Highlights from

HEPP-EPS 2005

International Europhysics Conference on High Energy Physics

Lisbon, Portugal, July 21st – 27th, 2005

Part I

Uta Stösslein

(DESY)

Zeuthen, September 7th, 2005

Programme http://www.lip.pt/events/2005/hep2005/

about 600 participants

- **2.5 days parallel sessions**
- 0.5 day ECFA-EPS joint session
- *1 day social event*
- **3 days plenary session** (conference summary B. Kayser)
  - hard QCD
  - tests of SM
  - CP violation / rare decays
  - hadronic physics
  - high energy nuclear physics
  - physics beyond the SM
  - neutrino physics
  - dark matter and dark energy
  - gravitational waves
  - non-perturbative field theory
  - astroparticle physics
  - string theory and extra dimensions
  - detectors and data handling (GRID)
  - new developments in accelerator physics and technology

Here, a personal selection is presented…

Highlights Part I

… in short

- LEPII data SM analyses are still ongoing.
  - combined LEP EW results.
  - new analyses.

- Beautiful physics and rare decays are coming from high statistics, low energy B-factories at KEK and PEP.

- Charming physics is coming from Cleo-C, Daphne and VEPP.

- New states of matter (QGP…) are explored in ultra-relativistic heavy-ion collisions at CERN and at RHIC.

- The spin structure of the nucleon is investigated to a new level with Hermes, Compass, Jlab Hall-A and Clas FT-experiments and at RHIC with polarized pp-collisions.

- At the high energy frontier, Tevatron and HERA are in their fruitful years and many results have been and will be coming.
  - Tevatron is the world's top-quark laboratory.
  - HERA is the world's best proton microscope.

- In two years, LHC will open a new high energy era for exploring high mass states (Higgs…), QuantumChromodynamics and new states of matter using protons and heavy ions.
  - machine, detectors and data handling were discussed.

- For the future International Linear Collider, a Global Design Effort has been launched based on a technical time schedule for which recent progress was presented.

- It was also pointed out, that beyond concrete plans for exciting new projects, *generic* accelerator and detector developments should be *not forgotten.*

Highlights Part I

... in selection

Tests of the ElectroWeak sector of the Standard Model

The Standard Model is a non-trivial structure with a few constants showing up in many places: Many opportunities to check !

In perturbation theory all these parameters tend to get connected and influenced by the mass scale they are considered at.

Strength of couplings in the EW interaction

$U(1) \otimes SU(2)$

g'   g

G_F $\tan\theta_w = g'/g$

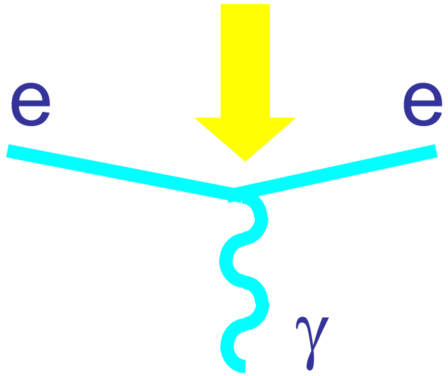
α_{QED} $\sin^2\theta_w$

many other combinations of 2 free parameters

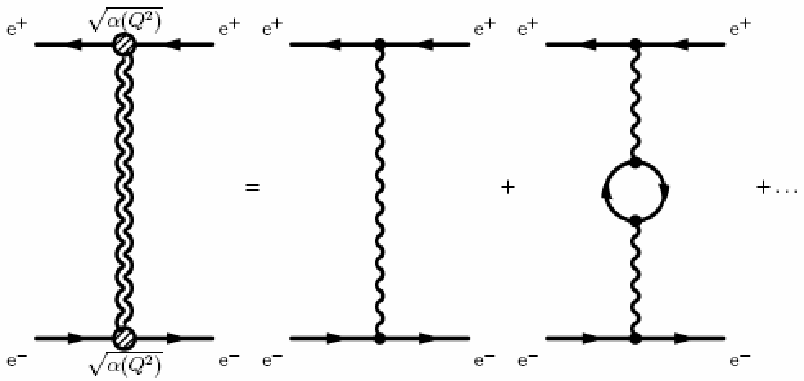
Large effort by theorists to provide predictions that match the experimental precision

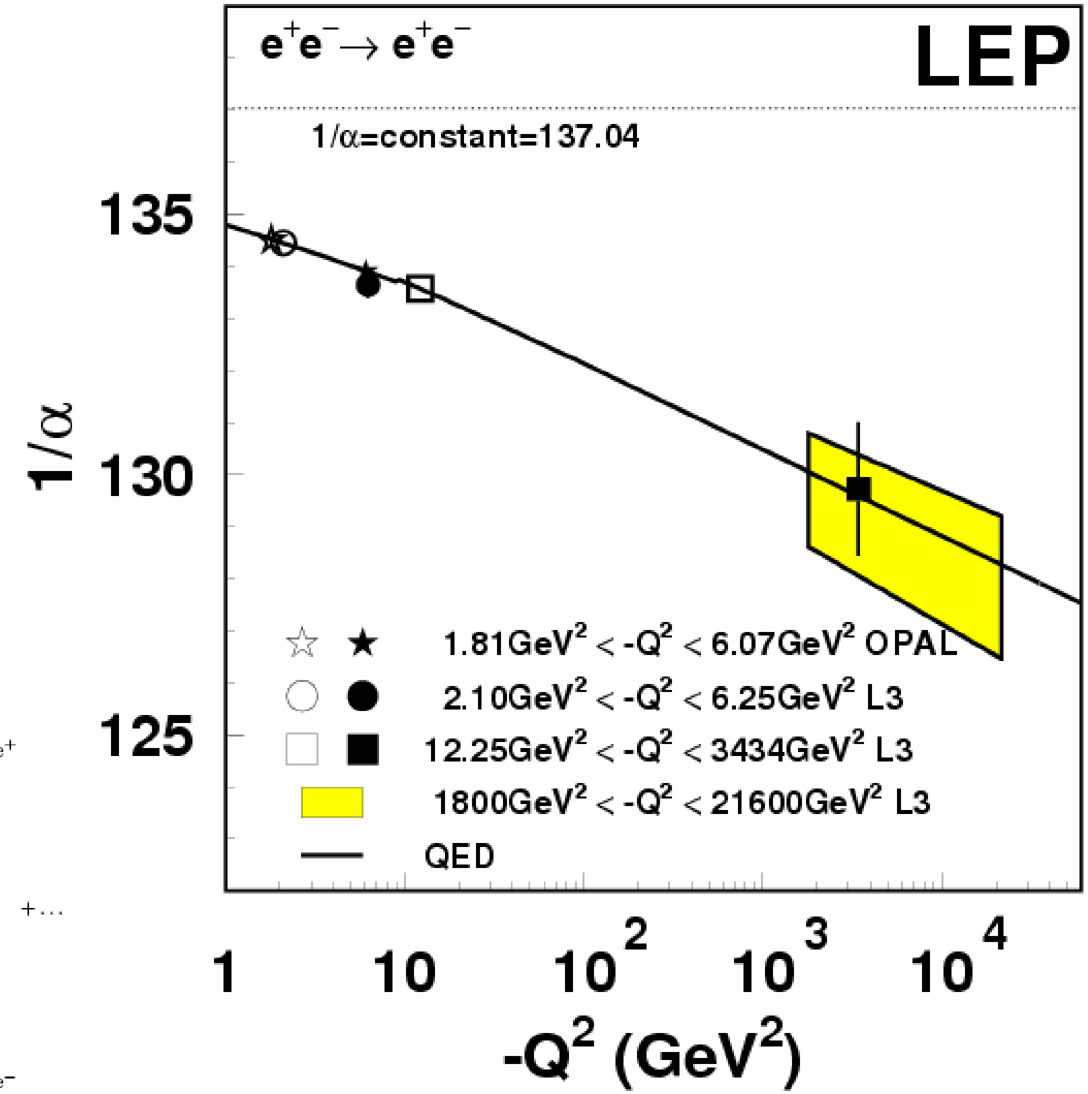
From Diagrammatica by M. Veltman

running α_{QED} at large momentum transfer



$$\alpha(Q^2) = \frac{\alpha_0}{1 - \Delta\alpha(Q^2)}$$

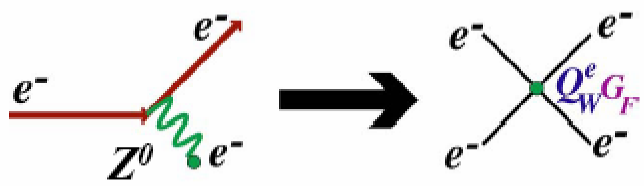




low energy hadronic contribution to
QED vacuum polarization: hep-ph/0506323

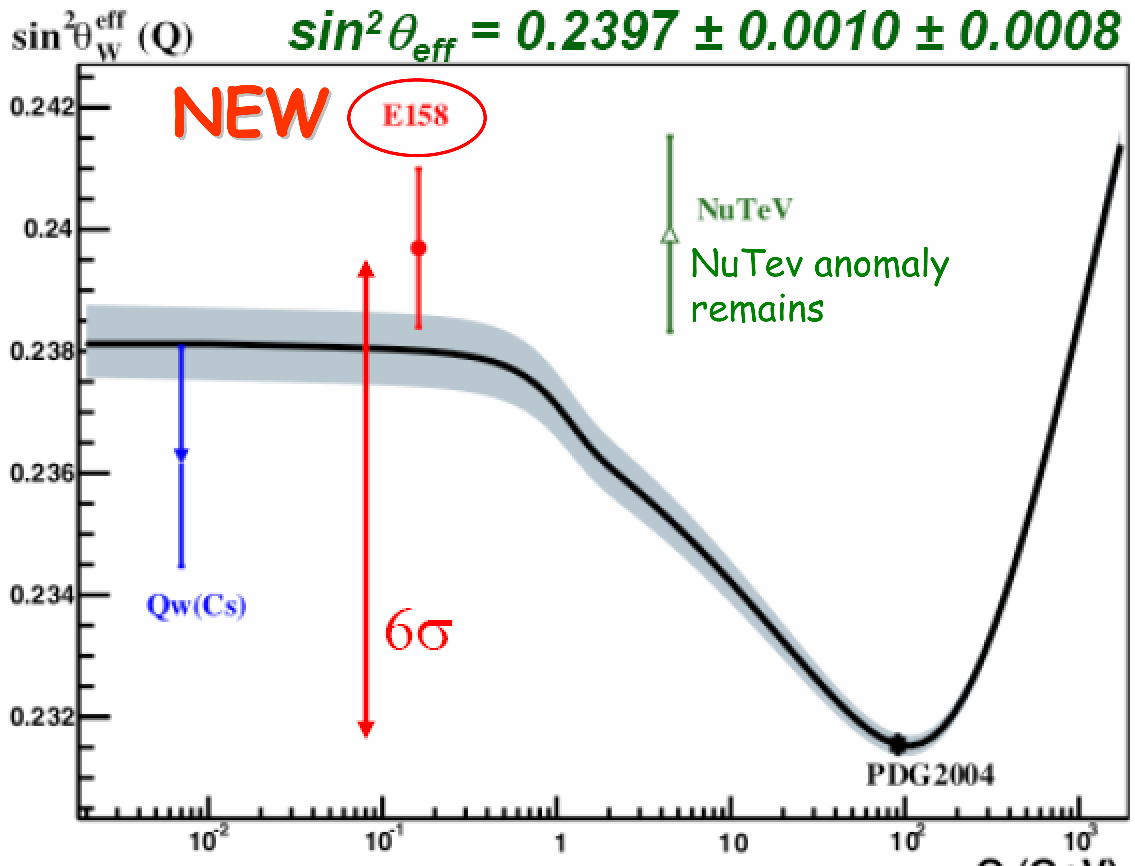
OPAL : CERN-Ph-EP-2005-014
L3 : hep-ex/0507078

$\sin^2\theta_W$

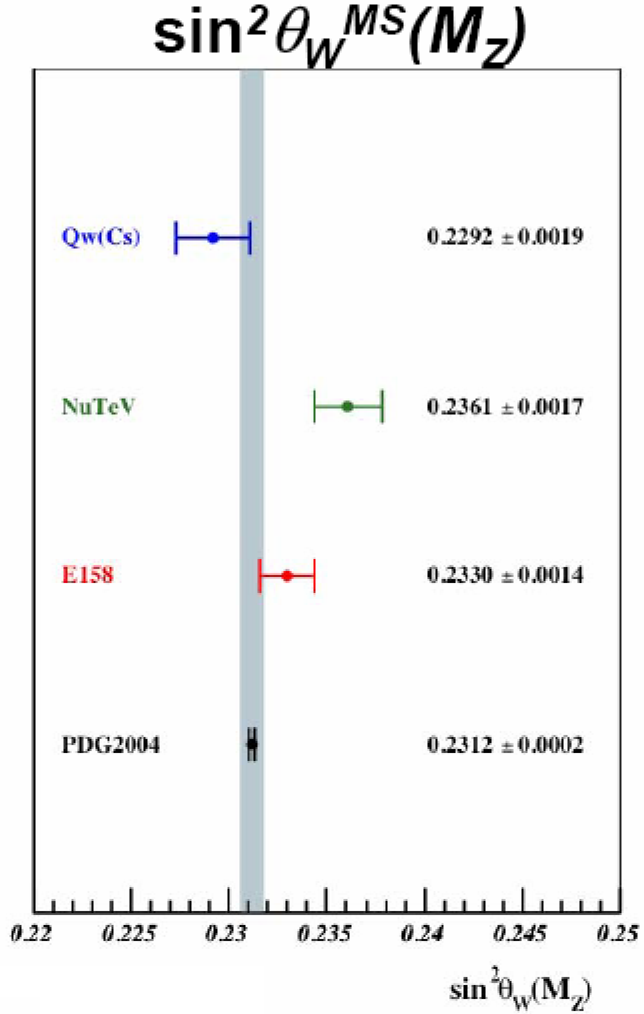


Purely leptonic reaction

$Q^e_W \sim 1 - 4\sin^2\theta_W$



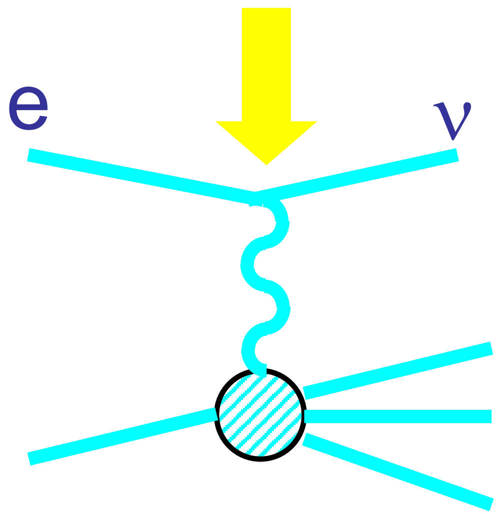
SLAC E158: hep-ex/0504049

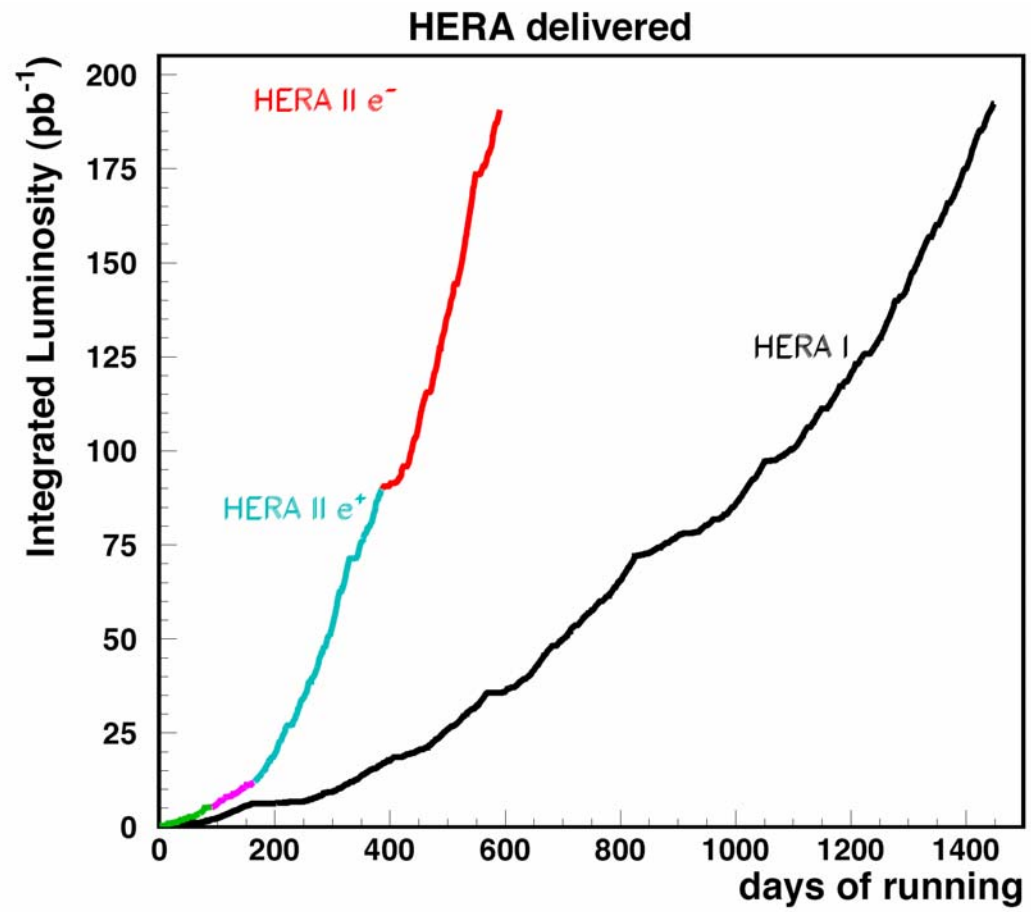


Weak Neutral Current experiments play a central role in testing the electroweak theory

$e^{\pm}p \quad \sqrt{s}$=319 GeV

V-A structure of the weak interaction





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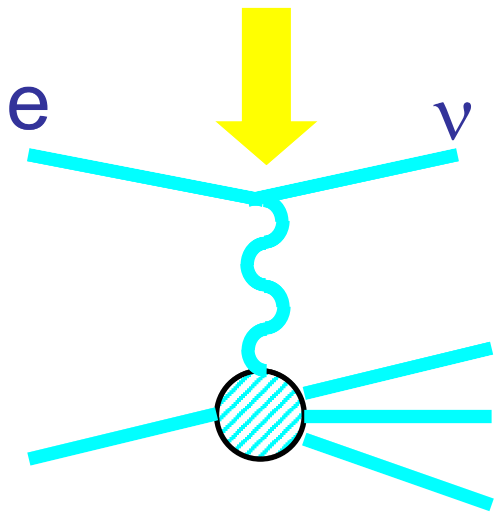
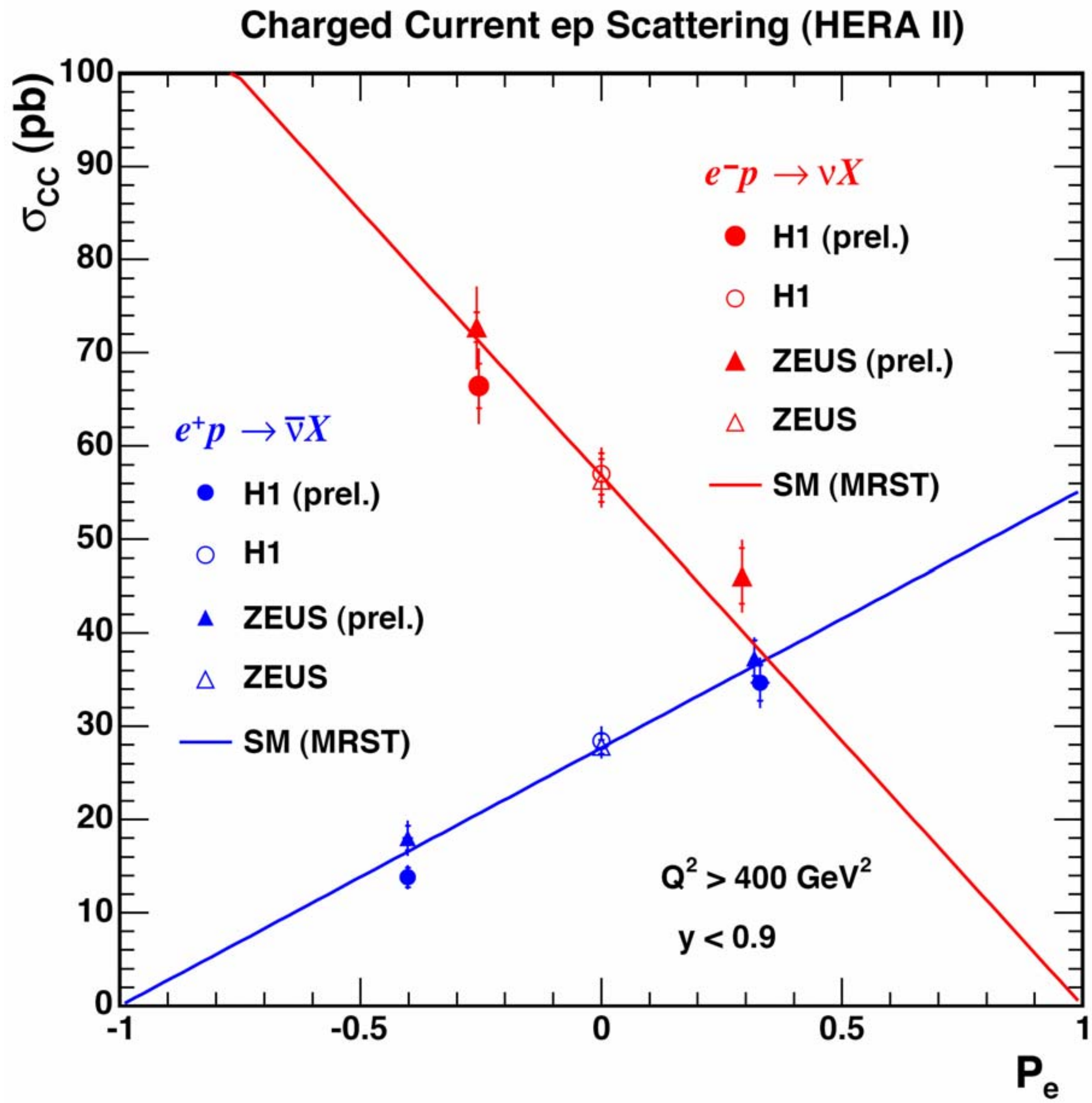
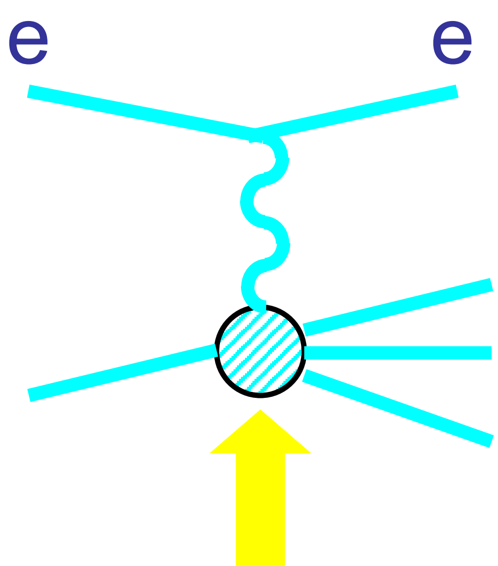
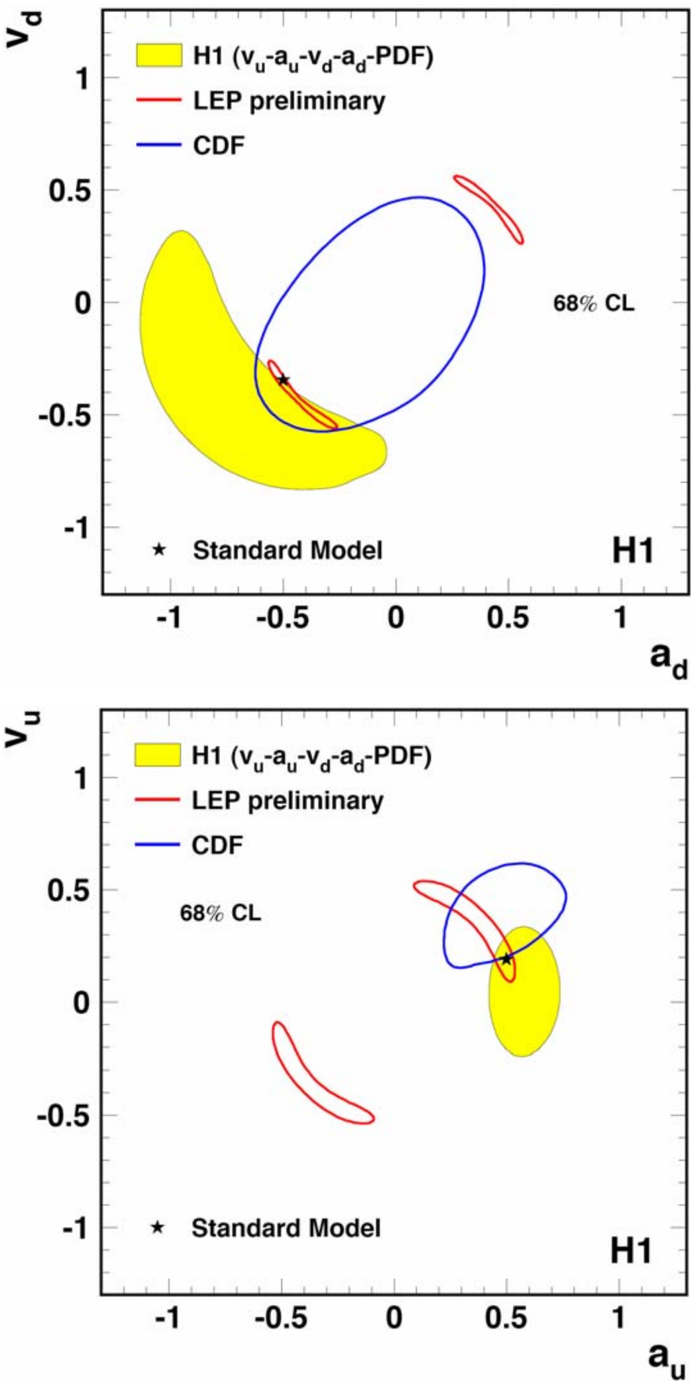




