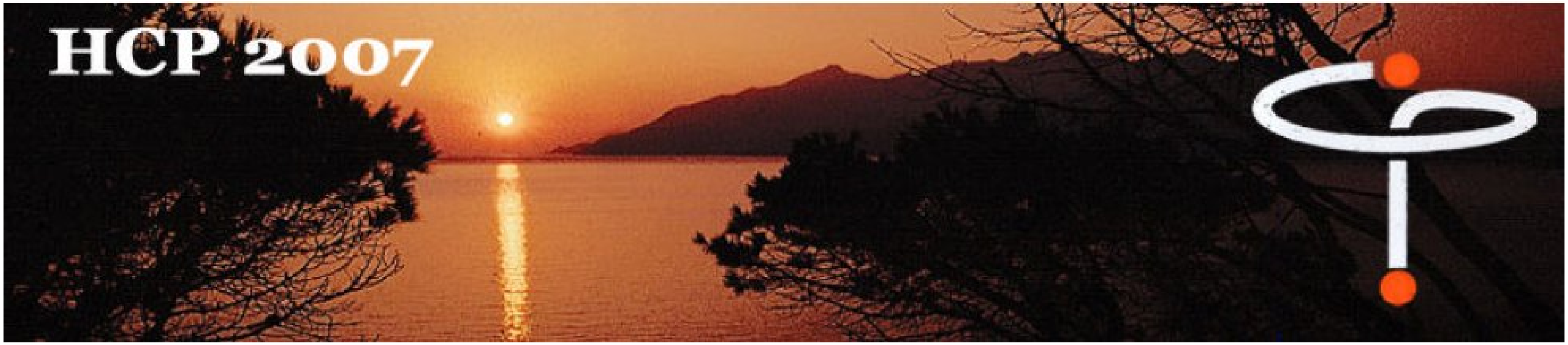


Hadron Collider Physics Symposium 2007

La Biodola, Isaola d'Elba (Italy). May 20-26, 2007

https://indico.pi.infn.it/conferenceDisplay.py?confId=0

Conference Summary:
What I found interesting and what seems important.

Jean-Roch VLIMANT

Conference Outlines

Agenda server:

https://indico.pi.infn.it/conferenceOtherViews.py?confId=0&view=standard&showDate=all&showSession=all&detailLevel=contribution

- Introduction
- Top and electroweak physics
- First measurements at LHC
- Heavy flavour physics
- Computing tools and analysis architectures
- Heavy ions collisions
- QCD and diffractive physics
- S-LHC and beyond
- Higgs searches
- Physics beyond the standard model
- Conclusions

Summary Outline

- Hadron collider saga
- HEP Computing
- Top Physics
- Higgs Searches
- Cross sections
- Forward physics
- QCD background in analysis

Tevatron

Hadron collider saga

More Uniform Pbar Intensities from Recycler

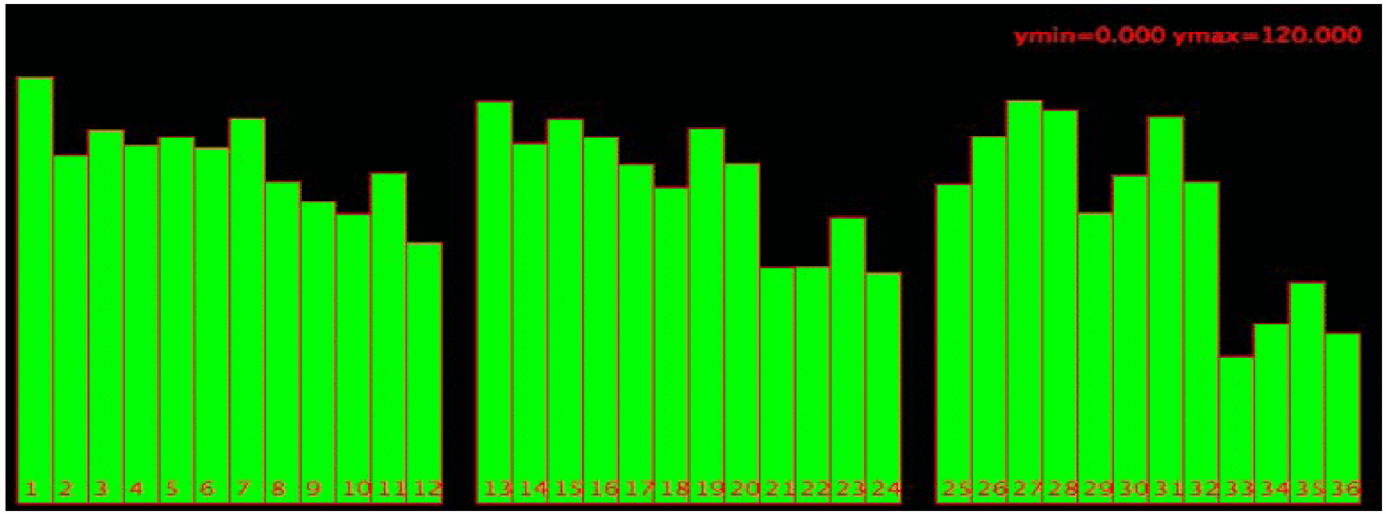
Store 5008

Without correction:

100% variation

25% RMS

Large variations in tune shifts and luminosity



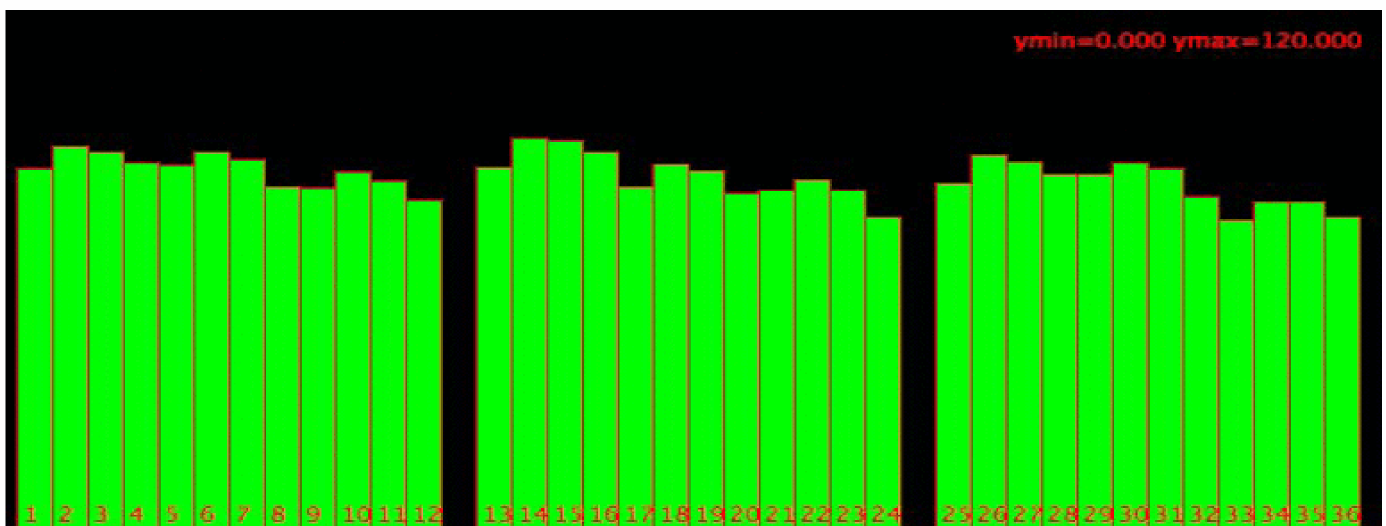
Intensities of 36 Pbar Bunches in Tevatron

Store 5245

With correction:

