Charged Higgs 2010
-Experimental summary and outlook-

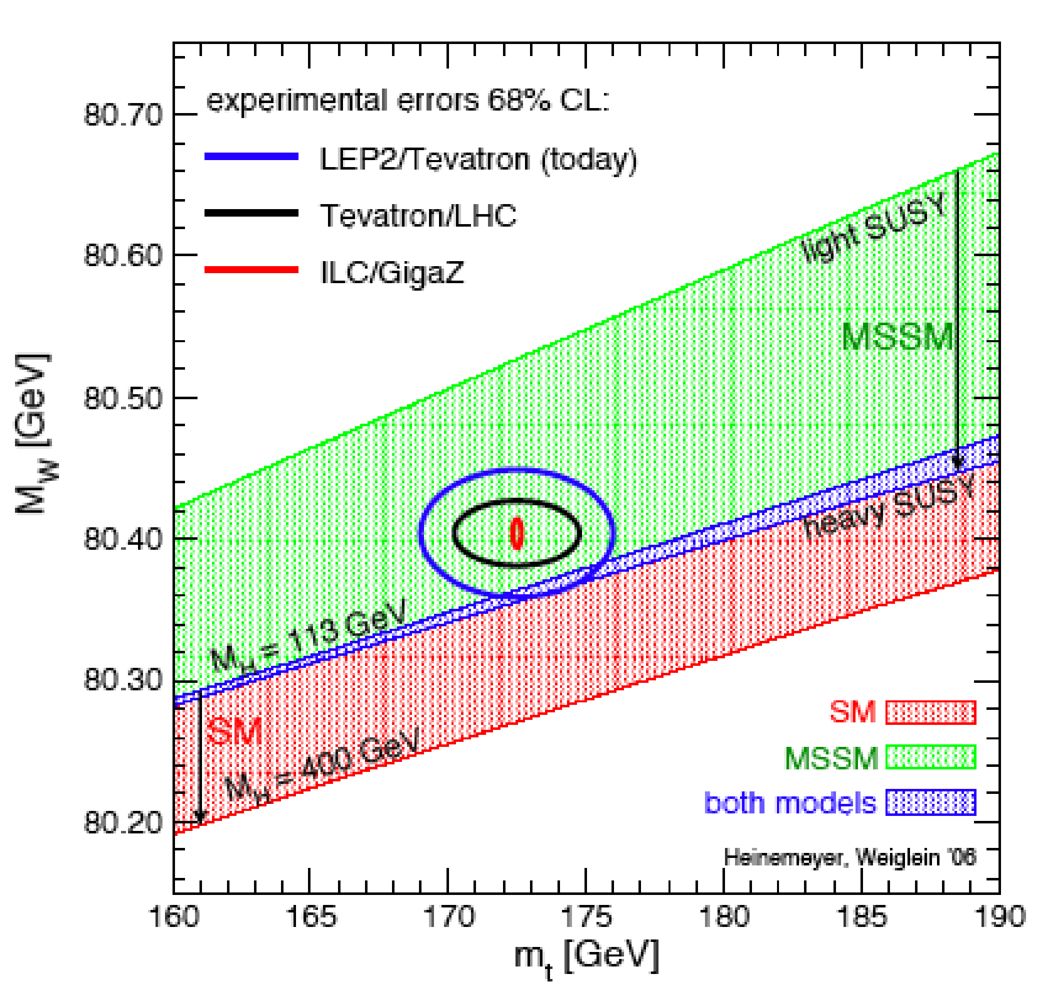
- Status of the accelerator
- ATLAS and CMS
  Detector performance with first data
- Results from the Tevatron
- Prospects for 2010/11 and beyond

CMS @ 2.36 TeV

Karl Jakobs
Physikalisches Institut
University of Freiburg / Germany

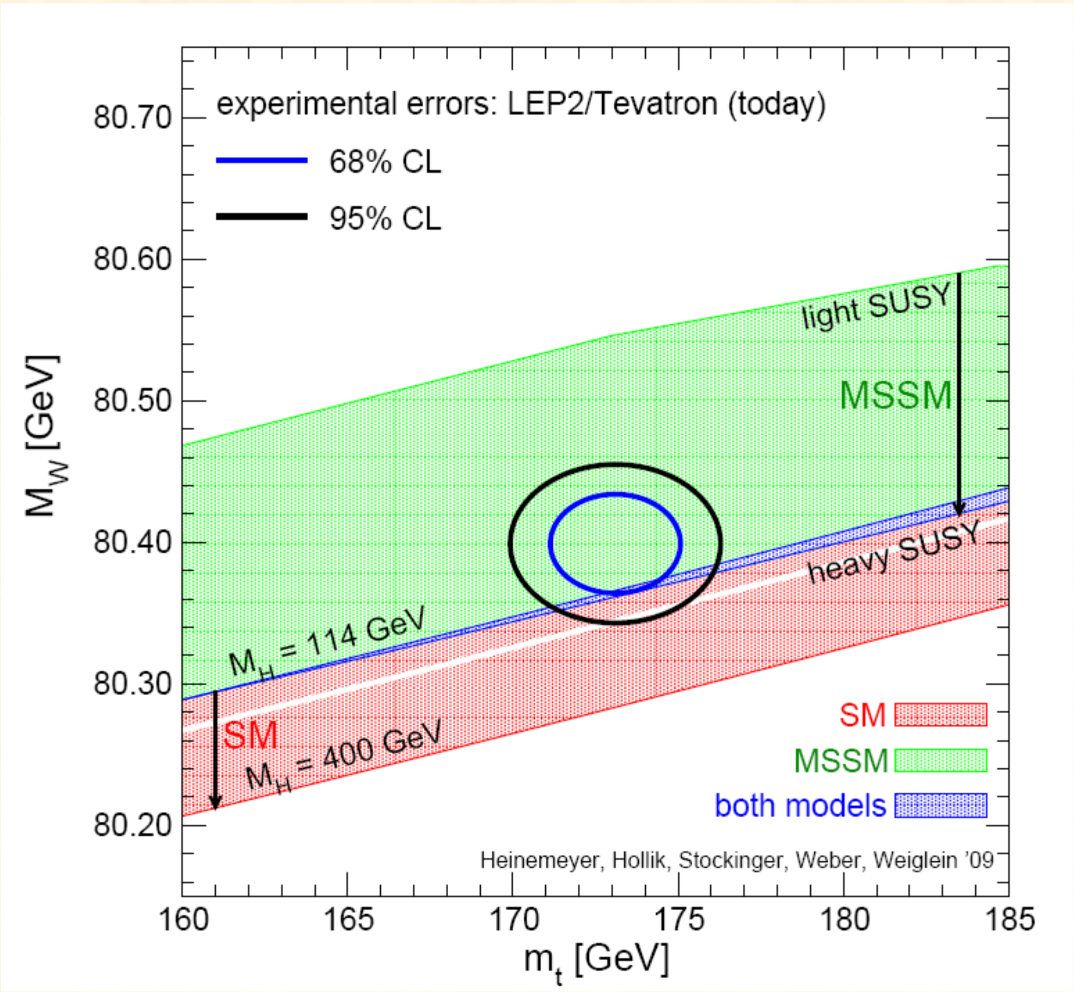
Charged Higgs 2006

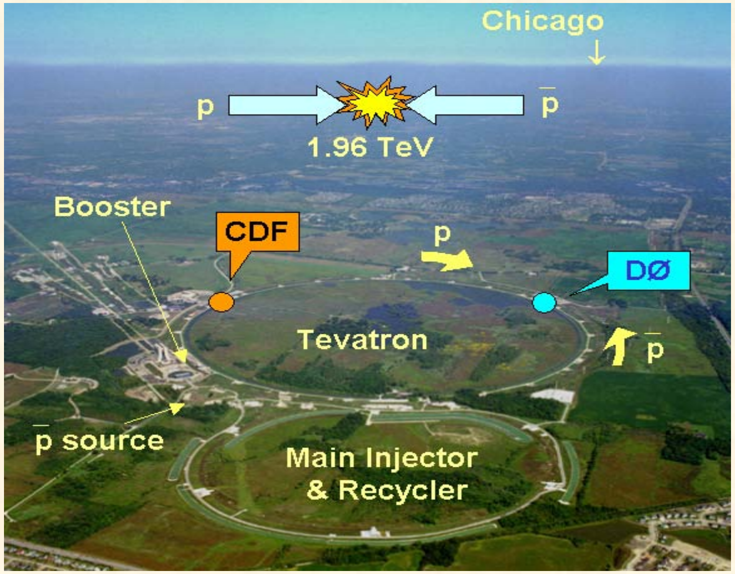
Sven et al. were telling us that the SM Higgs is light and that SUSY is around the corner



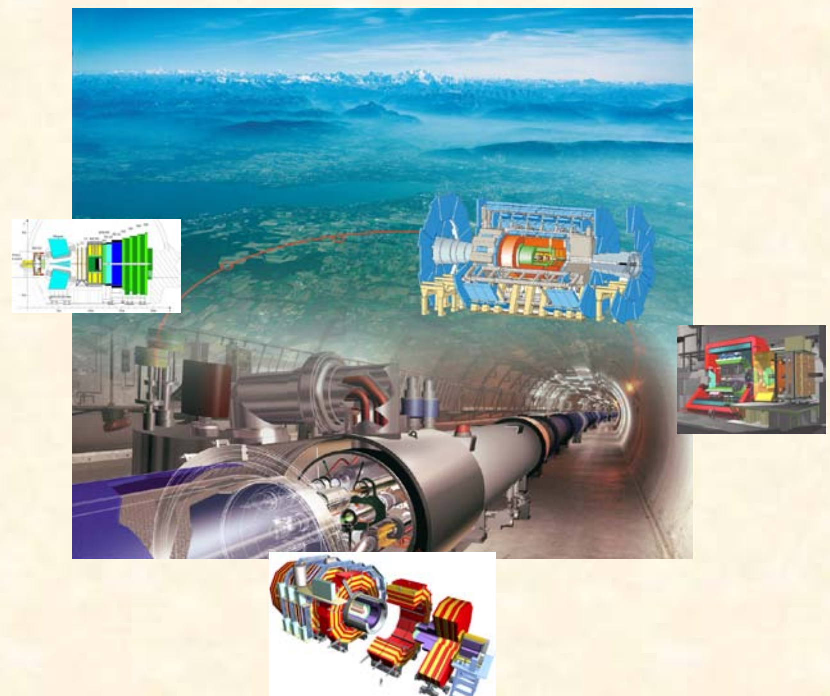
Charged Higgs 2010

Sven et al. keep telling us that the SM Higgs is light and that SUSY is around the corner





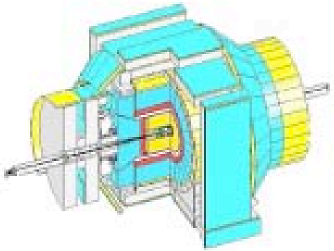
Progress on the experimental side



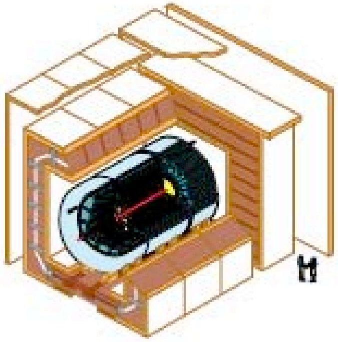
- Two colliders running
- First data at the LHC, Detector performance
- Less prospect and Monte Carlo talks

The Tevatron

$p\bar{p}$ $\sqrt{s} = 1.96$ TeV $\int \mathcal{L}dt \gtrsim 8\ \mathrm{fb}^{-1}$



