# Prompt Photon Results from the Tevatron

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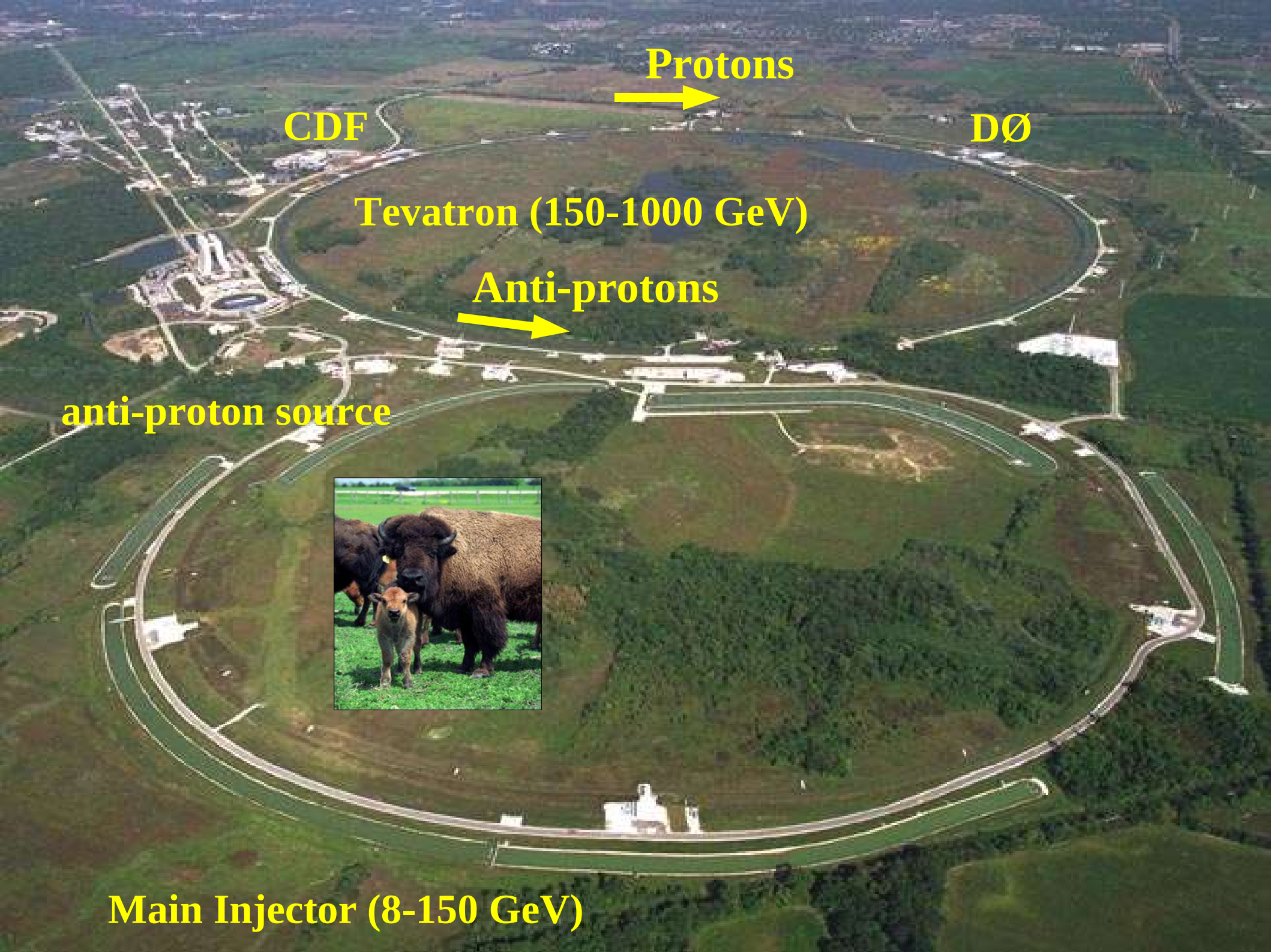
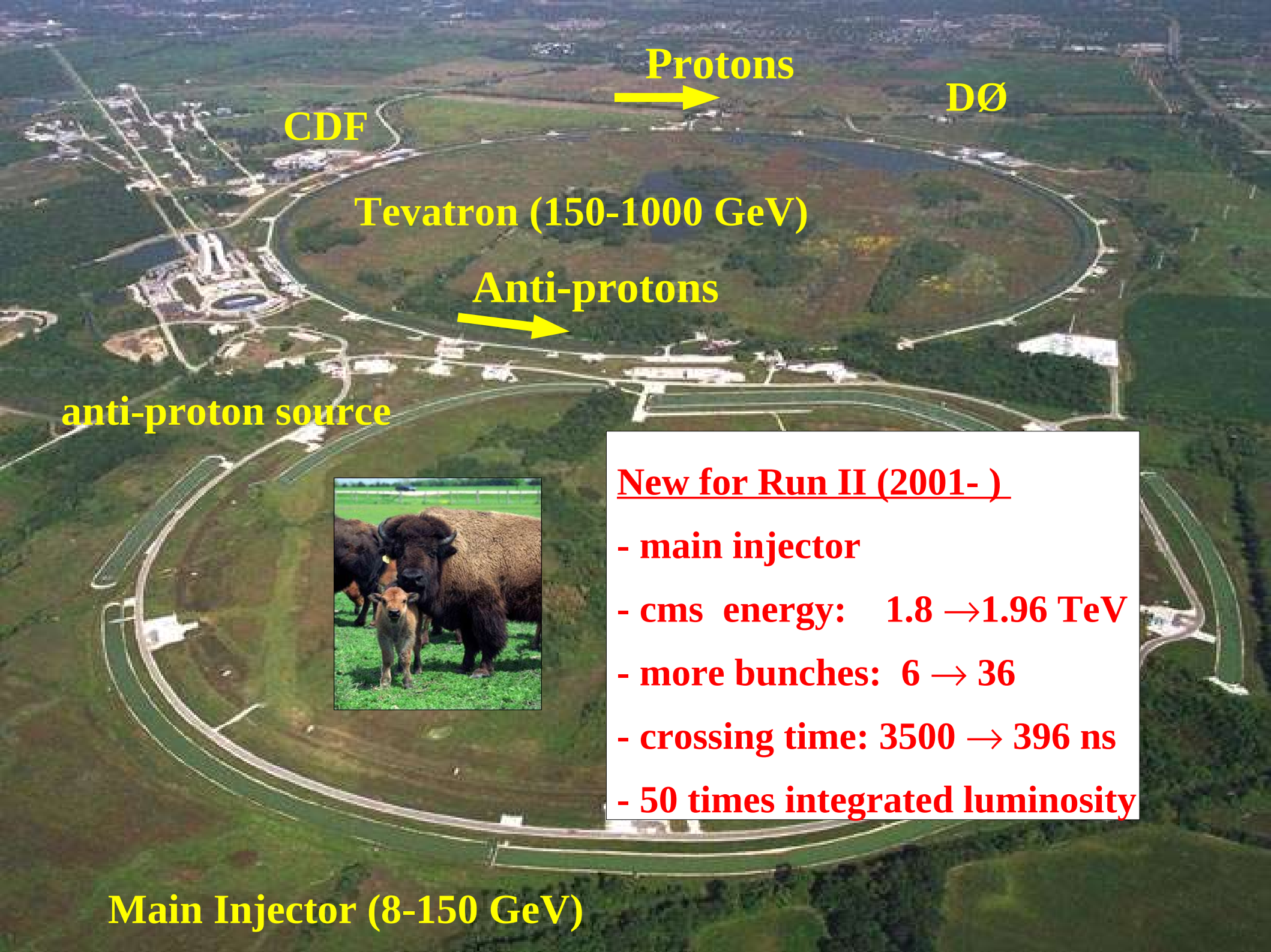
1824