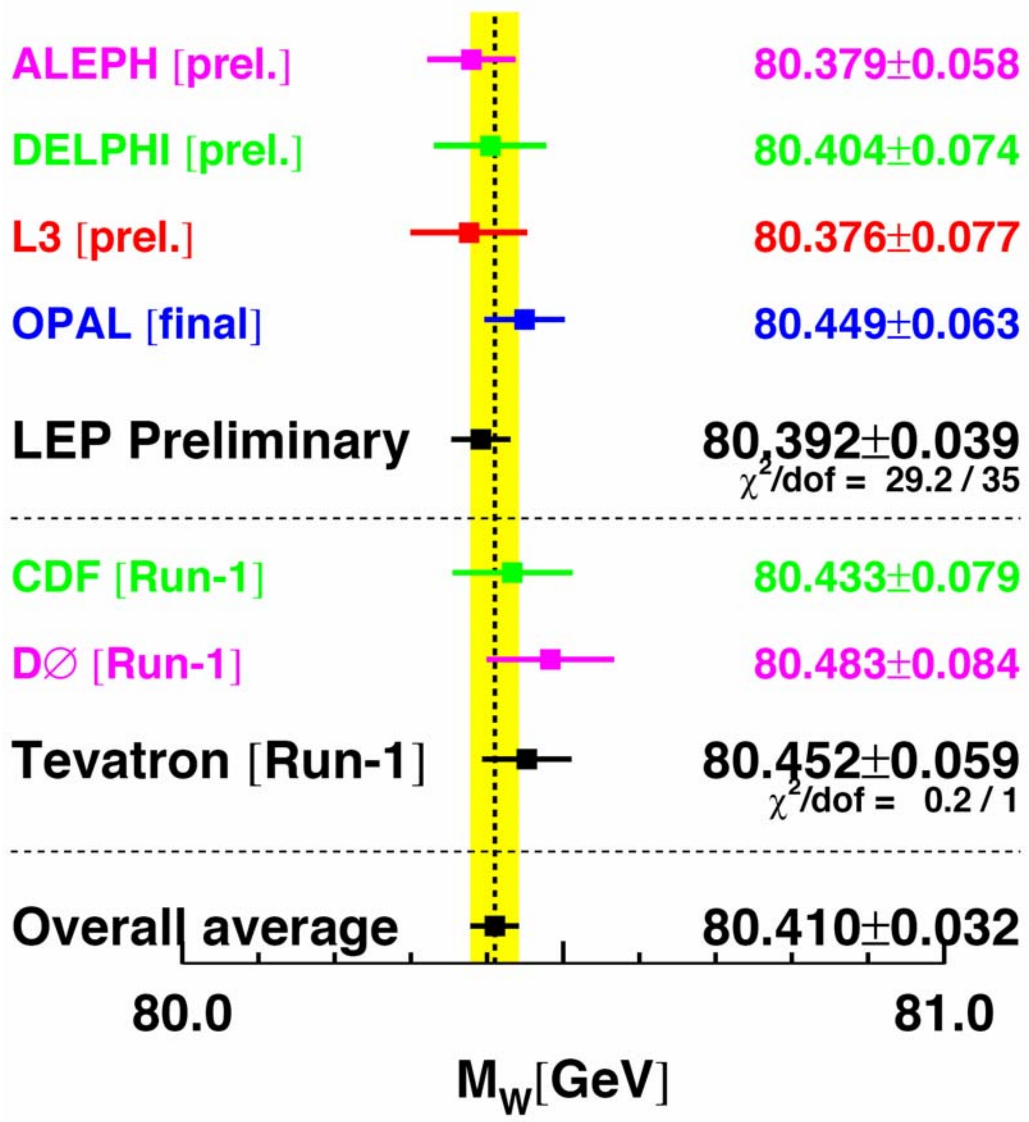
Z couplings to u and d quarks from H1 combined PDF-EW analysis





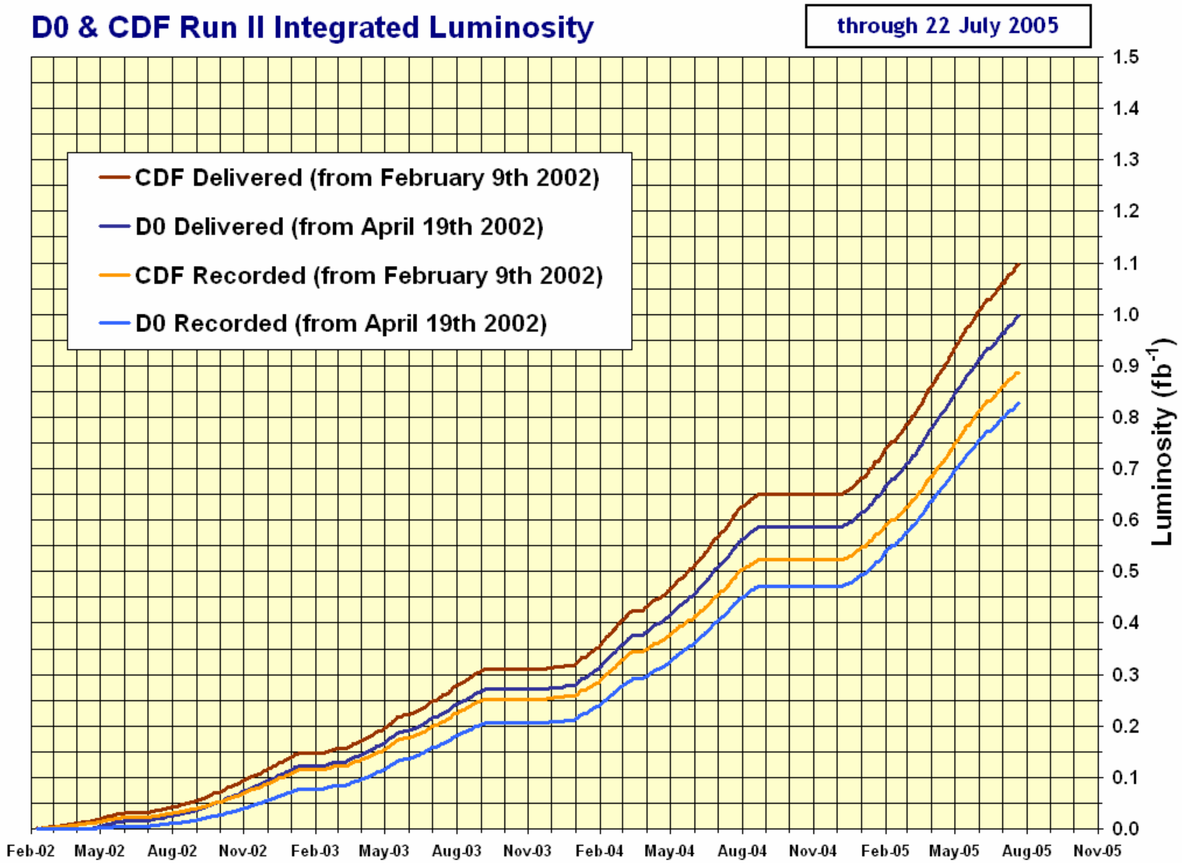
W mass

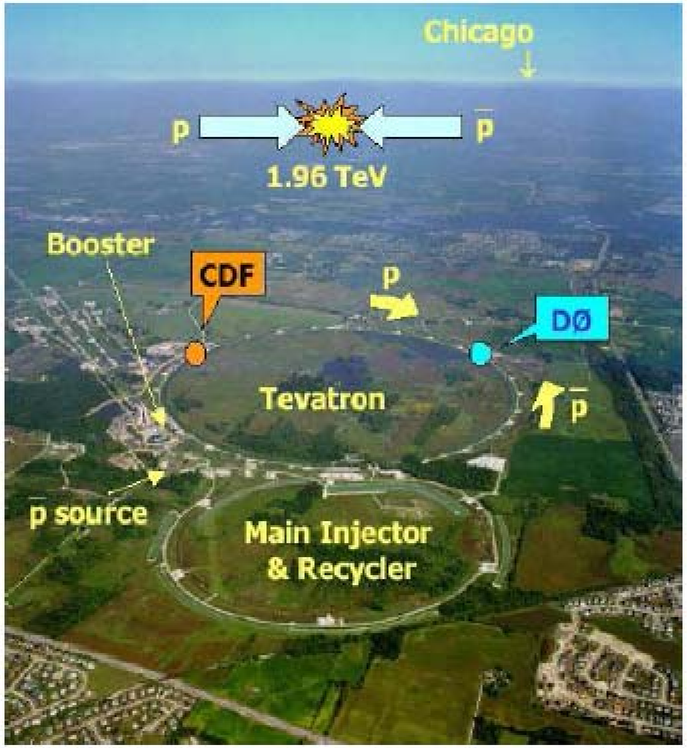
No Tevatron
Run II results
yet



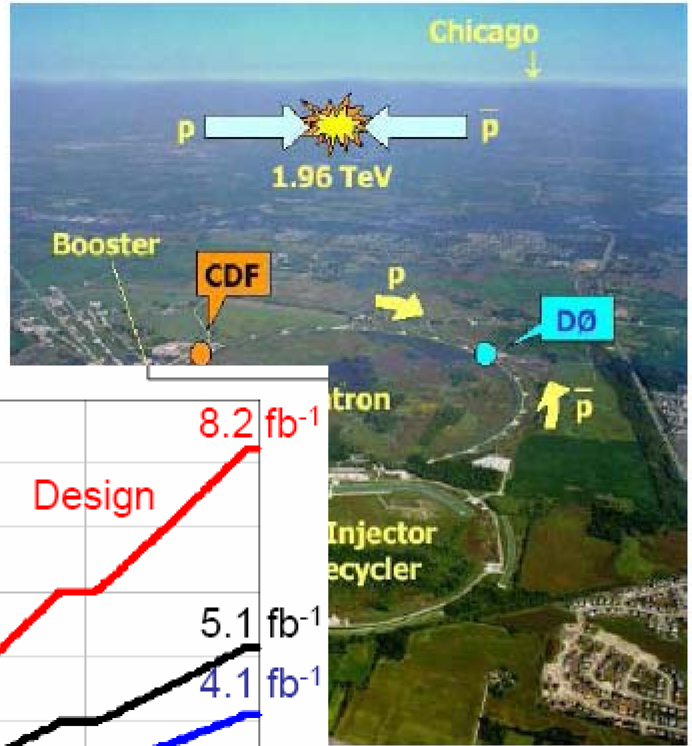
LEP-I+SLD: M_Z=91.1875±0.0021 GeV

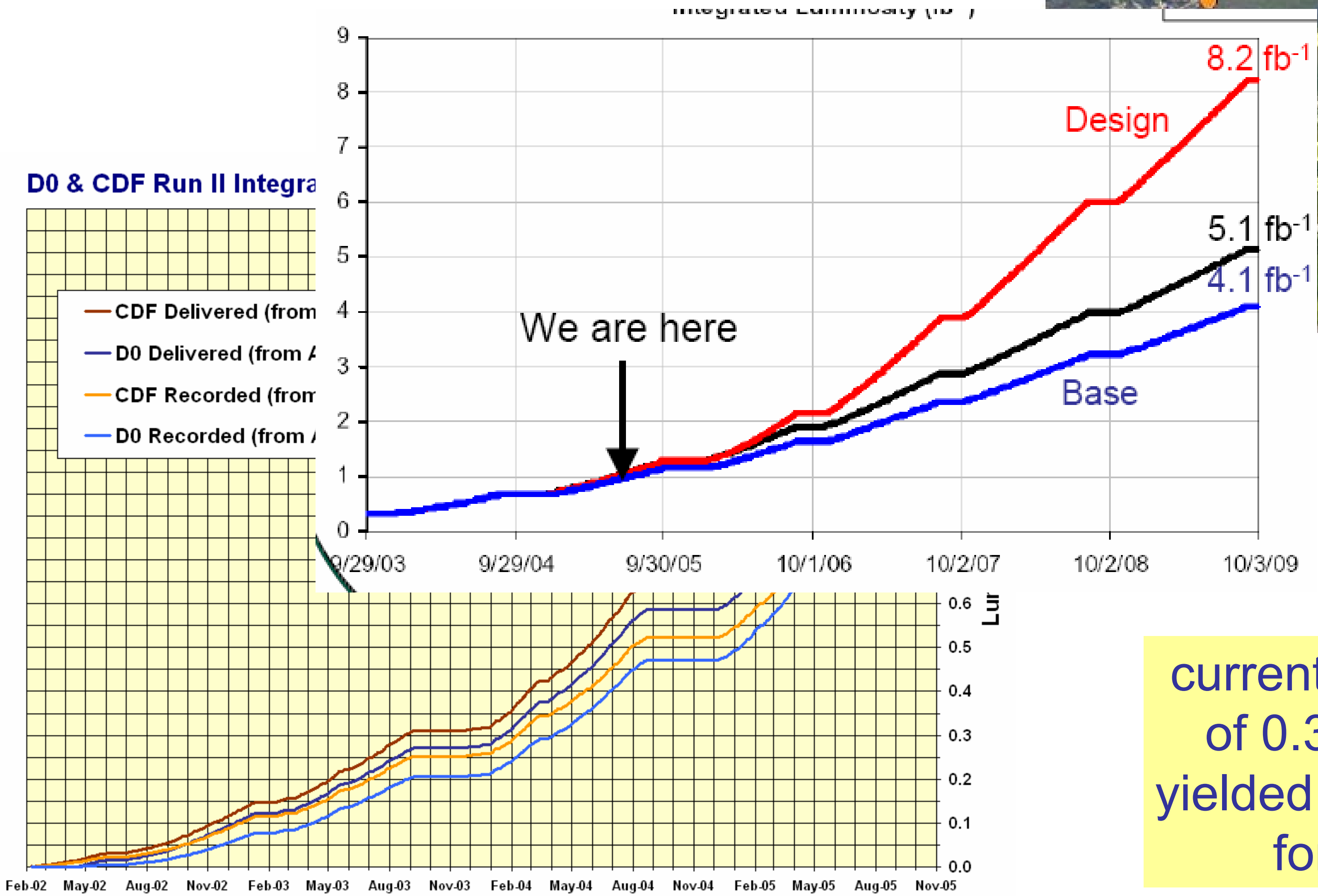
Tevatron


D0 & CDF Run II Integrated Luminosity
through 22 July 2005
CDF Delivered (from February 9th 2002)
D0 Delivered (from April 19th 2002)
CDF Recorded (from February 9th 2002)
D0 Recorded (from April 19th 2002)
Luminosity (fb^{-1})
0.0 0.1 0.2 0.3 0.4 0.5 0.6 0.7 0.8 0.9 1.0 1.1 1.2 1.3 1.4 1.5
Feb-02 May-02 Aug-02 Nov-02 Feb-03 May-03 Aug-03 Nov-03 Feb-04 May-04 Aug-04 Nov-04 Feb-05 May-05 Aug-05 Nov-05


Chicago
p
$\bar{p}$
1.96 TeV
Booster
CDF
p
DØ
Tevatron
$\bar{p}$
$\bar{p}$ source
Main Injector
& Recycler