25% variation

7% RMS

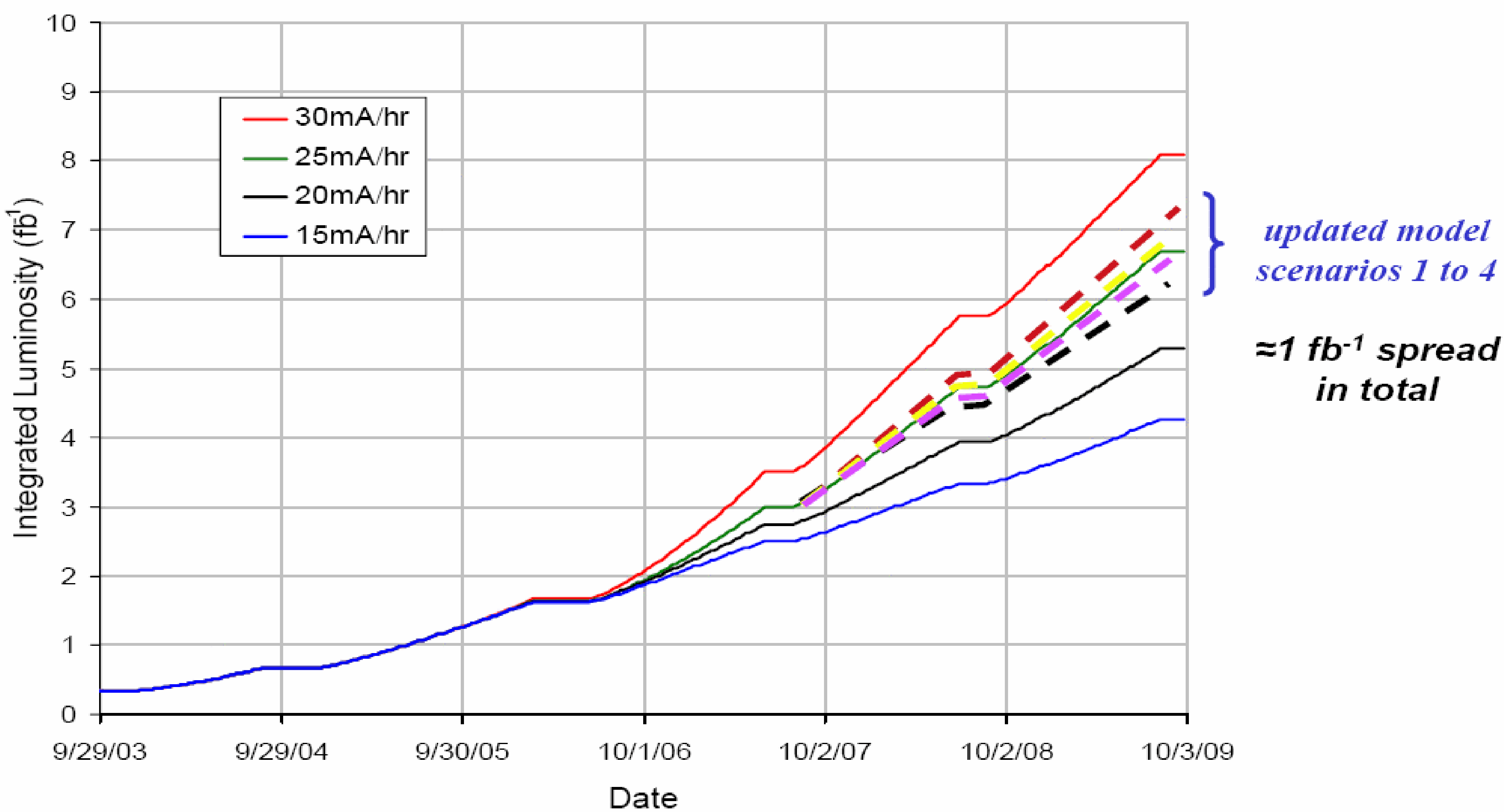


R. Moore

Tevatron

Hadron collider saga

Luminosity Projections with Updated Model Scenarios

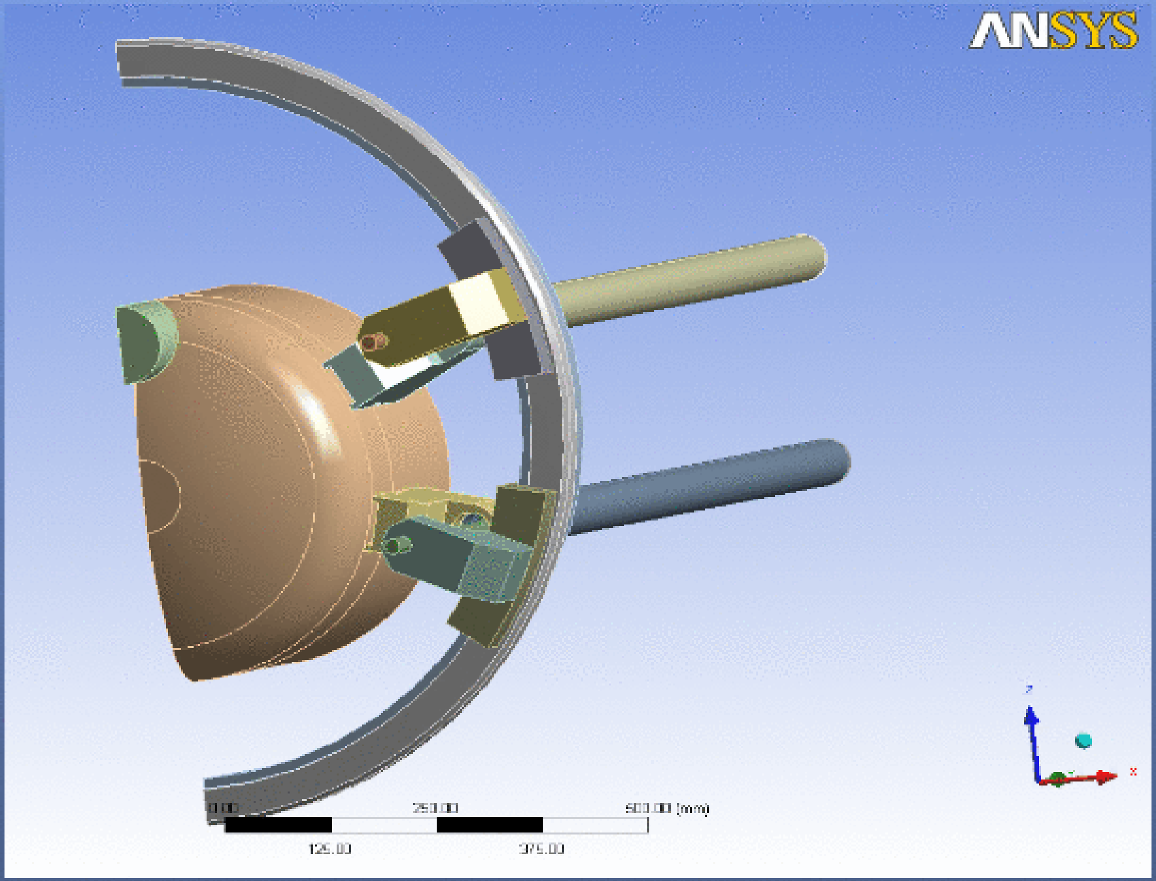


R. Moore

Hadron collider saga

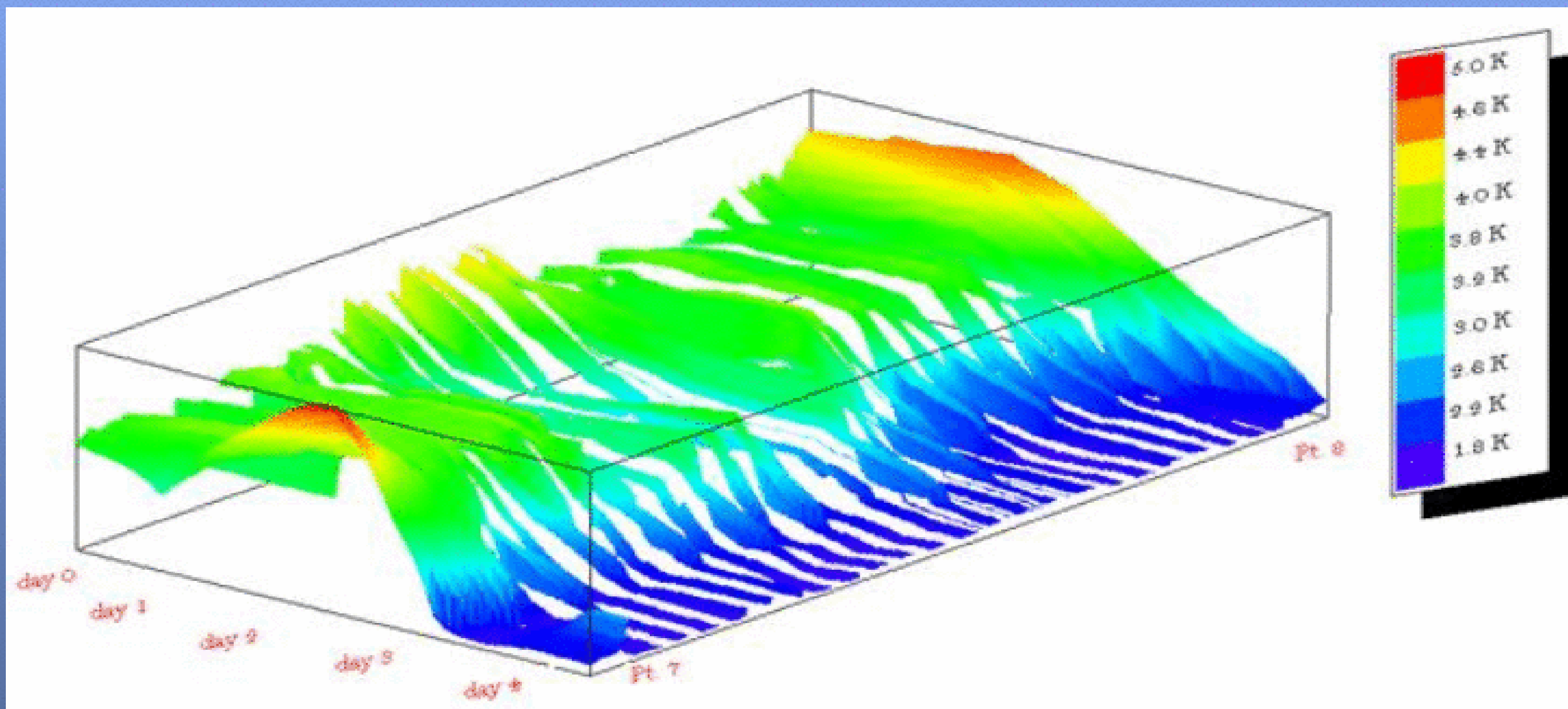
Repair cartridge

- Affixed at Q1 non-IP end and at Q3 IP end
- Transfer load at all temperatures
- Limits support deflections
- Compound design with Invar rod and aluminium alloy tube
- Attached with brackets to cold mass and cryostat outer vessel



Hadron collider saga

First cool-down of Sector 7-8

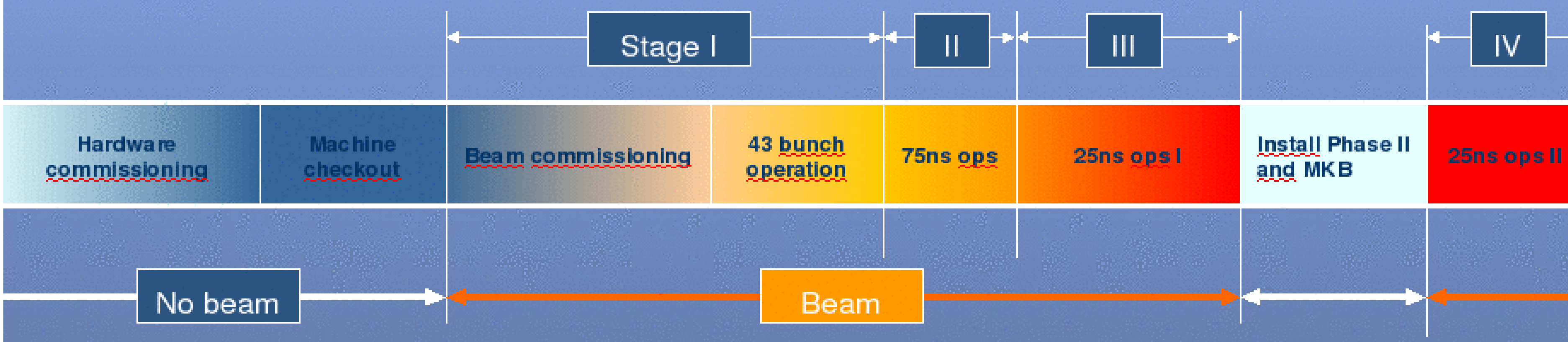


Magnet temperature profile along Sector 7-8 during final cool down to He II

LHC

Hadron collider saga

Staged commissioning plan for protons (R. Bailey)



I. **Pilot physics run**
- First collisions
- 43 bunches, no crossing angle, no squeeze, moderate intensities
- Expected performance ~10^{31} cm^{-2} s^{-1} at ~1 event/crossing
- Push performance (156 bunches, partial squeeze in 1 and 5, push intensity)
- Performance limit 10^{32} cm^{-2} s^{-1} (event pileup)

II. **75ns operation**
- Establish multi-bunch operation, moderate intensities
- Relaxed machine parameters (squeeze and crossing angle)
- Expected performance ~10^{32} cm^{-2} s^{-1} at ~1 event/crossing
- Push squeeze and crossing angle
- Performance limit 10^{33} cm^{-2} s^{-1} (event pileup)