CDF



DØ

The LHC machine…

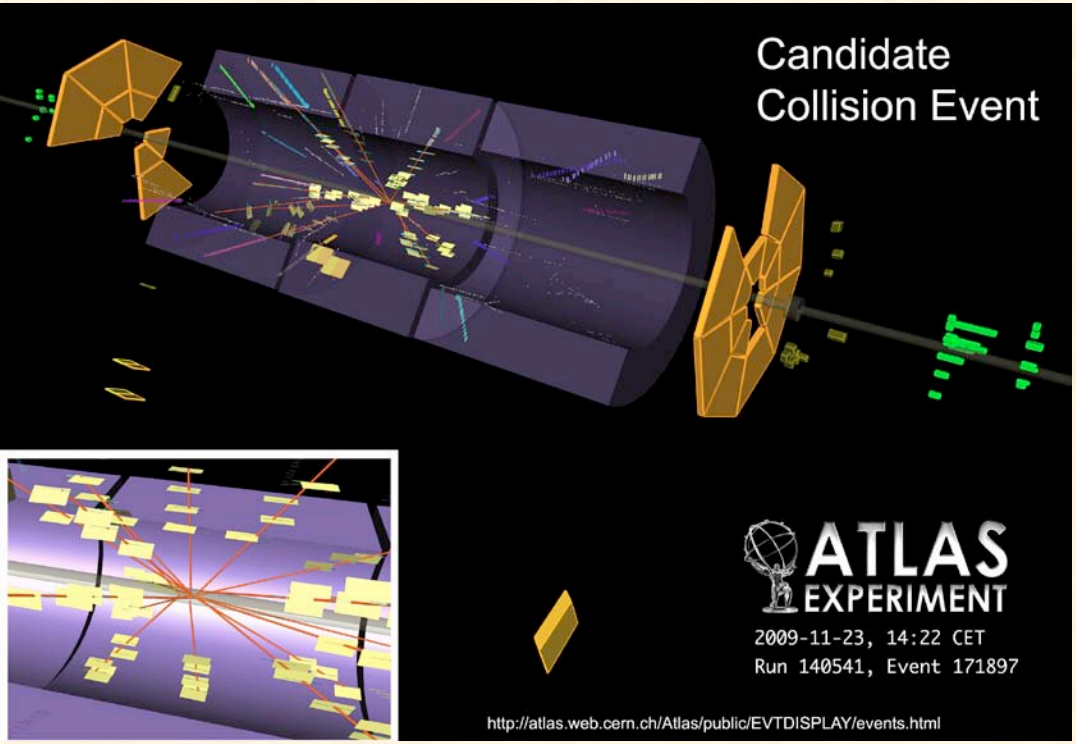
Beam energy	3.5 → 7 TeV
Luminosity (nominal)	10^{32} - 10^{34} $cm^{-2}s^{-1}$
→	**1 - 100 fb^{-1} / year**
Superconducting dipoles	1232, 15 m, 8.33T
Stored energy	350 MJ/beam

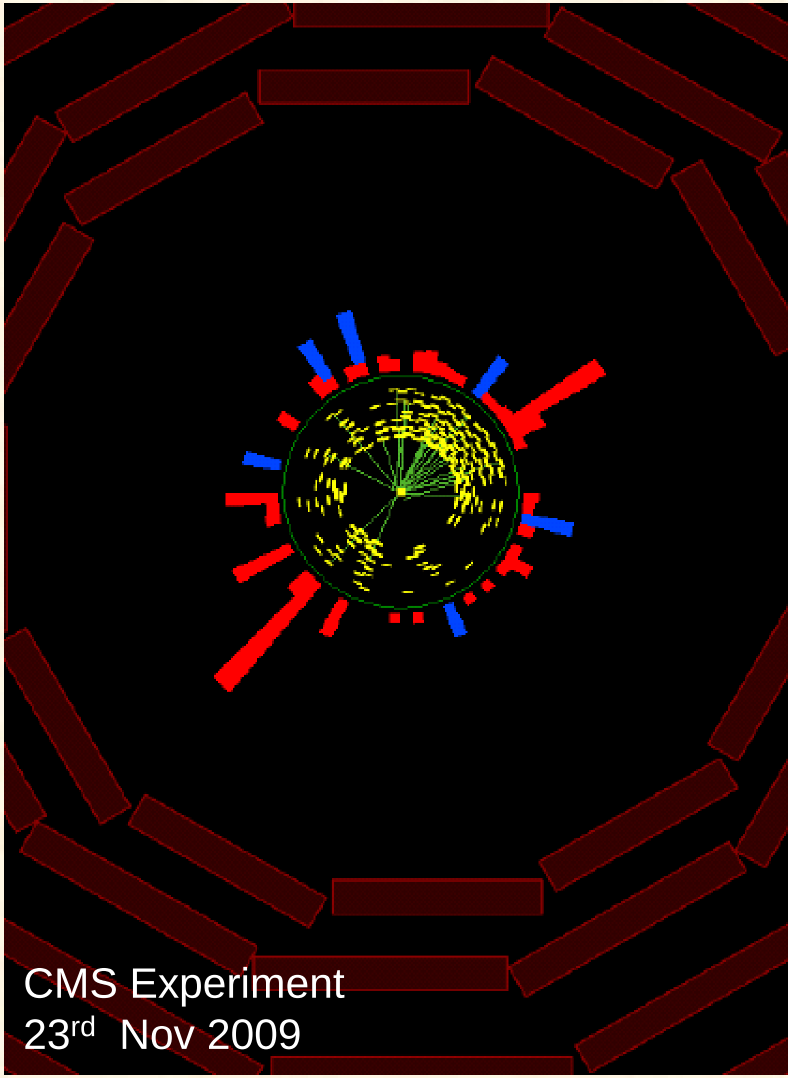
… became a reality after ~15 years of hard work

LHC re-start as seen from the experiments

Praying for beam

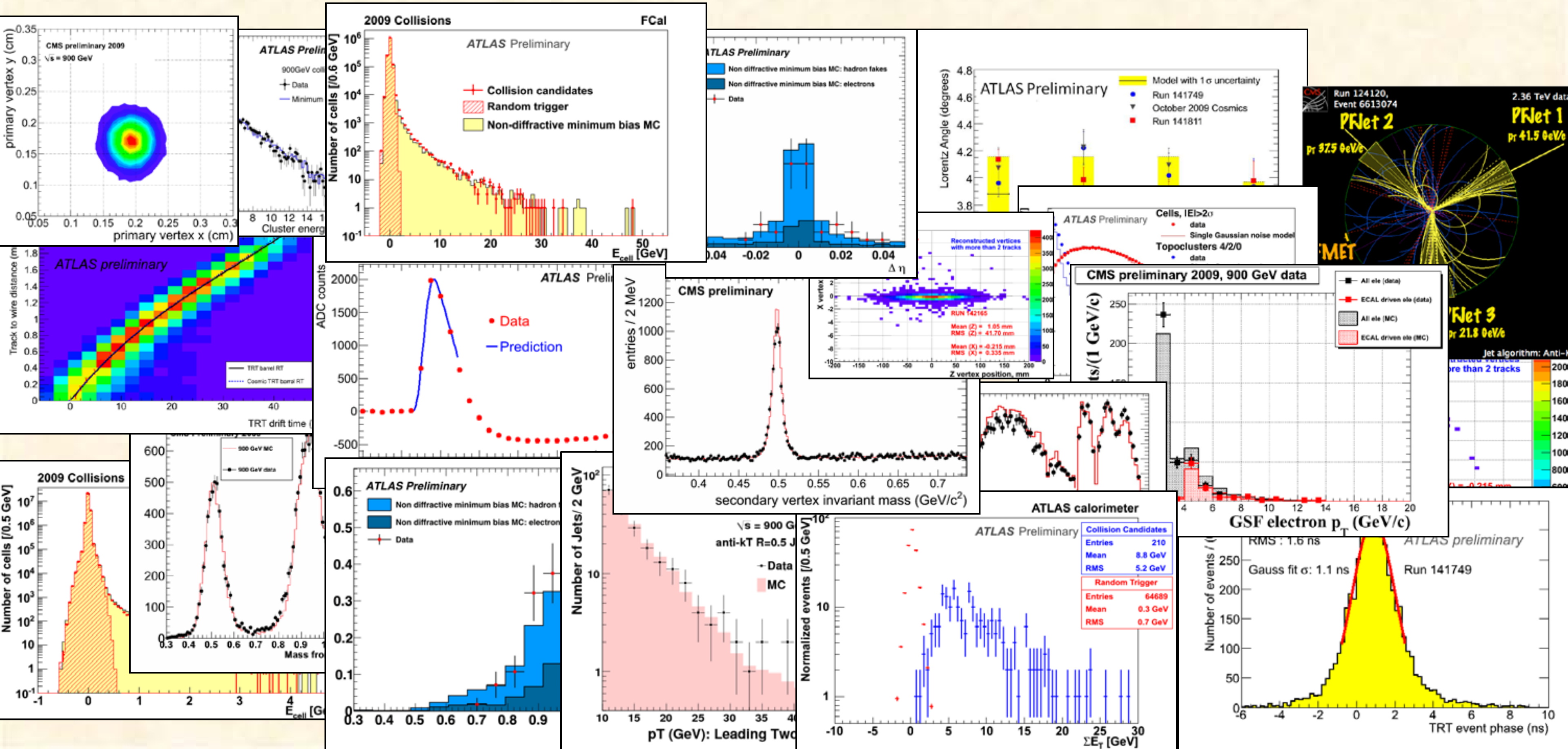
23rd Nov 2009: First collisions at 900 GeV