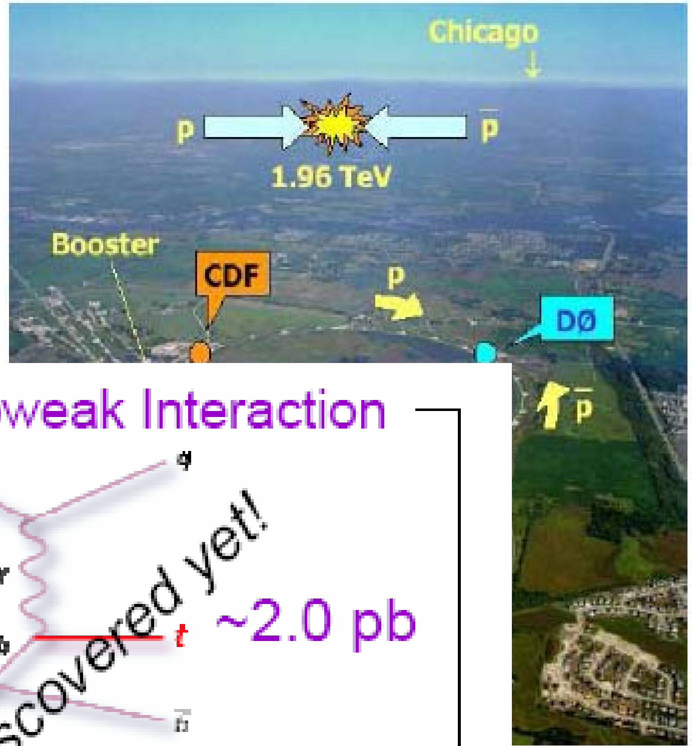
Tevatron

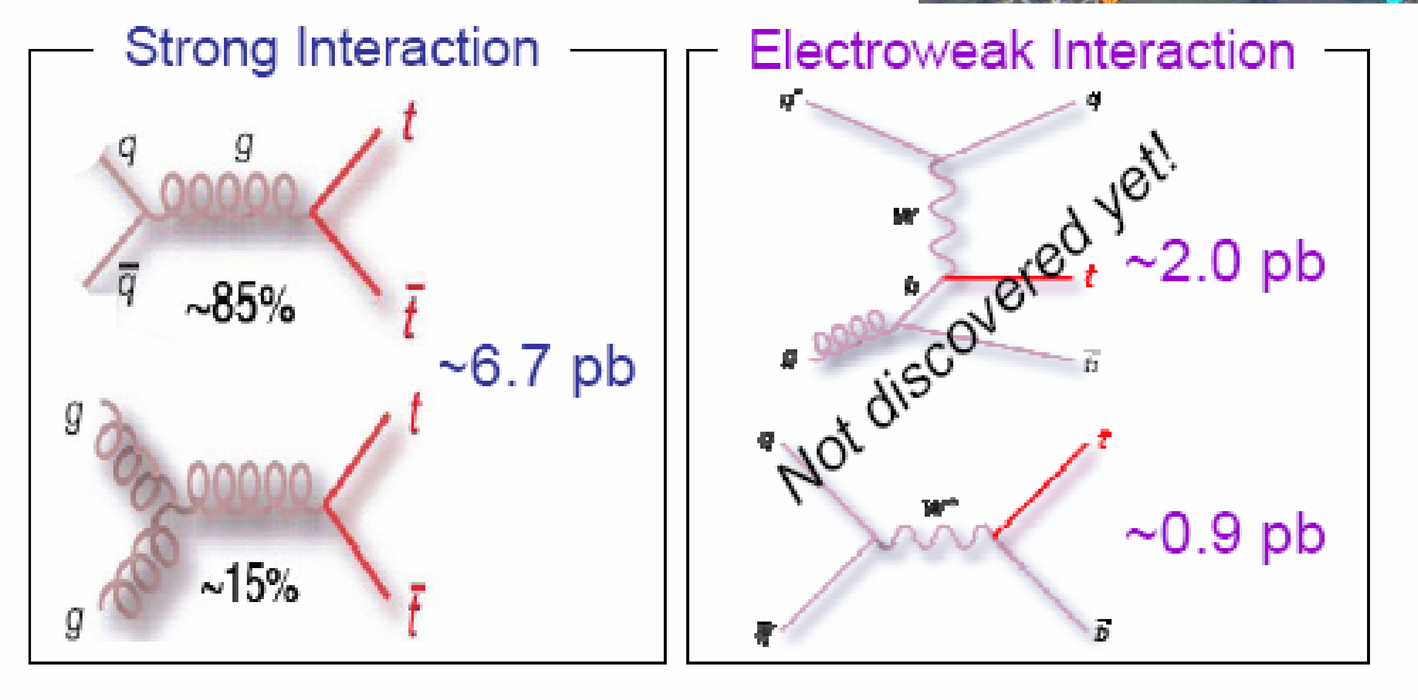


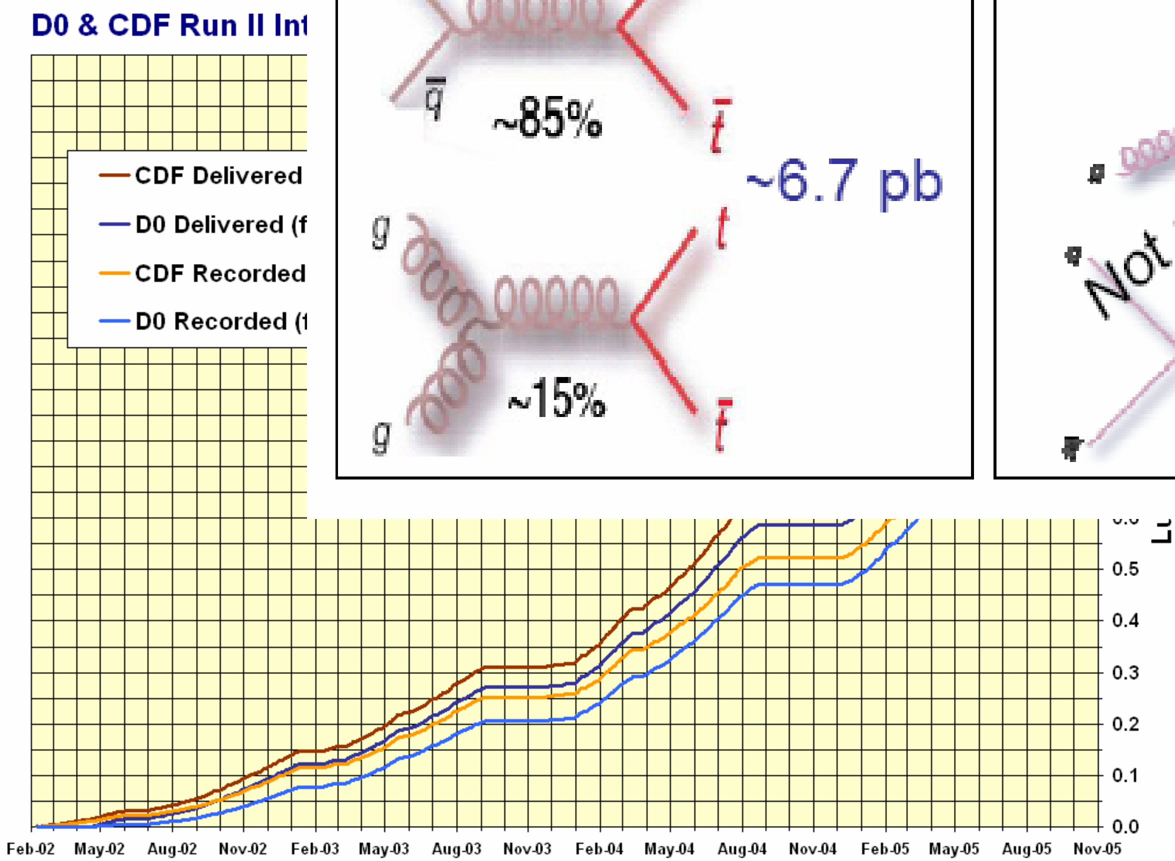


current analyses of 0.3-0.4 fb^{-1} yielded new value for M_{top}

Tevatron







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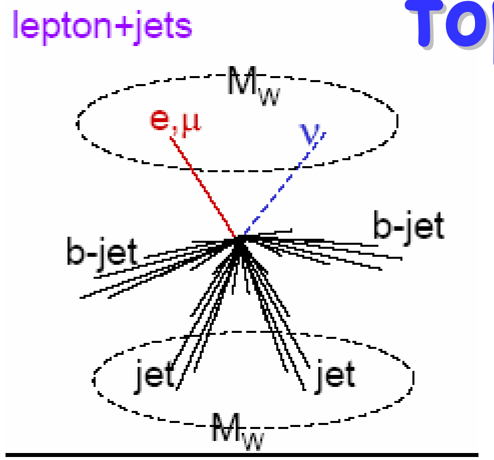
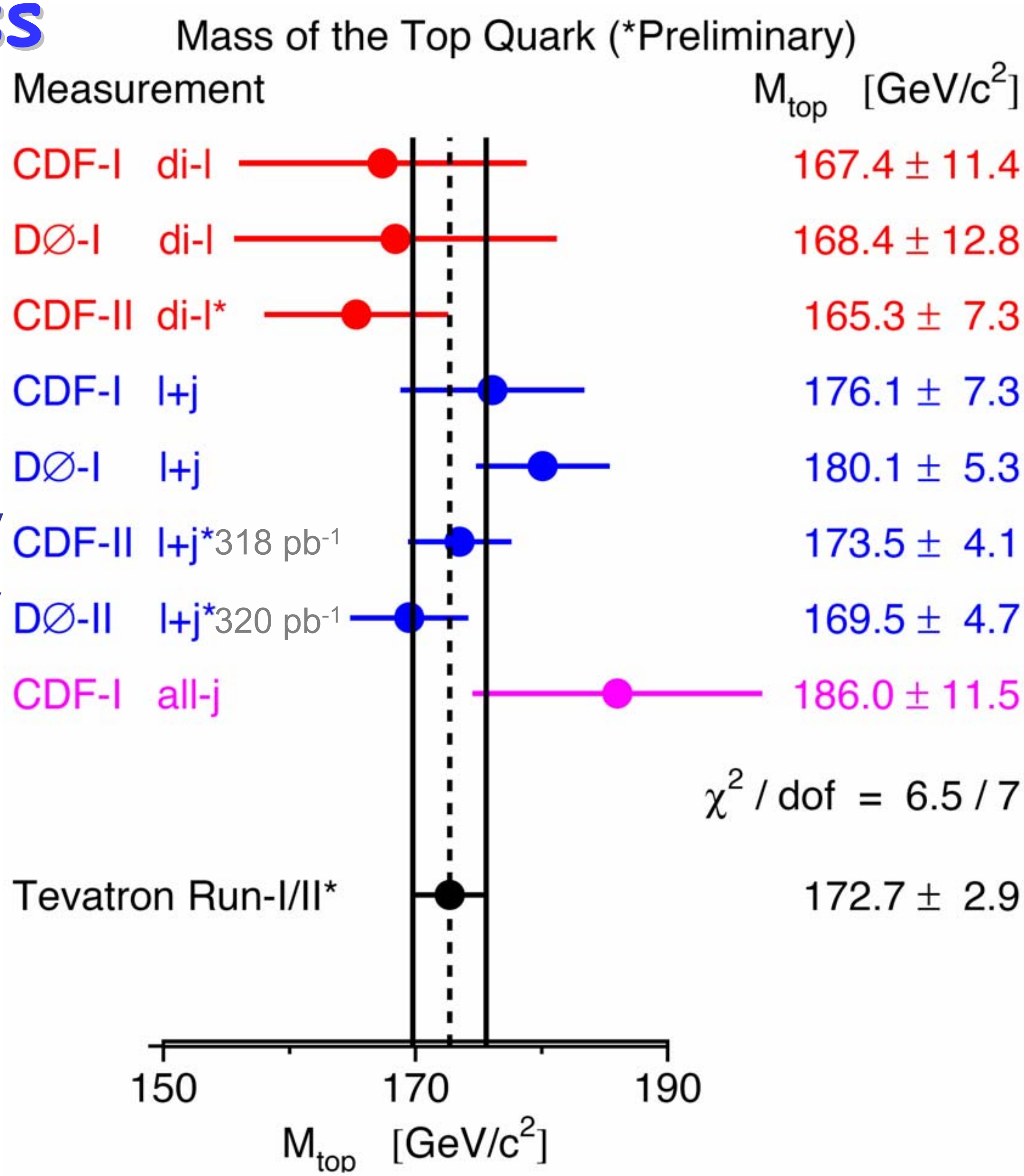
top mass



CDF: $173.5 \pm^{3.7}_{3.6} \pm 1.7$ GeV
DØ: $169.5 \pm 4.4 \pm^{1.7}_{1.6}$ GeV

stat + jet energy scale syst



<u>biggest remaining systs:</u>

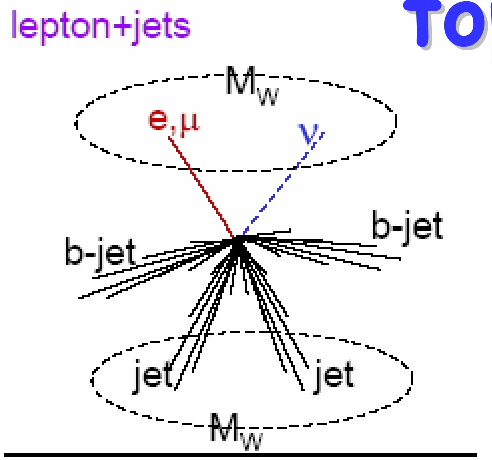
background shape

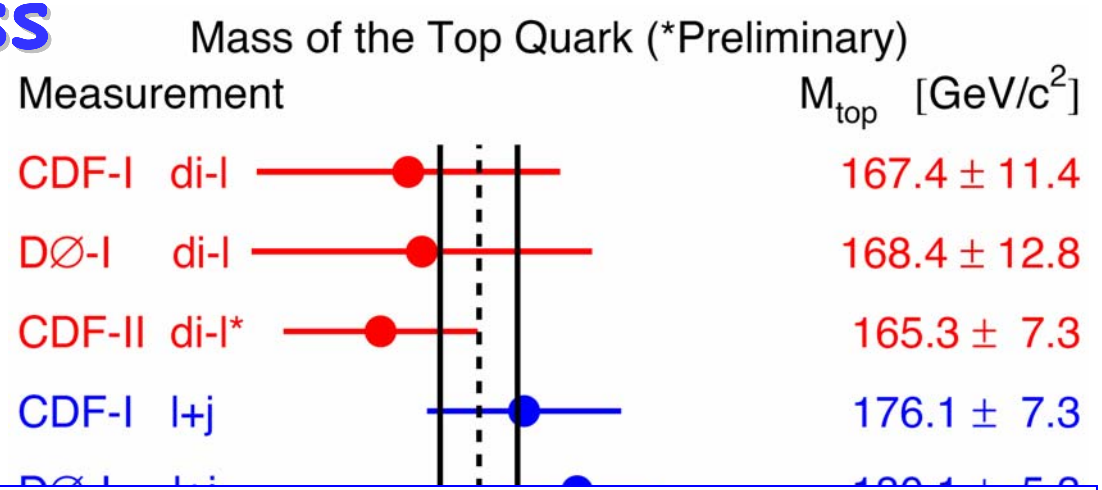
b-jet energy scale

gluon radiation

Expect $\sigma(m_t)$<2 GeV/exp

top mass





CDF: 173.5±

DØ: 169.5±4

stat + jet energy s

<u>biggest rema</u>

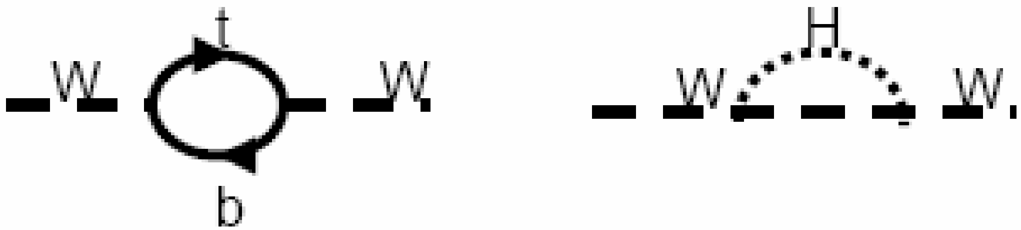
background s

b-jet energy s

gluon radiati

Expect $\sigma(m_t)$

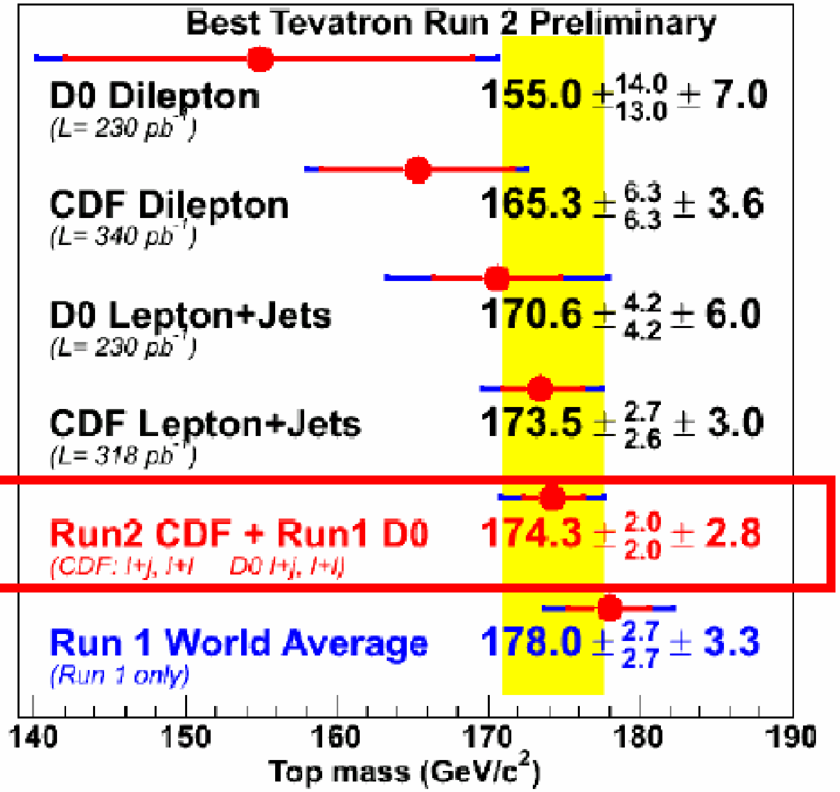
Important ingredient for EW precision analyses at the quantum level:



$\delta M_W \propto m_t^2$ $\delta M_W \propto \ln(M_H)$

which were initially used to indirectly determine m_t.

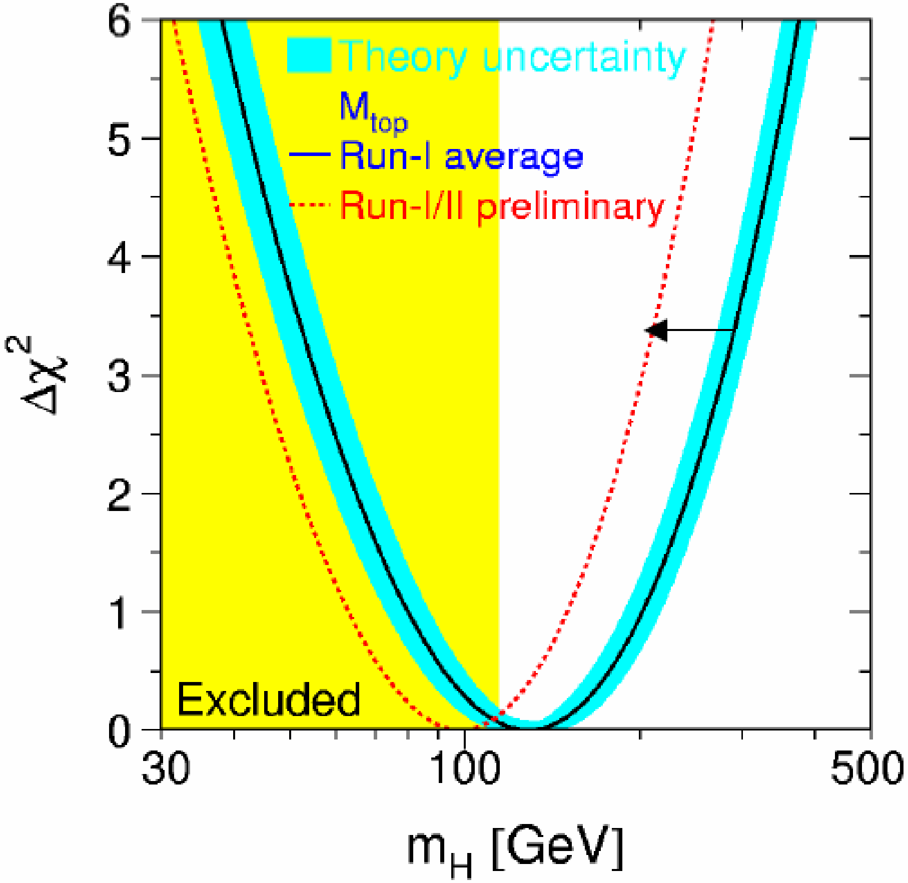
After the top quark discovery, use precision measurements of M_W and m_t to constrain M_H.



- New Run II single measurements achieving uncertainties comparable to/better than current Run I world average.
- BREAKING NEWS: New preliminary world average combining CDF Run II and DØ Run I.

$$m_t = 174.3 \pm 3.4\,\text{GeV};\ \chi^2/dof = 3.6/3$$

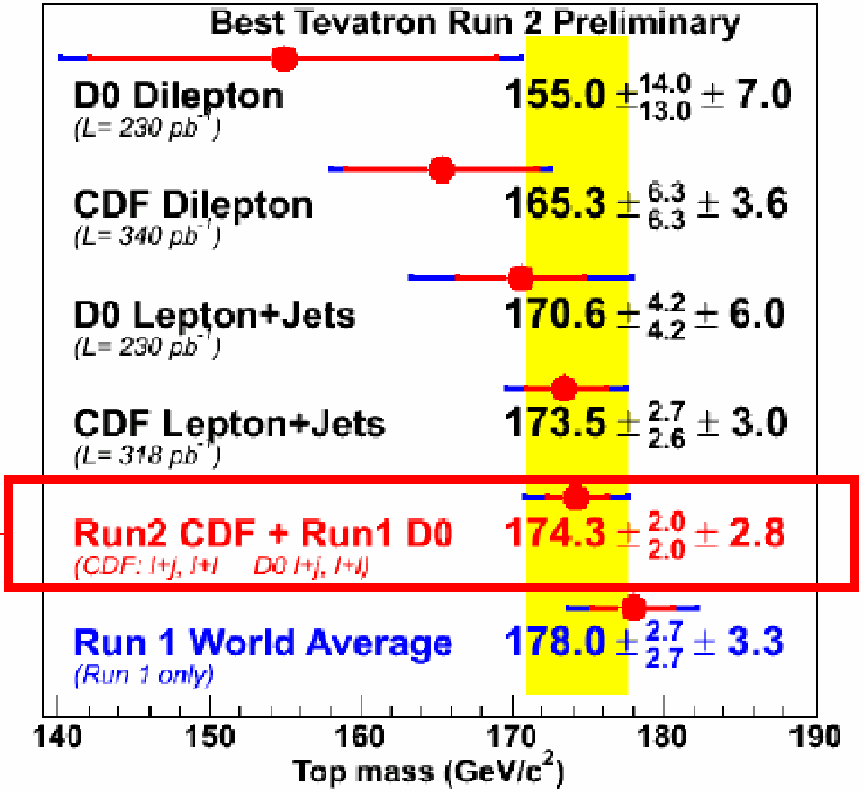
Impact on SM Higgs mass prediction



$$M_H = 129^{+74}_{-49}\,\text{GeV};\ M_H < 285\,\text{GeV}\ @\ 95\%\text{CL}$$

$$M_H = 98^{+52}_{-36}\,\text{GeV};\ M_H < 208\,\text{GeV}\ @\ 95\%\text{CL}$$

Juste LP05/deJong EPS05



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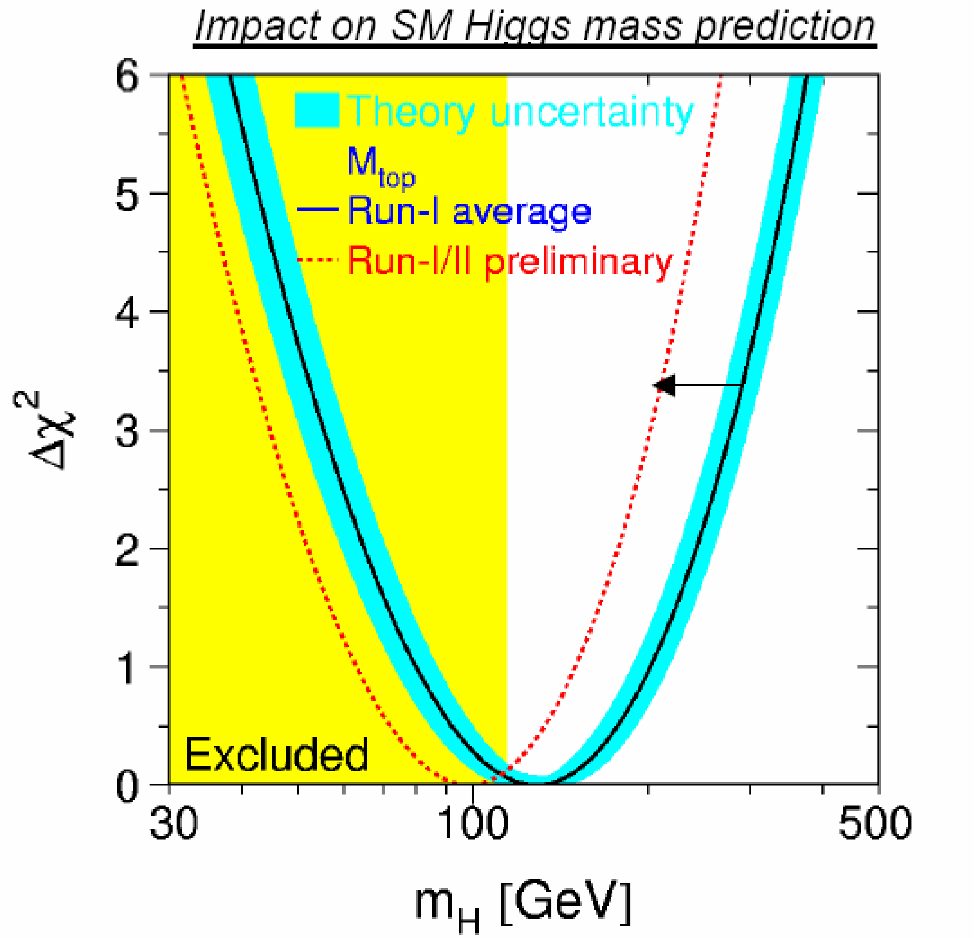