# Outline

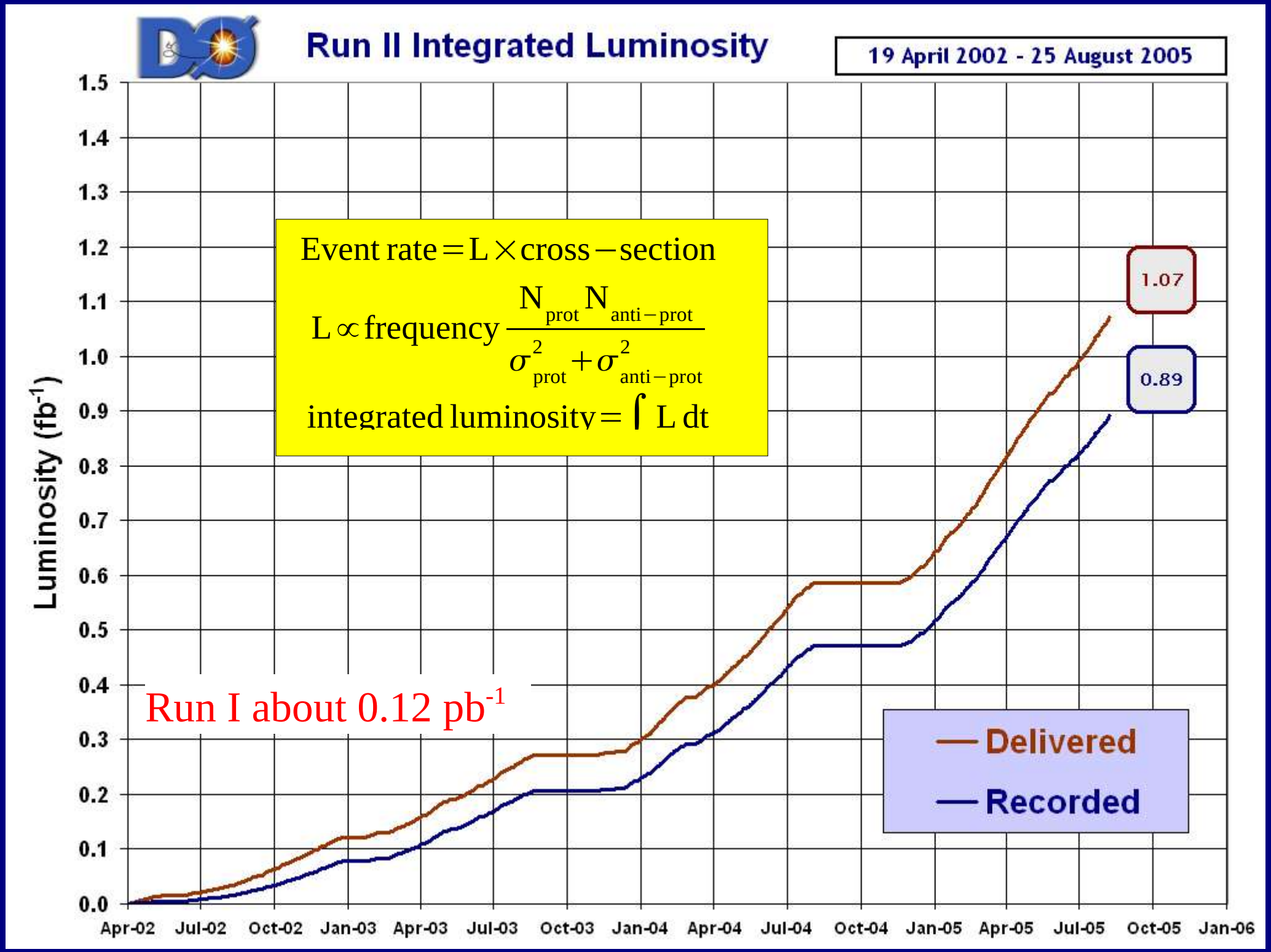
- Tevatron and DØ/CDF
- Prompt Photon Production (DØ)
- Di-photon Production (CDF)


Protons
CDF
DØ
Tevatron (150-1000 GeV)
Anti-protons
anti-proton source
Main Injector (8-150 GeV)




**New for Run II (2001- )**

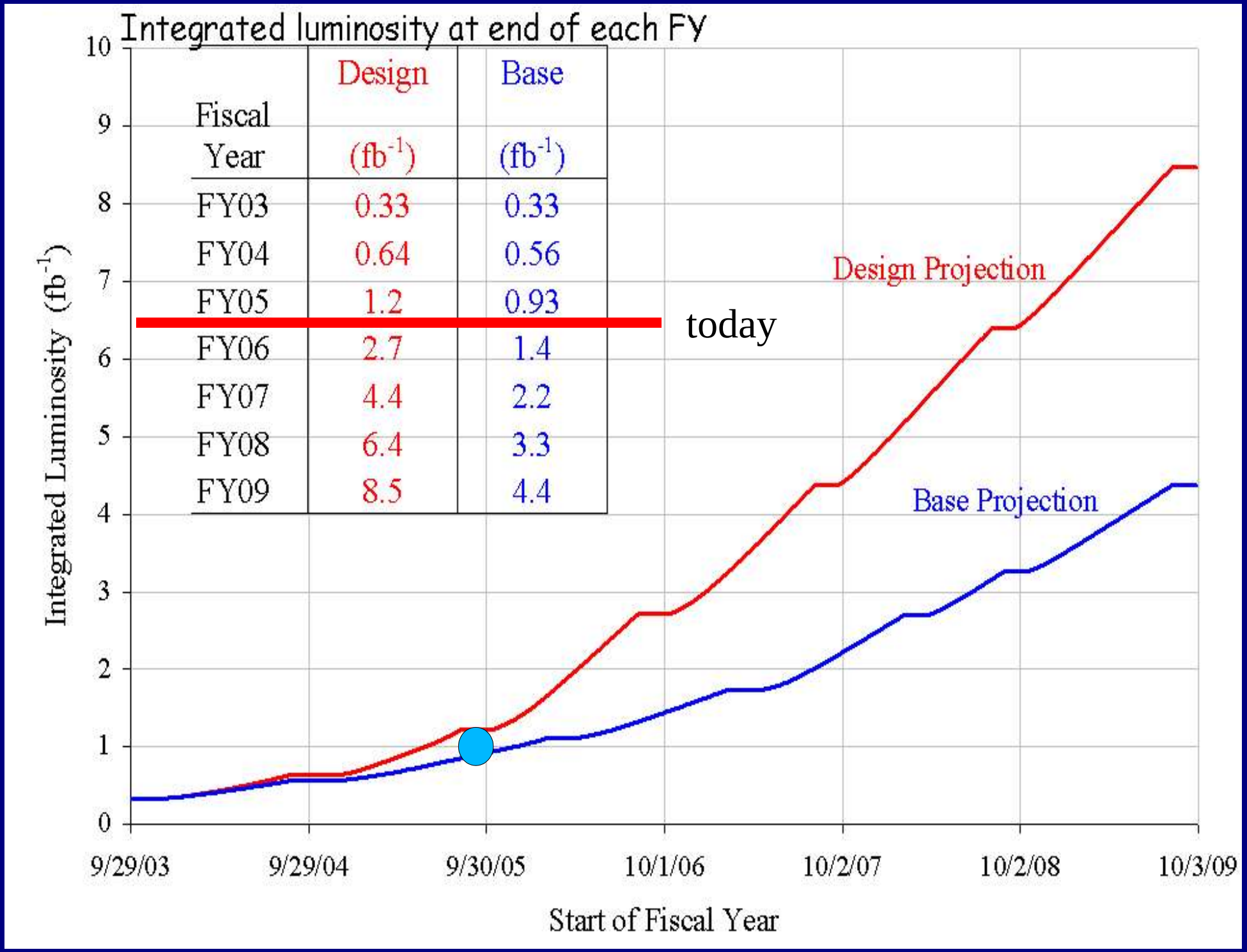
- main injector
- cms energy: 1.8 → 1.96 TeV
- more bunches: 6 → 36
- crossing time: 3500 → 396 ns
- 50 times integrated luminosity




$$\text{Event rate} = L \times \text{cross-section}$$

$$L \propto \text{frequency} \frac{N_{prot} N_{anti-prot}}{\sigma^2_{prot} + \sigma^2_{anti-prot}}$$

