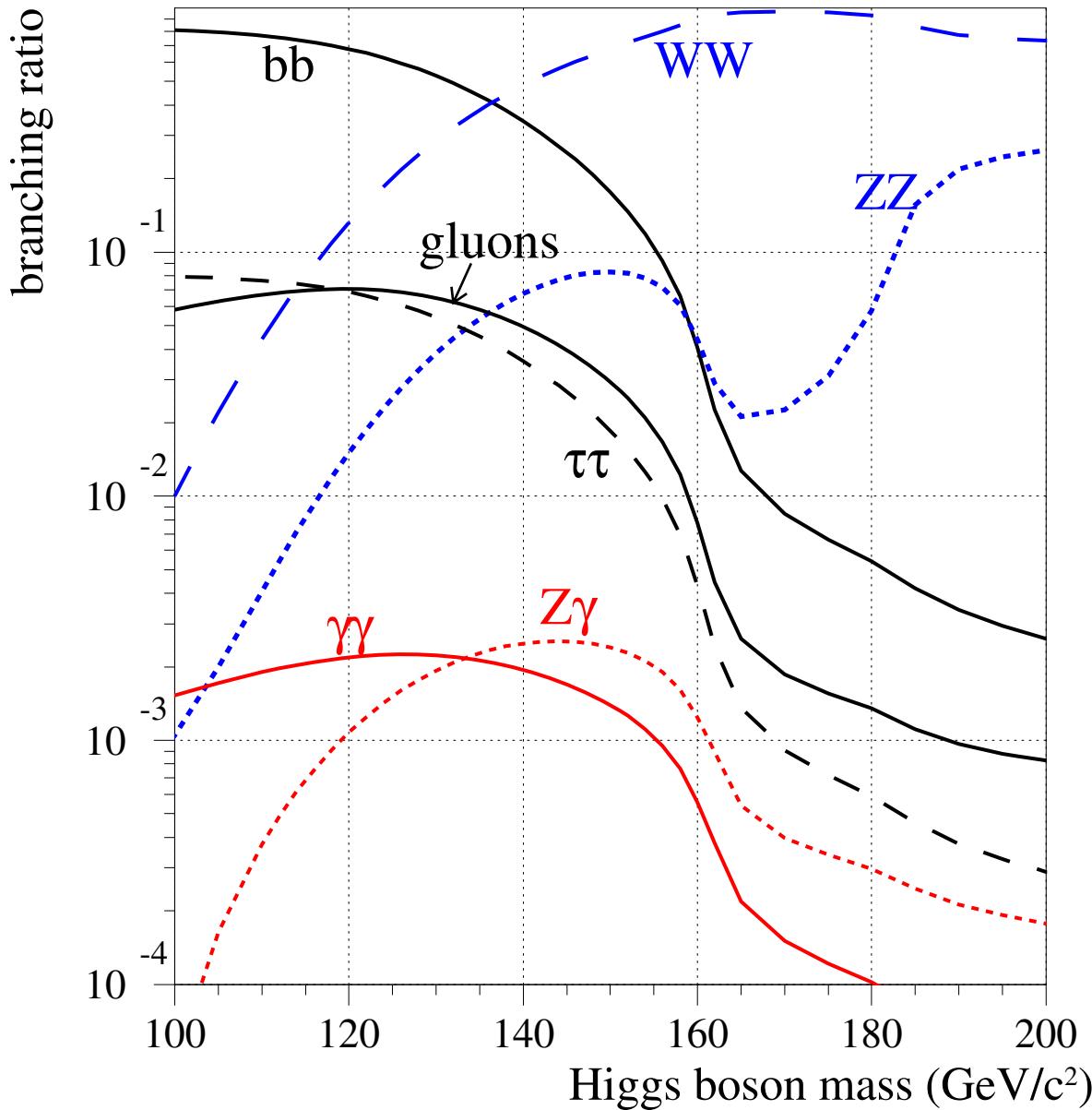




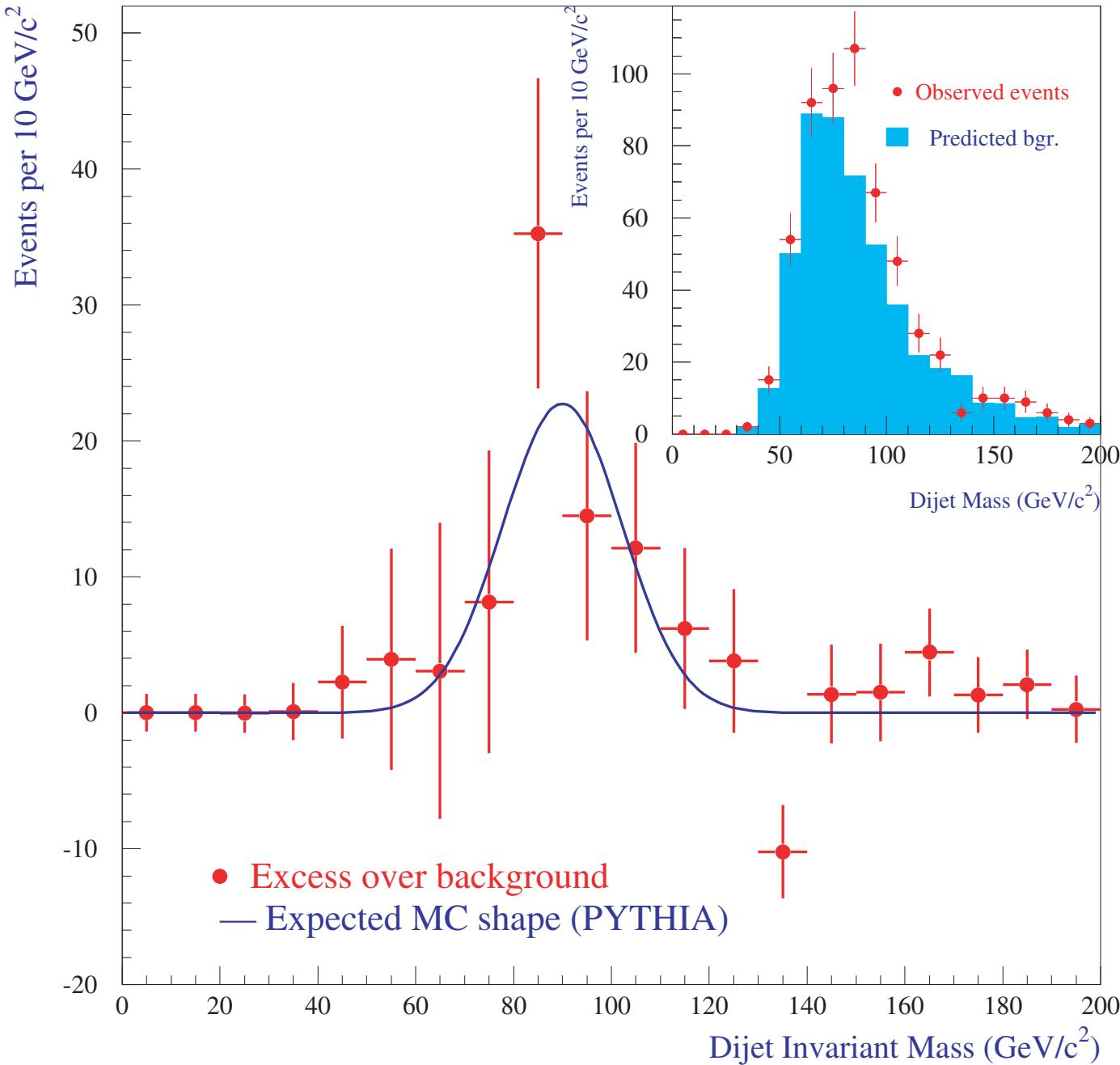




Higgs Branching Fractions from HDECAY



CDF PRELIMINARY



Events

DØ

$L = 174 \text{ pb}^{-1}$

$W + 2 \text{ b-tagged jets}$

- Data
- ◻ $W + \text{jets}$
- █ QCD
- █ $t\bar{t}$
- █ $Wb\bar{b}$
- █ other
- █ WH