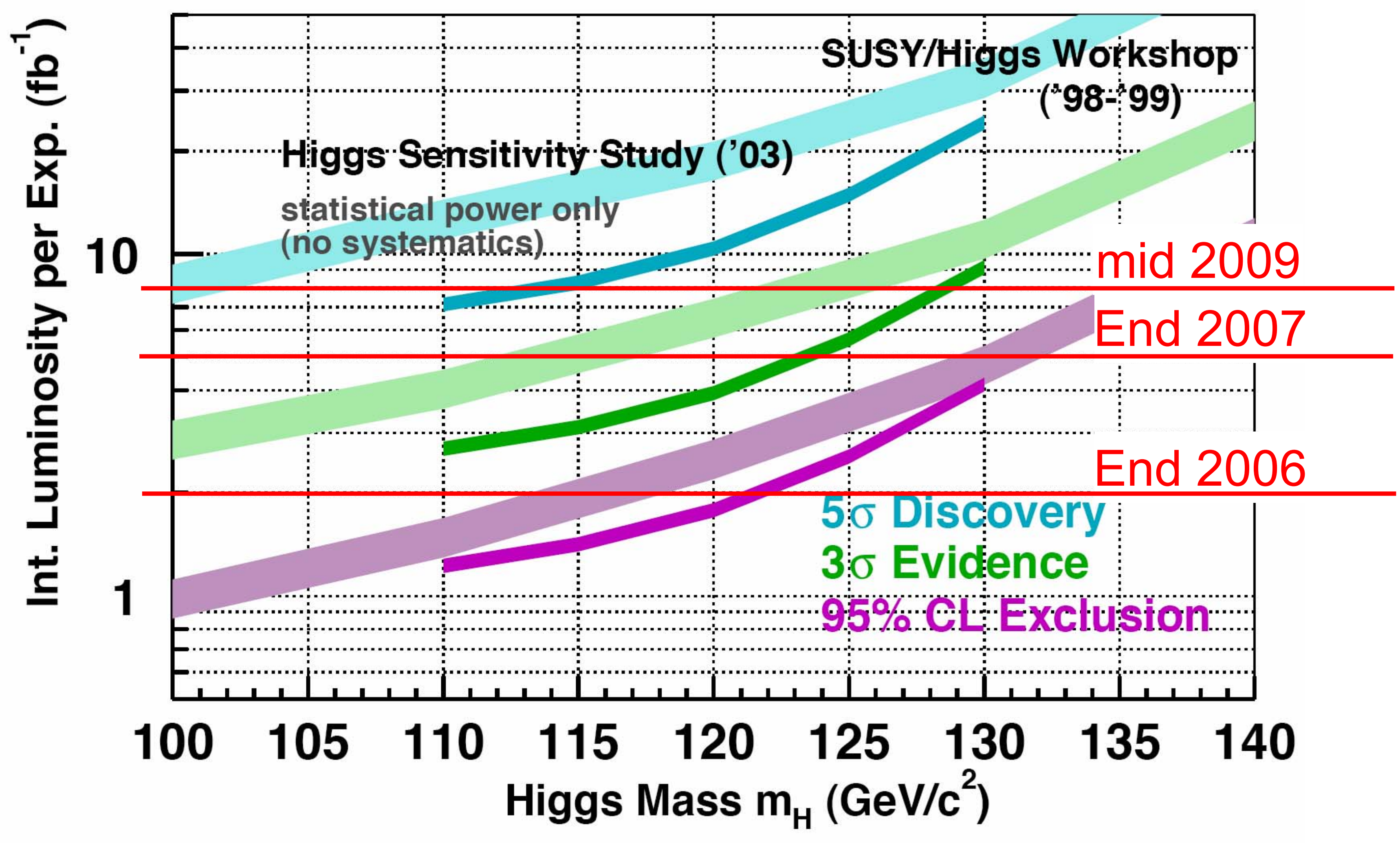
$$M_H = 129^{+74}_{-49}\,\mathrm{GeV};\ M_H < 285\,\mathrm{GeV} @ 95\%\mathrm{CL}$$

Renormalise probability for M_H>114 GeV to 100%:

M_{Higgs} < 219 GeV (95%CL)

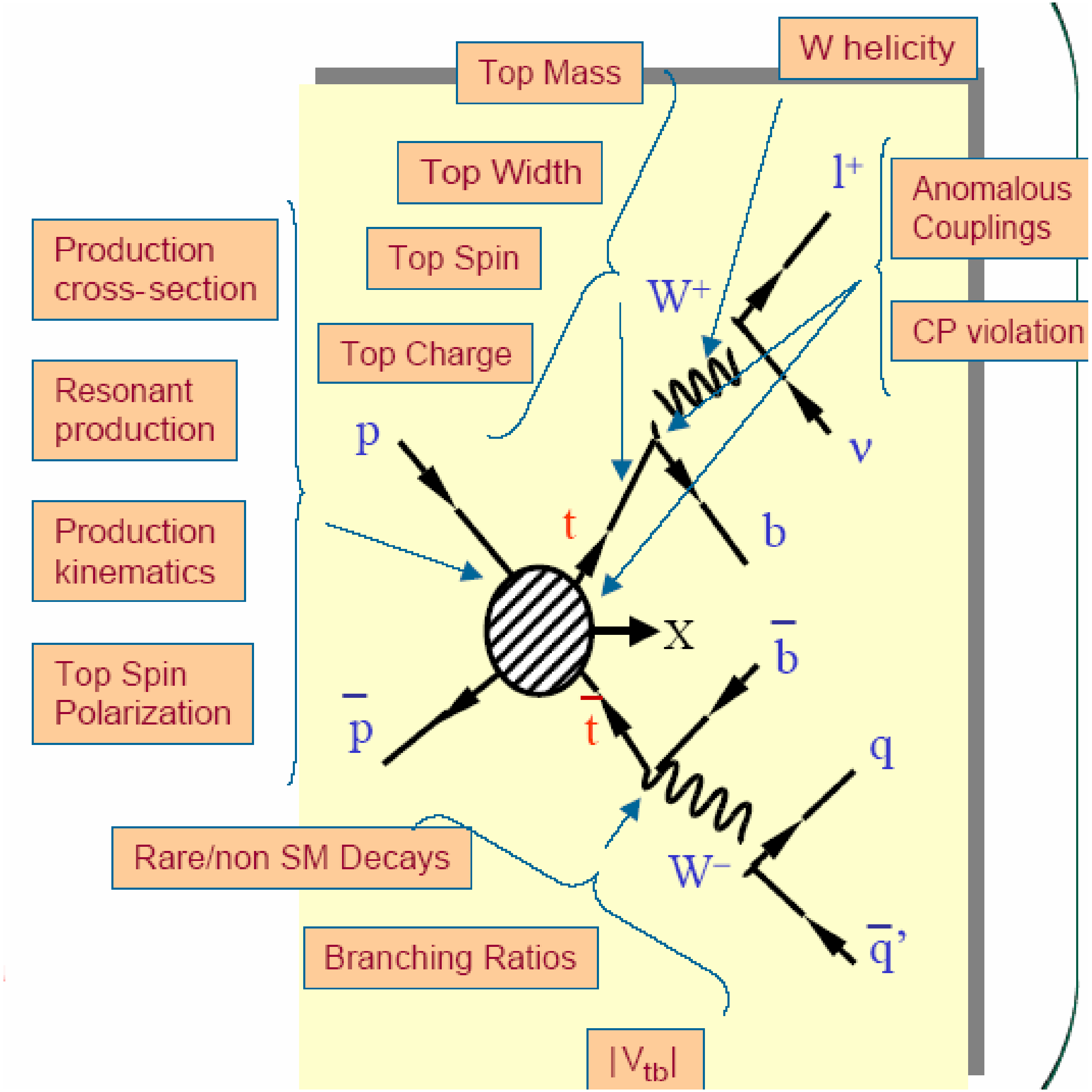
Juste LP05/deJong EPS05

Higgs prospects for discovery/exclusion



- Top quark may play a key role in EWSB

➔ explore top quark properties
➔ will allow to make stringent tests of SM



Juste LP05

CP violation and quark flavor physics

$$\begin{pmatrix} u \\ d \end{pmatrix} \quad \begin{pmatrix} c \\ s \end{pmatrix} \quad \begin{pmatrix} t \\ b \end{pmatrix}$$

Heavy flavours !

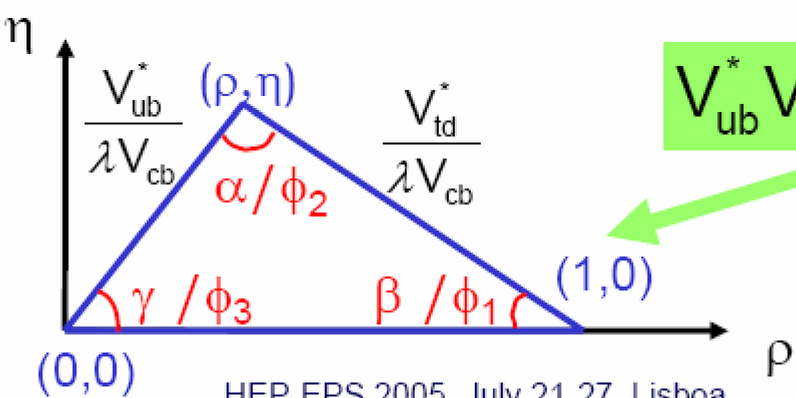
Frame: CKM matrix

$\lambda = \sin(\theta_c) = 0.2256 \pm 0.0014$

$$V_{CKM} = \begin{pmatrix} V_{ud} & V_{us} & V_{ub} \\ V_{cd} & V_{cs} & V_{cb} \\ V_{td} & V_{ts} & V_{tb} \end{pmatrix} = \begin{pmatrix} 1-\lambda^2 & \lambda & A\lambda^3(\rho - i\eta) \\ -\lambda & 1-\lambda^2/2 & A\lambda^2 \\ A\lambda^3(1-\rho-i\eta) & -A\lambda^2 & 1 \end{pmatrix} + O(\lambda^4)$$

CP violation

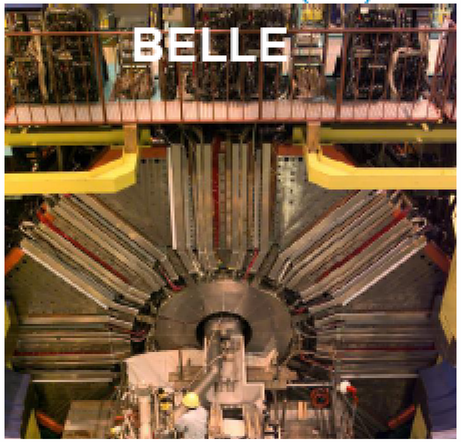
The unitarity triangle :

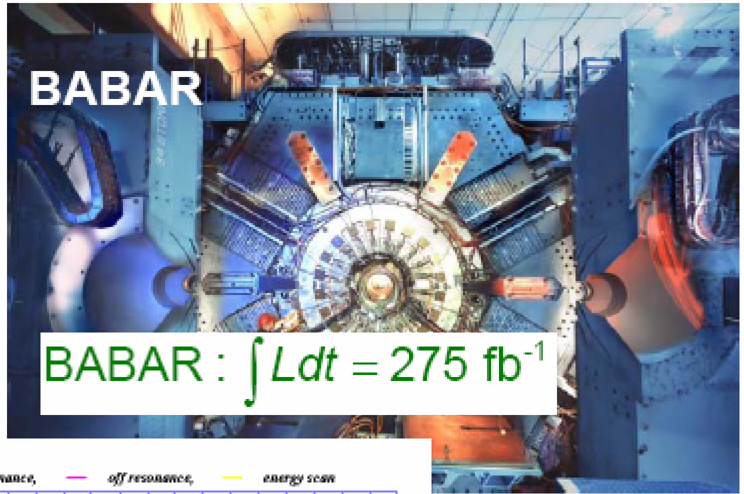


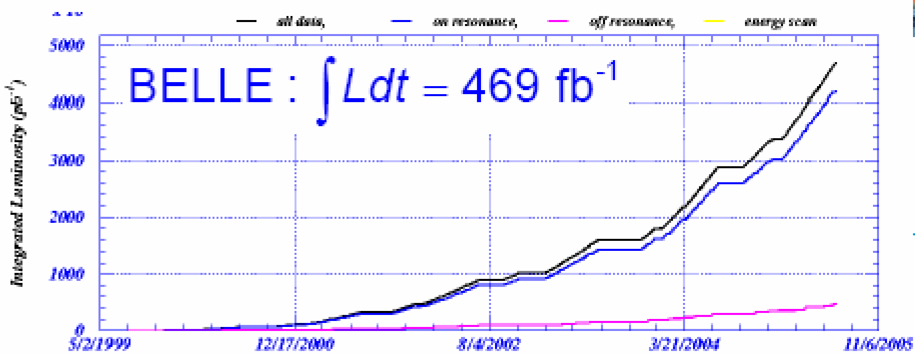
$$V_{ub}^* V_{ud} + V_{tb}^* V_{td} + V_{cb}^* V_{cd} = 0$$

Schune EPS05

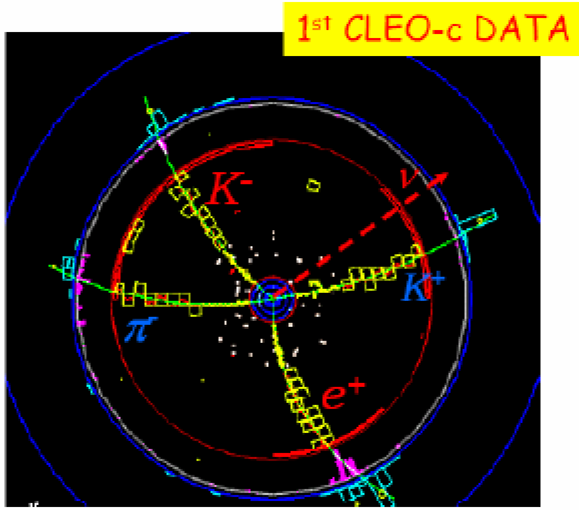
$e^+e^- \to \Upsilon(4s)$







$e^+e^- \to \psi''(3770)$

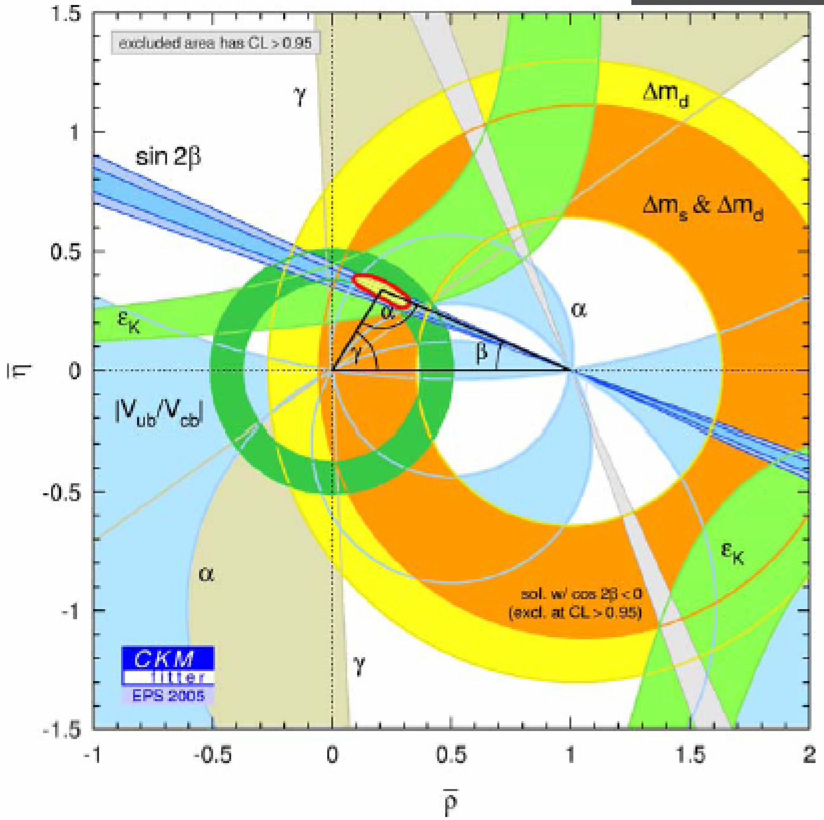


$\overline{D}^0 \to K\pi$ $D^0 \to Ke\nu$

Collider	Integrated luminosity	N($b\bar{b}$) in the central part of the detector	Boost	Main points
Tevatron	1.0 fb^{-1}×2	~40 10^9 ×2	~2-4	$\sigma_{b\bar{b}}/\sigma_{had}$~$10^{-3}$ ⇒trigger ; Incoherent production. All B species
B factories	275-469 fb^{-1}	0.28-0.47 10^9	~.5	$\sigma_{b\bar{b}}/\sigma_{had}$~0.2 Coherent $B\bar{B}$ production Only $B^\pm$ and B_d.

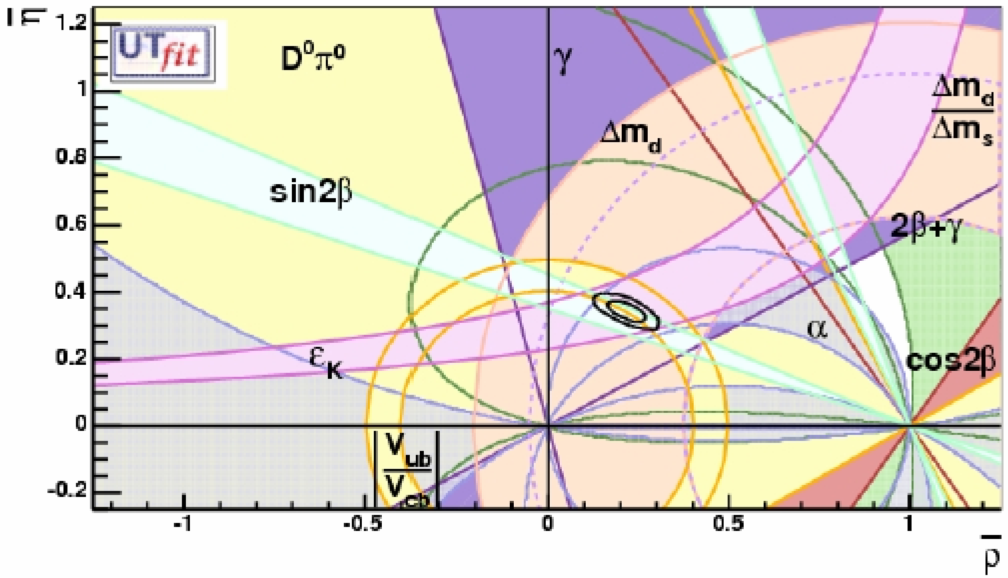
Schune EPS05

General overall agreement !



$\bar{\rho} = 0.208^{+0.038}_{-0.043}$

$\bar{\eta} = 0.337^{+0.024}_{-0.022}$



$\bar{\rho} = 0.216 \pm 0.036$

$\bar{\eta} = 0.342 \pm 0.022$

Schune EPS05

Besides slightly different theoretical inputs and different statistical treatments

Coherent picture of CP violation in the SM framework

The CKM mechanism works well… NP should appear as correction to this framework

Mastering QCD

The correctness of QCD is well established.

Insights into QCD have recently been rewarded:
The 2004 Nobel Prize for Physics to David Gross, David Politzer, and Frank Wilczek "for the discovery of asymptotic freedom in the theory of the strong interaction".

But deducing the consequences of QCD is challenging.

So is studying QCD experimentally.