$$\text{integrated luminosity} = \int L\, dt$$

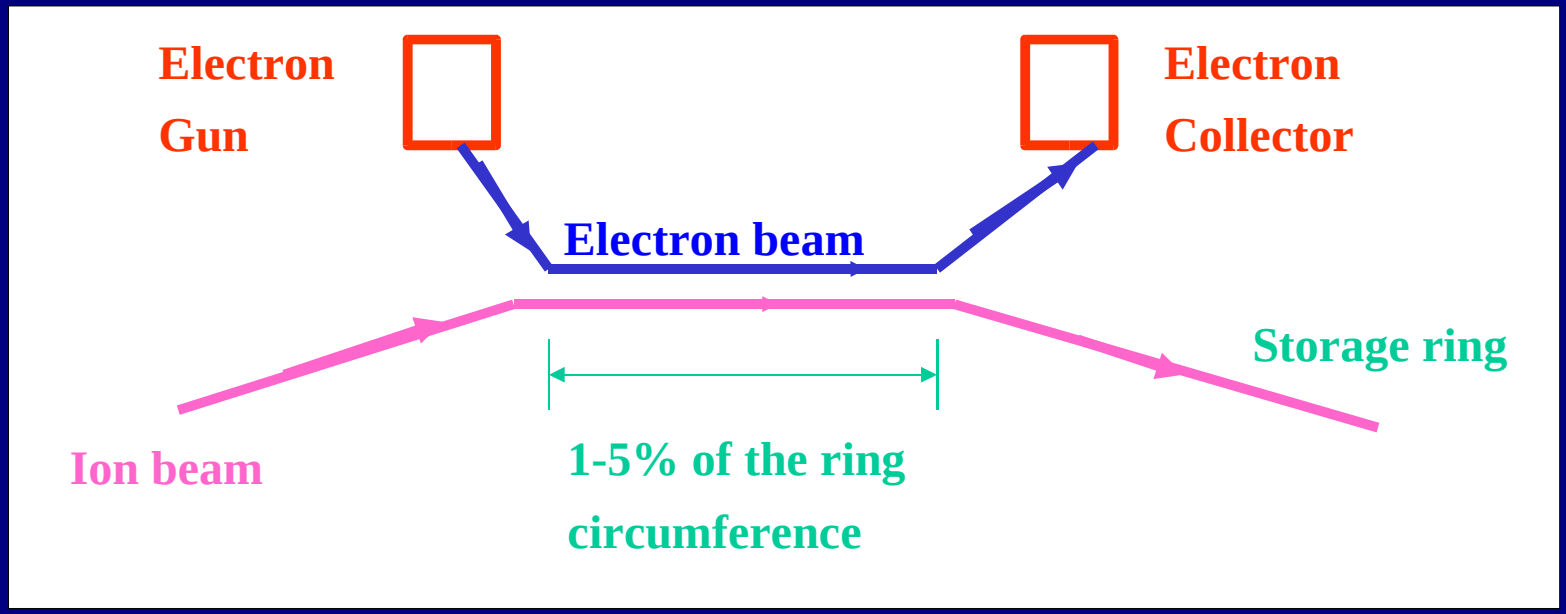



| Fiscal Year | Design ($fb^{-1}$) | Base ($fb^{-1}$) |
|---|---|---|
| FY03 | 0.33 | 0.33 |
| FY04 | 0.64 | 0.56 |
| FY05 | 1.2 | 0.93 |
| FY06 | 2.7 | 1.4 |
| FY07 | 4.4 | 2.2 |
| FY08 | 6.4 | 3.3 |
| FY09 | 8.5 | 4.4 |

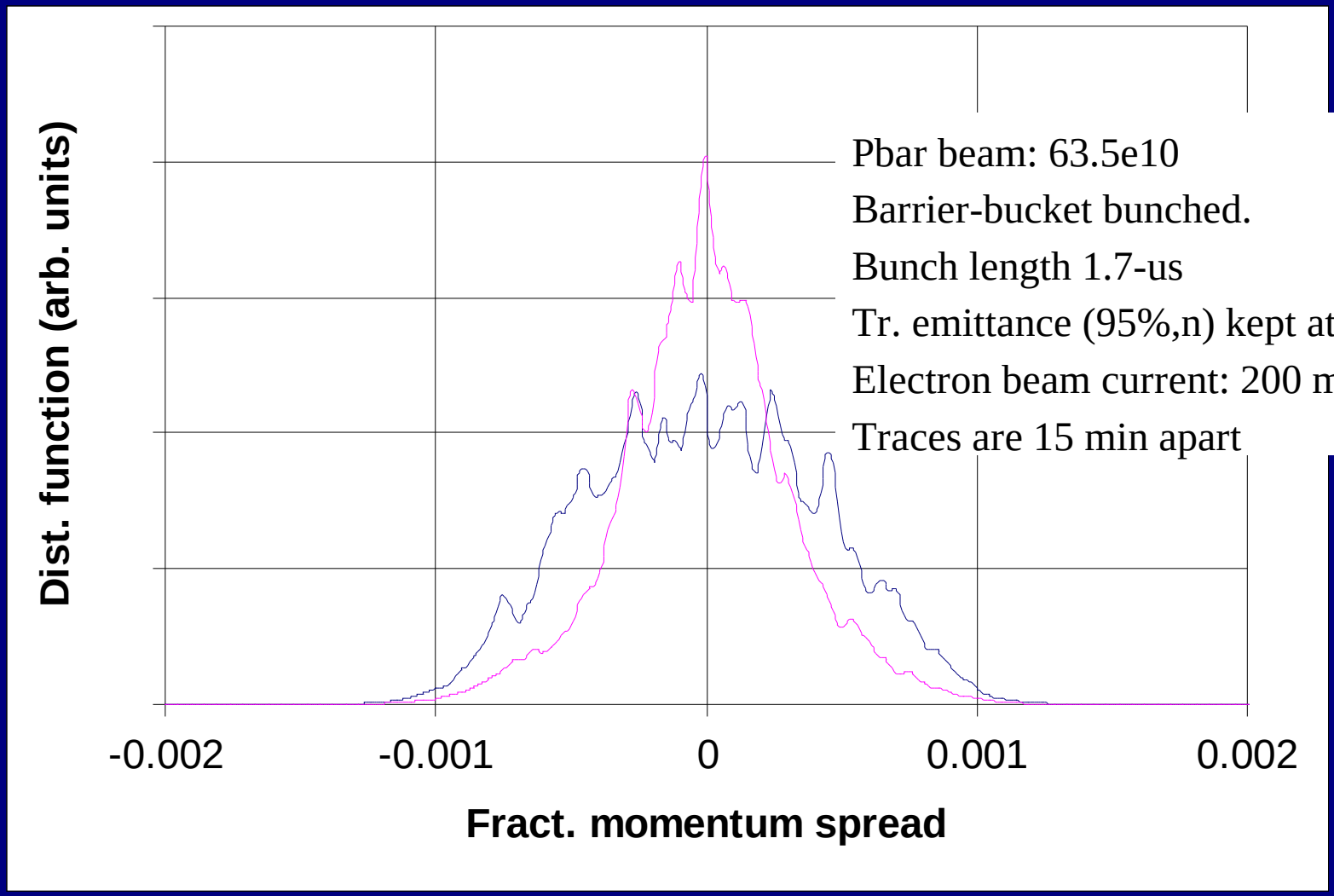
# How does electron cooling work ?

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

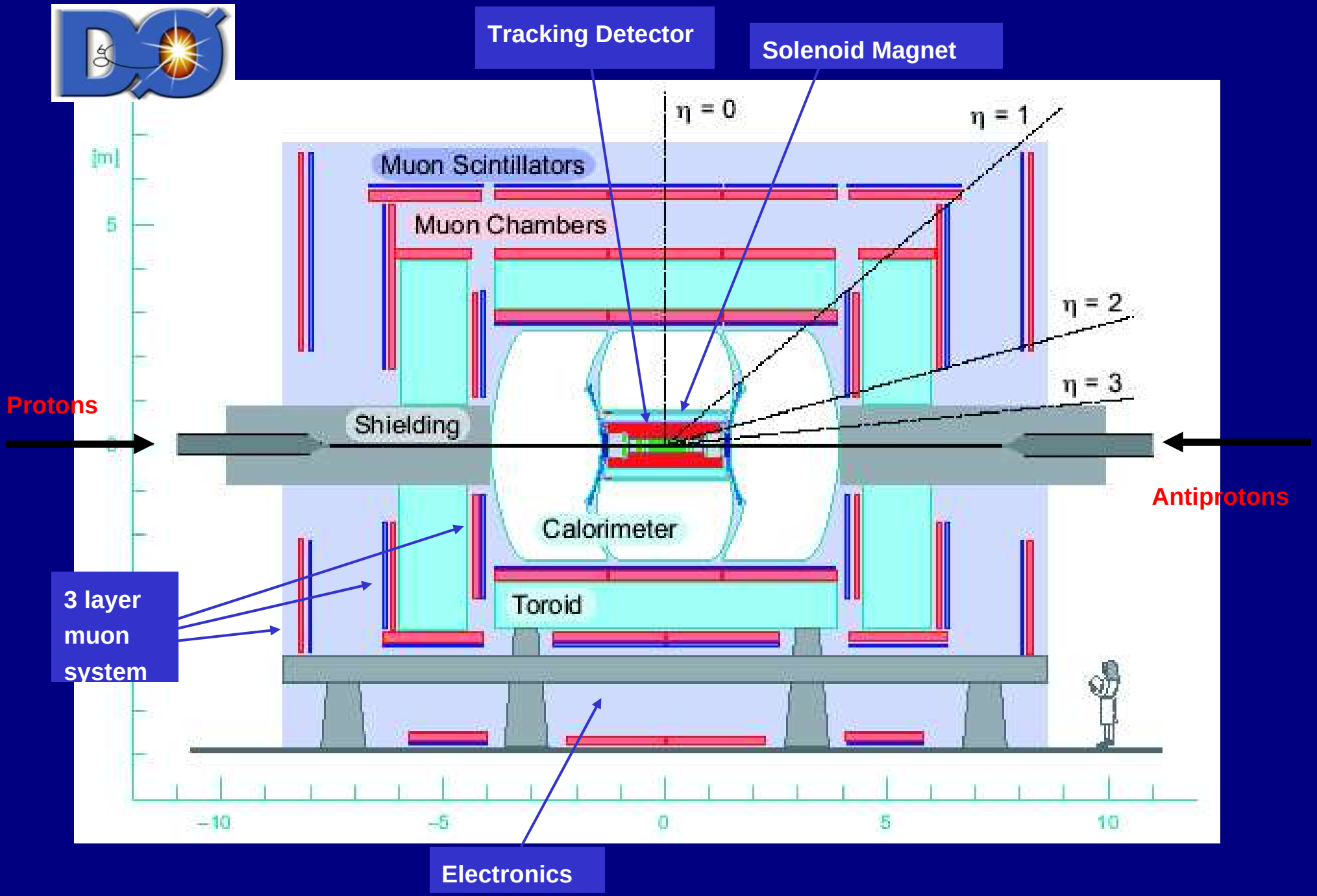
**The ions undergo Coulomb scattering in the electron "gas" and loose energy, which is transferred from the ions to the co-streaming electrons until some thermal equilibrium is reached.**