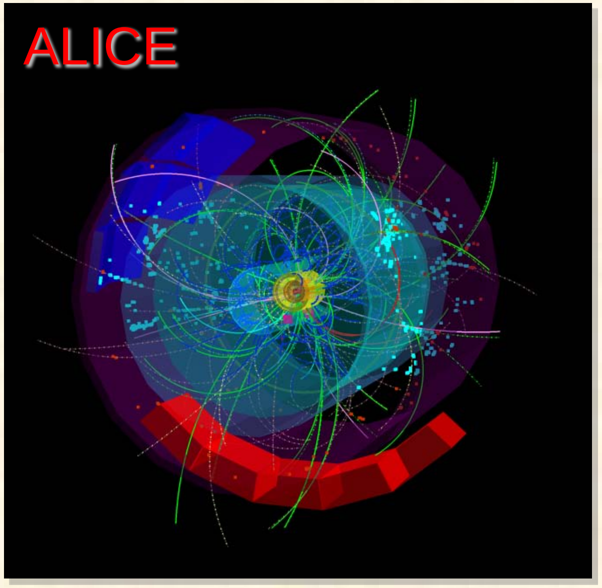


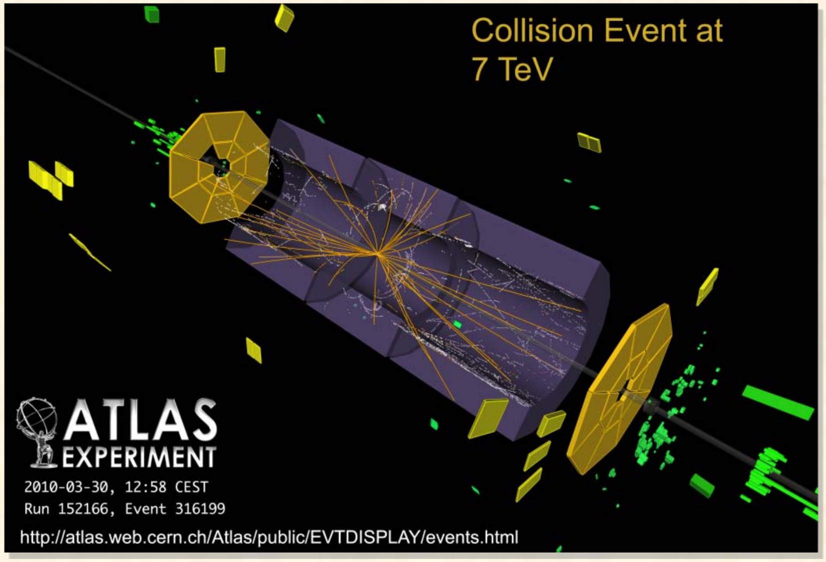
First results on Detector performance

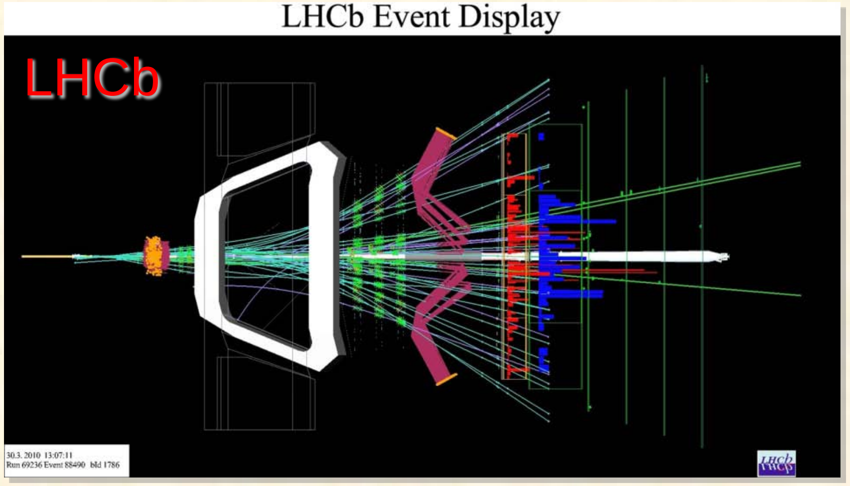
(already in Dec 09, Jan 10)

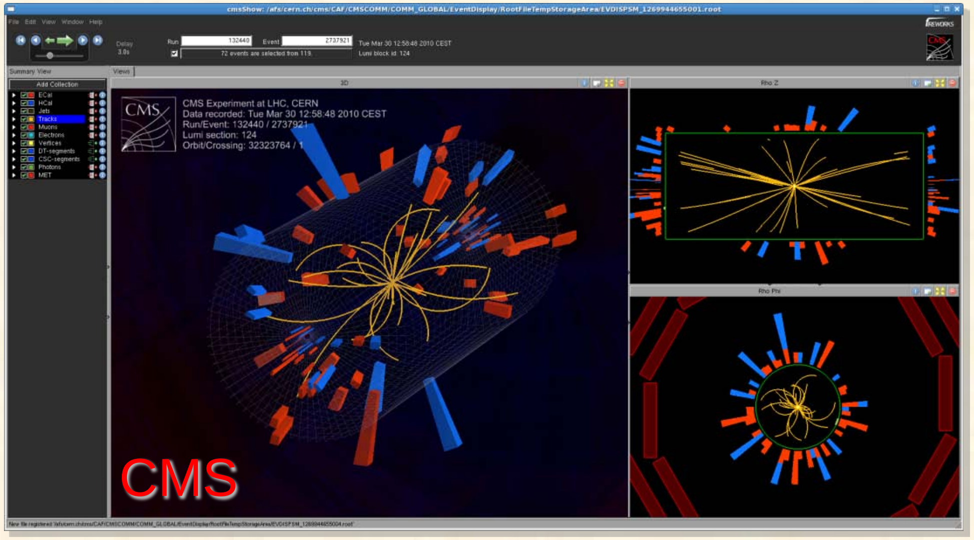


LHC: First collisions at 7 TeV on 30 March 2010

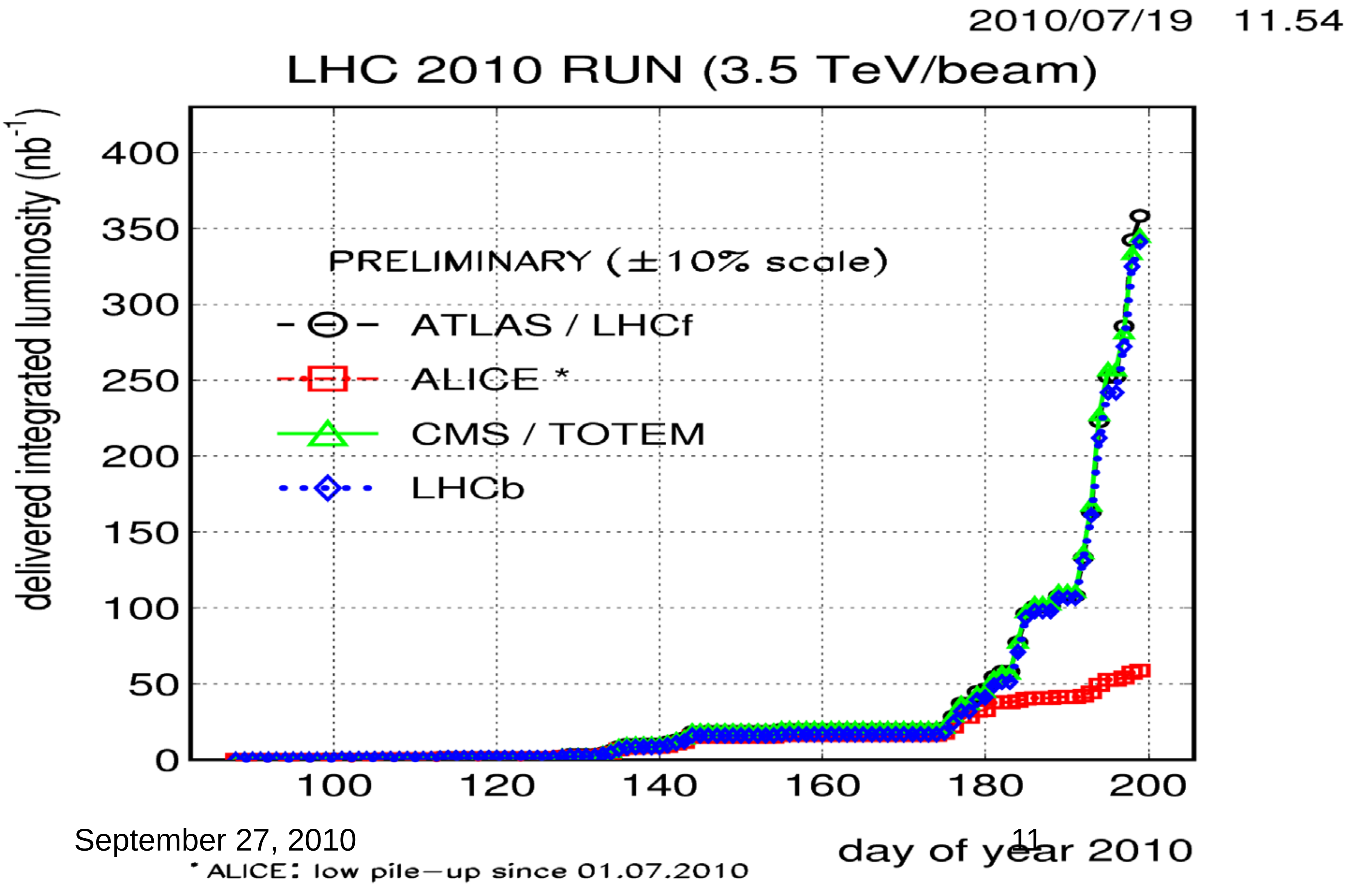








Integrated Luminosity ICHEP10 (350nb-1)



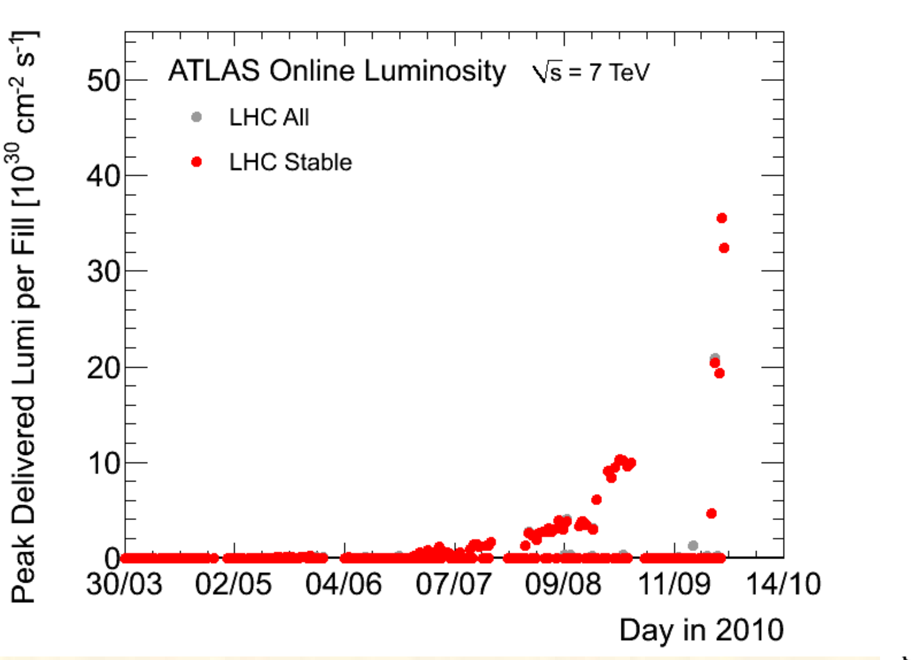
Plan for getting to 10^{32} before ion run

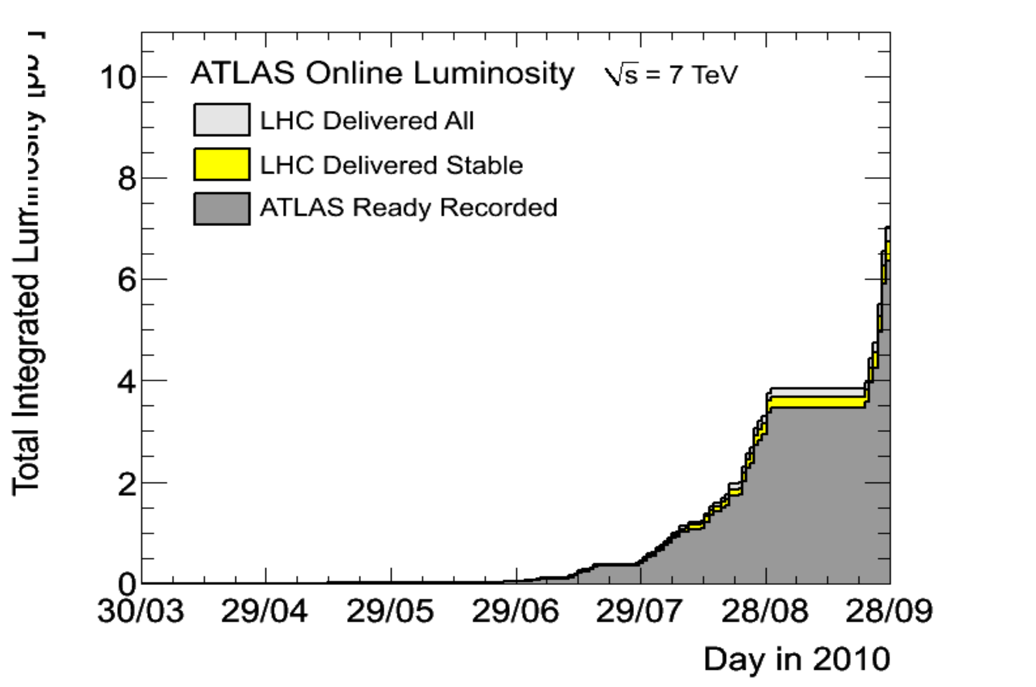
LMC 18th August.