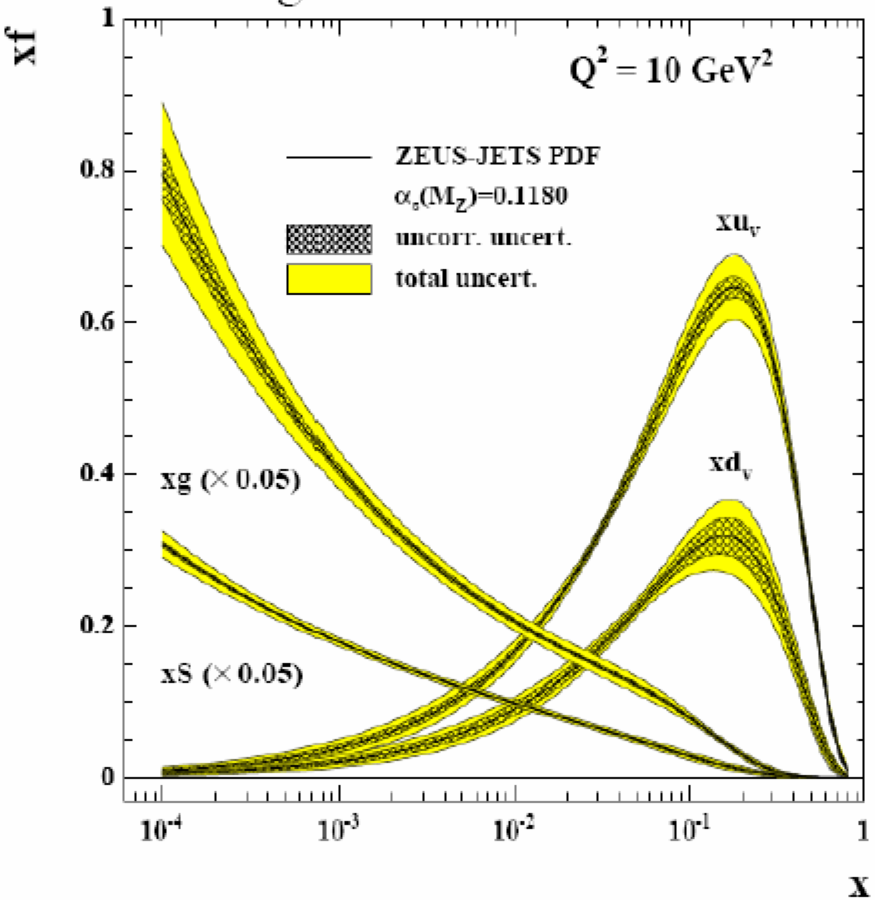
Kayser EPS05

Using jet data in PDF determinations

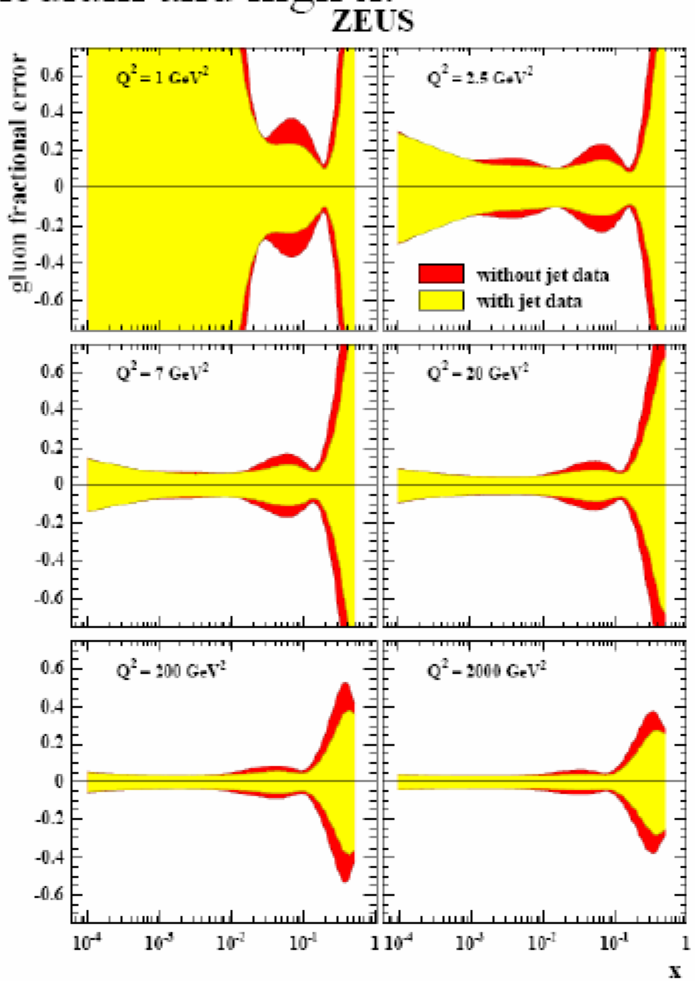
Structure of proton from HERA

Greenshaw EPS05

- $\alpha_s(m_Z) = 0.1183 \pm 0.0028$ (exp.) ± 0.0008 (mod.) ± 0.005 (scale).
- Resulting PDFs:



- Improved precision for gluon at medium and high x.



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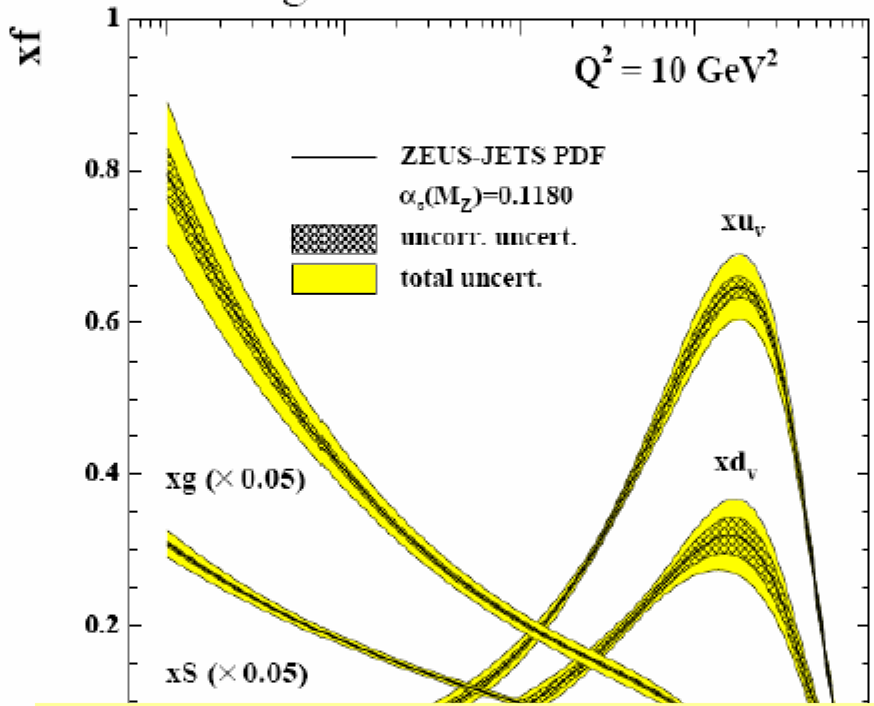

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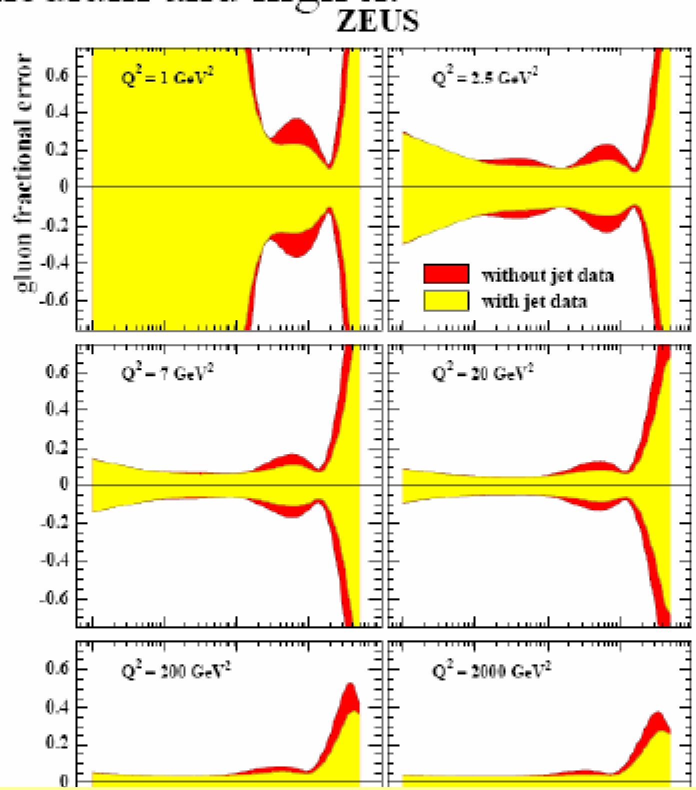
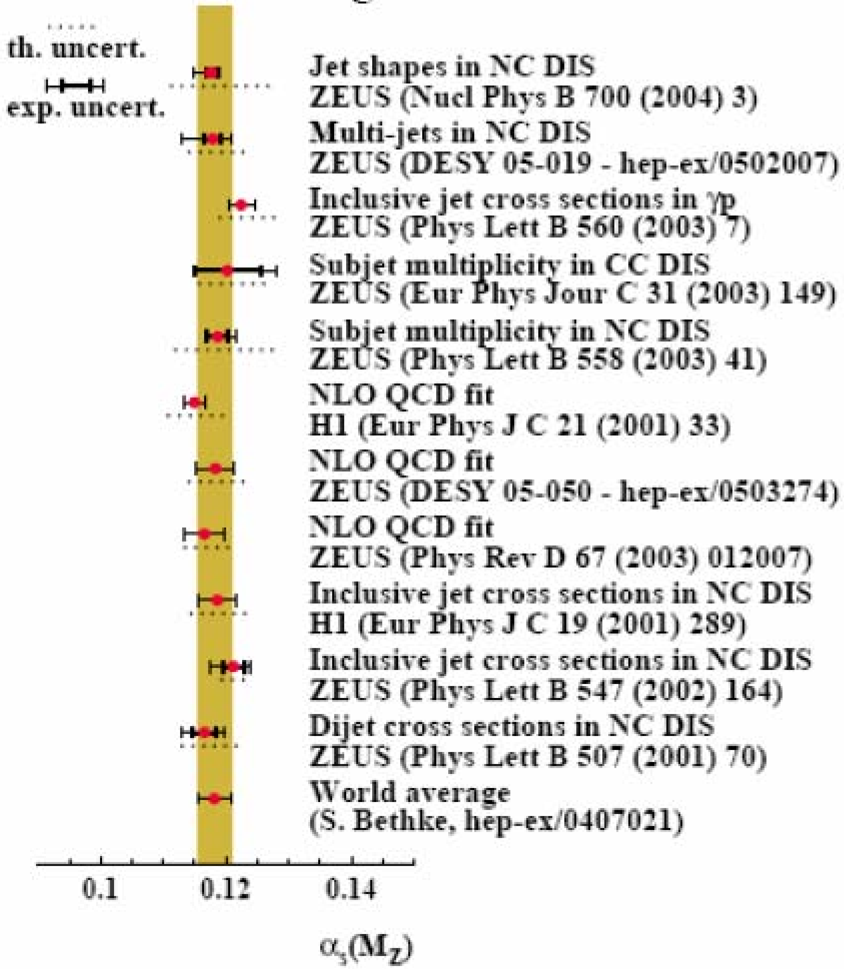


Inclusive HERA data call for NNLO → now available, thanks to S.Moch, J.A.M. Vermaseren, A.Vogt [hep-ph/0403192 & 0404111]

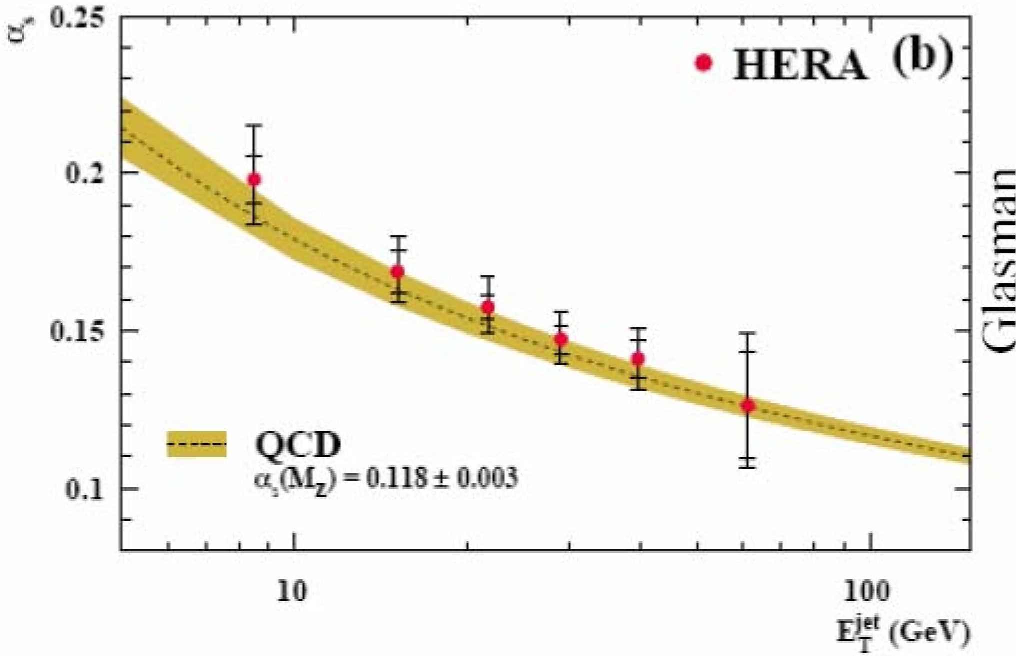
HERA α_s summary

Greenshaw EPS05

- C.f. HERA α_s measurements and world average:



- α_s measurements from jets.



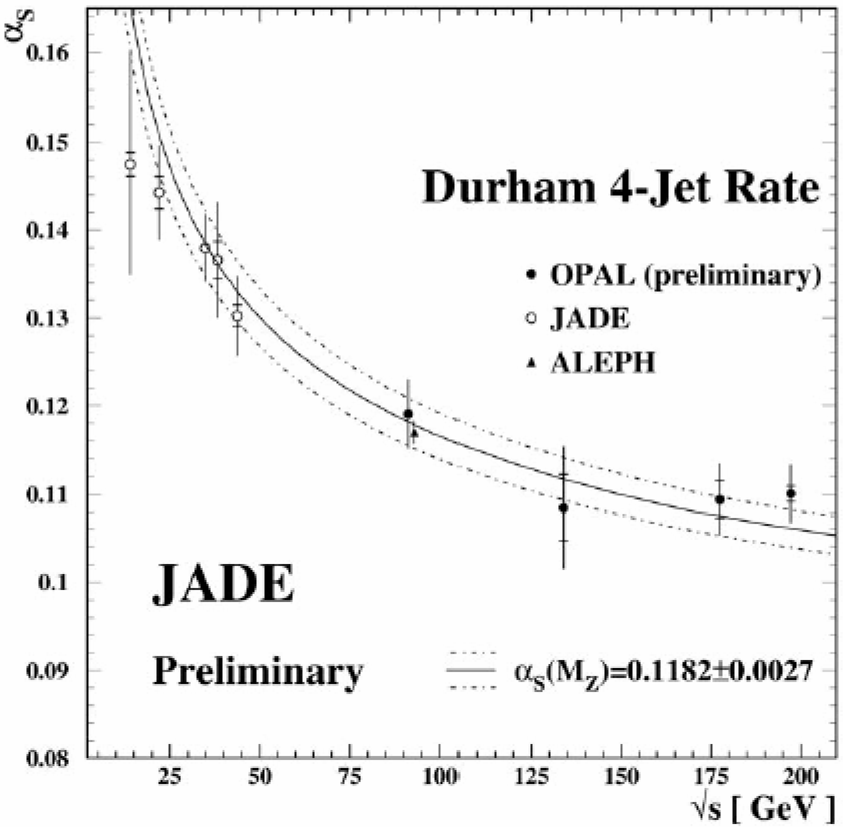
- Preliminary HERA average:

$$\alpha_s(m_Z^2) = 0.1186 \pm 0.0011(\text{exp.}) \pm 0.0050(\text{th.})$$

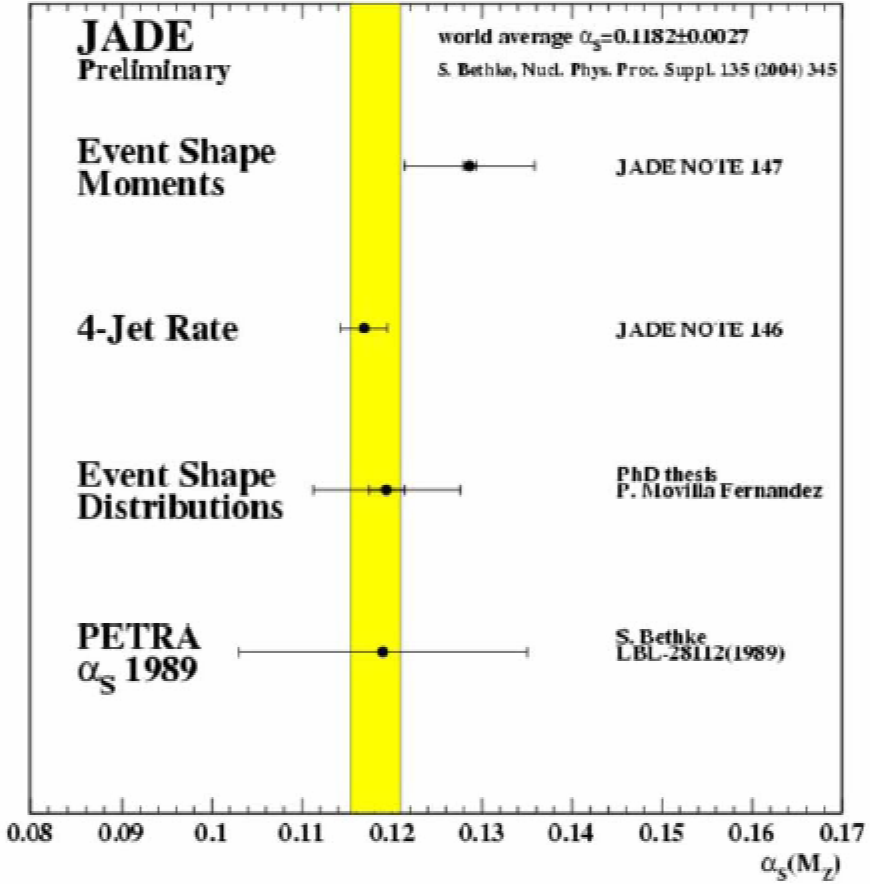
Reanalysis of JADE data

Greenshaw EPS05

- Study 4 jet rate using modern Monte Carlos to make hadronisation and detector corrections, c.f. NLO + NLL calculations.



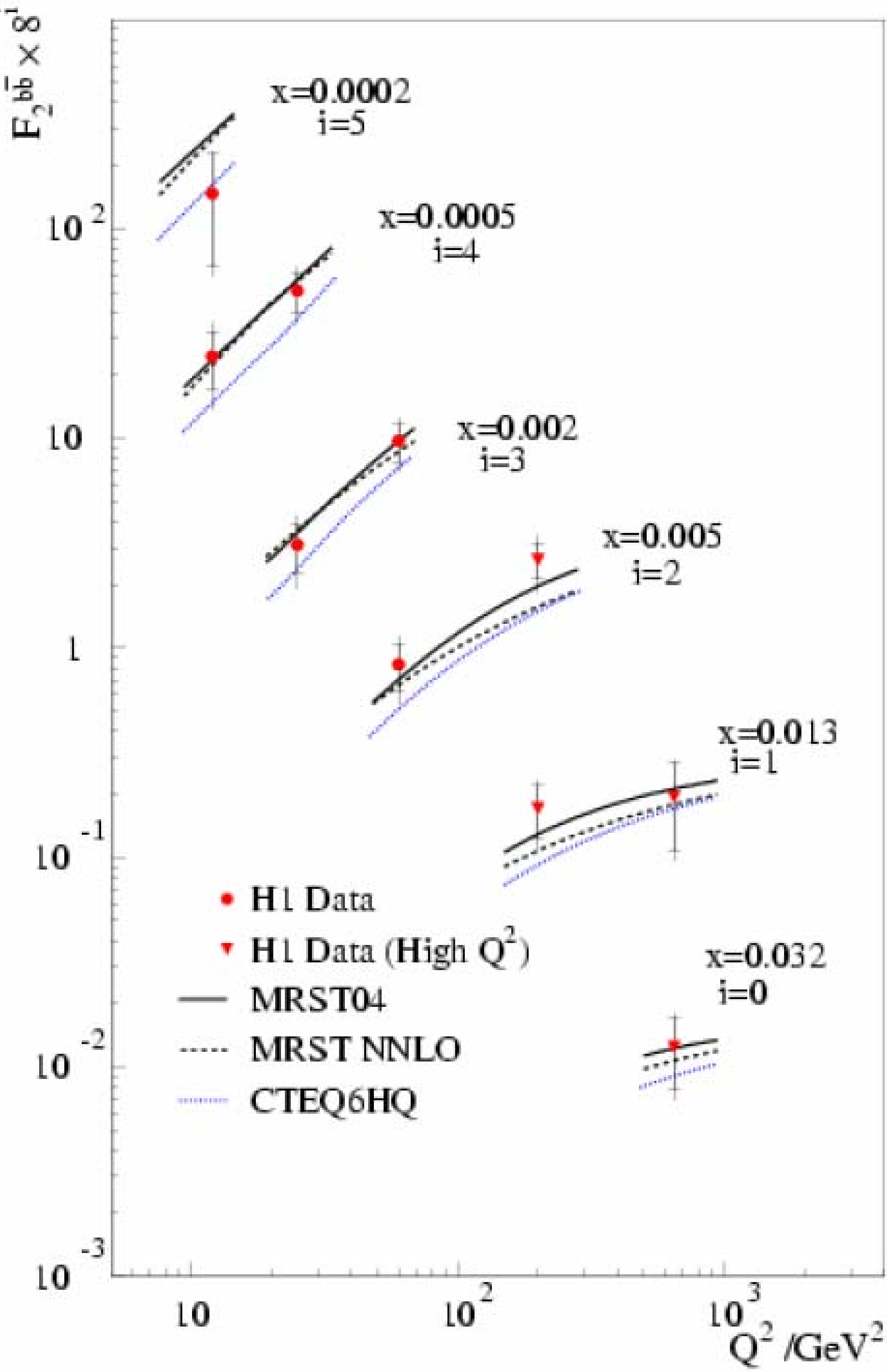
- Significant progress in determination of $\alpha_s(m_Z)$ in last ~15 years!