III. **25ns operation I**
- Nominal crossing angle
- Push squeeze
- Increase intensity to 50% nominal
- Performance limit 2 10^{33} cm^{-2} s^{-1}

IV. **25ns operation II**
- Push towards nominal performance

Ph. Lebrun

LHC

Hadron collider saga

General schedule

- Engineering run originally foreseen at end 2007 now precluded by delays in installation and equipment commissioning.
- 450 GeV operation now part of normal setting up procedure for beam commissioning to high-energy
- General schedule being reassessed, accounting for inner triplet repairs and their impact on sector commissioning
  - All technical systems commissioned to 7 TeV operation, and machine closed April 2008
  - Beam commissioning starts May 2008
  - First collisions at 14 TeV c.m. July 2008
  - Pilot run pushed to 156 bunches for reaching 10^{32} $cm^{-2}.s^{-1}$ by end 2008
  - winter 2008-09 shutdown to complete collimation system and dilution kickers, thus allowing high intensity operation
- No provision in success-oriented schedule for major mishaps, e.g. additional warm-up/cooldown of sector

Ph. Lebrun

sLHC

Hadron collider saga

parameter	symbol	25 ns, small β*	50 ns, long
transverse emittance	ε [μm]	3.75	3.75
protons per bunch	N_b [10^{11}]	1.7	4.9
bunch spacing	Δt [ns]	25	50
beam current	I [A]	0.86	1.22
longitudinal profile		Gauss	Flat
rms bunch length	σ_z [cm]	7.55	11.8
beta* at IP1&5	β* [m]	0.08	0.25
full crossing angle	θ_c [μrad]	0	381
Piwinski parameter	$\phi=\theta_c\sigma_z/(2^*\sigma_x^*)$	0	2.0
hourglass reduction		0.86	0.99
peak luminosity	L [10^{34} cm^{-2}s^{-1}]	15.5	10.7
peak events per crossing		294	403
initial lumi lifetime	τ_L [h]	2.2	4.5
effective luminosity ($T_{turnaround}$=10 h)	L_{eff}[10^{34} cm^{-2}s^{-1}]	2.4	2.5
	$T_{run,opt}$ [h]	6.6	9.5
effective luminosity ($T_{turnaround}$=5 h)	L_{eff}[10^{34} cm^{-2}s^{-1}]	3.6	3.5
	$T_{run,opt}$ [h]	4.6	6.7
e-c heat SEY=1.4(1.3)	P [W/m]	1.04 (0.59)	0.36 (0.1)
SR heat load 4.6-20 K	P_{SR} [W/m]	0.25	0.36
image current heat	P_{IC} [W/m]	0.33	0.78
gas-s. 100 h (10 h) τ_b	P_{gas} [W/m]	0.06 (0.56)	0.09 (0.9)
extent luminous region	σ_l [cm]	3.7	5.3
comment		D0 + crab (+ Q0)	wire comp.

New upgrade scenarios

challenges

injector upgrade

Crossing with large Piwinski angle

aggressive triplet

compromises between # of pile up events and heat load

W. Scandale

vLHC

Hadron collider saga

Very Large Hadron Collider

Parameters of the VLHC

	Stage 1	Stage 2
Total Circumference (km)	233	233
Center-of-Mass Energy (TeV)	40	200
Number of interaction regions	2	2
Peak luminosity ($cm^{-2}s^{-1}$)	1×10^{34}	2.0×10^{34}
Dipole field at collision energy (T)	2	11.2
Average arc bend radius (km)	35.0	35.0
Initial Number of Protons per Bunch	2.6×10^{10}	5.4×10^{9}
Bunch Spacing (ns)	18.8	18.8
β^* at collision (m)	0.3	0.5
Free space in the interaction region (m)	± 20	± 30
Interactions per bunch crossing at L_{peak}	21	55
Debris power per IR (kW)	6	94
Synchrotron radiation power (W/m/beam)	0.03	5.7
Average power use (MW) for collider ring	25	100

W. Scandale

Hadron collider saga

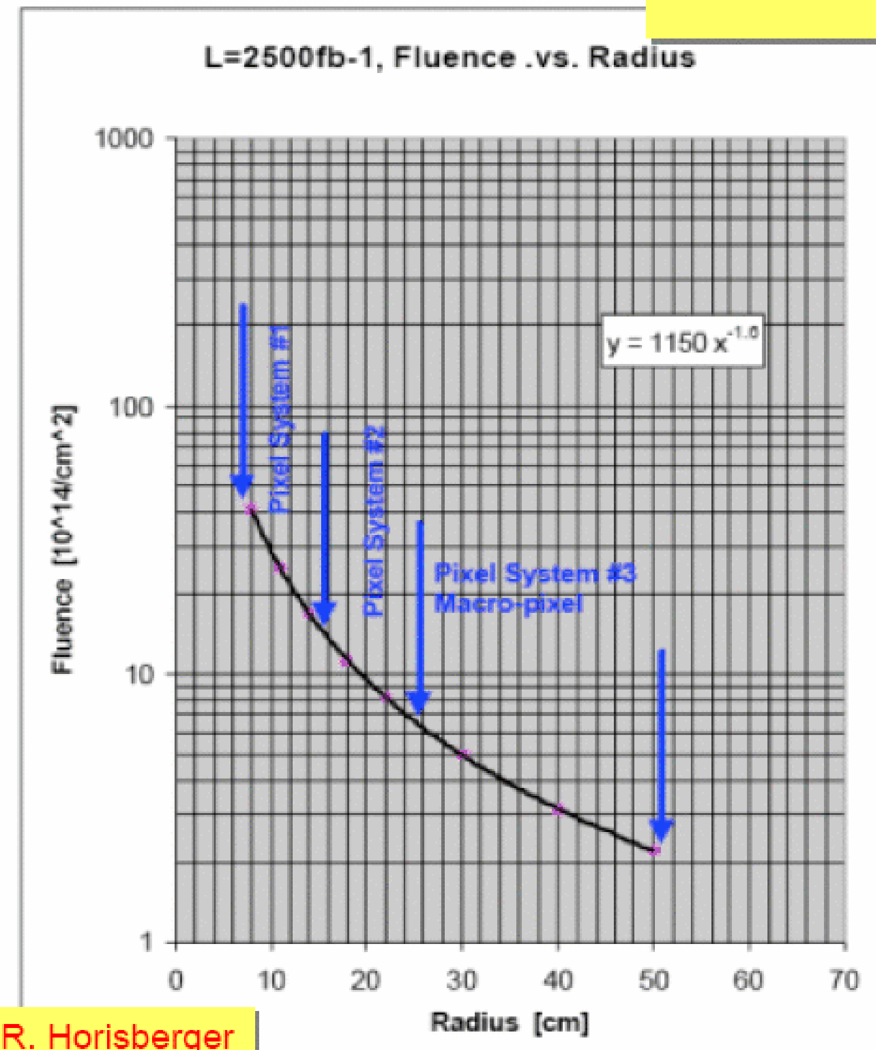
- Tevatron
  - has reach its instantaneous luminosity goal
  - Maximize integrated luminosity : ~6 fb^{-1} foreseen by 2009 (hoping for 8 fb^{-1})
  - Not much room for improvements
- LHC
  - Tight schedule but on track.
  - 900 GeV run period shorter than before.
  - Beam expected in May 2008.
- Future of hadron colliders
  - SLHC, dLHD, tLHC
    - Heat load is a limiting factor
    - Luminosity leveling is very important
    - Up to 400 pile-up events
  - VLHC (at Fermilab)
    - Usual technology, but bigger. Still challenging...