S. Meyers

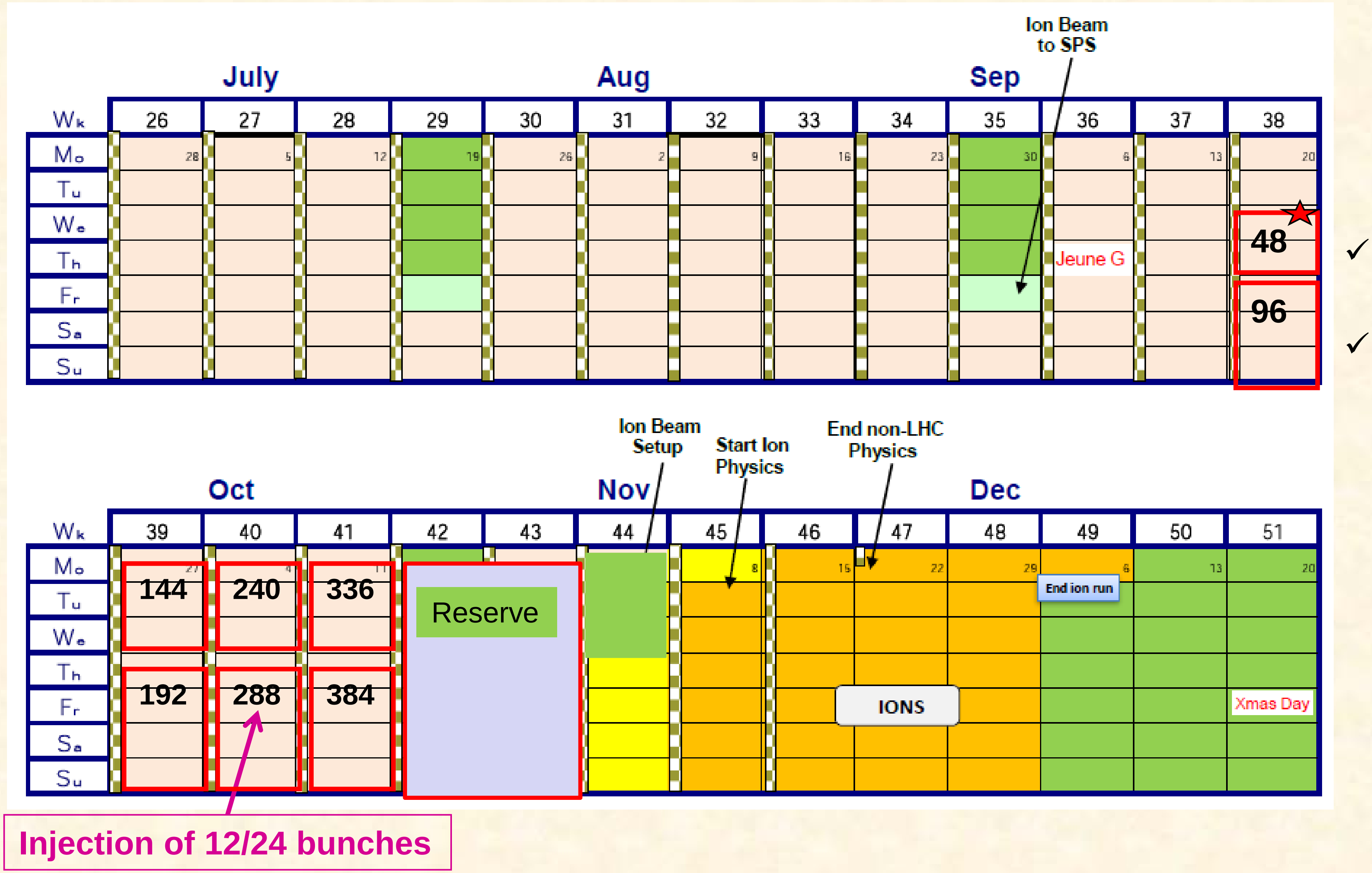
- Parameters and Conditions
  - Nominal bunch intensity 1.1E11
  - Stick to $\beta^* = 3.5$ m
  - Commission bunch trains
    - Complete re-do of the whole machine protection set-up
  - Go to 150 ns bunch spacing
  - Commission faster ramp (10 A/s)

Reached luminosities as of Monday, 27. Sept 2010





Aggressive Schedule (short term)



Status of the ATLAS and CMS Detectors

- Impressive performance figures
- High data taking efficiencies
- Trigger and detector components working well
- Grid computing performing well
- Standard Model Physics re-discovered

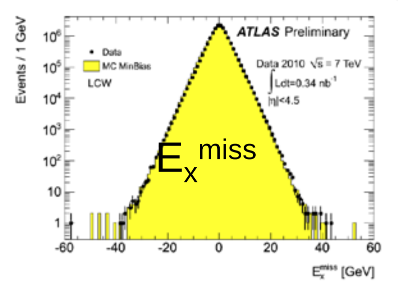
D. Orestano

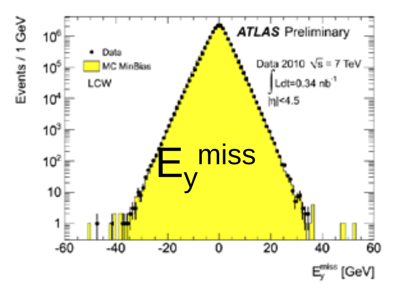
A. Nikitenko

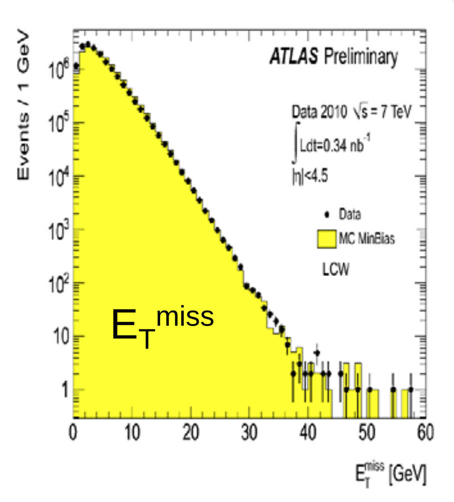
Missing E_T

D. Orestano

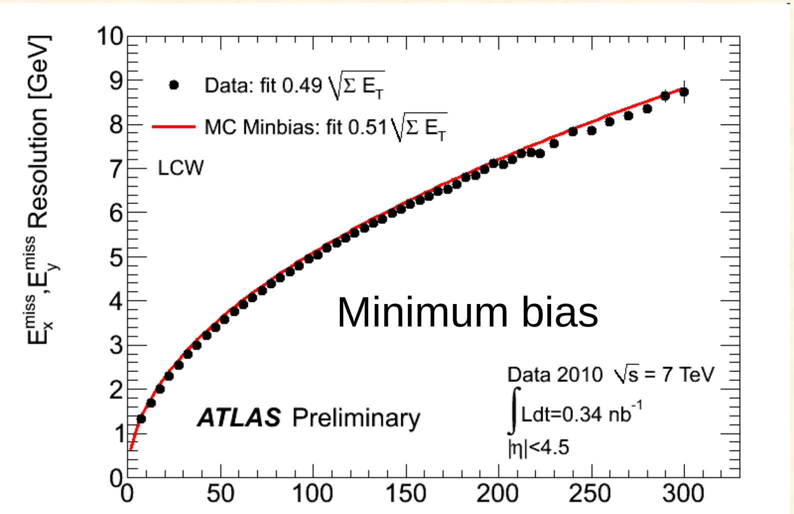
- A complex object!
- Relative energy scales need careful intercalibration

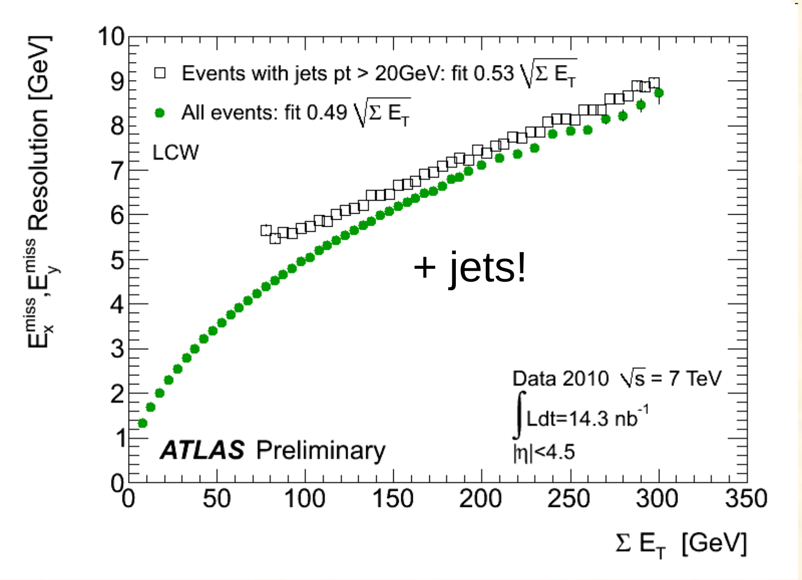






Detector hermeticity in minimum bias events

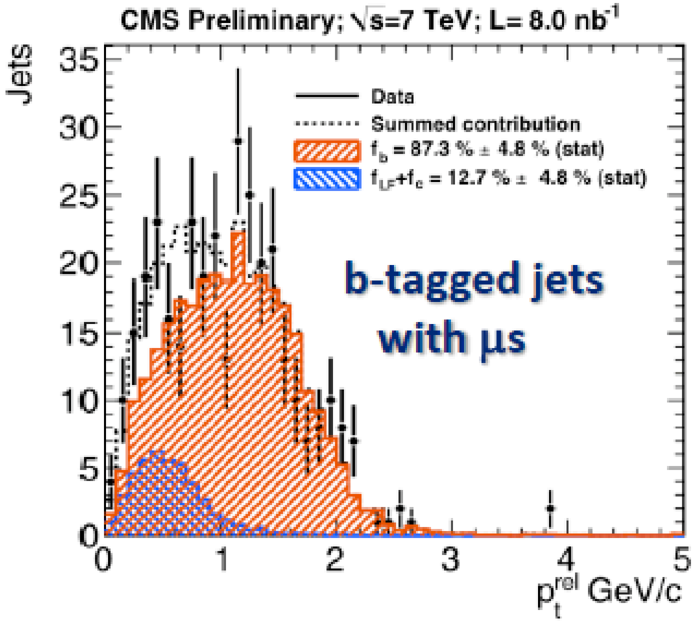




B-tagging efficiency

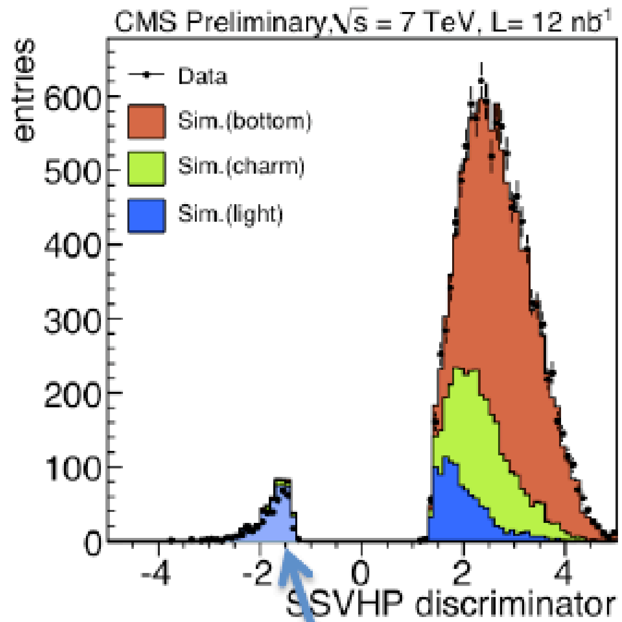
$$\epsilon_b^{data} = \frac{f_b^{tag} \cdot N_{data}^{tag}}{f_b^{tag} \cdot N_{data}^{tag} + f_b^{untag} \cdot N_{data}^{untag}}$$