Beauty in proton

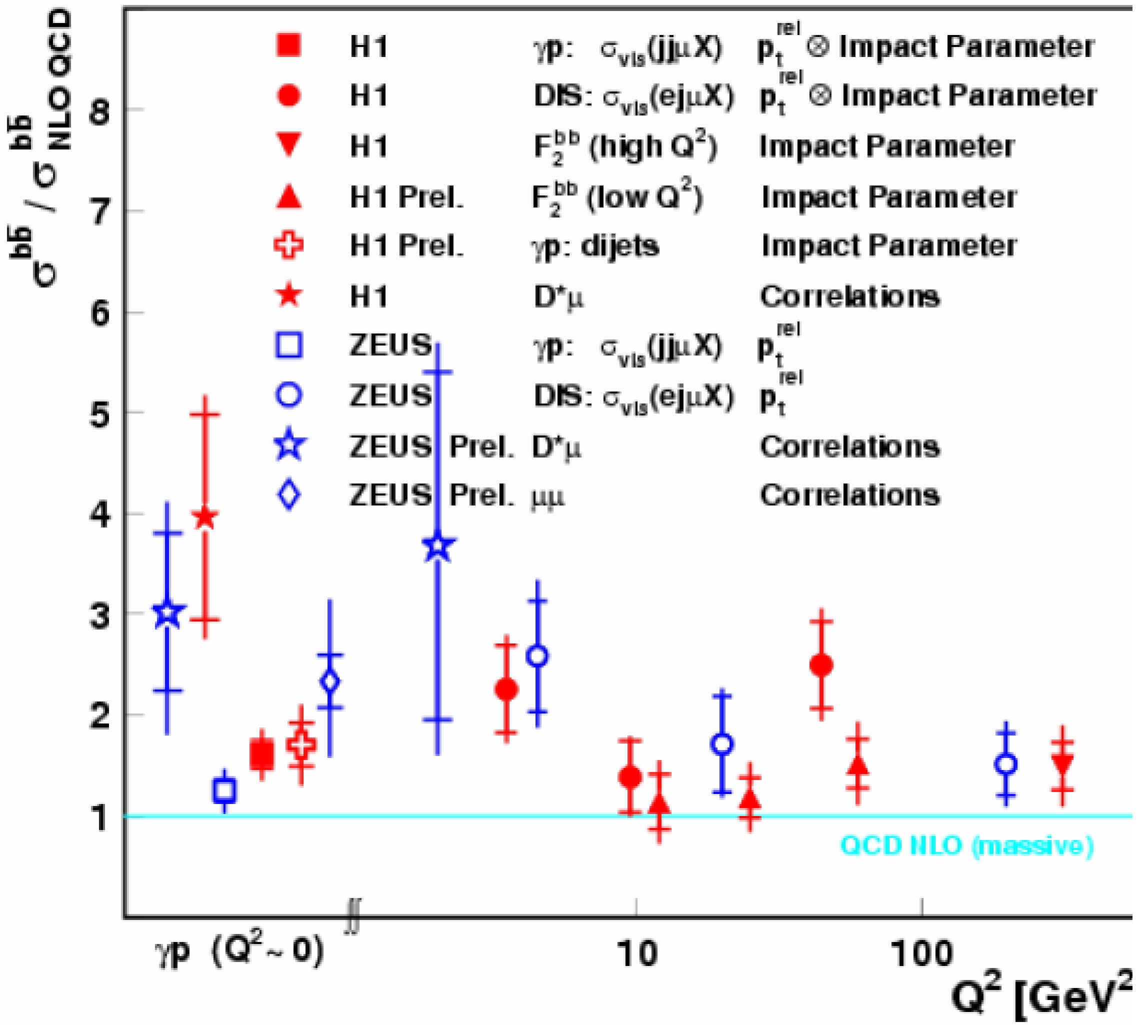
- Proportion of b events found to be 0.3 to 3%, inc. with Q^2.
- Hence obtain first ever measurements of $F_2^{b\bar{b}}$.
- Well described by higher order QCD calculations.
- Of interest to LHC, e.g. $b\bar{b} \to H$.
- $b\bar{b}$ contributes ~ 5% to $pp \to ZX$.
- Need better than 20% accuracy on b distribution for 1% Z cross sections at the LHC.

Greenshaw EPS05



Summary of beauty measurements at HERA.

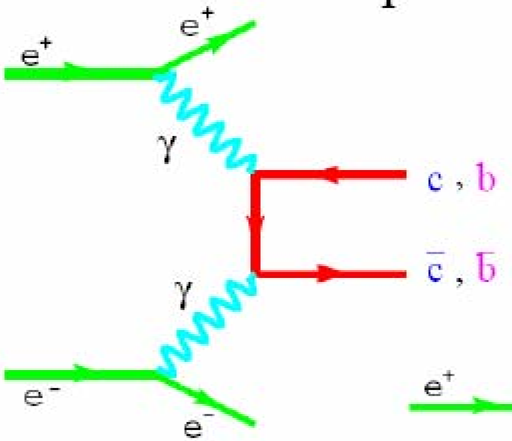
- Many measurements of beauty production now available.
- "Massive" NLO calcs tend to lie somewhat below the data (FMNR in photoproduction, HVQDIS for higher Q^2).
- Evidence that shapes of distributions poorly described in some places (e.g. in ejμX at low muon p_T and in proton direction).
- "Double tag" analyses with no jet requirement started, aim is to study production of $b\bar{b}$ with low p_T.



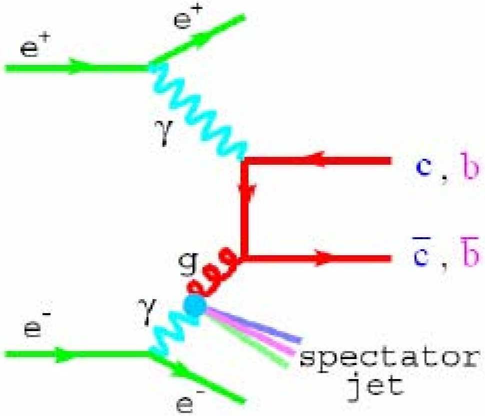
Greenshaw EPS05

Heavy flavours in γγ scattering

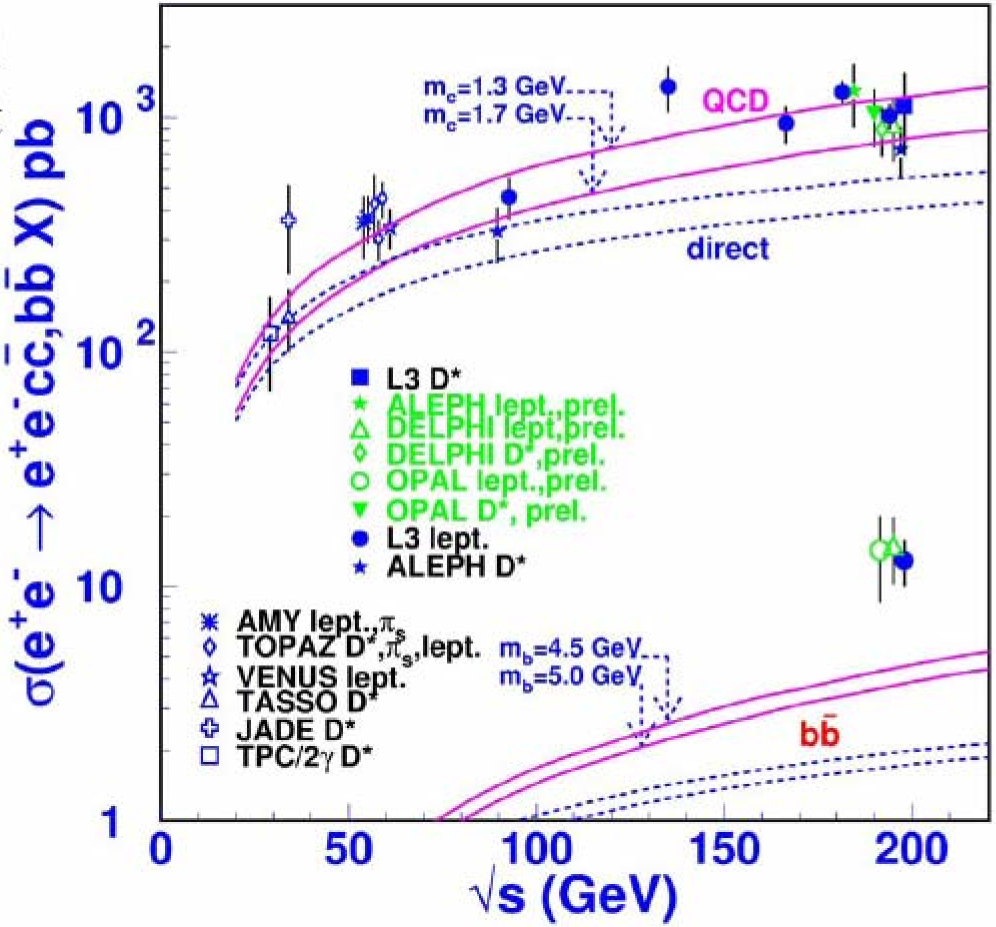
- Recent measurements of heavy flavour production by L3 show good agreement with NLO QCD for c, but lie above expectations for b.



Direct



Single Resolved

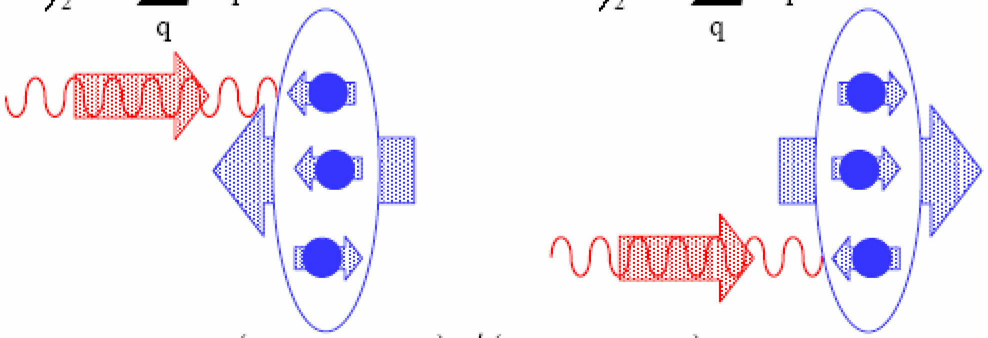


Greenshaw EPS05

Spin structure measurements

- $\frac{1}{2} = \frac{1}{2}\Delta\Sigma + \Delta G + L_z$
- Meas. with pol. target and pol. beam.

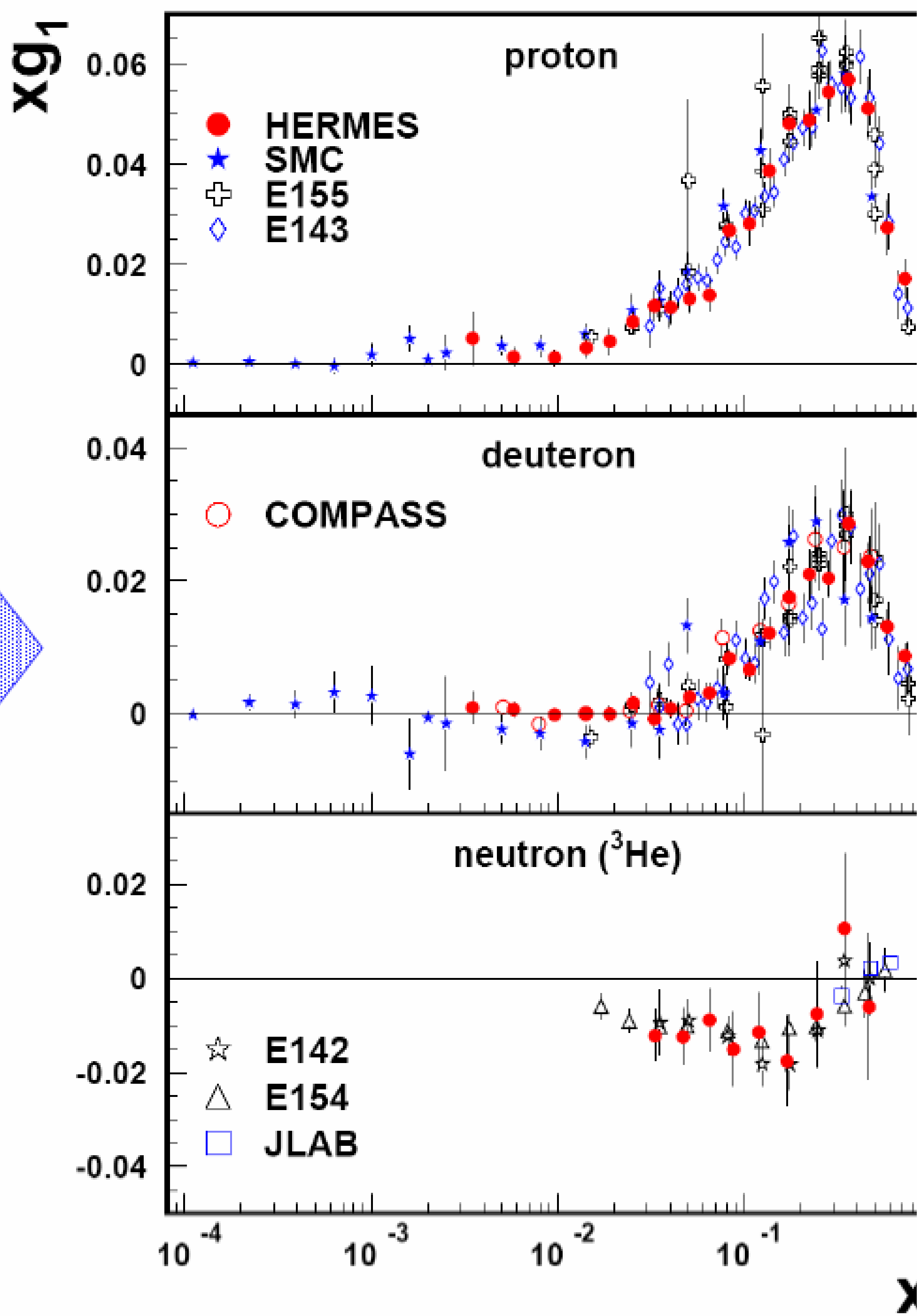
$$\sigma_{1/2} \sim \sum_q e_q^{\,2} q^+(x) \qquad \sigma_{3/2} \sim \sum_q e_q^{\,2} q^-(x)$$



- $A = \left(\sigma_{1/2} - \sigma_{3/2}\right) / \left(\sigma_{1/2} + \sigma_{3/2}\right)$

$$\sim \frac{\sum e_q^{\,2}\left(q_+ - q_-\right)}{\sum e_q^{\,2}\left(q_+ + q_-\right)} \sim \frac{g_1(x)}{F_1(x)}$$

- New data from COMPASS.
- $\Delta\Sigma = 0.202^{+0.042}_{-0.077} \rightarrow 0.237^{+0.024}_{-0.029}$

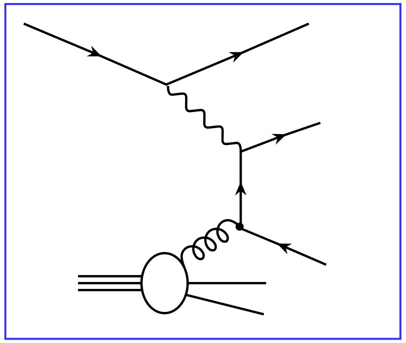


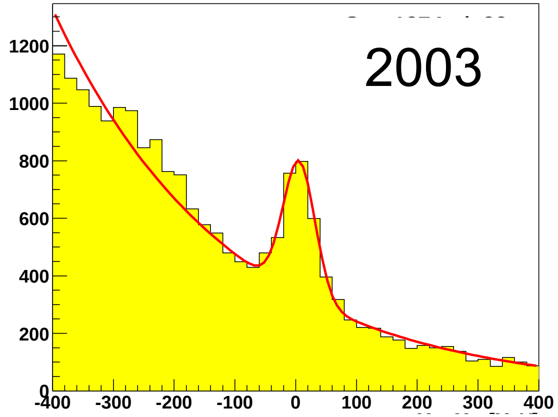
Direct measurement of ΔG(x)

LeGoff LP05,
Greenshaw EPS05

Compass:

- Open charm (2002+2003)
  $\Delta G/G=-1.08 \pm 0.76$
  not enough stat yet





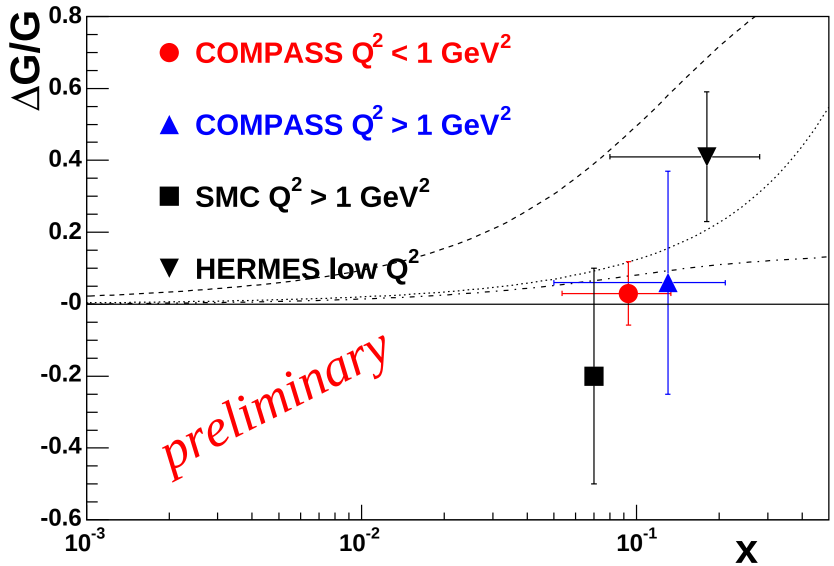
$D^* \rightarrow D^0\pi$
$\rightarrow K\pi\pi$

$$M_{K\pi} - M_{D^0}\,(MeV)$$

- High pt hadrons
  2002+2003 data Q^2<1 GeV^2
  R_{PGF} & A_{Bkg} estimated using Pythia

$$A_{\parallel} = R_{PGF}\, a_{PGF}\, \frac{\Delta G}{G} + A_{Bkg}$$

$\Delta G/G=0.024 \pm 0.089 \pm 0.057$

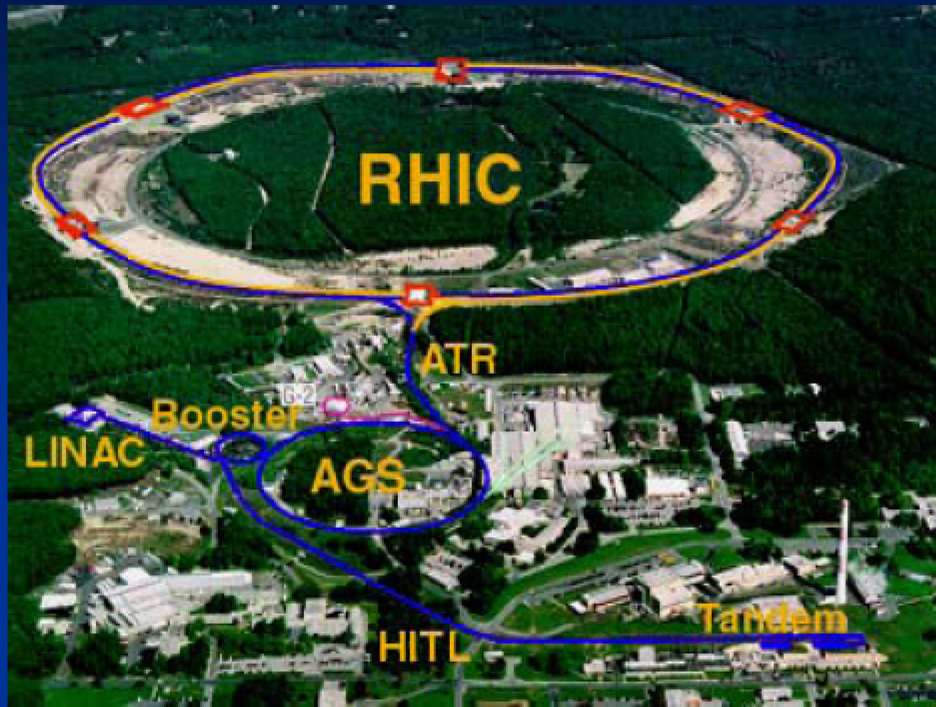


GRSV curves min, std and max ΔG:
$\Delta G=\int \Delta G(x)dx$ = 0.2, 0.6, 2.5
→ either ΔG small or ΔG(x) crosses 0

Ultra-Relativistic Heavy Ion Beams

CERN

BNL



SPS (1986 - 2004)

O & S @ 60, **200** GeV/n

Pb & In @ 40, 80,**158** GeV/n

LHC (2008 - ?)

Pb-Pb @ $\sqrt{s_{NN}}$=**5.5** TeV

AGS (1986 - 2000)

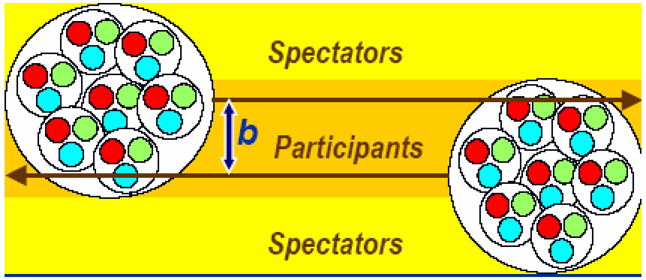
O & Si @ 15 GeV/n

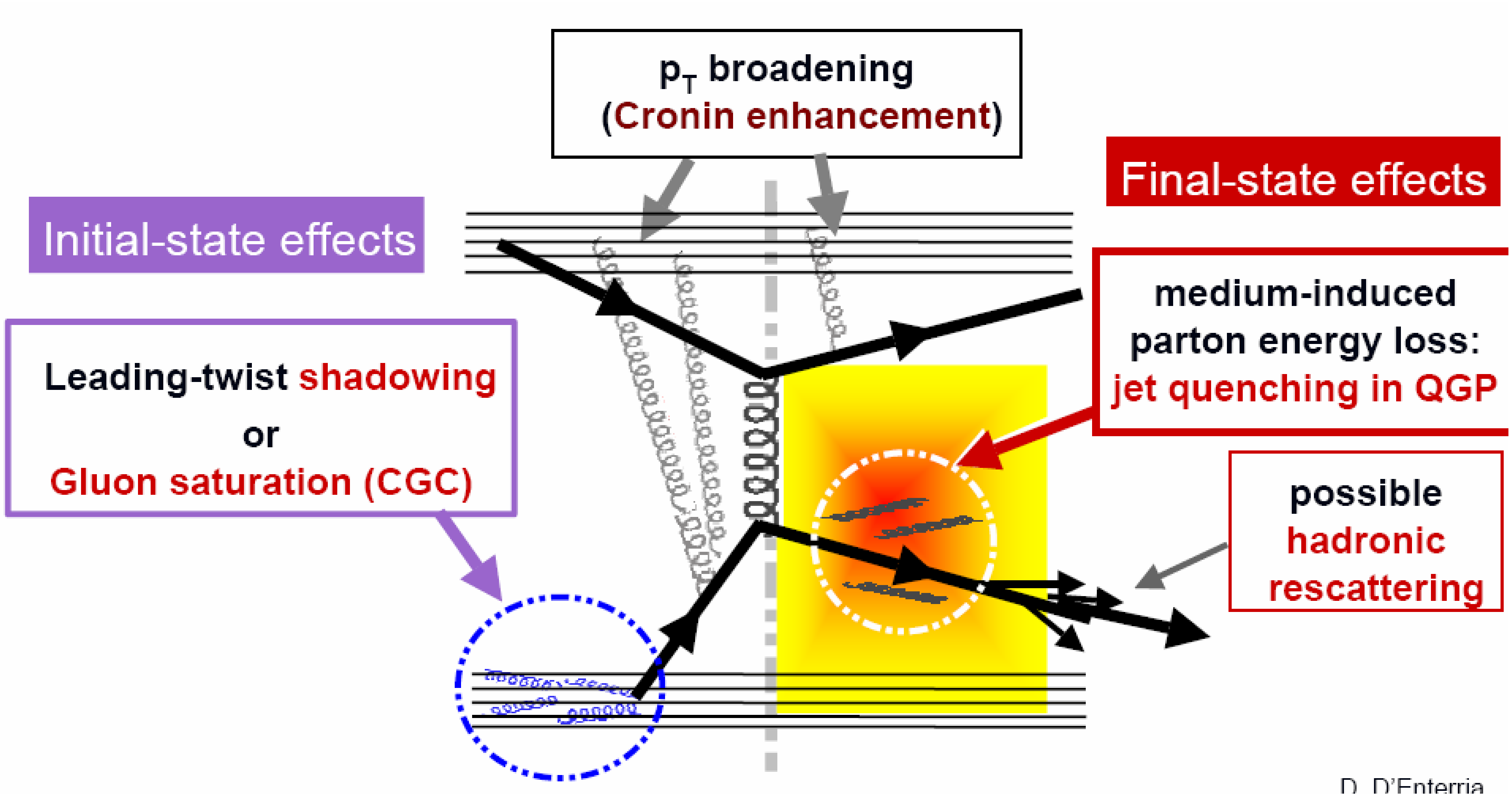
Au @ 11 GeV/n

RHIC (2000 - ?)