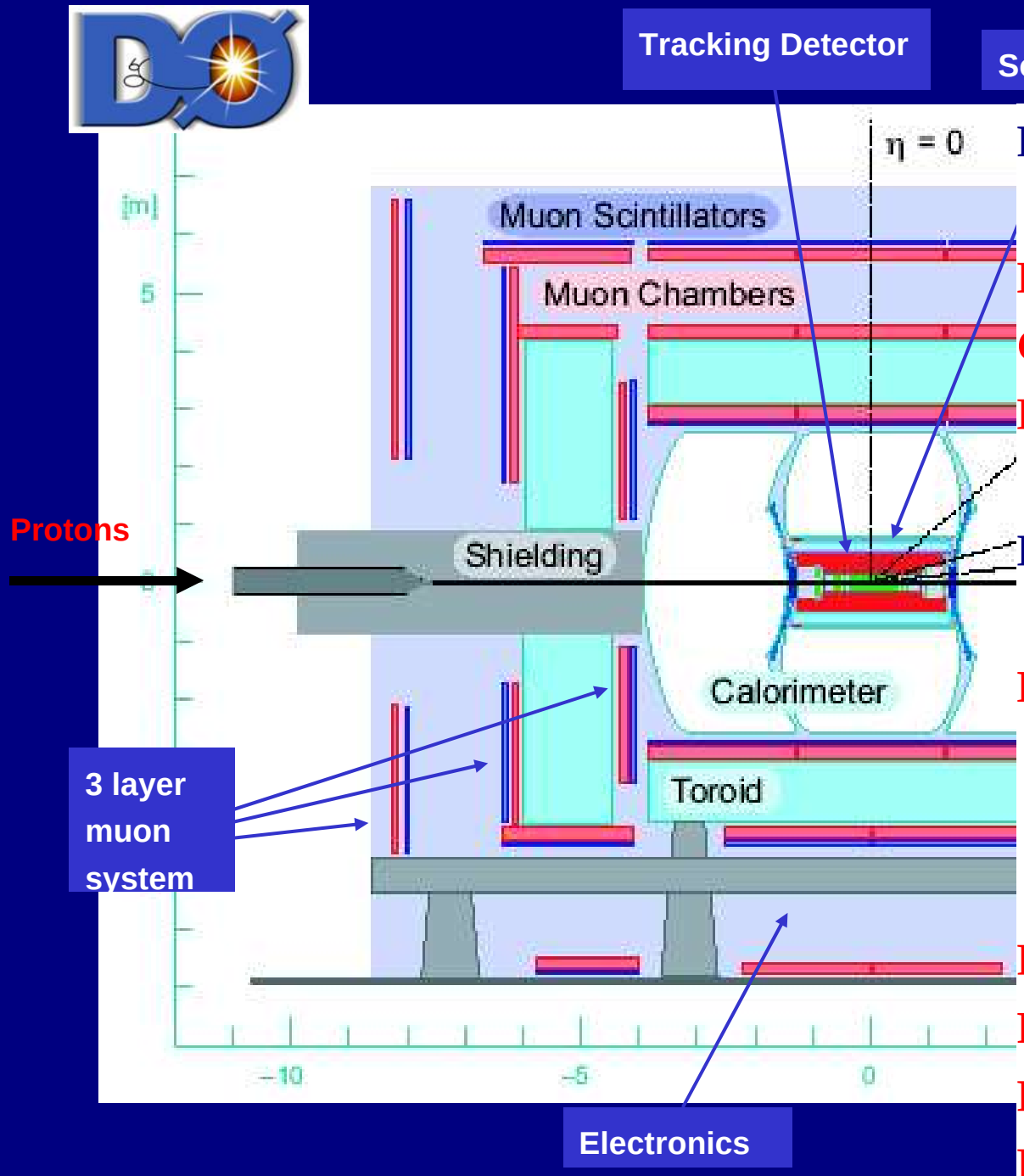


# First e-cooling demonstration – 07/15/05




Pbar beam: 63.5e10
Barrier-bucket bunched.
Bunch length 1.7-us
Tr. emittance (95%,n) kept at 4-pi mm-mrad
Electron beam current: 200 mA
Traces are 15 min apart


Tracking Detector
Solenoid Magnet
η = 0
η = 1
η = 2
η = 3
Muon Scintillators
Muon Chambers
Shielding
Calorimeter
Toroid
Protons
Antiprotons
3 layer muon system
Electronics
[m]
5
0
−10
−5
0
5
10

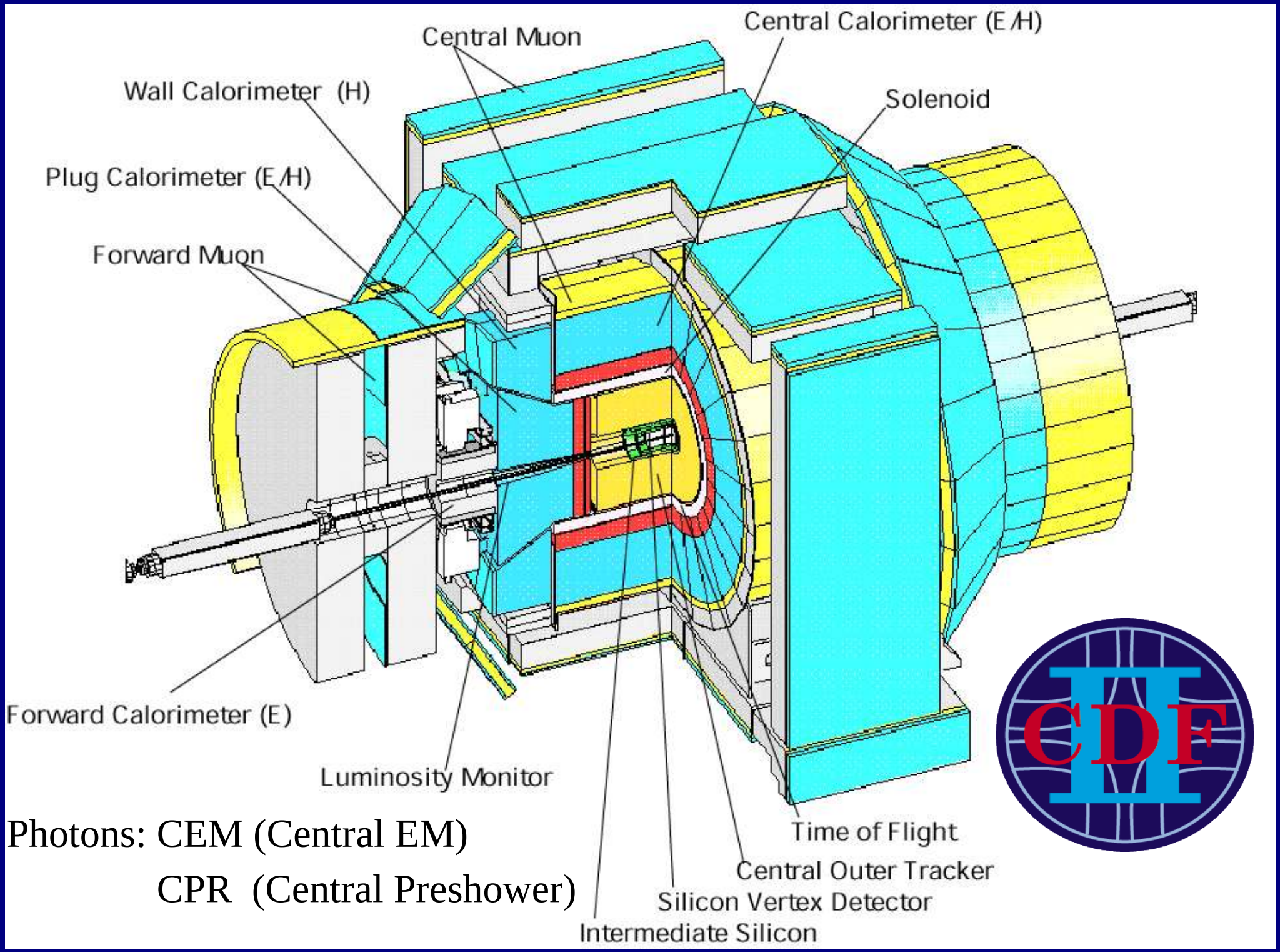



**Retained from Run I:**

- LAr calorimeter
- Central muon detector
- Muon Toroid

**New for Run II:**

- Magnetic Tracker
  - 2 Tesla Solenoid
  - Silicon Microvertex Tracker (SMT)
  - Central Fiber Tracker (CFT)
- Pre-shower detectors
- Forward muon detector
- Forward proton detector
- FE electronics, Trigger & DAQ