sLHC

Hadron collider saga

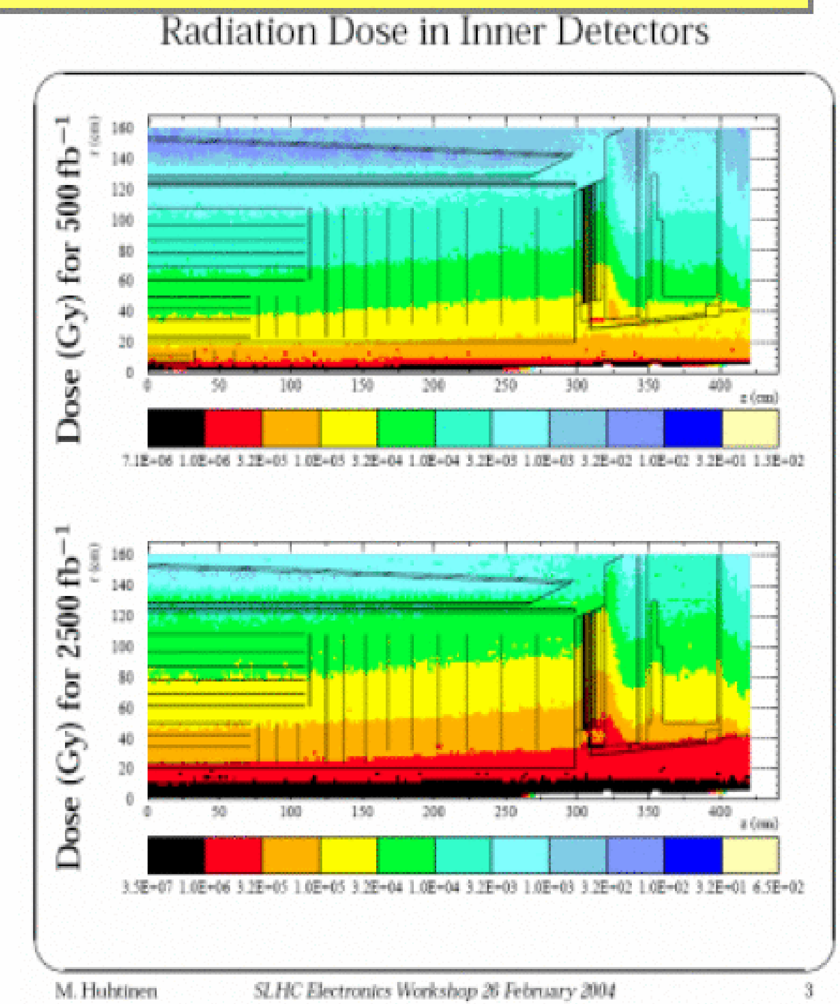
Radiation environment for trackers

Except for the very innermost layers current technologies should survive SLHC



R. Horisberger

Radiation Dose in Inner Detectors



J. Nash

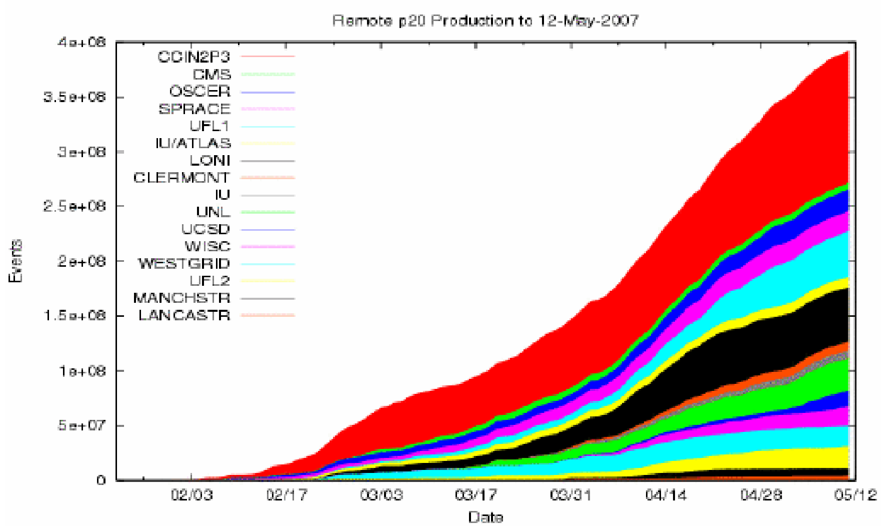
Hadron collider saga

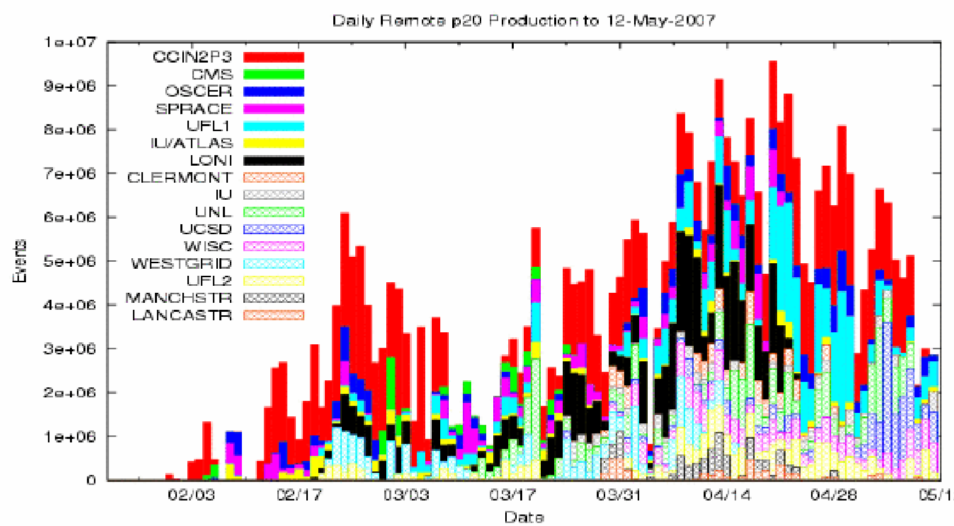
- LHC detector R&D
  - sLHC beam condition equivalent to heavy ion collision
  - Need to include tracker primitives at trigger level
  - Huge radiation damage for innermost layers
  - Ongoing R&D to keep up with upgrade plans

HEP computing

Example: D0 Reprocessing 2007

- OSG Trouble shooting team setup to solve problems. → Much higher efficiencies seen at OSG sites
- SAM Grid team also solved many causes of inefficiencies
- Successful reprocessing effort: D0 able to process up to 8M/day when all sites available and 4M in average per day off-site: higher rate as originally anticipated





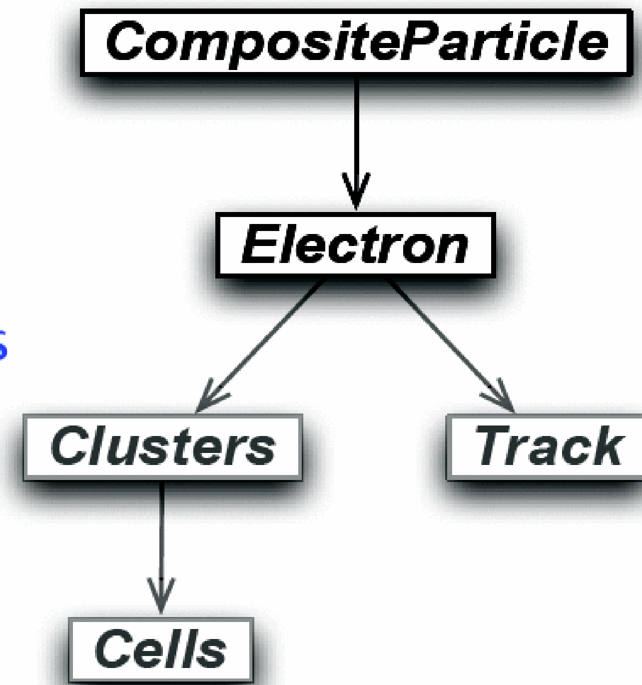
V. Shary

HEP computing

Constituent Navigation

A common feature of our EDM classes is the ability to Navigate from an object to its constituents

- Relational structure is decoupled from physical location in the files!



The ESD will have cells, clusters, & tracks

The AOD will have electrons, clusters & tracks, but will not have the cells

The DPD may have a composite particle and the electrons it was made from, but not store the clusters or track

It is possible to navigate from Composite Particle to cells if one has access to ESD & AOD

- navigating between files called “Back Navigation”

ATLAS/LHCb

HEP computing

Table 2-2 The assumed event data sizes for various formats, the corresponding processing times and related operational parameters.

Item	Unit	Value
Raw Data Size	MB	1.6
ESD Size	MB	0.5
AOD Size	kB	100
TAG Size	kB	1
Simulated Data Size	MB	2.0
Simulated ESD Size	MB	0.5
Time for Reconstruction (1 ev)	kSI2k-sec	15
Time for Simulation (1 ev)	kSI2k-sec	100
Time for Analysis (1 ev)	kSI2k-sec	0.5
Event rate after EF	Hz	200
Operation time	seconds/day	50000
Operation time	days/year	200
Operation time (2007)	days/year	50
Event statistics	events/day	10^7
Event statistics (from 2008 onwards)	events/year	$2{\cdot}10^9$

K. Cranmer

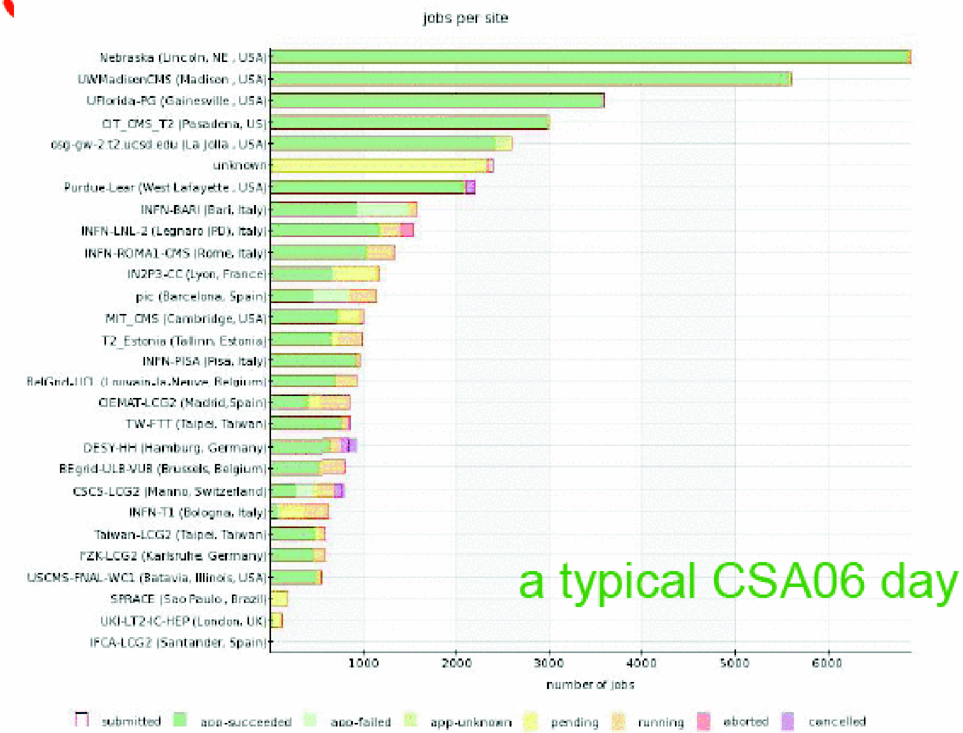
HEP computing

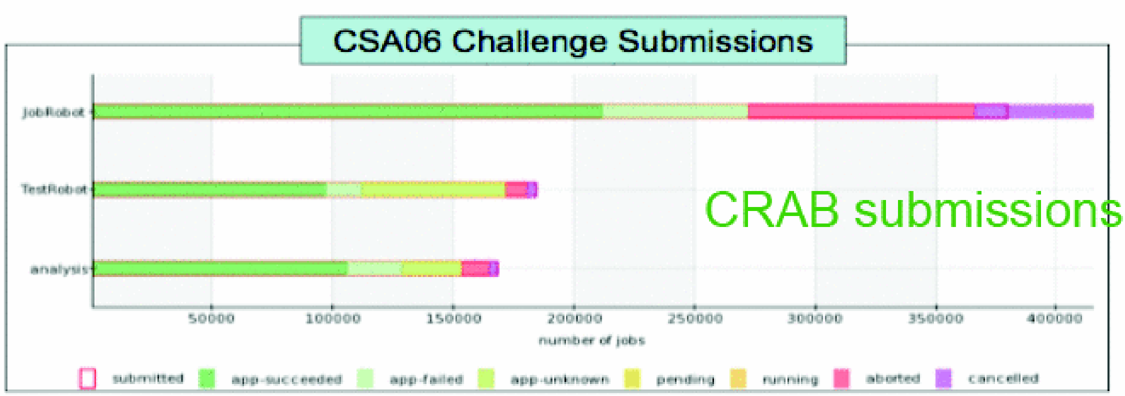
CSA06: job submission

>50K jobs/day in final week

- 30K/day robot jobs
- production jobs managed by Production Agent
- analysis jobs submitted via CRAB to the Grid