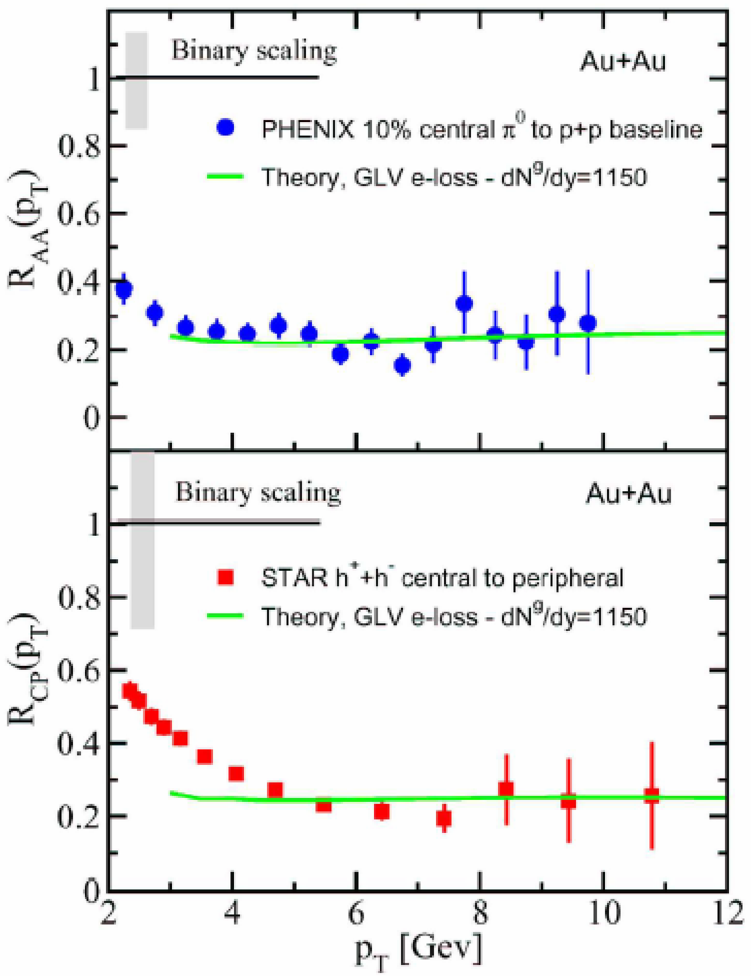
Au-Au @ $\sqrt{s_{NN}}$=62,130, **200** GeV

URHI


Spectators
b
Participants
Spectators


p_T broadening
(Cronin enhancement)
Final-state effects
Initial-state effects
medium-induced
parton energy loss:
jet quenching in QGP
Leading-twist shadowing
or
Gluon saturation (CGC)
possible
hadronic
rescattering
D. D'Enterria

suppression of hadron yields at high p_t in central AuAu collisions

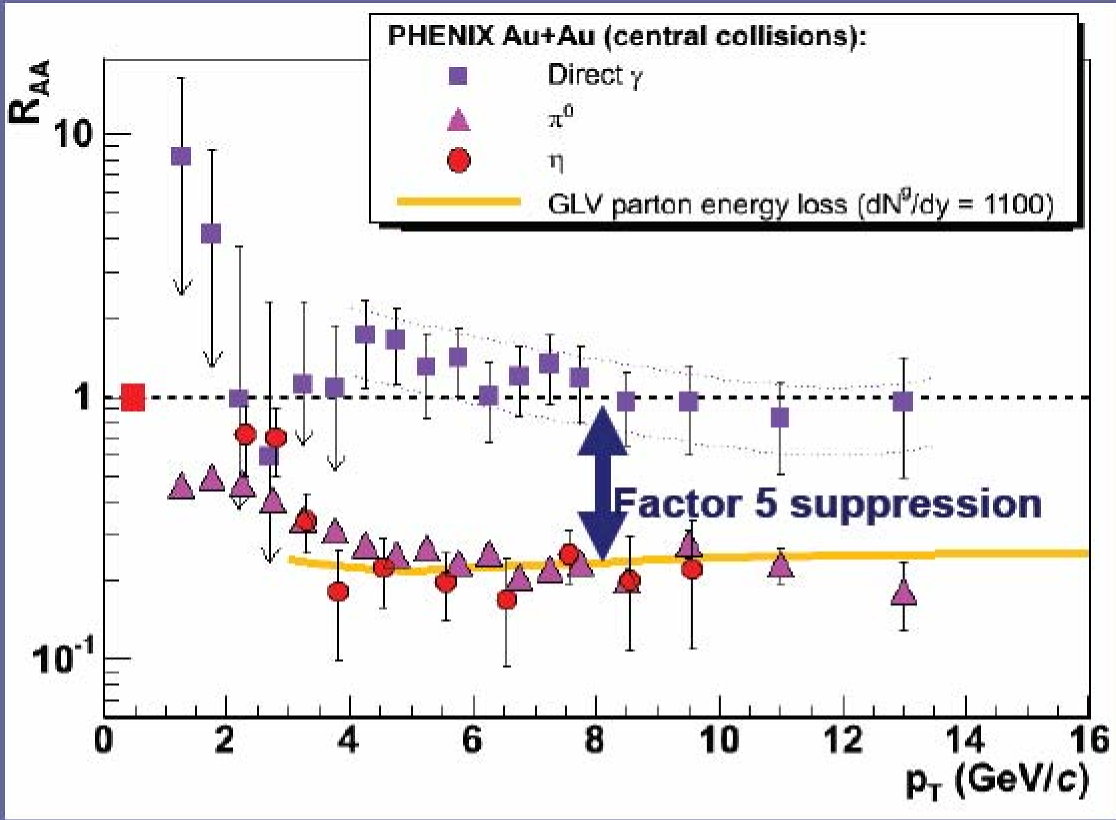


AuAu compared to pp scaled with number of binary collisions

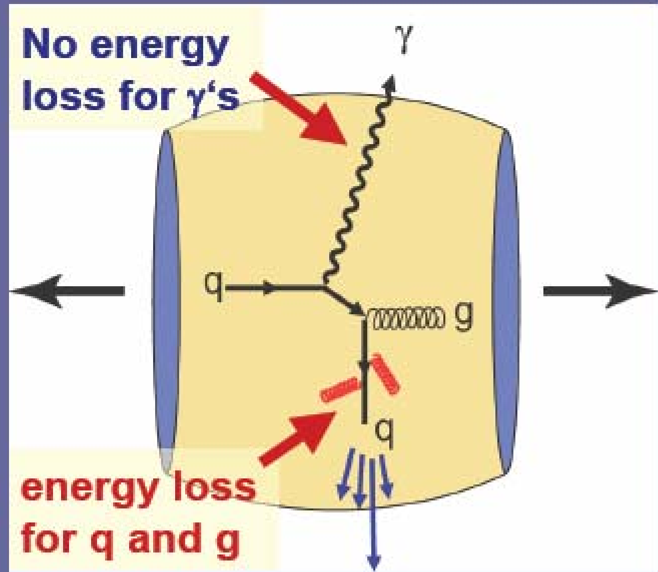
AuAu central collisions compared to peripheral collisions scaled with number of binary collisions

in central collisions hadron yields suppressed indicative of jet quenching due to parton energy loss due to high gluon density

Nuclear Modification Factor R_{AB}

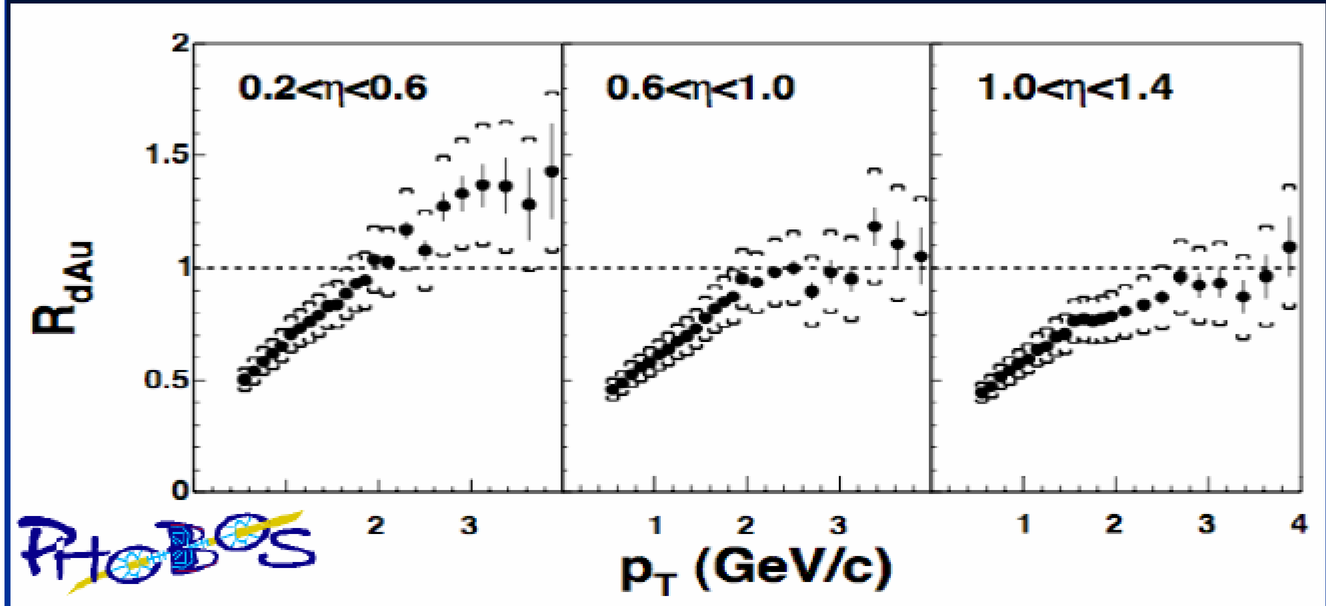


$$R_{AB} = \frac{dN/dp_T\big|_{A+B}}{\langle T_{AB}\rangle \times d\sigma/dp_T\big|_{p+p}}$$



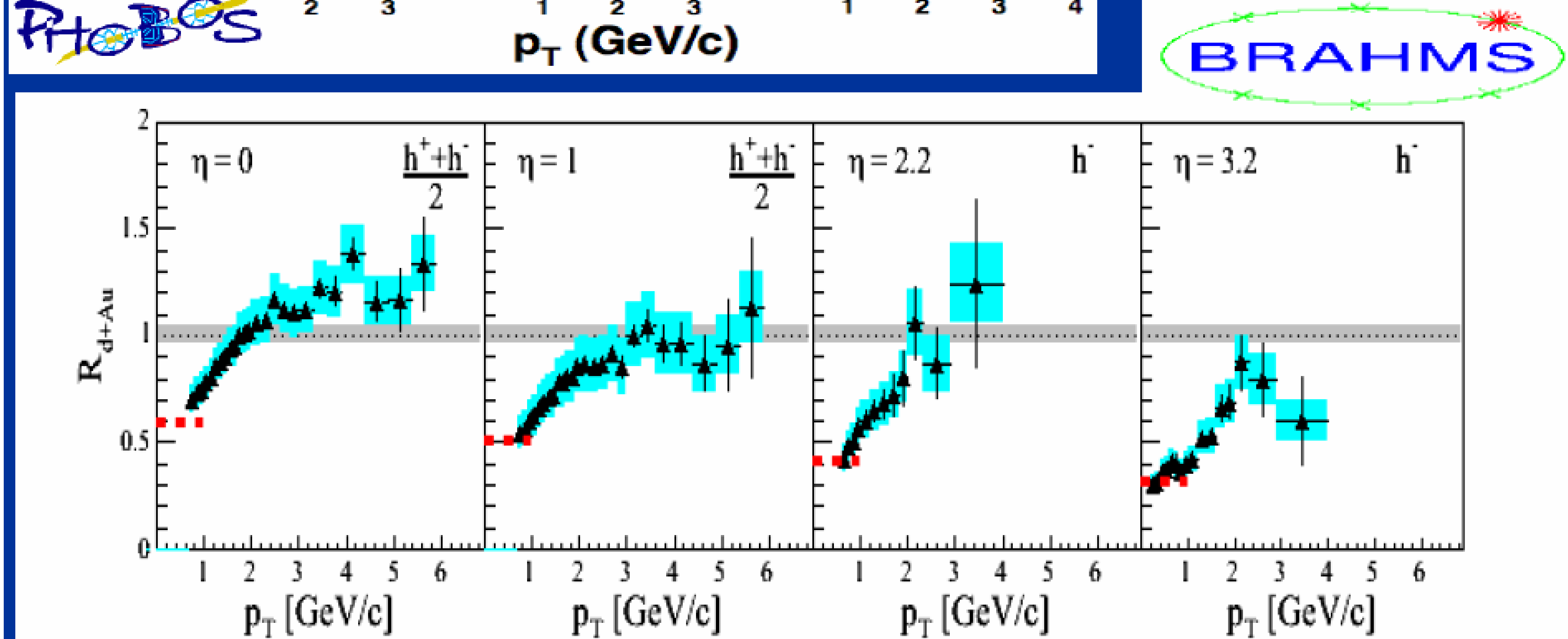
Hadrons are suppressed while direct photons are not: Evidence for parton energy loss (as expected in the QGP)

Suppression in d-Au Forward Region

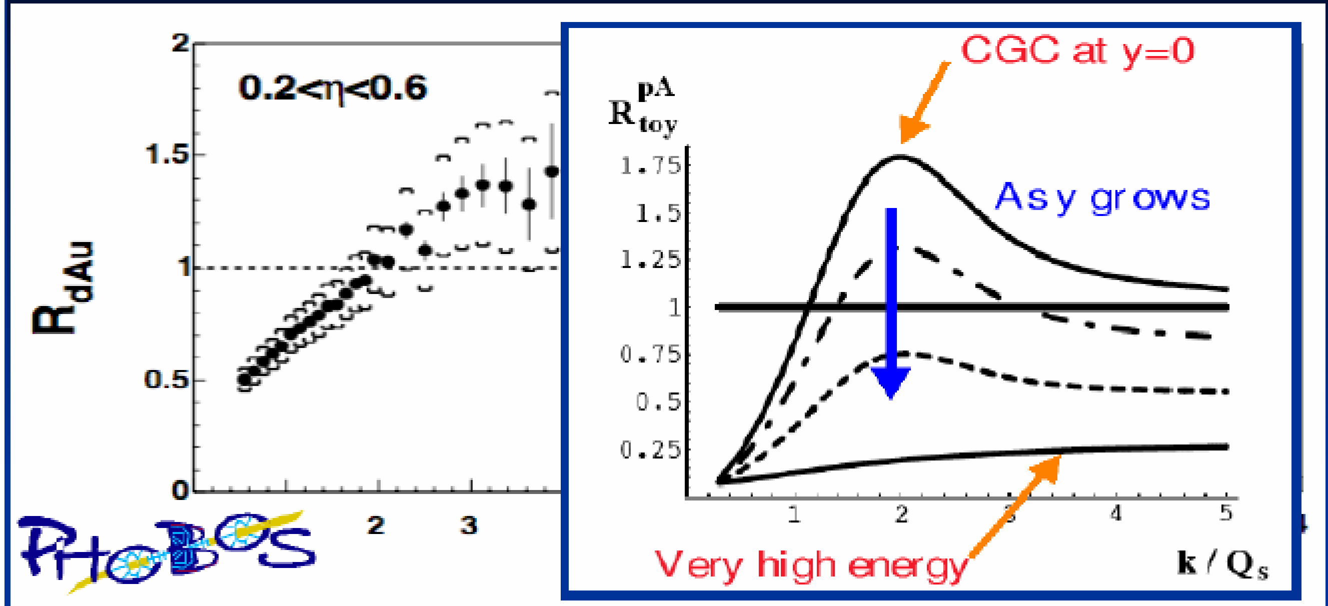


@ $\sqrt{s_{NN}}$ = 200 GeV

p_T suppression is observed in d-Au forward rapidities as expected – CGC ?



Suppression in d-Au Forward Region



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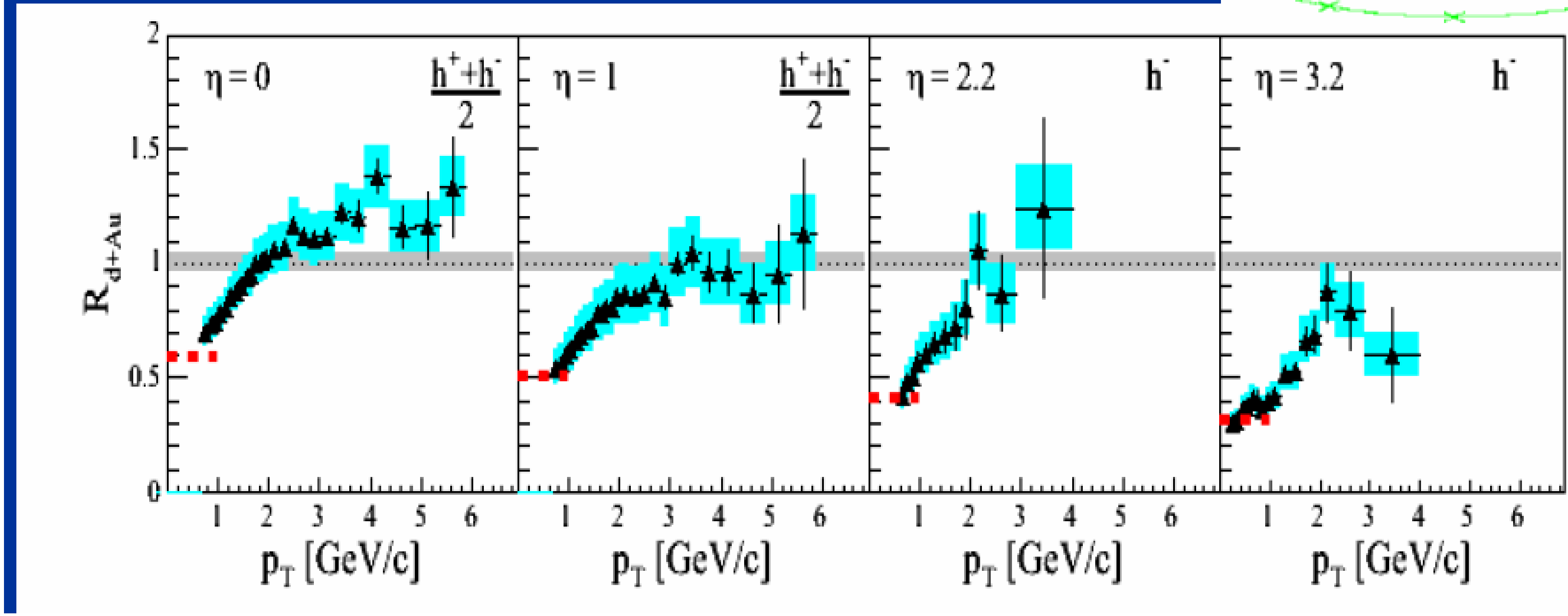


Has the Quark-Gluon-Plasma been seen?

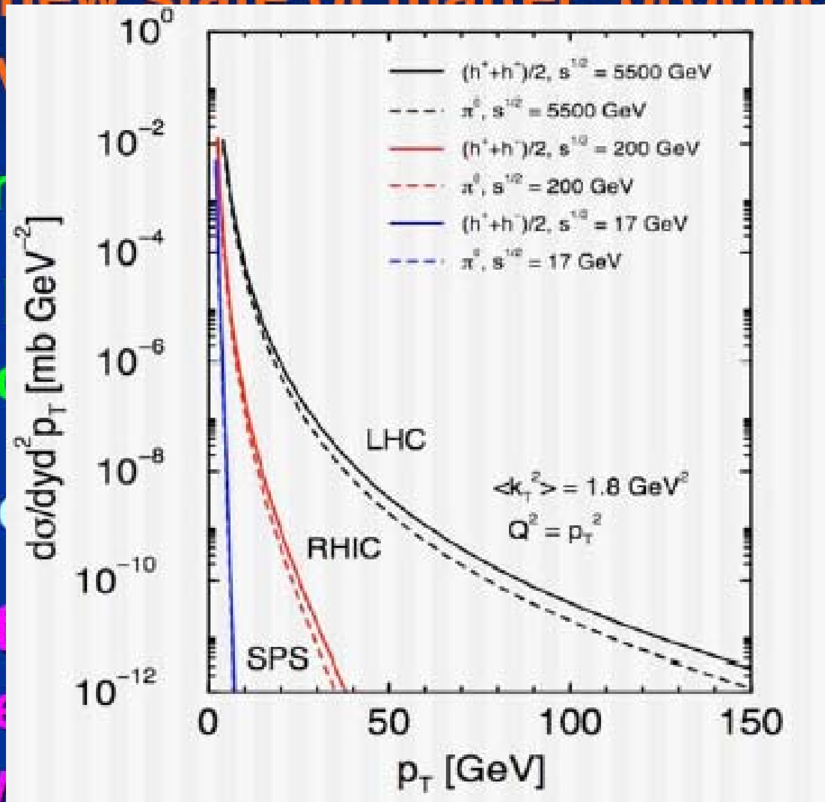
- Is QGP, the new state of matter, produced in ultra-relativistic heavy ion collisions?
  - ✓ In February 2000, CERN announced the QGP discovery
  - ✓ Recently, RHIC has announced that the state of matter formed is more like a liquid than a gas

Maybe we are facing a philosophical question

Whatever the state created is, it produces a lot of interesting results, exhibiting anomalous behaviours, signal of New Physics and so a long and bright future is foreseen at RHIC and at LHC

Has the Quark-Gluon-Plasma been seen?