Extract f_b^{tag}, f_b^{untag} from fit of $p_{t\mu}^{rel}$ for b-tagged (untag) jets with muons



- in general good agreement between ε_b^{data} and ε_b^{MC}

Fake rate

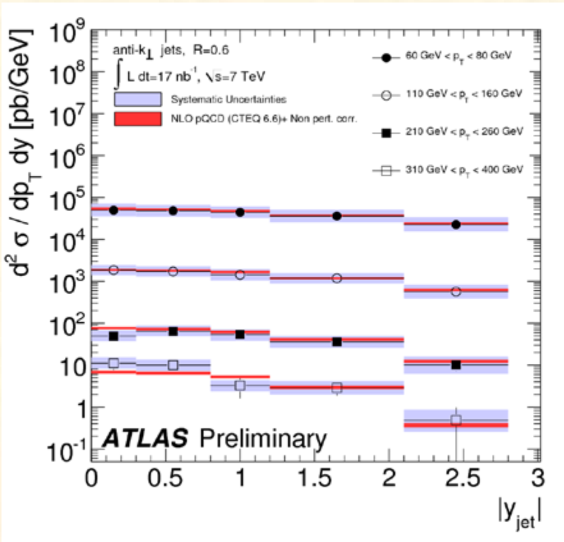


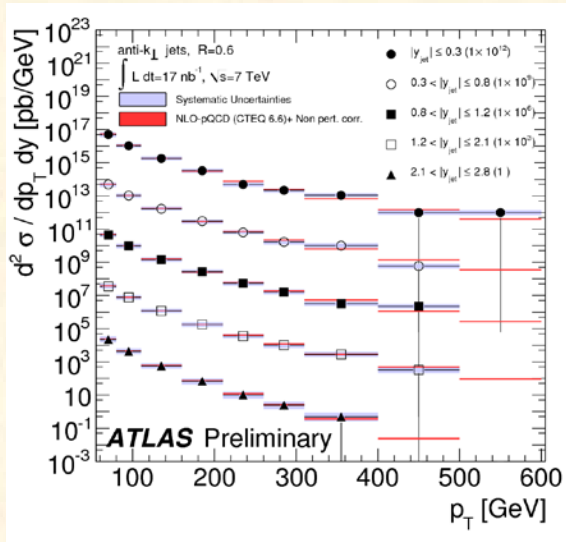
$$\varepsilon_{data}^{mistag} = \varepsilon_{data}^{-} \cdot R_{light}$$

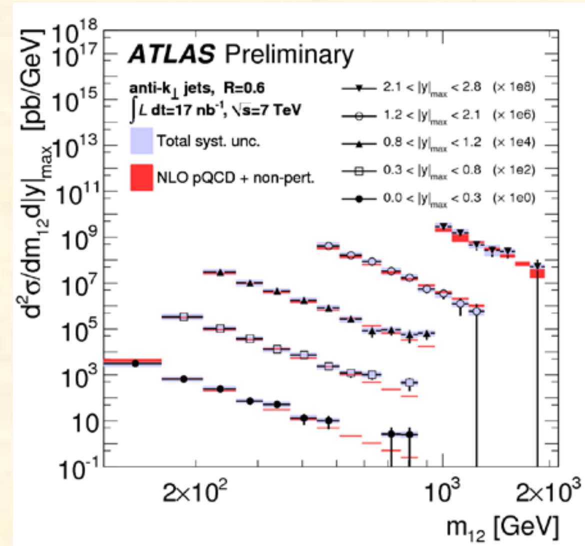
$$R_{light} = \varepsilon_{MC}^{mistag} / \varepsilon_{MC}^{-}$$

- $\varepsilon_{data}^{mistag} / \varepsilon_{MC}^{mistag} = f(p_T^{jet}, \eta^{jet})$ slightly less than 1.

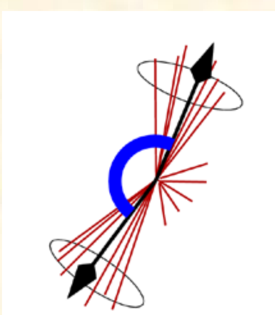
QCD cross-sections



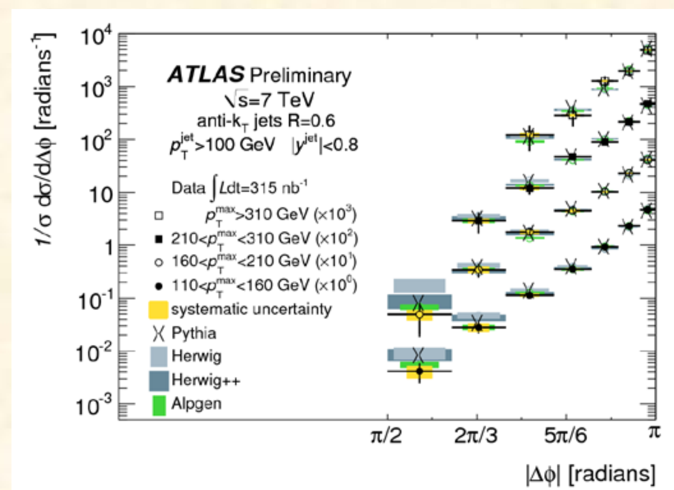




Double differential cross-sections in very good agreement with NLO predictions



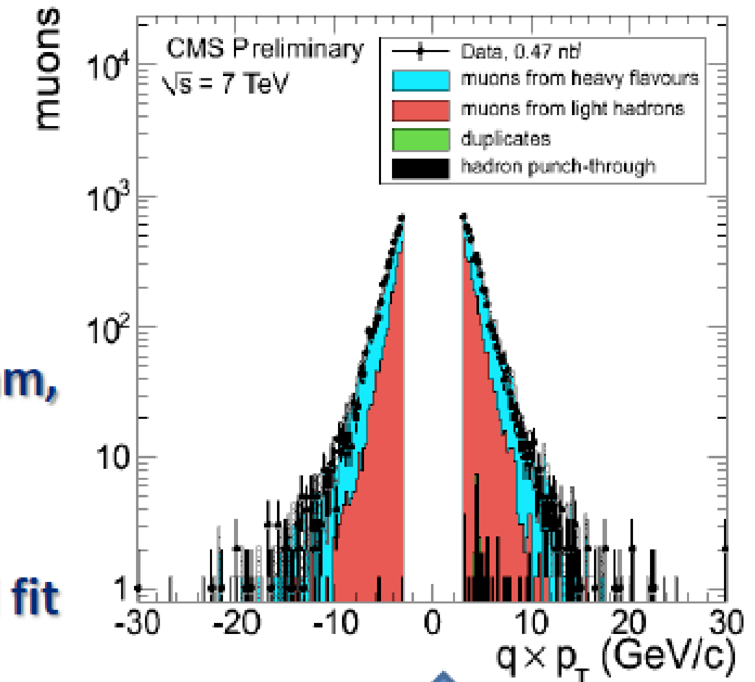
Soft radiation probed by di-jets angular decorrelation



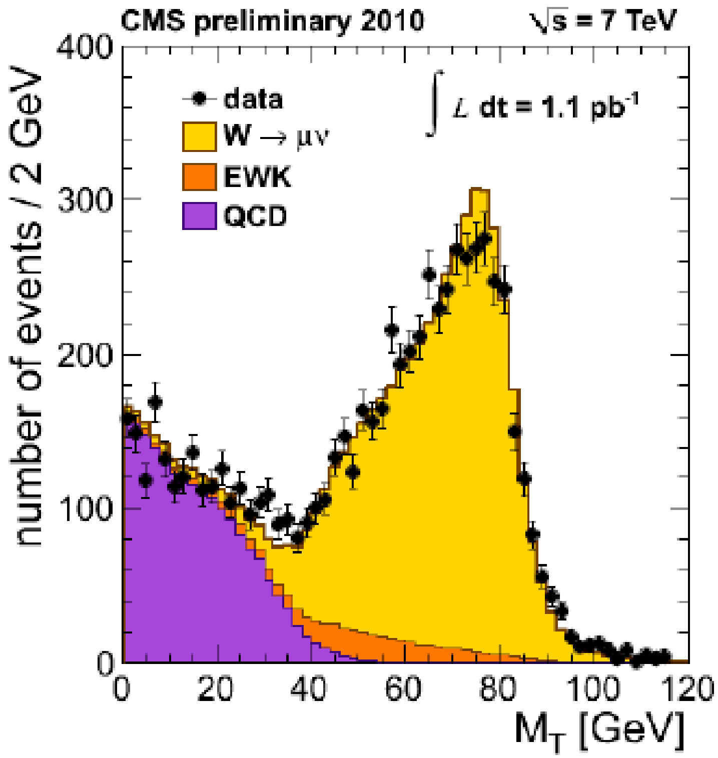
D.Orestano

"Tight muons"

- Tight muon: is "global" AND "tracker" muon, $\chi_{gl.trk}^2 < 10$, > 0 muon hits, > 1 matched muon segments, > 10 trk. Hits, >0 pixel hits, ip_{xy} < 2 mm, p_T > 3 GeV
  - "tracker muon" : inside-out approach
  - "global muon": outside-in approach+global fit