90% job efficiency





M. Paganoni

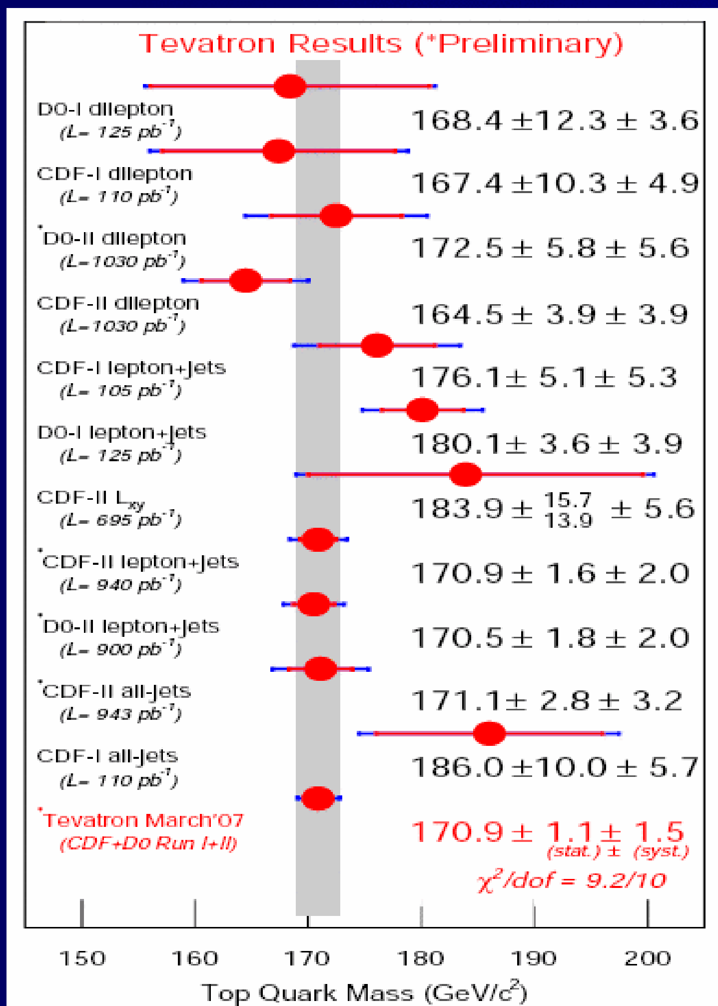
HEP computing

- ATLAS and LHCb share the same framework (ATHENA)
  - Not ROOT based (prior to ROOT)
- Similar reco/analysis global architecture
- CMS computing: 50 to 100 nodes clusters as a starting point
- Some high scope work has been duplicated yet (GRID related mostly)
  - DIRAC, CRAB, GANGA, pATHENA
-

Tevatron

Top Quark Physics

World Average



$$m_t = 170.9 \pm 1.8 \text{ GeV}$$

The total uncertainty in the top quark mass is ≈ 1%

$$m_t^{all-hadronic} = 172.2 \pm 4.1 \text{ GeV}$$

$$m_t^{\ell+jets} = 171.2 \pm 1.9 \text{ GeV}$$

$$m_t^{\ell\ell+jets} = 163.5 \pm 4.5 \text{ GeV}$$

The top quark mass in the different analysis channels are consistent with one other

TEVEWWG hep-ex/0703034

M. Begel

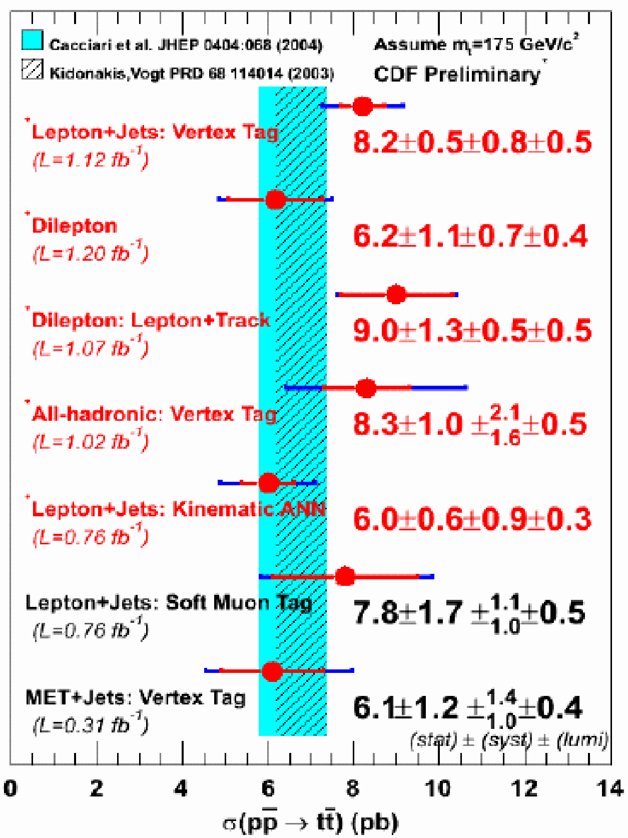
Top Quark Physics

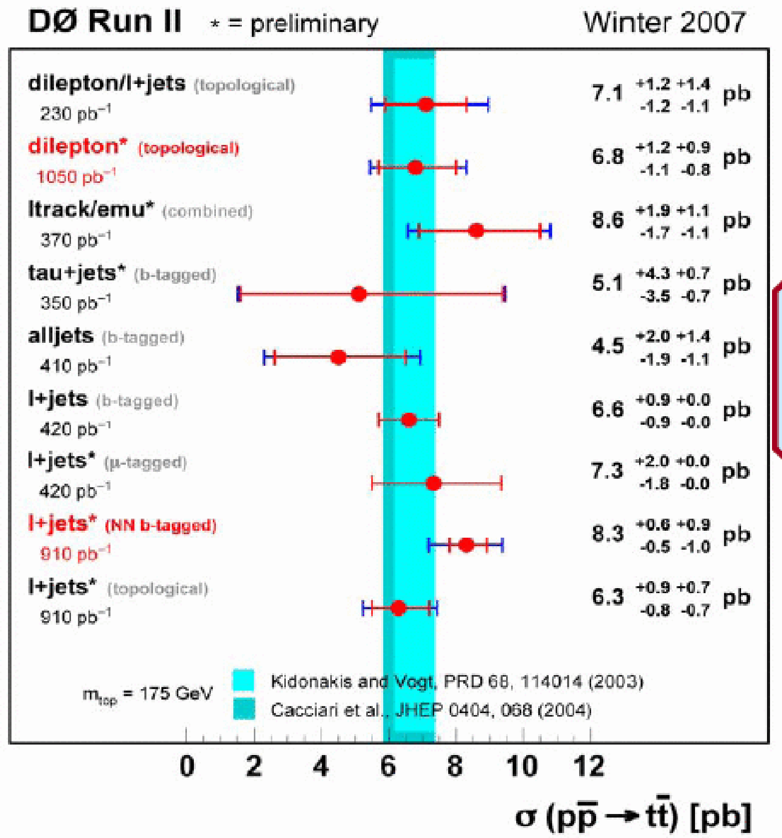
And to know the top mass…

- Lesson from ATLAS & CMS
  - Main quoted Systematics are:
    - ATLAS DiLeptons → PDF ⇒ 1.2 GeV on m_{top}
    - ATLAS Single Lepton → bJES 1% ⇒ 0.7 GeV on m_{top}
    - ATLAS Full Hadronic → FSR ⇒ 2.8 GeV on m_{top}
    - CMS DiLeptons → JES 1% ⇒ 1 GeV on m_{top}
    - CMS Single Lepton → bJES 2% ⇒ 1.2 GeV on m_{top}
    - CMS Full Hadronic → JES 1% ⇒ 2.3 GeV on m_{top}
  - Both for ATLAS and CMS, JES and bJES errors ~1% are extrapolation → Long Term Program to control JES at this level
  - Why almost only Iterative Cone Algo has been investigated?
    - Lack of Corrections functions…
    - Historical tradition…
  - We have more sophisticated/robust algos (FastJet, midPoint…)… let's use them!
- Lesson from Common Sense… and Tevatron
  - To reach Tevatron precision is not a few months task…

Top Quark Physics

Cross-section Summary





Measurements in all channels using different methods are consistent

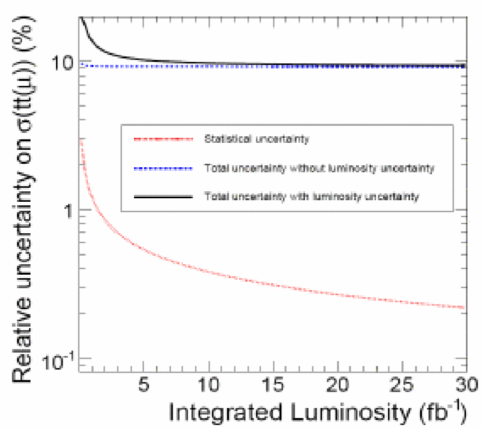
- Uncertainties in Lepton+Jets cross-section measurements becoming comparable to the theoretical uncertainty
- Current best Lepton+Jets cross section measurement is limited by systematic uncertainties ⇒ *Major sources: luminosity (~6%), b-tagging (~6%), Jet Energy Scale (~4-6%), Parton Density Functions, signal and background modeling*

Top Quark Physics

INFN Istituto Nazionale di Fisica Nucleare Sezione di Perugia

$t\bar{t}$ xSection @ 1fb^{-1}

- Main channel is again the SemiLeptonic $t\bar{t}$ decay
- At 1fb^{-1} we have already reached the point were only few systematic effects really counts…
  - bTag efficiency (used a conservative 7% → hope to reach few % level)
  - PDF → 3.4%
  - PileUp → can we do better than 3.2%?
  - Luminosity… depend on Luminosity



CMS

	$\Delta\hat{\sigma}_{t\bar{t}(\mu)}/\hat{\sigma}_{t\bar{t}(\mu)}$
Statistical Uncertainty (1fb^{-1})	1.2%
Statistical Uncertainty (5fb^{-1})	0.6%
Statistical Uncertainty (10fb^{-1})	0.4%
Simulation samples (ϵ_{sim})	0.6%
Simulation samples (F_{sim})	0.2%
Pile-Up	3.2%
Underlying Event	0.8%
Jet Energy Scale (light quarks)	1.6%
Jet Energy Scale (heavy quarks)	1.6%
Radiation	2.6%
Fragmentation	1.0%
b-tagging	7.0%
Parton Density Functions	3.4%
Background level	0.9%
Total Systematic Uncertainty	9.2%
Integrated luminosity (1fb^{-1})	10%
Integrated luminosity (5fb^{-1})	5%
Integrated luminosity (10fb^{-1})	3%
Total Uncertainty (1fb^{-1})	13.7%
Total Uncertainty (5fb^{-1})	10.5%
Total Uncertainty (10fb^{-1})	9.7%