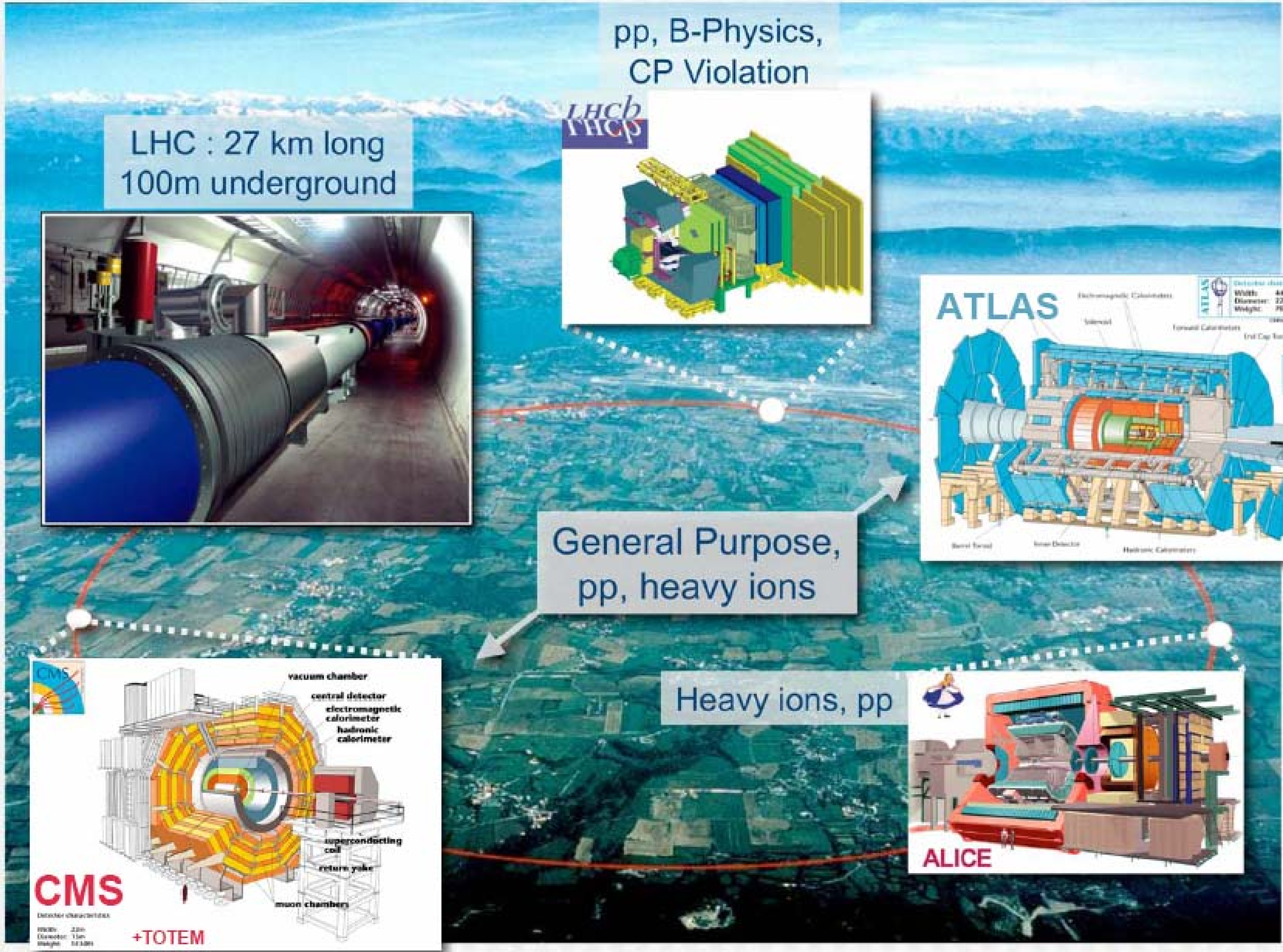
- Is QGP, the new state of matter, produced in ultra-relativistic hea[…]
  - ✓ In Februar[…] […]he QGP discovery
  - ✓ Recently, […] […]he state of matter formed is m[…]



Maybe w[…] […] question

Whatever t[…] […]uces a lot of interesting r[…] […]s behaviours, signal of New […] […]d bright future is foreseen at RHIC and at LHC

The near future



Summary of current status

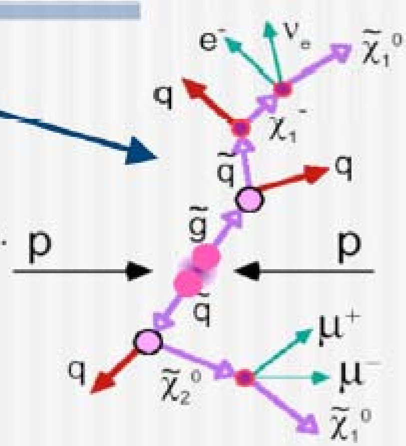
ETH Instit
Particle Ph

- LHC (L. Evans, RRB, April 2005)
  - QRL installation now proceeding smoothly, machine installation has started
  - Hardware commissioning finished by end June 2007. Ready for beam.
- ATLAS
  - Component construction (almost) complete for most sub-systems. Very good progress on magnet assembly. Inner detector : very tight planning.
  - Emphasis now : integration, installation, commissioning
- CMS
  - Civil engineering off critical path, magnet getting ready for first test
  - HCAL, Muon systems : well advanced
  - To watch : ECAL crystal delivery, Tracker hybrids and integration at CERN
  - Note : ECAL end-caps and pixels will be installed during first shutdown (2007-2008)
- LHCb
  - Most sub-systems : very good progress. Muon chambers : tight planning
- ALICE
  - Initial working detector ready for data in 2007 (basic elements : TPC, trigger detectors, HMPID, TOF, ITS, part of TRD, PHOS, DAQ)

- ALL : Will be ready to exploit LHC collisions starting on day 1 !

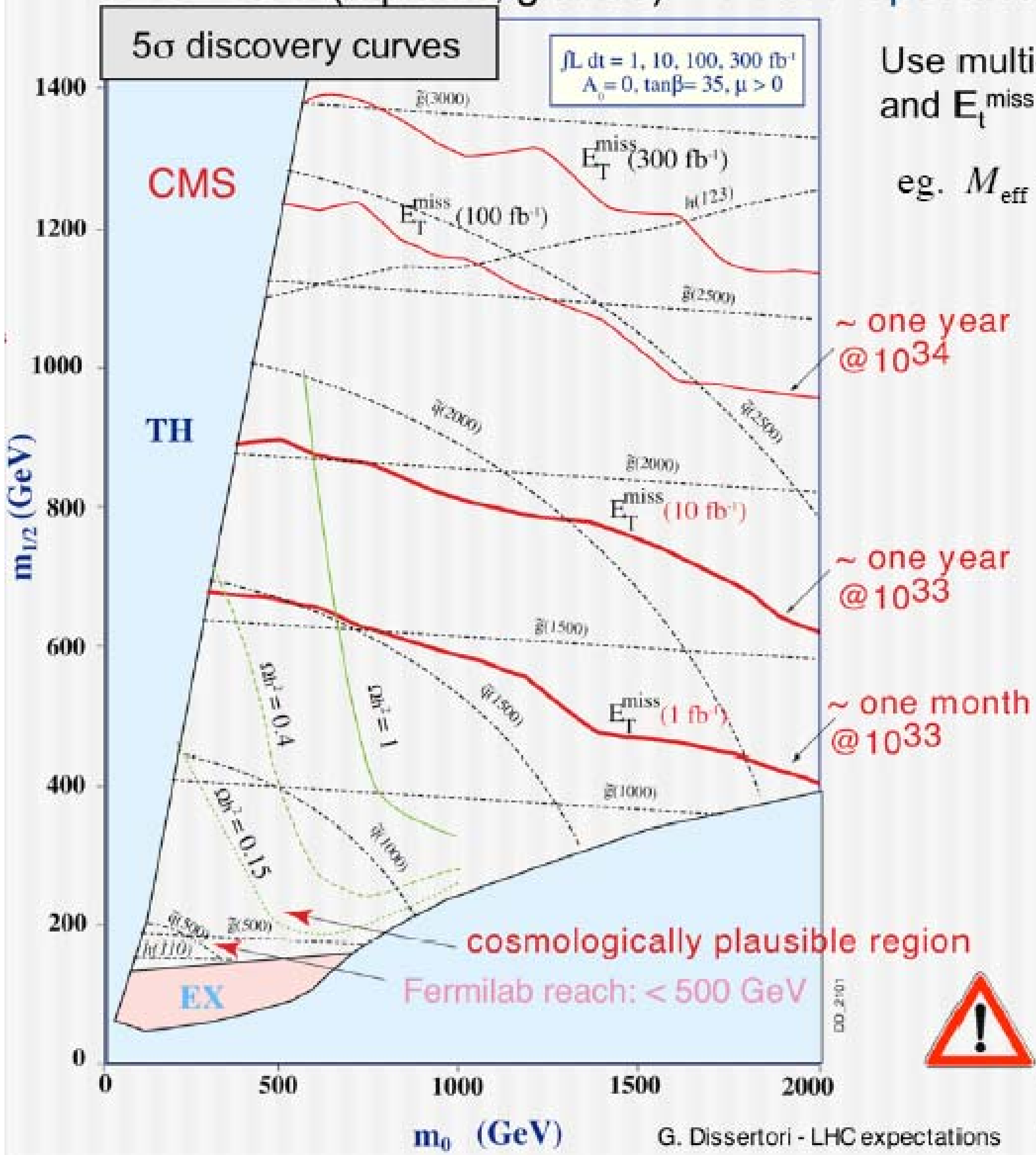
Early SUSY discovery?

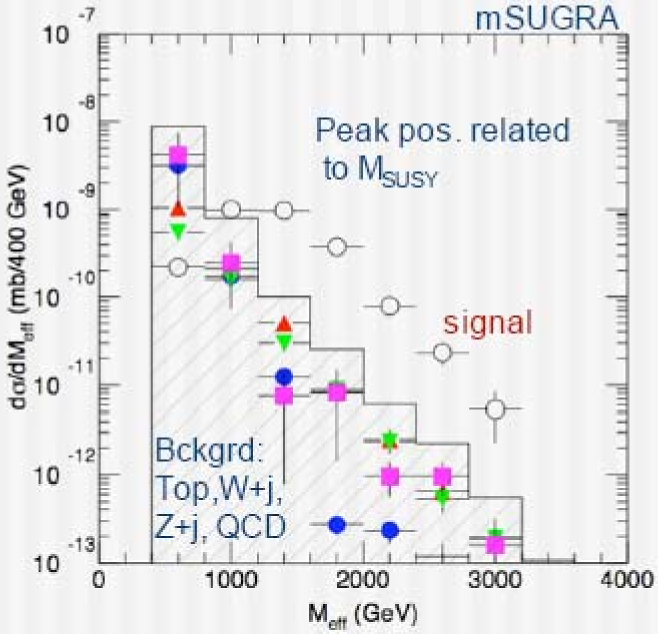
- Large squark/gluino pair prod. cross sections, ~100 evts/day at 10^{33} for m(squarks, gluinos) ~1 TeV. Spectacular signatures



Use multi-jet, multi-leptons and E_t^{miss} for discrimination.

eg. $M_{\text{eff}} = E_T^{\text{miss}} + \sum_{\text{jets}} p_T(\text{j})$





Beware ! : Good understanding of detector and SM bckgrds needed! eg. parton shower not enough!

SEMICONDUCTOR DETECTORS	**RADIATION HARD SOLID STATE DETECTORS:** *MATERIAL ENGINEERING:* OXIGENATED, CZOCHRALSKI, THIN EPITAXIAL *DEVICE ENGINEERING:* PIXELS, MONOLITHIC ACTIVE PIXELS, 3D DETECTORS
GAS MICROPATTERN DETECTORS	**GAS ELECTRON MULTIPLIER:** *HIGH RATE TRACKING AND TRIGGERING* *TIME PROJECTION CHAMBERS READOUT* *UV PHOTON DETECTION, RICH*
SCINTILLATORS RADIATORS	**CALORIMETRY:** *LEAD TUNGSTATE CRYSTALS* **NEW SCINTILLATORS:** *LSO, LYSO, LuYAP,* $LaCl_3$
PHOTON DETECTORS	**AVALANCHE PHOTODIODES** **SILICON PHOTOMULTIPLIERS** **HYBRID PHOTODIODES**

~ 30 TALKS IN PARALLEL SESSIONS ON DETECTORS
LHC DETECTORS: DISCUSSED BY GÜNTHER DISSERTORI
ILC DETECTORS: DISCUSSED BY KLAUS DESCH

SEMICONDUCTOR

RADIATION HARD SOLID STATE DETECTORS:

MATERIAL ENGINEERING:

OXIGENATED, CZOCHRALSKI, THIN EPITAXIAL

CONCLUSIONS

MOTIVATED BY PARTICLE PHYSICS EXPERIMENTATION, GREAT PROGRESS HAS BEEN MADE FOR MASS PRODUCTION OF RELIABLE, RAD HARD DETECTORS

INNOVATIVE DEVICES HAVE BEEN DEVELOPED, OLD ONES IMPROVED

THE CHALLENGE OF THE NEXT GENERATION OF ACCELERATORS (SUPER-LHC, ILC, …..) REQUIRE FURTHER DEVELOPMENTS AND INNOVATIONS

APPLICATIONS IN ASTROPHYSICS, SPACE, BIOMEDICS ARE BLOSSOMING

DETECTORS R&D REQUIRES NEW FORCES AND INVESTMENTS!

~ 30 TALKS IN PARALLEL SESSIONS ON DETECTORS
LHC DETECTORS: DISCUSSED BY GÜNTHER DISSERTORI
ILC DETECTORS: DISCUSSED BY KLAUS DESCH

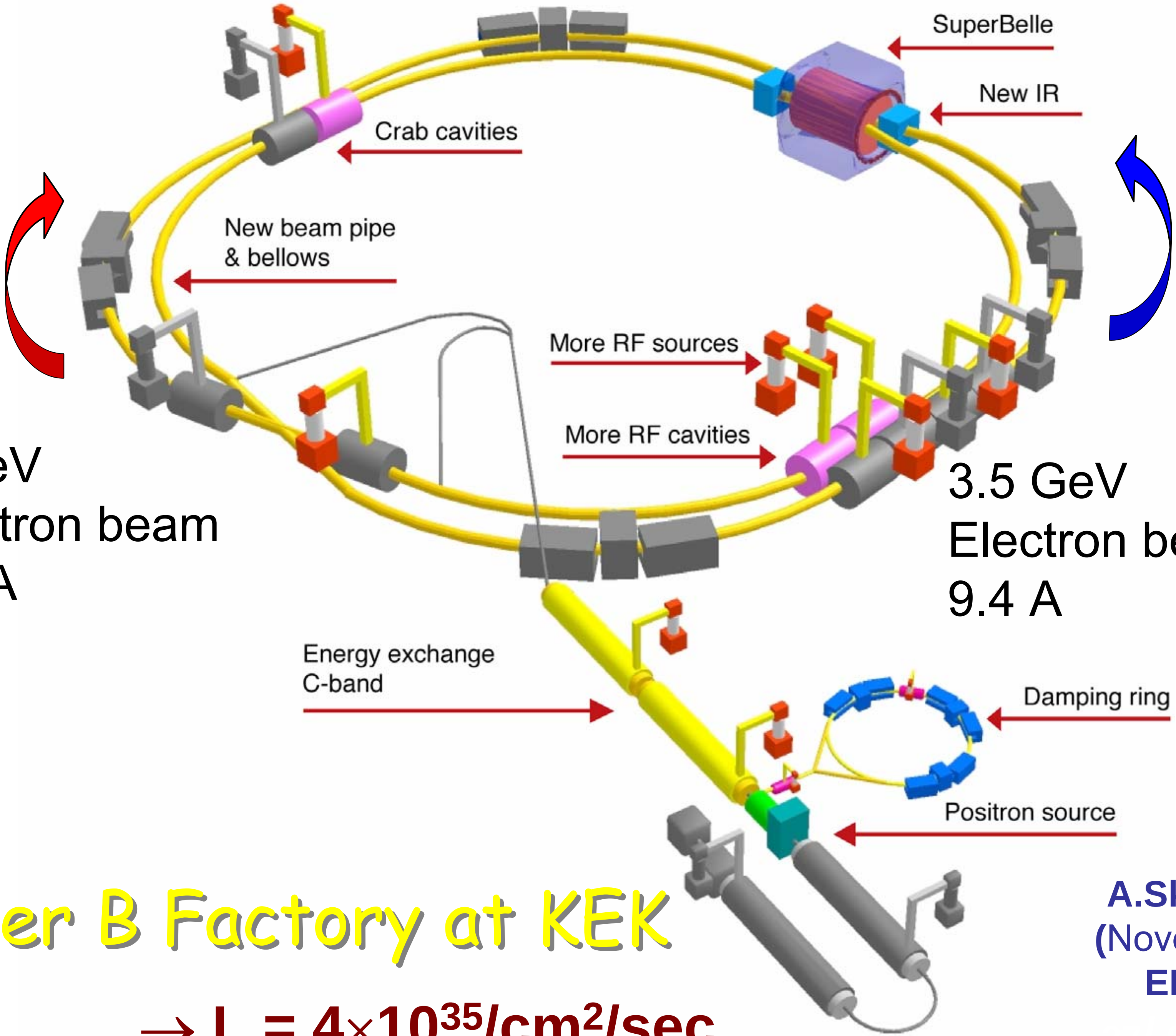
Accelerators: Achievements and inventions in "technology" and particle dynamics,

which give background for the modern era flowering of the accelerator based High Energy Physics and applications.

- **Intensive use of "sophisticated" colliding beams (incl. "single pass").**
- **Superconductivity for magnets and RF.**
- **Development and wide use of beam cooling methods.**
- **Polarized beams, esp. in colliders, including longitudinal polarization.**
- **Impedance hygiene progress ➔ short and intense bunches.**
- **"Electron cloud" instability suppression.**
- **Digital bunch-by-bunch feedbacks ➔ to suppress instabilities.**
- **Improved ultra-high vacuum technology.**
- **Energy recovery linacs and recyclers.**
- High power targetry – yet at the start.
- Plasma (wake-field) accelerators (still in infancy – but promises high!)

A.Skrinsky
(Novosibirsk**)**
EPS05

Super B Factory at KEK



8 GeV
Positron beam
4.1 A

3.5 GeV
Electron beam
9.4 A

$\rightarrow$ **L = 4×10^{35}/cm^2/sec**

A.Skrinsky
(Novosibirsk)
EPS05

The International Linear Collider

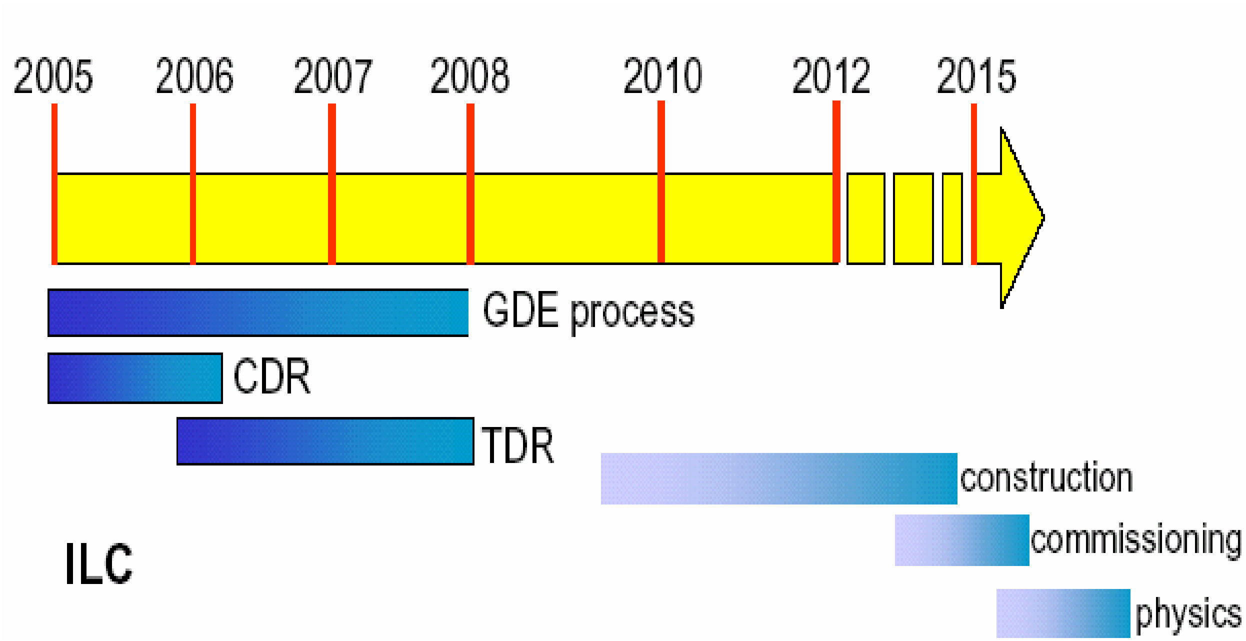
This will be the instrument that can carry out precision studies of the physics found at the LHC.

Cold technology has been chosen for the core accelerator.

A Global Design Effort has been launched.

The Global Design Effort

Formal organization begun at LCWS 05 at Stanford in March 2005 when B.Barish became director of the GDE



Technically Driven Schedule

Barish EPS05

It was an interesting conference… and we are all looking forward to exciting years.

All mistakes are mine…