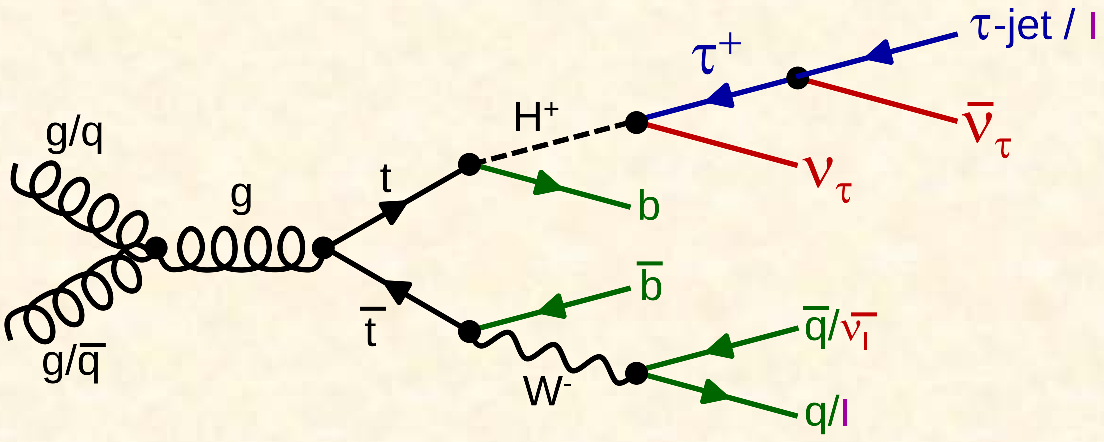
from min. bias trigger



used in W->μν and tt~ analyses

A. Nikitenko

To Physics of the Charged Higgs



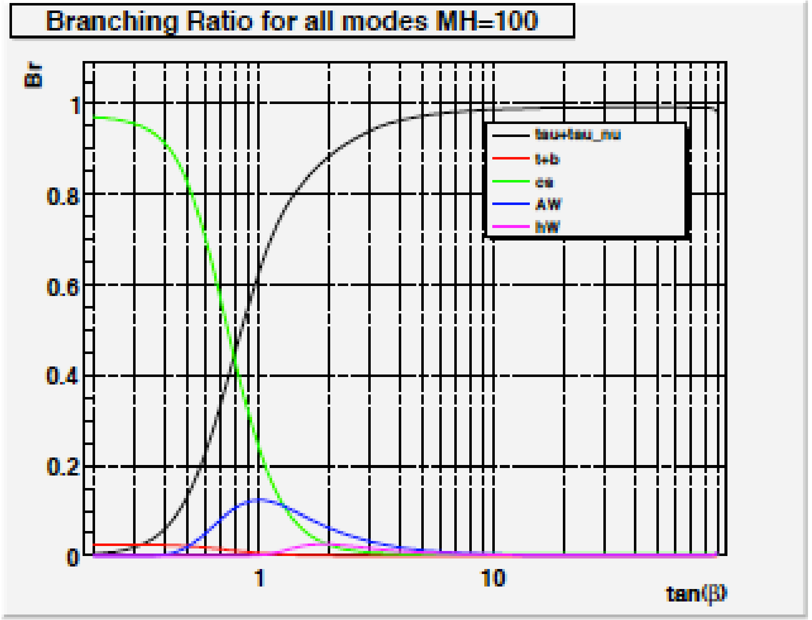
What is important ??

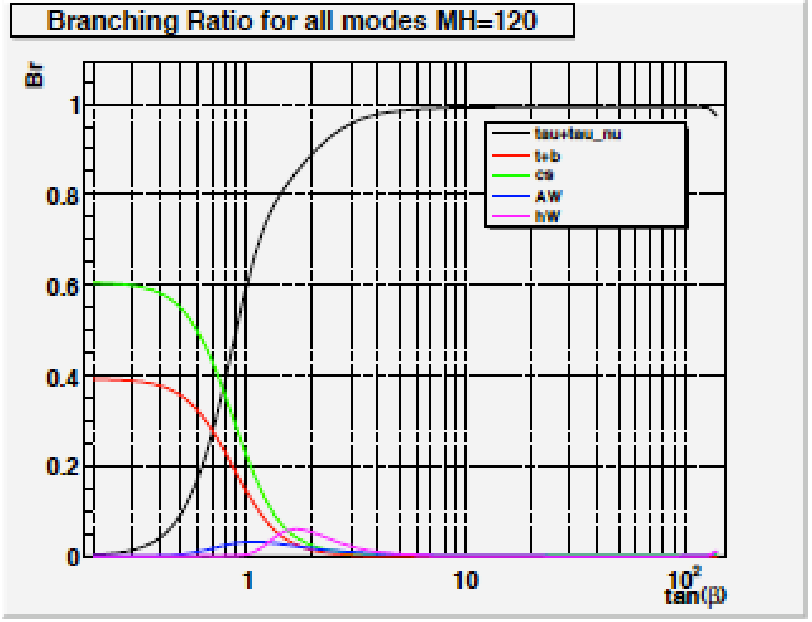
Everything !! Taus, b-jets, leptons, missing E_T, jets,.....

Tevatron Higgs Boson Searches

P. Gutierrez

- Analysis are based on type 2 models
  - Concentrate on $m_{H^\pm} < m_t + m_b$
  - Search for: $H^\pm \to \tau\nu_\tau$ $H^\pm \to cs$ $H^\pm \to h^0 W^\pm$ $H^\pm \to A^0 W^\pm$ $H^\pm \to t^* b \to W^\pm \bar{b} b$

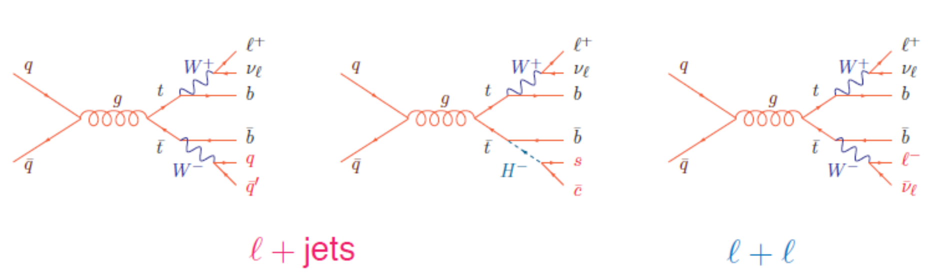


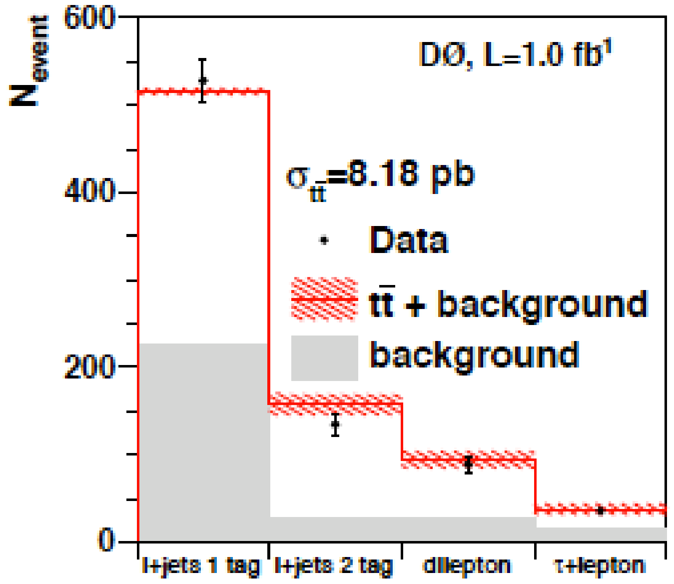


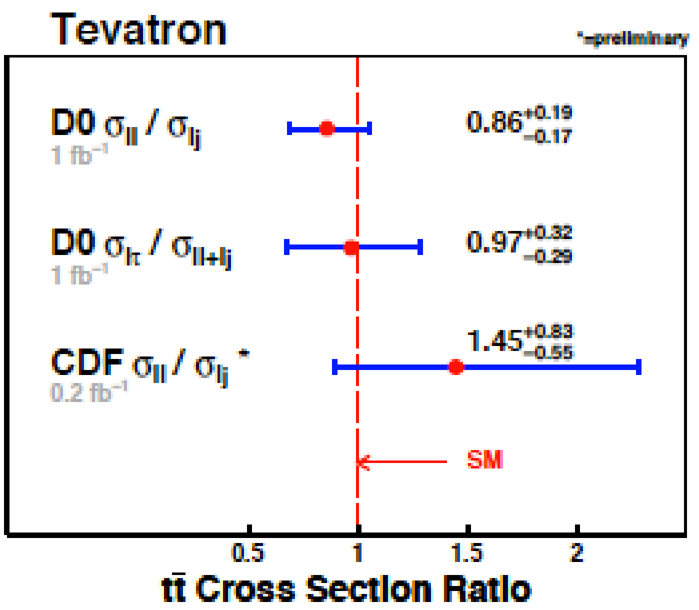
Tevatron Higgs Boson Searches

$$\sigma_{t\bar{t}}^{\exp} = \frac{[\sigma_{t\bar{t}} \cdot \mathrm{B}(t\bar{t} \to X)]_{\exp}}{[\mathrm{B}(t\bar{t} \to X)]_{\mathrm{SM}}} = \sigma_{t\bar{t}} \cdot f_X$$

$$\sum_X \mathrm{B}(t\bar{t} \to W^{\pm}b \to X) + \sum_X \mathrm{B}(t\bar{t} \to H^{\pm}b \to X) = 1$$



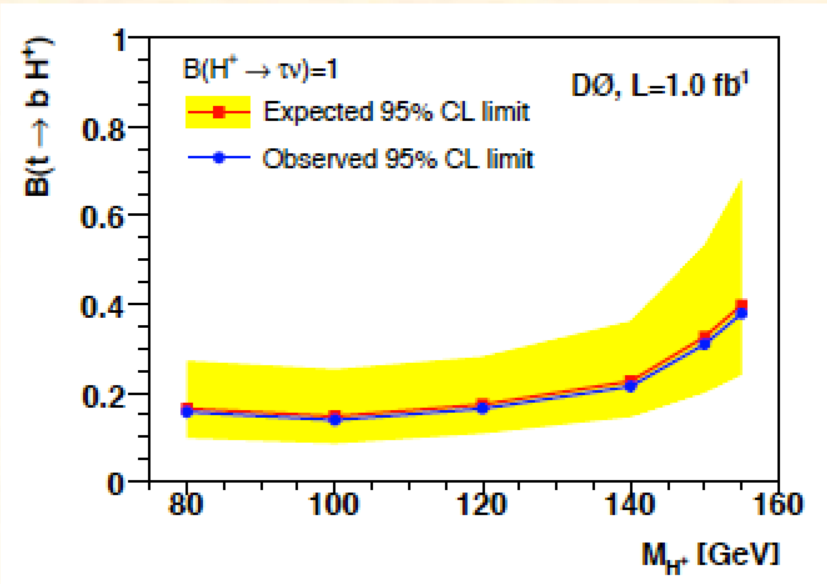


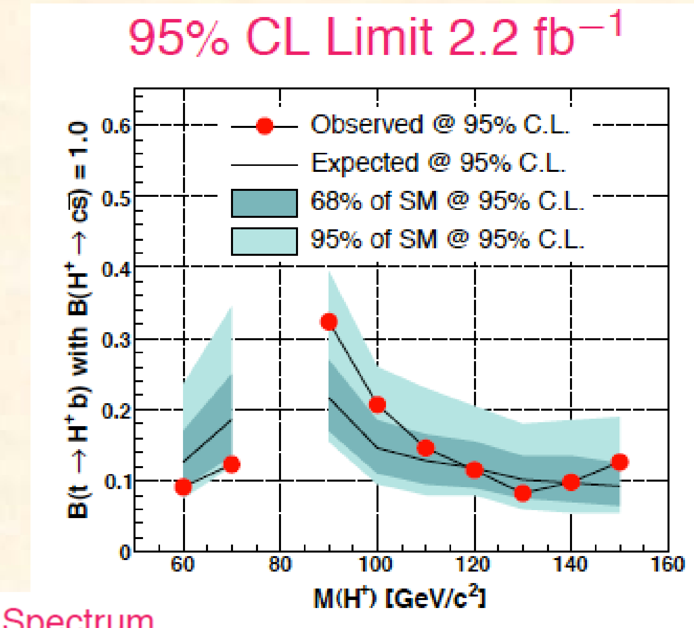


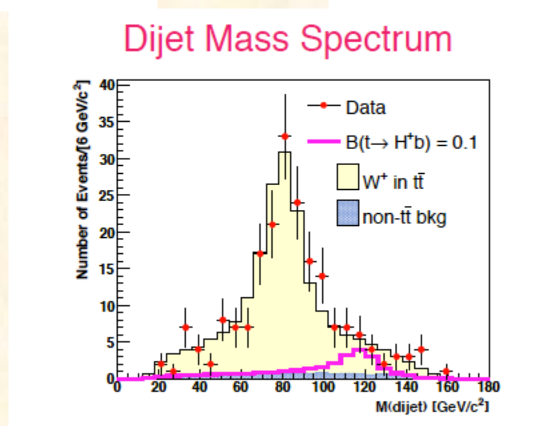
95% C.L. limits on branching ratios from indirect searches (tt decays)

assuming BR ($H^+ \rightarrow \tau\nu = 1$)