Photons: CEM (Central EM)

CPR (Central Preshower)

# Prompt Photon Production

**Dominant production mechanism for prompt photons with $p_T$<150 GeV is Compton scattering**

$$\mathbf{q} + \mathbf{g} \rightarrow \mathbf{q} + \gamma$$

**The production cross-section is sensitive to the gluon distribution**

**Test of NLO pQCD, soft gluon resummation and models of gluon radiation and photon isolation**

# Data Selection

**Integrated luminosity about 326 $pb^{-1}$**

**At least one isolated shower in the electromagnetic (EM) calorimeter**

**no associated track**

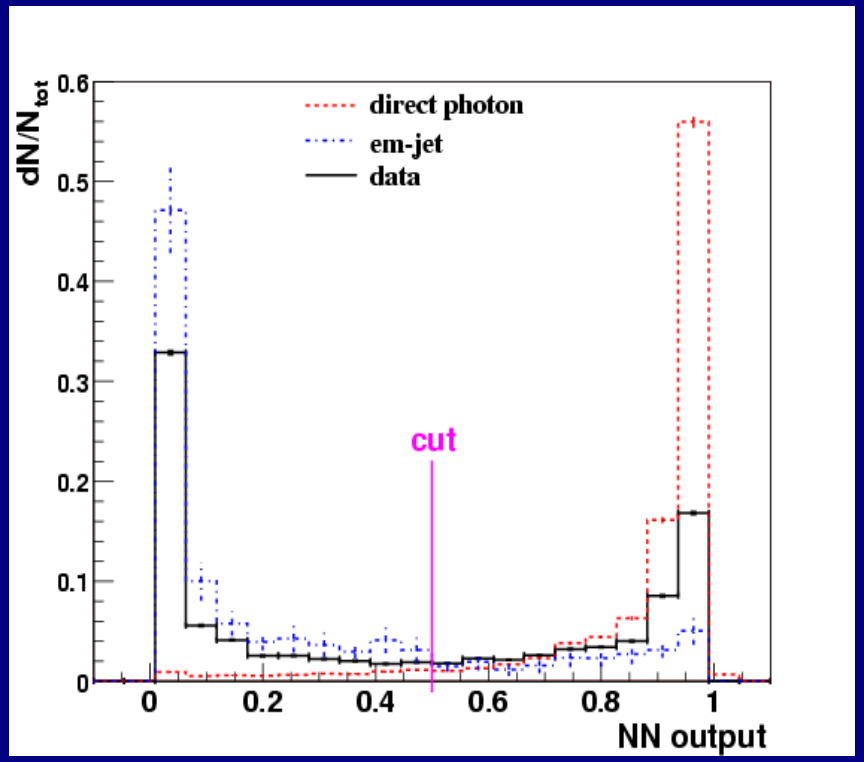
**pseudorapidity $|\eta| < 0.9$**

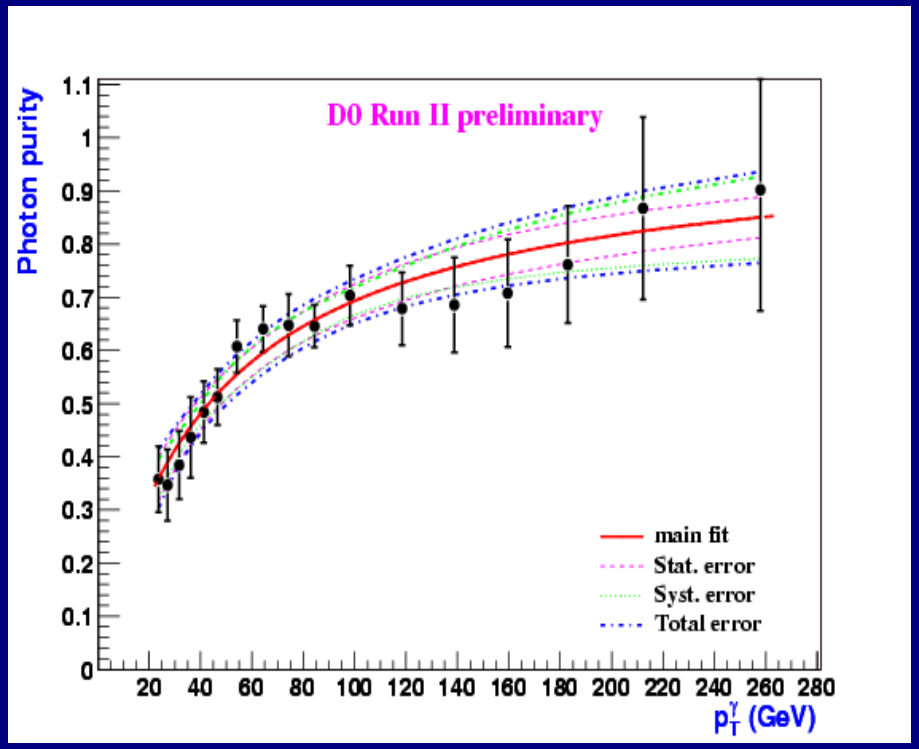
**transverse momentum $p_T^{\gamma} > 23$ GeV**