Top Quark Physics

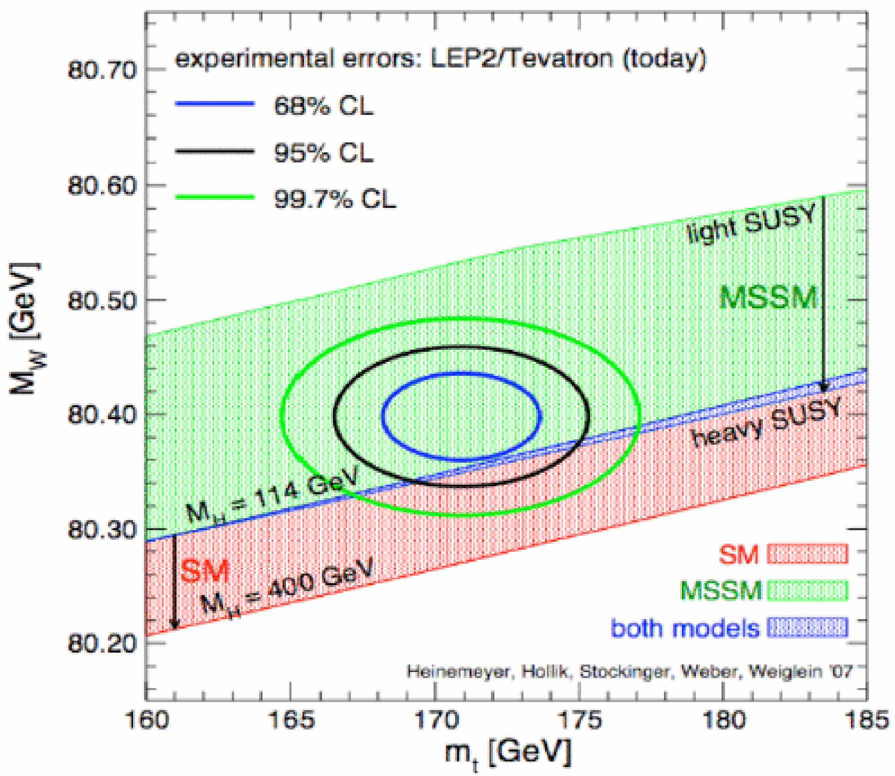
- Dominant systematics is jet energy scale.
  - LHC can only do little better than Tevatron on same amount of luminosity (although Xsec is 100 times more)
  - Definitely a good idea to avoid this systematics (Lxy)
- Of course, cross section measurement relies on luminosity measurement precision
- There will be time before top quark precision measurement at LHC, except if good strategy is taken.
- Now is time to know exactly what is the meaning of the top mass.

Tevatron

Higgs Searches

Implications for the Standard Model

- Current state of m_t, m_W, m_H plane



- m_W up from 80392 to 80398 MeV
- Uncertainty from 29 to 25 MeV
- SM prediction for Higgs from:

$$85^{+39}_{-28}\text{ GeV} \Rightarrow 76^{+33}_{-24}\text{ GeV LEPEWG}$$

- The 95%CL upper limit on m_H drops from 199 to 182 GeV
  - Includes direct search lower bound and recent top mass

Tevatron

Higgs Searches

21
G. Hesketh

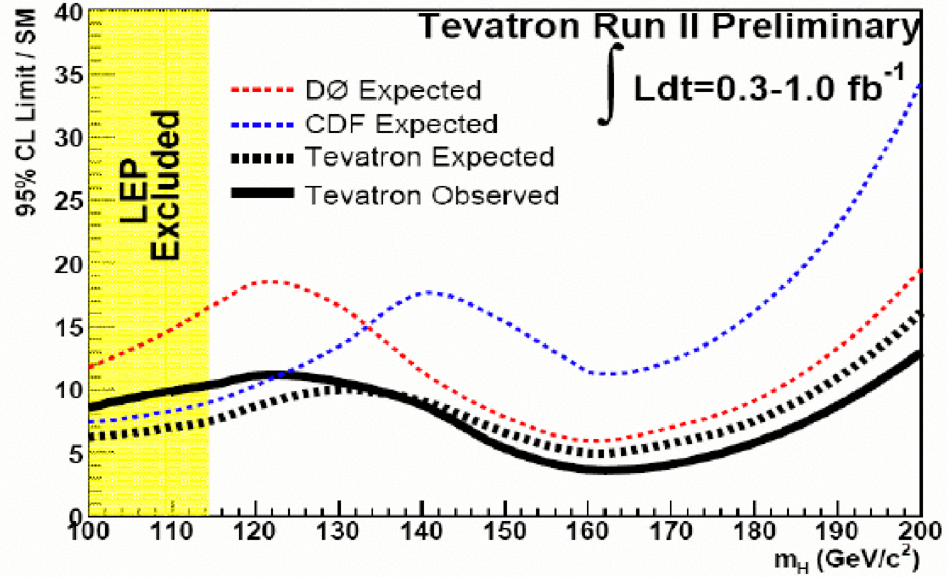
Combinations

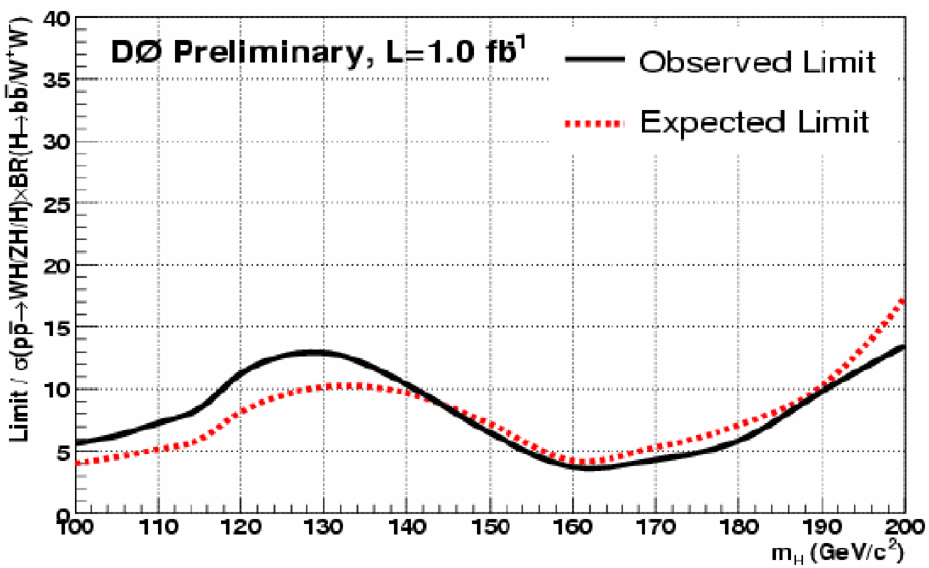
Tevatron combination in Summer '06.

Been working hard since then!
- improving sensitivity in all channels
  - looser lepton ID
  - trigger redundancy
  - di-jet mass resolution
- Advanced analysis techniques:
  - neural nets
    - b-tagging
    - signal – background separation
  - matrix element methods
- accelerator delivered > 2x luminosity

Many of these results are new
  - combinations ongoing.

- DZero alone now has tighter limits:
  - ratios to SM, obs (exp):
  - 8.4 (5.9) @ 115 GeV
  - 3.7 (4.2) @ 160 GeV

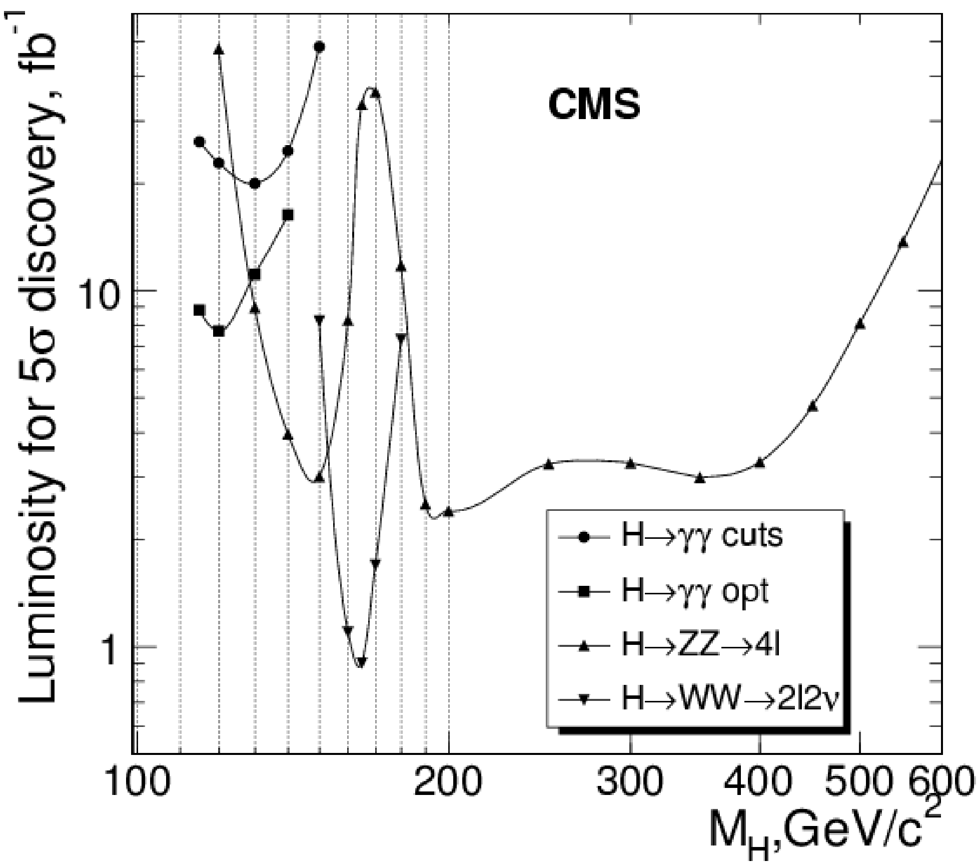




G. Hesketh

Higgs Searches

- More precise top mass and W mass
  - MSSM Higgs seems favored by EW fit : mH~80 GeV
- First Higgs exclusion (or observation) in next year sample at Tevatron
- LHC experiments show 10-30 fb^{-1} significance expectations
  - Should have shown the expectation of the required luminosity of 5σ discovery