95% C.L. limits on branching ratios from direct searches
assuming BR ($H^+ \rightarrow cs = 1$)





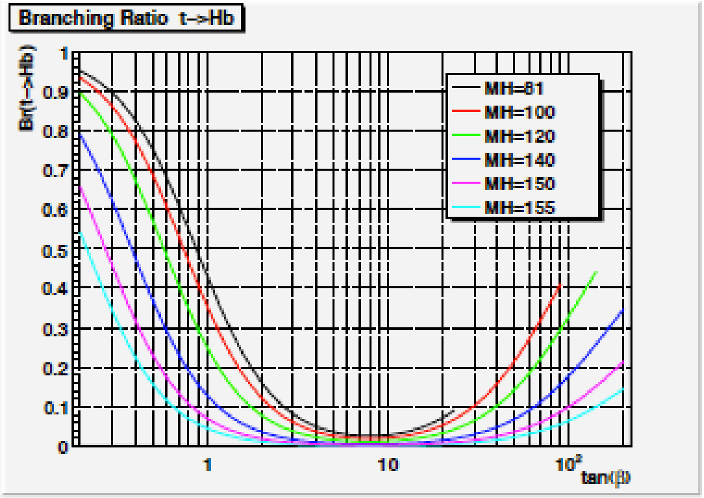


Phys. Rev. Lett. 103, 101803 (2009) CDF

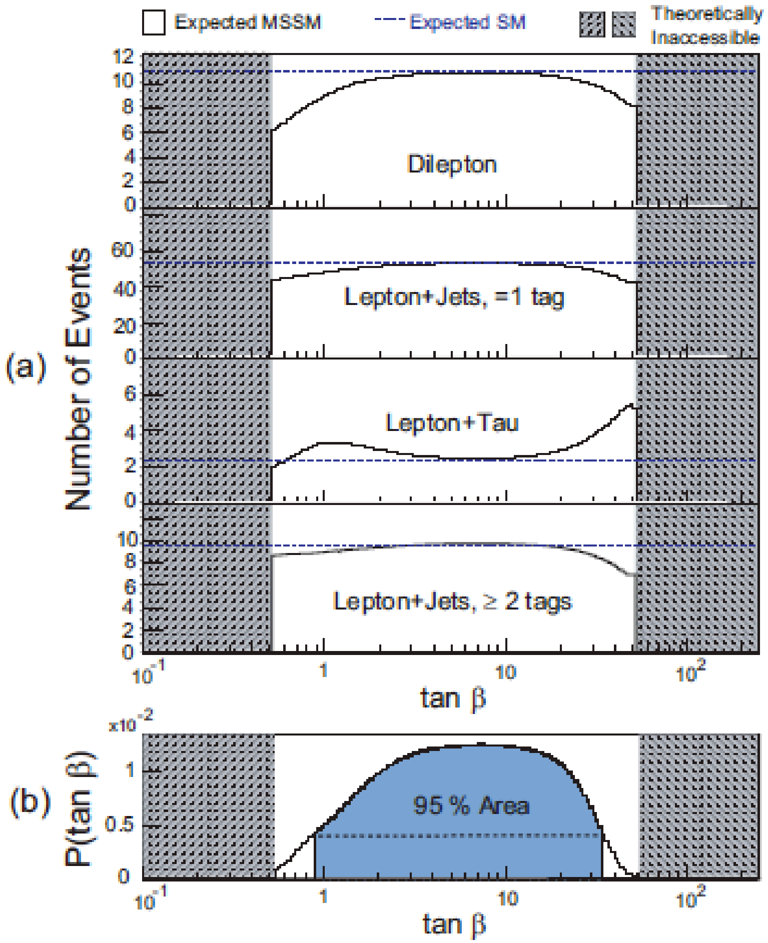
CDF MSSM

- $\int L dt = 193\ \text{pb}^{-1}$
- Covers full tan β range
- Expected number of events SM, MSSM (2HDM)
- Exclusion based on CPsuperH
- Bayesian limit

$t \rightarrow H^{\pm} b$



FeynHiggs



CDF MSSM

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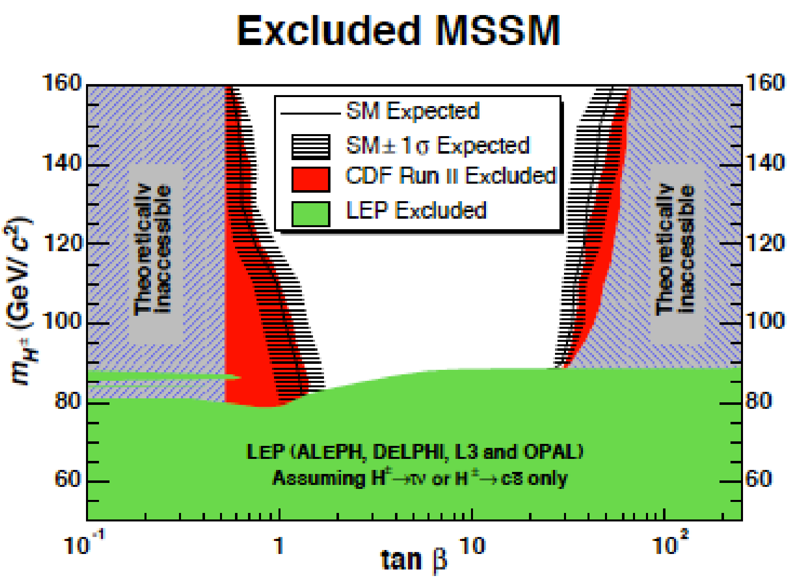
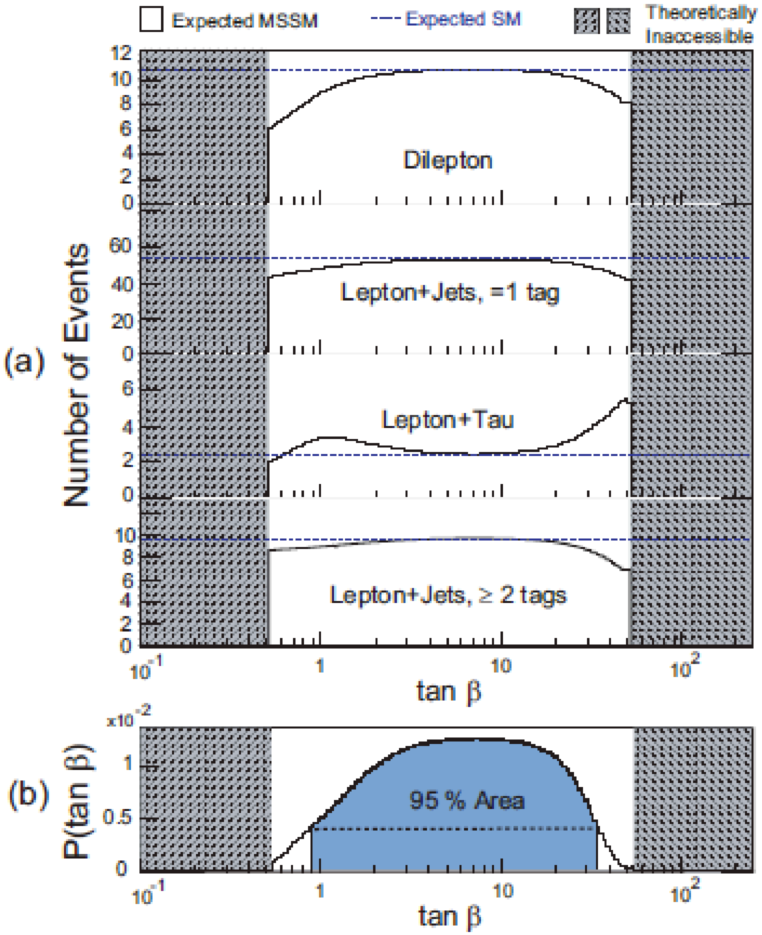




Phys. Rev. Lett 96, 042003 CDF

MSSM Higgs Boson Search at the LHC

Important channels in the MSSM Higgs boson search:

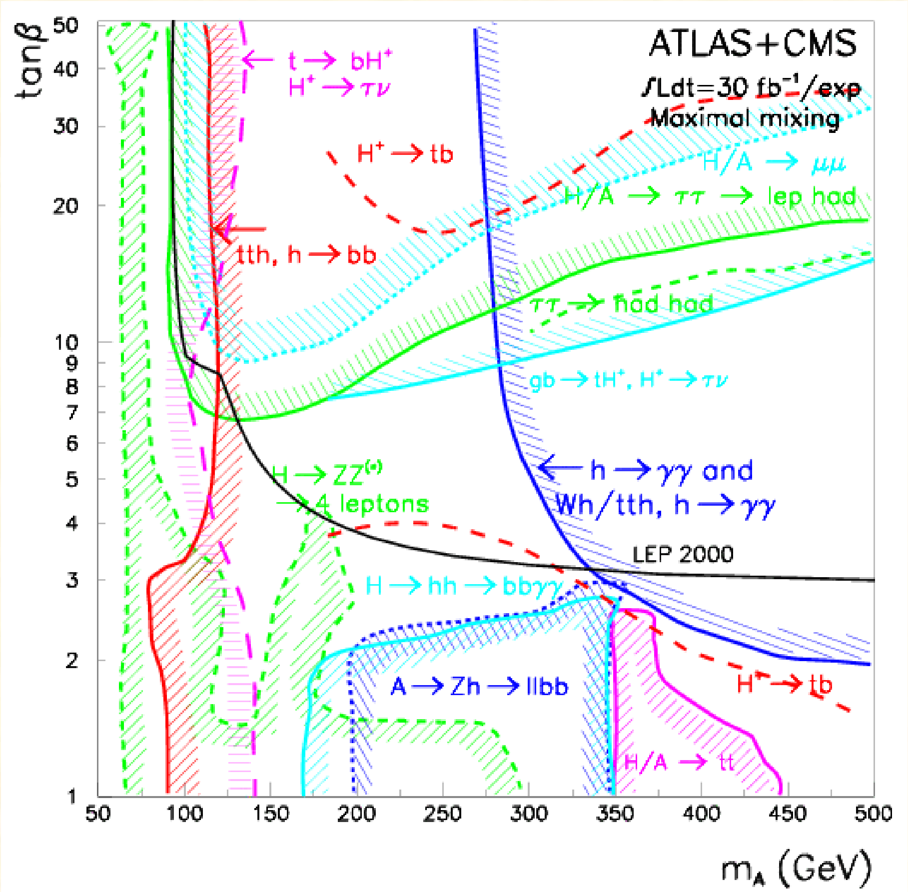
1. The Standard Model decay channels
   - $h \to \gamma\gamma$
   - $t\bar{t}\,h,\ h \to b\bar{b}$
   - $qq\,h,\ h \to \tau\tau$

   evaluation of performance is based on SM results

2. Modes strongly enhanced at large tan β:
   - **H/A** $\to \tau^+\tau^-$ $H^+ \to \tau\nu$
   - **H/A** $\to \mu^+\mu^-$