**small missing transverse energy $ME_T/p_T^{\gamma} < 0.7$**

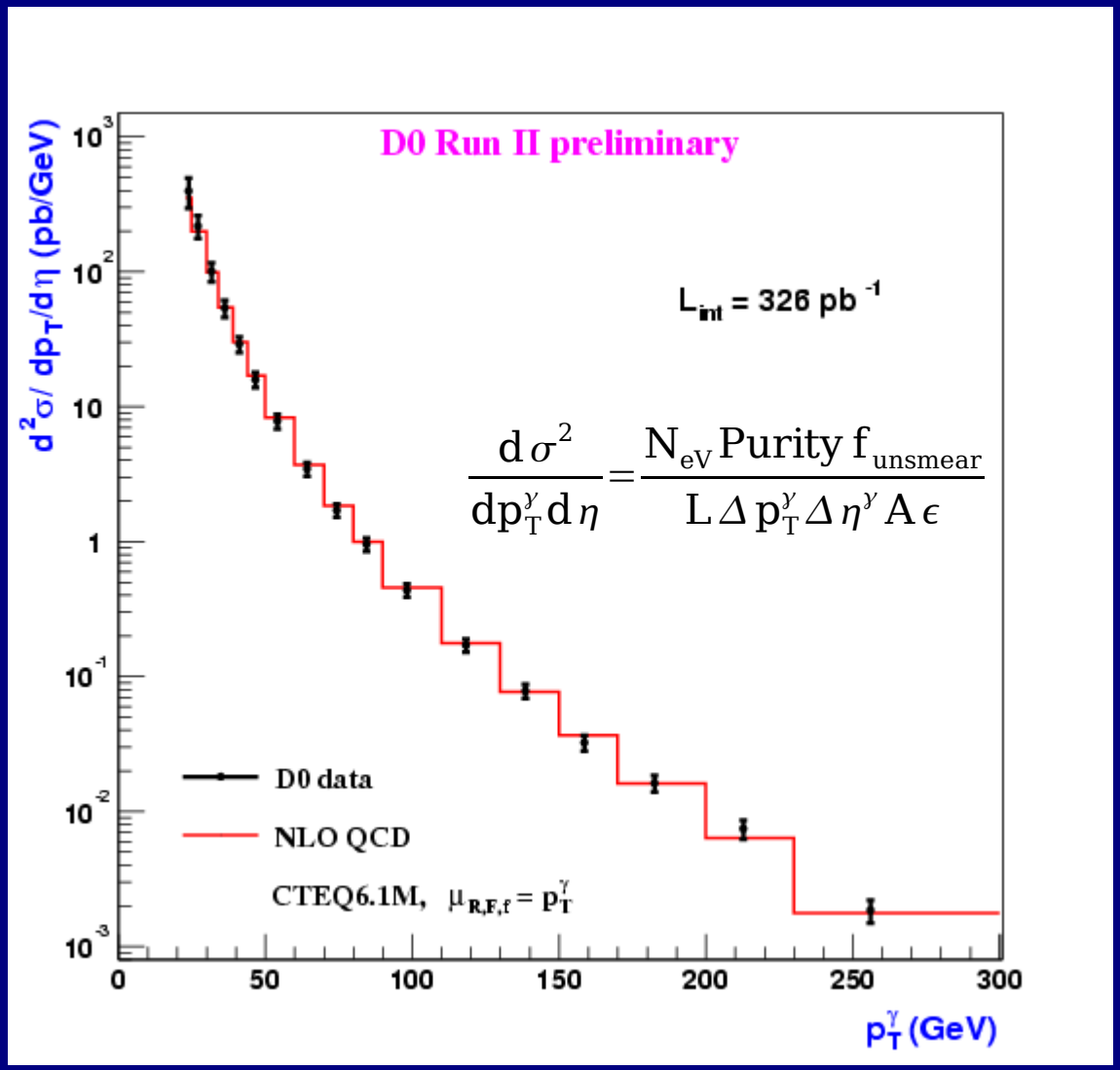
**D0 preliminary**

**An Artificial Neural Net (ANN) is used to distinguish prompt photons and fakes from jets (including $\pi^0$)**




**Photon purity is obtained from fitting ANN output in data to ANN outputs from Monte Carlo photon and jets samples**



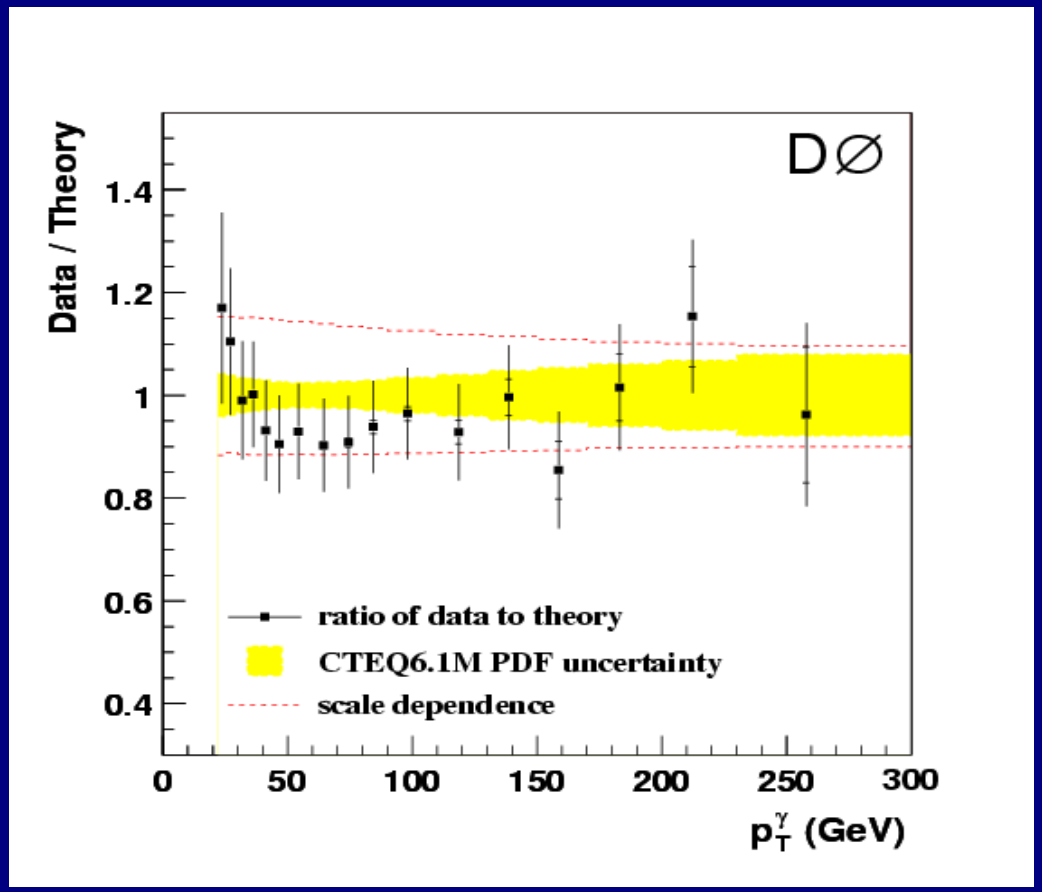

**2.7 million photon candidates**

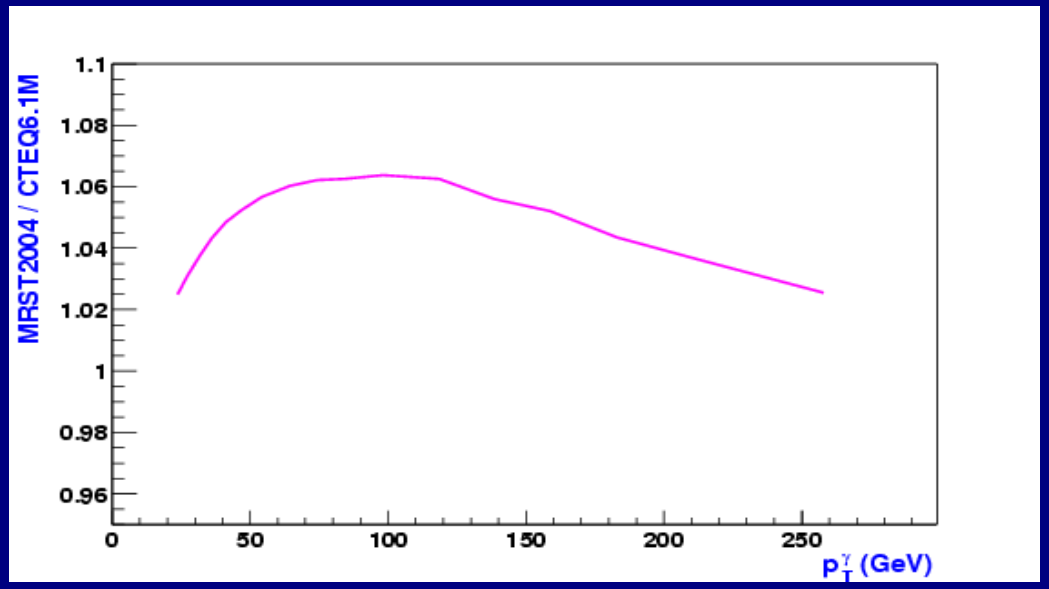
**Uncertainties are sum of statistical and systematic uncertainties**

**Analytical unsmearing of calorimeter resolution**

**Compared to NLO QCD calculation JETPHOX (P. Aurenche et al.) with $\mu_R=\mu_F=\mu_f=p_T^\gamma$**

**Good agreement within experimental uncertainties**




**CTEQ6.1M**

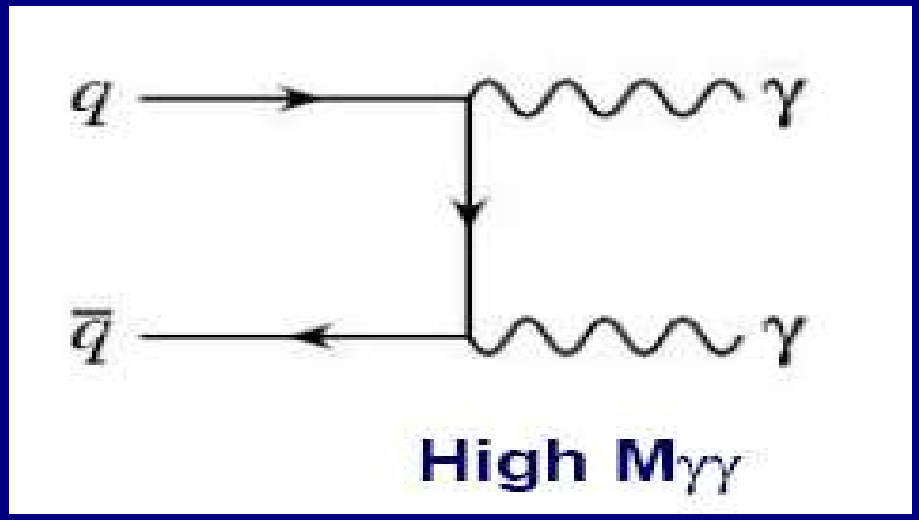
**$0.5p_T^\gamma<\mu_R=\mu_F=\mu_f<2p_T^\gamma$**