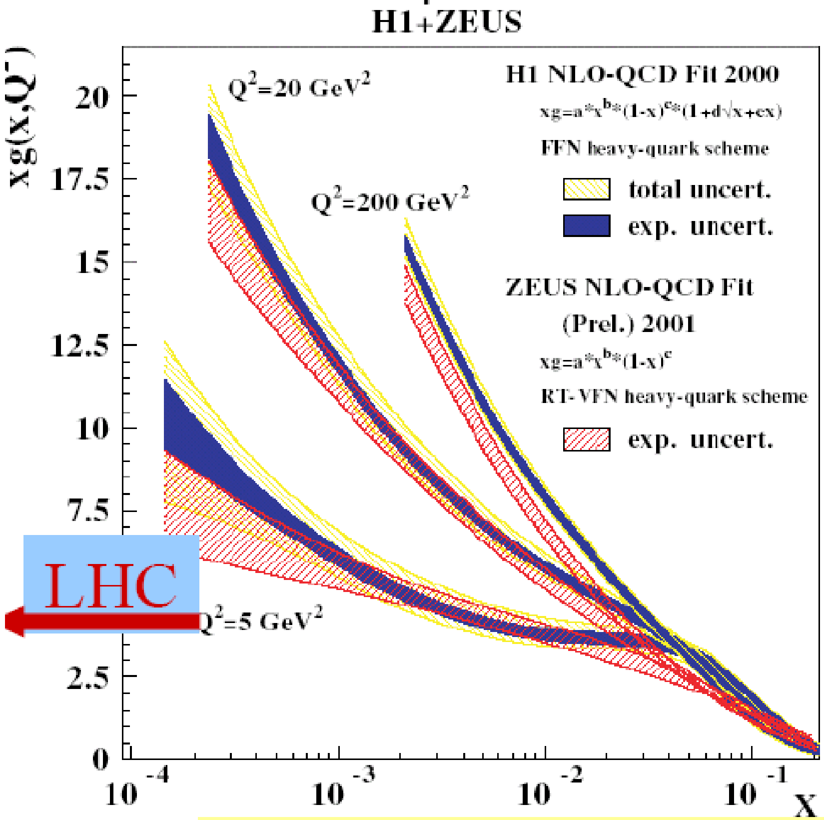


K. Cranmer

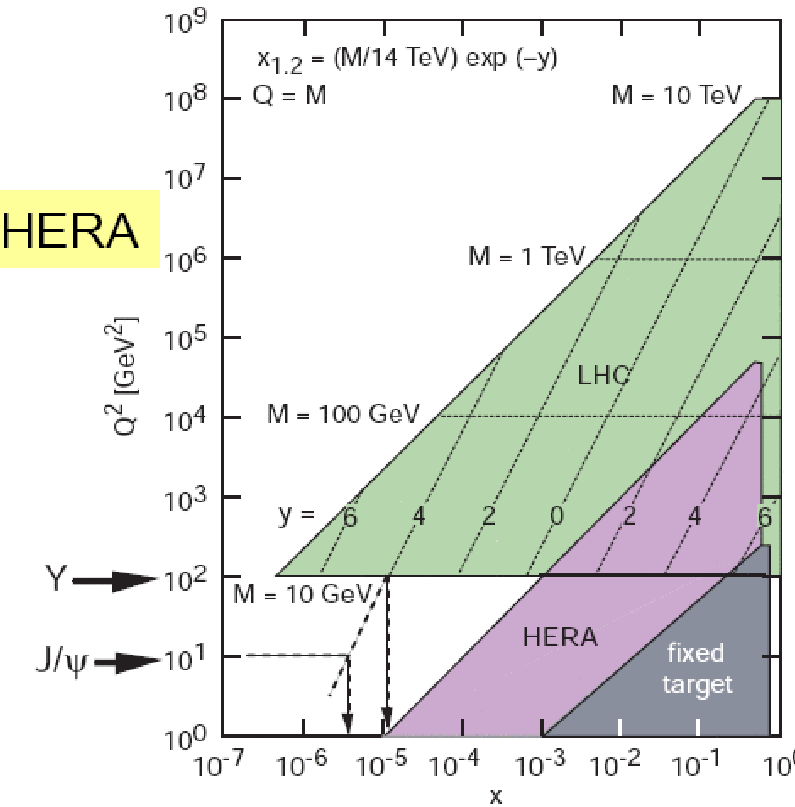
Cross sections

Is this new regime accessible in pp collisions at LHC?

- As low x (~Q^2/s) values are reached, **both the parton density and the parton transverse sizes increase**, there must be a scale (at $q^2 < Q_s^2$) where partons overlap. When this happens, the increase in the number of small x partons becomes limited by gluon fusion ($gg \rightarrow g$).



Beyond HERA



What is new at LHC is that this overlap should occur for relatively high p_T partons ~ 1 GeV/c (Kharzeev Q_s^2 ~ 0.7 GeV^2), where the effect must be visible

J.-P. Revol

Cross sections

Observing parton saturation at LHC

- Therefore, at 14 TeV, **we expect**:

$$\frac{\sigma_{tot}(14TeV)}{\sigma_{tot}(0.9TeV)} = \frac{\left.\frac{dn}{d\eta}\right|_{\eta=0}(14TeV)}{\left.\frac{dn}{d\eta}\right|_{\eta=0}(0.9TeV)} + small\ corrections$$

- The good news is that both of these ratios, can be measured at LHC to a precision of a few % (ALICE multiplicity: 3-4 % absolute, 2.5 % ratio; TOTEM total cross section: 1%) **Therefore, this can be precisely tested, provided we get some data at 0.9TeV.**

- Definite predictions are available, such as with the "immorally successful" Quark Gluon String Model of Kaidalov, where the cross section ratio is 1.55 while the central multiplicity ratio is 1.67, a 8% difference!

- In passing, we will verify that pp and ppbar do behave the same at high energy:

  At $\eta=0$, $(dN_{ch}/d\eta)_{ap\text{-}p} - (dN_{ch}/d\eta)_{p\text{-}p} \sim (s/s_0)^{-1/2}$ (from Regge theory)

  - at $s \sim 10^3\ GeV^2$ it's measured to be 1%, therefore, at 900 GeV, we expect:

  $(dN_{ch}/d\eta)_{ap\text{-}p} - (dN_{ch}/d\eta)_{p\text{-}p} = 0.001$

  - The precision of anti-p–p measurement at SppbarS was a few %, therefore, it is sufficient to measure with similar precision, the 1/1000 level cannot be tested.

Cross sections

An experimenters wishlist...

[from talk by Cambpell]

An experimenter's wishlist

- Hadron collider cross-sections one would like to know at NLO

Run II Monte Carlo Workshop, April 2001

Single boson	Diboson	Triboson	Heavy flavour
$W + \leq 5j$	$WW + \leq 5j$	$WWW + \leq 3j$	$t\bar{t} + \leq 3j$
$W + b\bar{b} + \leq 3j$	$WW + b\bar{b} + \leq 3j$	$WWW + b\bar{b} + \leq 3j$	$t\bar{t} + \gamma + \leq 2j$
$W + c\bar{c} + \leq 3j$	$WW + c\bar{c} + \leq 3j$	$WWW + \gamma\gamma + \leq 3j$	$t\bar{t} + W + \leq 2j$
$Z + \leq 5j$	$ZZ + \leq 5j$	$Z\gamma\gamma + \leq 3j$	$t\bar{t} + Z + \leq 2j$
$Z + b\bar{b} + \leq 3j$	$ZZ + b\bar{b} + \leq 3j$	$WZZ + \leq 3j$	$t\bar{t} + H + \leq 2j$
$Z + c\bar{c} + \leq 3j$	$ZZ + c\bar{c} + \leq 3j$	$ZZZ + \leq 3j$	$t\bar{b} + \leq 2j$
$\gamma + \leq 5j$	$\gamma\gamma + \leq 5j$		$b\bar{b} + \leq 3j$
$\gamma + b\bar{b} + \leq 3j$	$\gamma\gamma + b\bar{b} + \leq 3j$		
$\gamma + c\bar{c} + \leq 3j$	$\gamma\gamma + c\bar{c} + \leq 3j$		
	$WZ + \leq 5j$		
	$WZ + b\bar{b} + \leq 3j$		
	$WZ + c\bar{c} + \leq 3j$		
	$W\gamma + \leq 3j$		
	$Z\gamma + \leq 3j$		

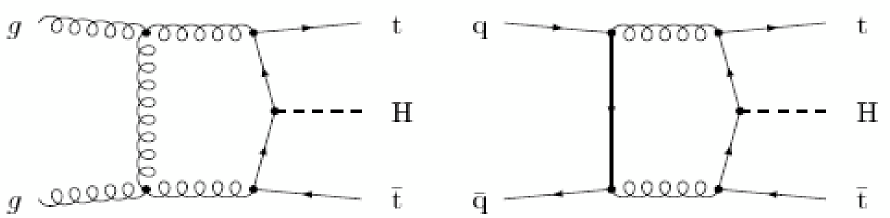
M. Krämer

Cross sections

An experimenters wishlist...

- Theorists reply: In your dreams...

- main bottleneck: tensor-reduction of Pentagon/Hexagon/Heptagon loop integrals, e.g.



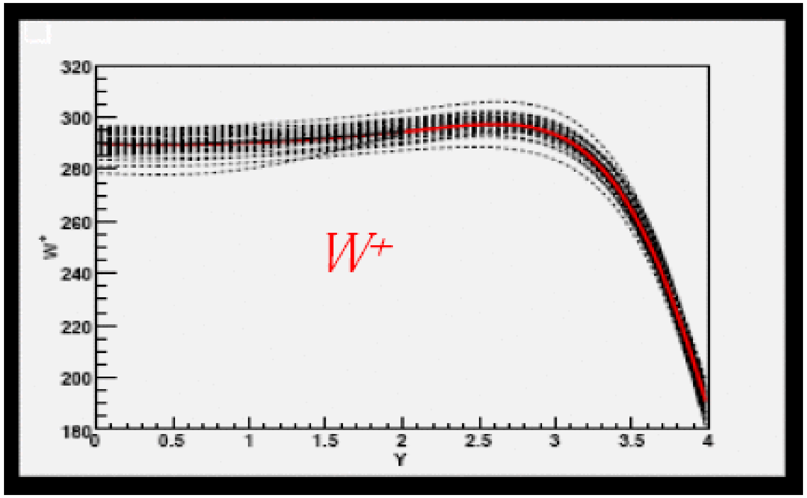
etc.

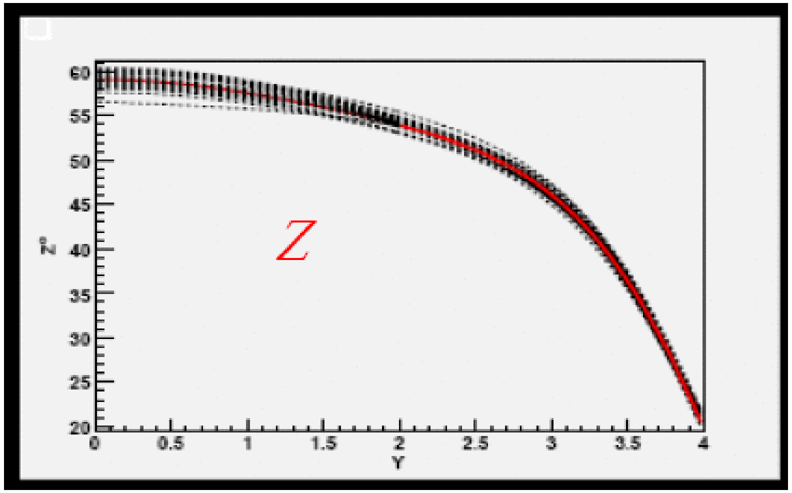
- NLO (parton-level) Monte Carlo programs will *not* be available for all potentially relevant (background) processes in the near future

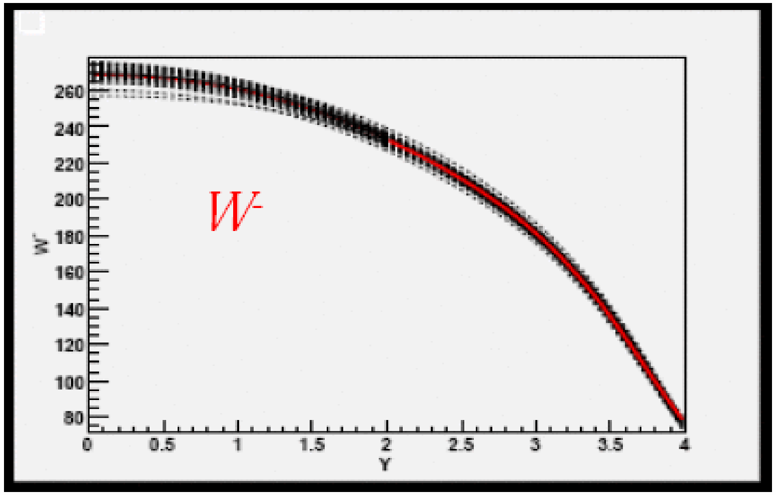
M. Krämer

Cross sections

W/Z rapidity distributions at the LHC







- Only positive y (symmetric in pp collision) is shown.
- The spread of 41 sets of CTEQ6.5 PDF is about 7% (not full error, calculated using quadratic form).