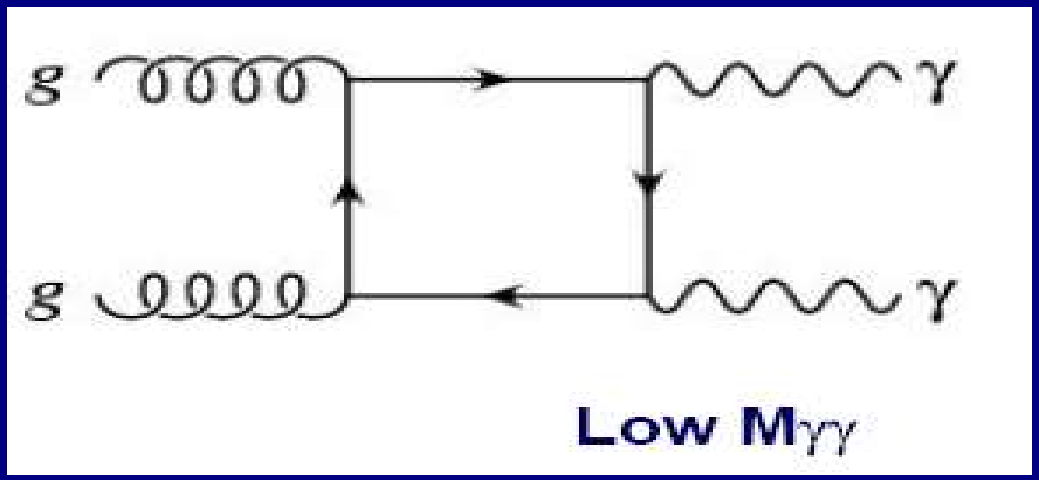
**Model by Gordon and Vogelsang**

**Largest systematic uncertainty due to purity estimation (only uncorrelated uncertainties shown in ratio)**

**Future: data at medium/high transverse momentum can be used in pdf fits**

# Di-photon Production




**Possible signature of new physics, such as Large Extra Dimensions**

**Di-photon final state is one of the main Higgs discovery channels at the LHC**

**Gluon-gluon process suppressed by a factor of $\alpha_s^2$, but noticable at low di-photon masses**

**CDF, Phys.Rev.Lett.95:022003,2005**

# Data Selection

**Integrated luminosity about 207 $pb^{-1}$**

**Two isolated showers in the electromagnetic (EM) calorimeter**

**no associated track**

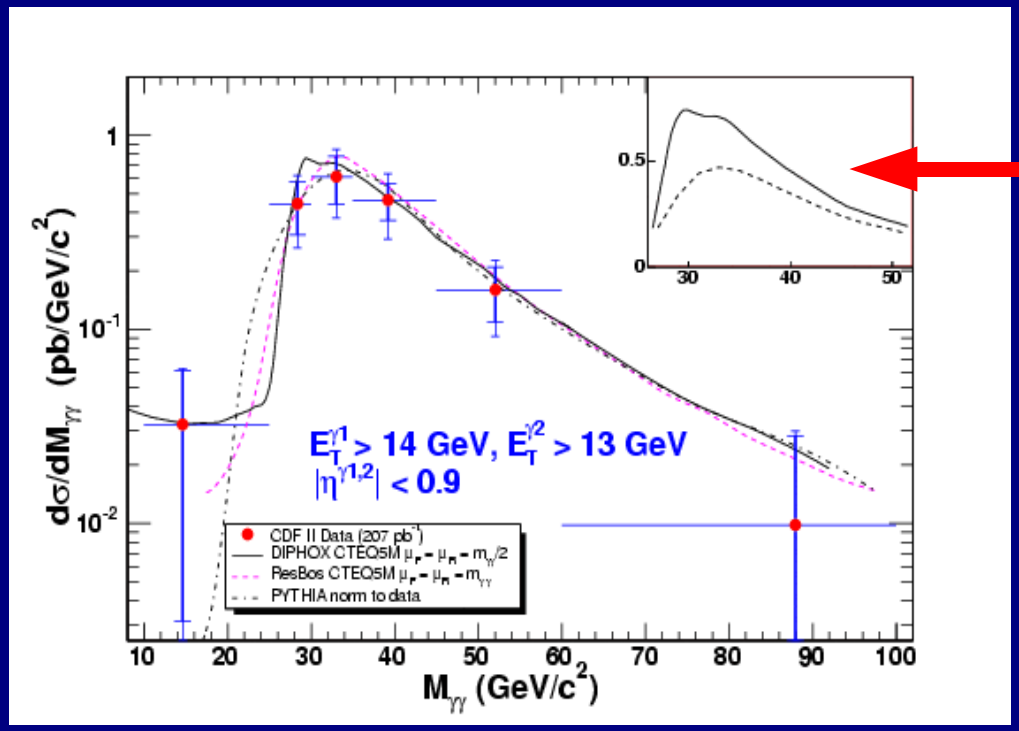
**pseudorapidity $|\eta| < 0.5$**

**transverse momentum $p_T^{\gamma} > 13$ & 14 GeV**

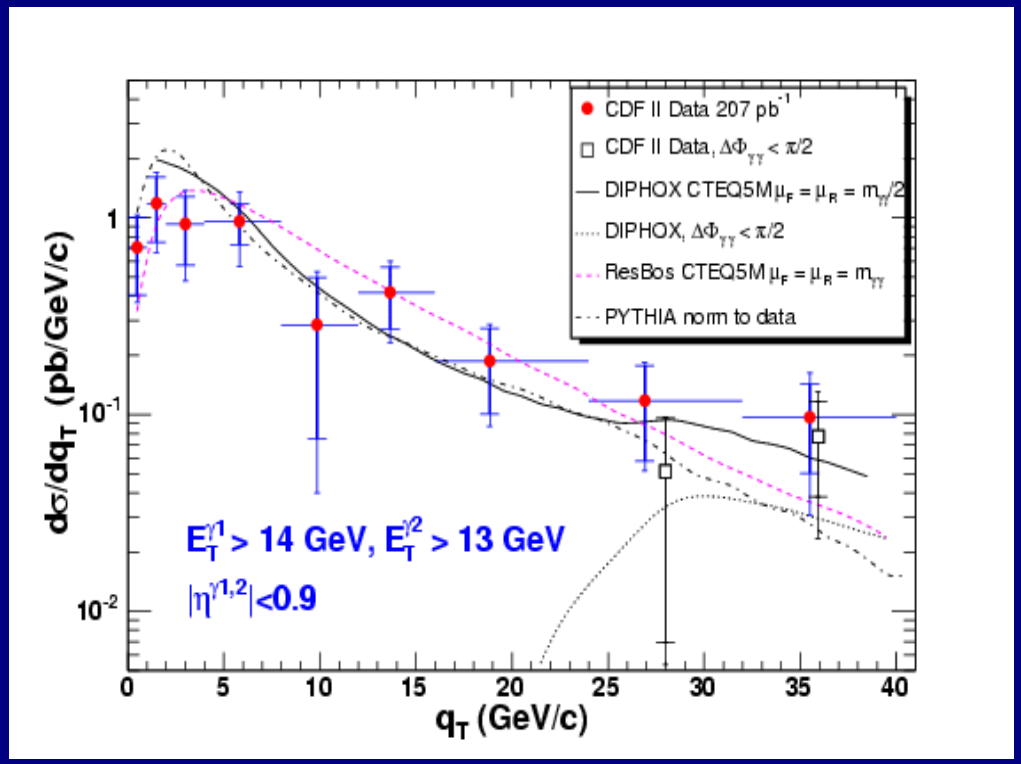
**(asymmetric cuts avoid divergencies in NLO calculation)**

**889 two-photon candidate events with 15.2% total efficiency**

**and about 50% purity**



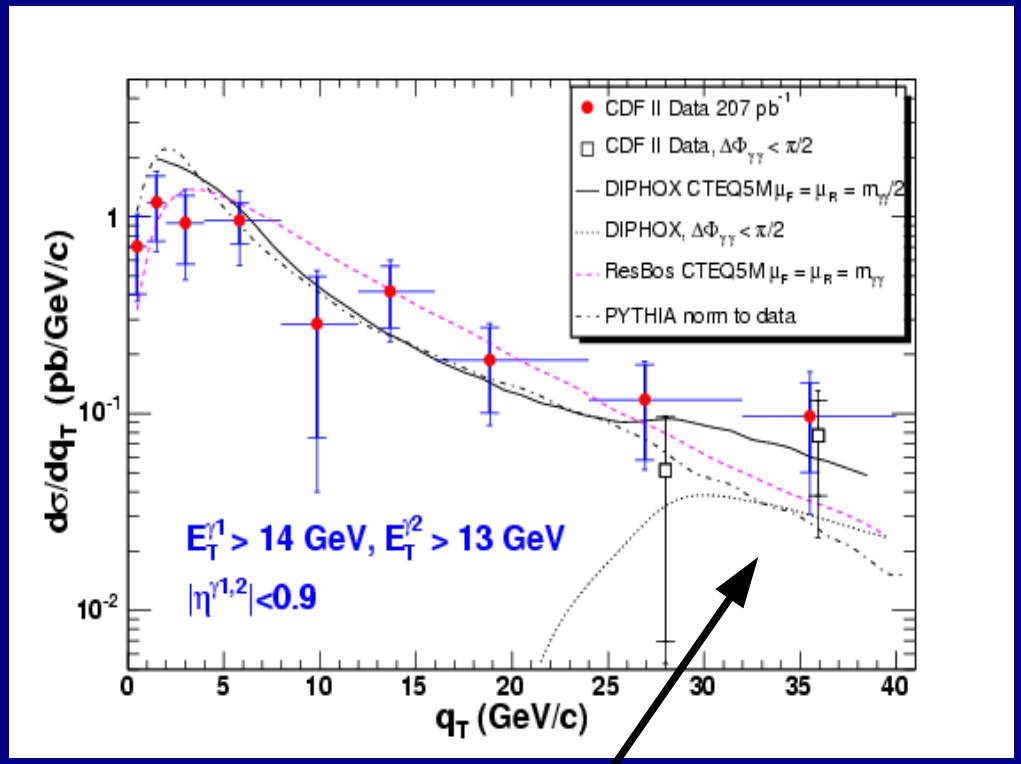

**DIPHOX preduction with and without gluon-gluon graph (leads to shoulder)**

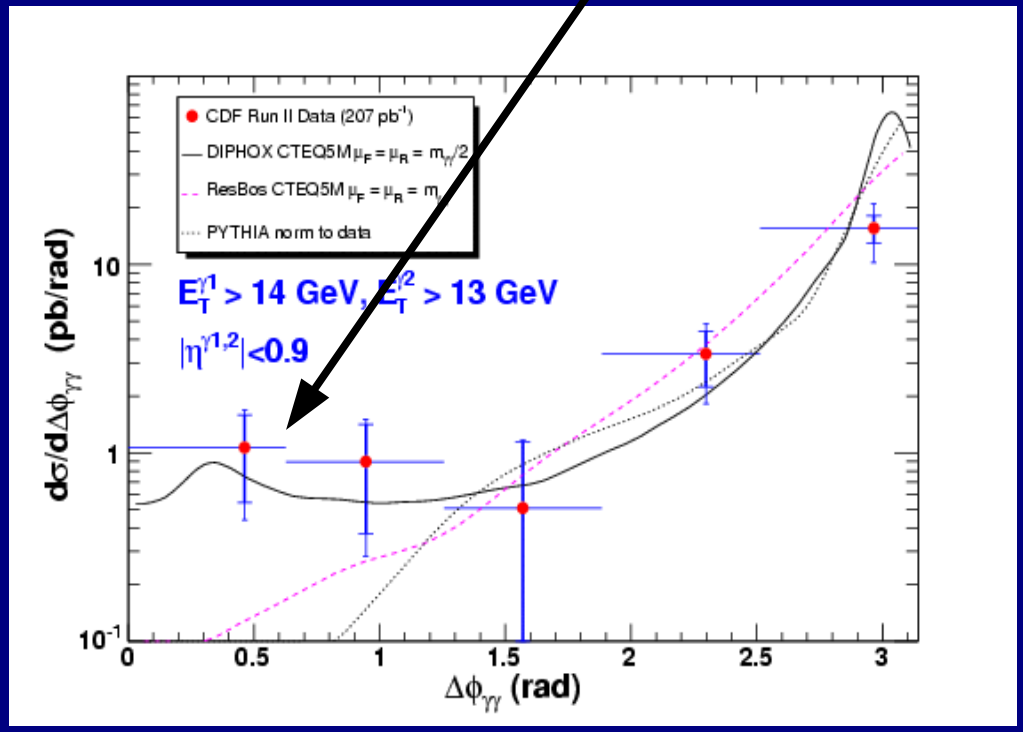



**DIPHOX:** fixed order at NLO
diverges at low $q_T$

**ResBos:** NLO for hard process
LO fragmentation contributions
resummed intial state gluon radiation
(important for $q_T$)

**PYTHIA:** multiplied by two




## Fragmentation contribution (NLO)

$$qg \rightarrow gq(\rightarrow \gamma)\gamma$$

**included in DIPHOX,**

**but not in ResBos**

**mainly at high $q_T$, low $\Delta\phi$, low mass**

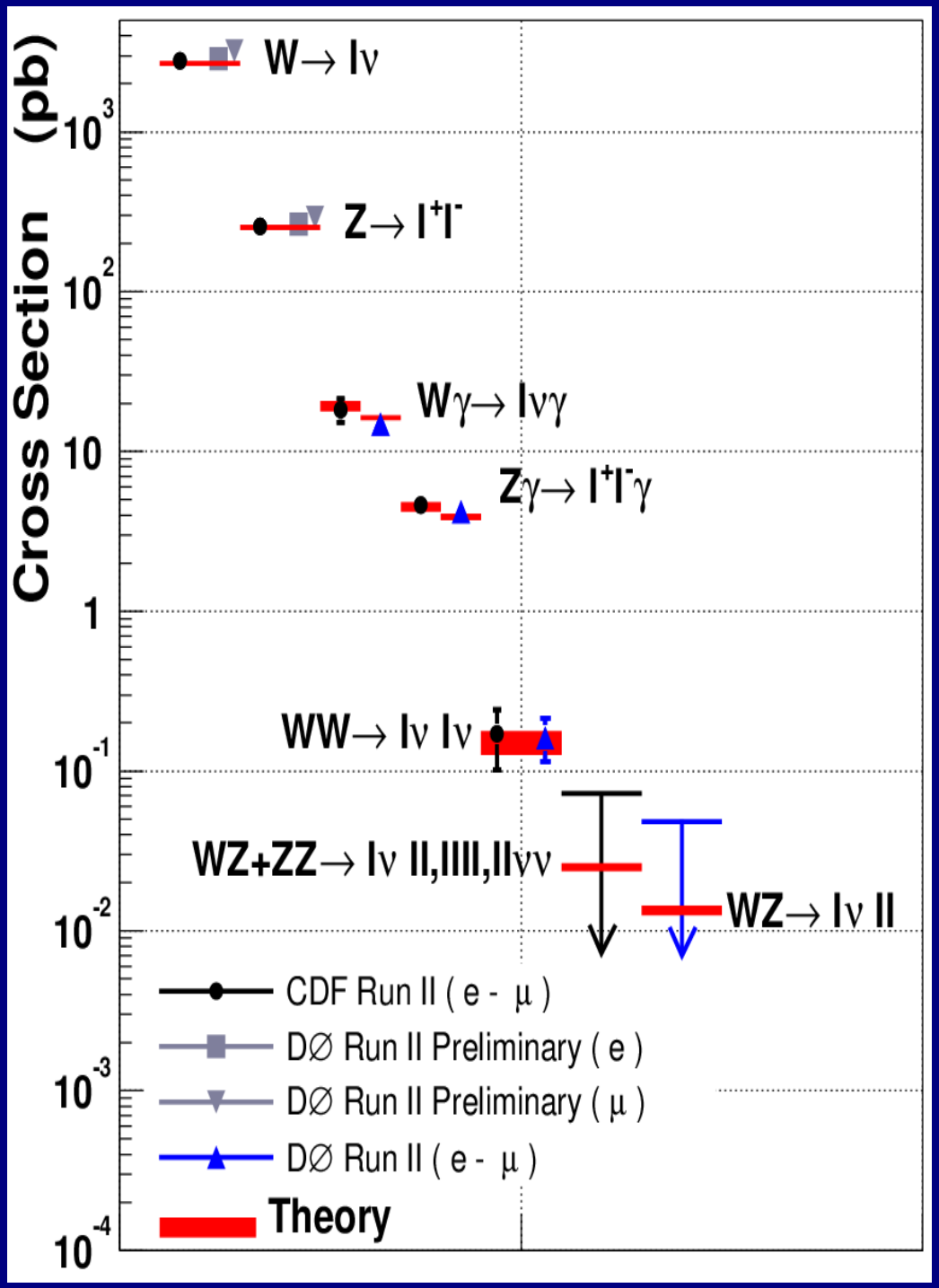
## Systematic uncertainties:

- **selection efficiencies (11%)**
- **background subtraction (20-30%)**
- **luminosity (6.5%)**

**Other di-boson cross-sections:**

- W+photon
- Z+photon
- WW
- WZ+ZZ (limit)

These measurements are also used to set limits on anomalous couplings




Events in $L=100\ pb^{-1}$

100,000

10,000

1,000

100

10

1

# Summary

**Tevatron is well on track in achieving its luminosity goals**

**DØ measurements of prompt photon production and CDF measurement of di-photon distributions help to understand qualitative and quantitative features of QCD calculations in next-to-leading order**

Thanks to D. Bandurin