Not good as a standard luminosity monitor at the LHC

T. Tait for C.P Yuan

Cross sections

- **NEW** CTEQ6.5 pdfs
- Early test of Regge Theory and non saturation regime with early LHC data possible only if we get 900 GeV collisions
- **Not** all relevant SM background NLO parton level Monte Carlo will be available
  - Use reweighting and extrapolation
- W,Z production cross section is predicted at 7% level : not so good for standard candle.

Forward physics

pp Total Cross-Section

Current models predict for
14 TeV: 90 – 130 mb

Aim of TOTEM: ~ 1%
First year : ~5%

Luminosity independent method:

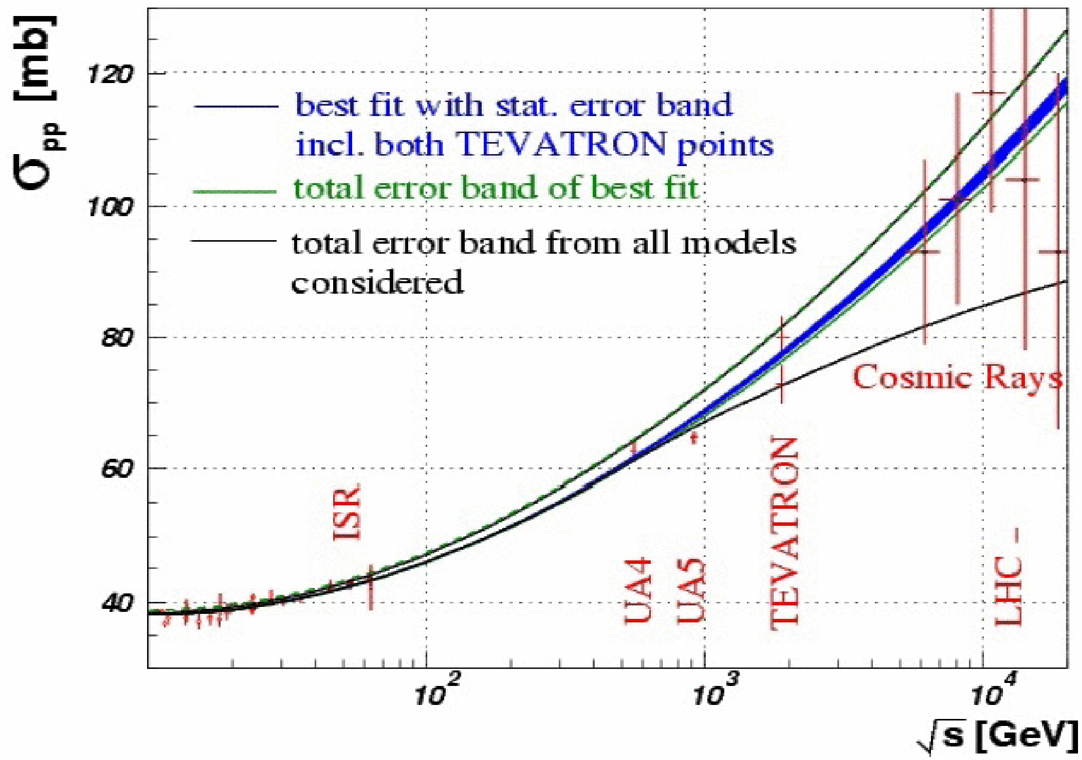
Optical Theorem $$L\sigma_{tot}^2 = \frac{16\pi}{1+\rho^2} \times \left.\frac{dN}{dt}\right|_{t=0}$$

$$L\sigma_{tot} = N_{elastic} + N_{inelastic}$$

⇩

$$\sigma_{tot} = \frac{16\pi}{1+\rho^2} \times \frac{(dN/dt)|_{t=0}}{N_{el} + N_{inel}}$$

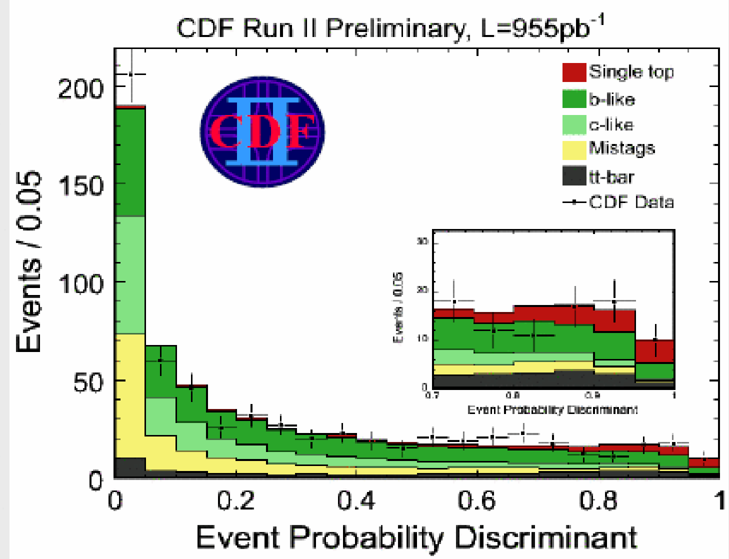
COMPETE Collaboration:

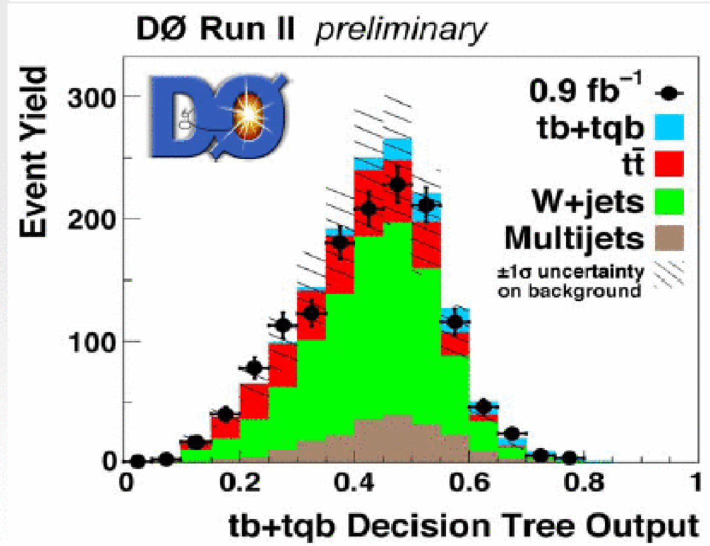


QCD background in analysis

Multivariate Analyses

	Multivariate Methods	Expected Significance Assuming SM Rates (Combined s+t channels)
CDF	Likelihood Discriminant	2.0σ
CDF	Neural Network (NN)	2.6σ
CDF	Matrix Element (ME)	2.5σ
DØ	Matrix Element (ME)	1.8σ
DØ	Bayesian NN	1.3σ
DØ	Boosted Decision Trees (DT)	2.1σ





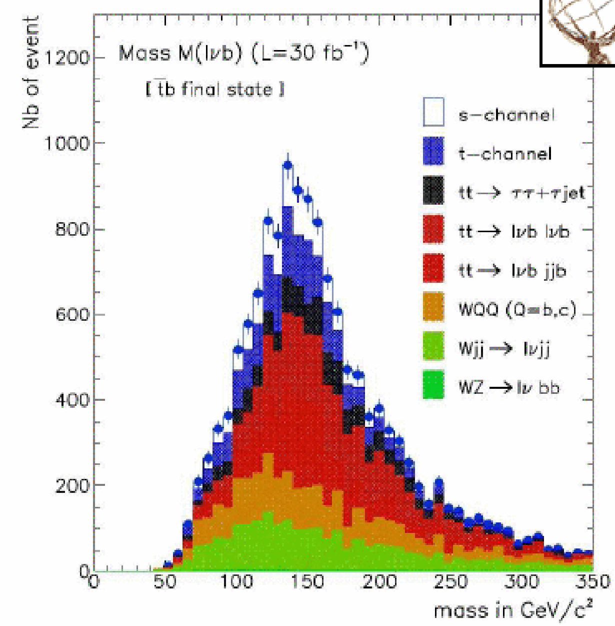
M. Datta

QCD background in analysis

Istituto Nazionale di Fisica Nucleare
Sezione di Perugia

Single Top @ 30 fb^{-1}

- Typical Selection cut:
  - 1 lepton, p_T>25GeV
  - High Missing E_T
  - ≥2 jets (at least 1 bJet)
- Separate Channels by (N_J;N_B) in final state:
  - t Channel → (N_J;N_B)=(2,1)
  - Wt Channel → (N_J;N_B)=(3,1)
  - s Channel → (N_J;N_B)=(2,2)



Channel	N_{events} After Sele	S/B	Main Systematic	δσ/σ stat	exp	bckgd theo	lumi
t-Channel $t\bar{b}q$ 2J-3J	2710 - 2680	~1.2	JES - bTag - ISR/FSR	1%	11%	6%	5%
Wt-Channel	18504	0.081	JES - bTag - ISR/FSR	1.5%	11%	9.1%	5%
s-Channel $t\bar{b} - \bar{t}b$	385 - 275	0.139 - 0.123	bTag - ISR/FSR	12%	12%	11%	5%

A. Santcocchia

QCD background in analysis

- Tevatron analysis often shows a QCD background, measured from data
- LHC analysis cannot obviously estimate it from data
  - ATLAS gets it from high rejection streaming of QCD Monte Carlo
  - CMS ? Need for a task force ? (existing task force ?)