3. Other interesting channels:
   - H/A $\to$ tt
   - H/A $\to$ Zh $\to \ell\ell\,\gamma\gamma$
     $\to \ell\ell$ bb
   - H $\to$ hh

MSSM benchmark plot for nearly 10 years



Updated LHC discovery potential for charged Higgs bosons

A. Ferrari

- Strategy has to be changed, according to LHC energy and luminosity expectations

- More attention now on the „low mass region“ $m_{H^+} < m_t - m_b$

$\sqrt{s}$ = 7 TeV, $L_{int} \approx$ 1 fb^{-1}

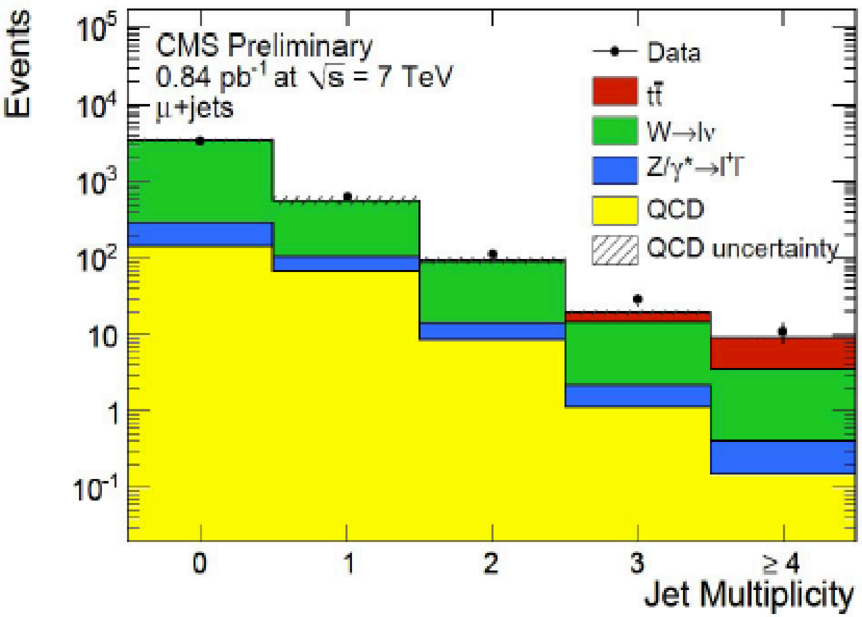
- In addition, high mass studies relevant for higher luminosity

$\sqrt{s}$ = 14 TeV, $L_{int} \approx$ 10-30 fb^{-1}

Plans for search

M. Gallinaro

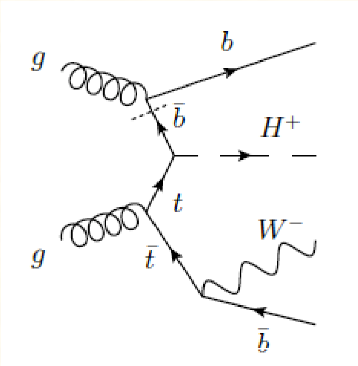
- $1\text{-}10\ pb^{-1}$:
  - study tau fake rates in multi-jet samples
  - leptons/jets/MET
  - validate data-driven background methods
- $10\text{-}100\ pb^{-1}$:
  - estimate tau fake background
  - look for ttbar events with taus
- $100\text{-}1000\ pb^{-1}$:
  - set limits/find signal



LHC discovery potential for charged Higgs bosons

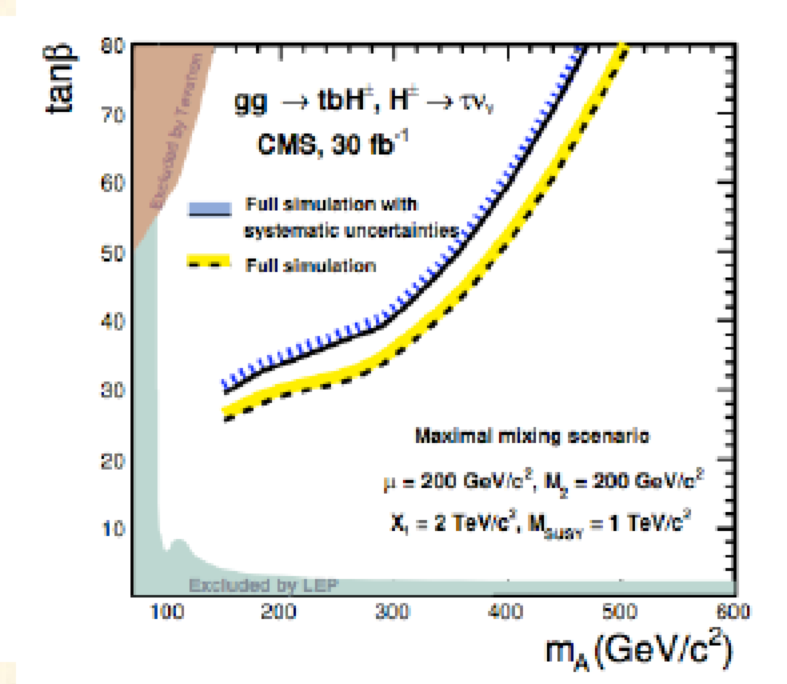
A. Ferrari
M. Gallinaro

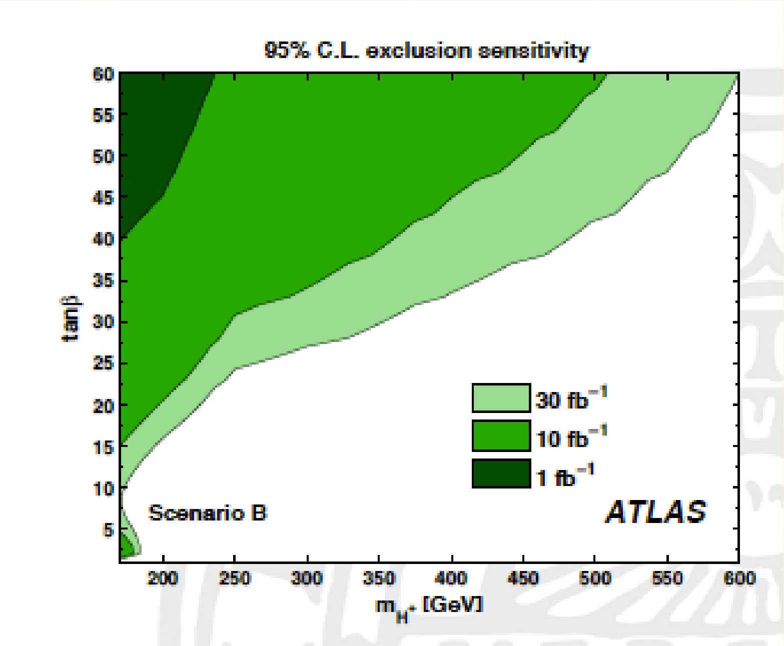
ATLAS CSC studies, $\sqrt{s}$ = 14 TeV



Two channels considered:

gg/gb → t (b) H+ → bqq (b) $\tau_{had}\,\nu$
gg/gb → t (b) H+ → t(b) tb → blν (b) b qqb

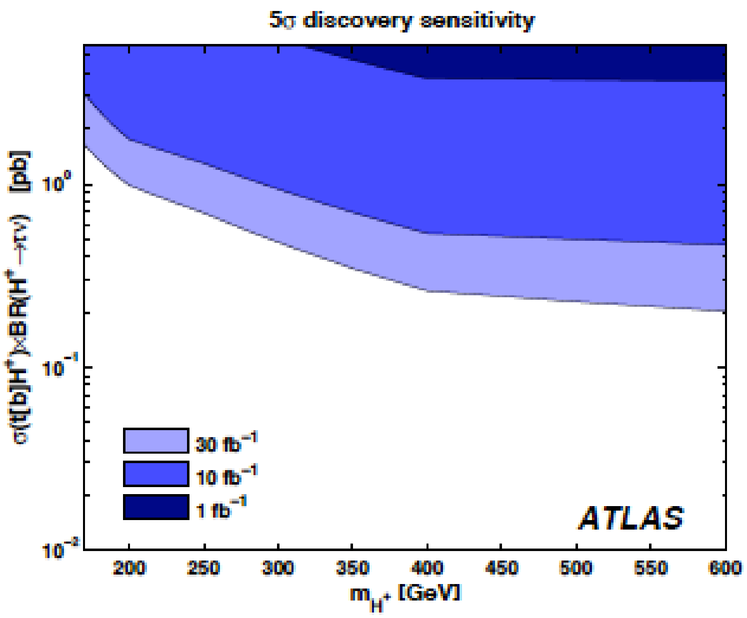


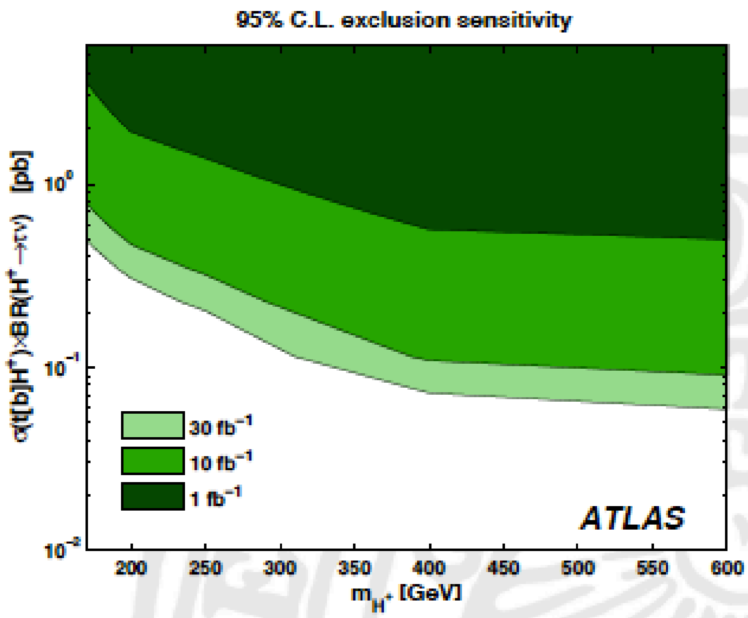


mhmax scenario, systematic uncertainties included

$H^+ \to tb$: contribution to H^+ sensitivity

No discovery or exclusion power was extracted for this channel on its own, but it contributes to the combined ATLAS sensitivity for charged Higgs bosons.





Model-independent contours, with systematic and statistical uncertainties.

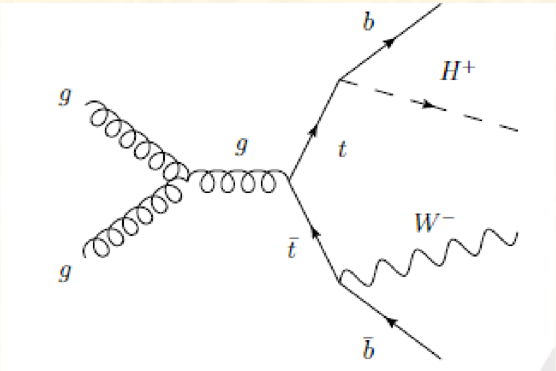
LHC discovery potential for charged Higgs bosons

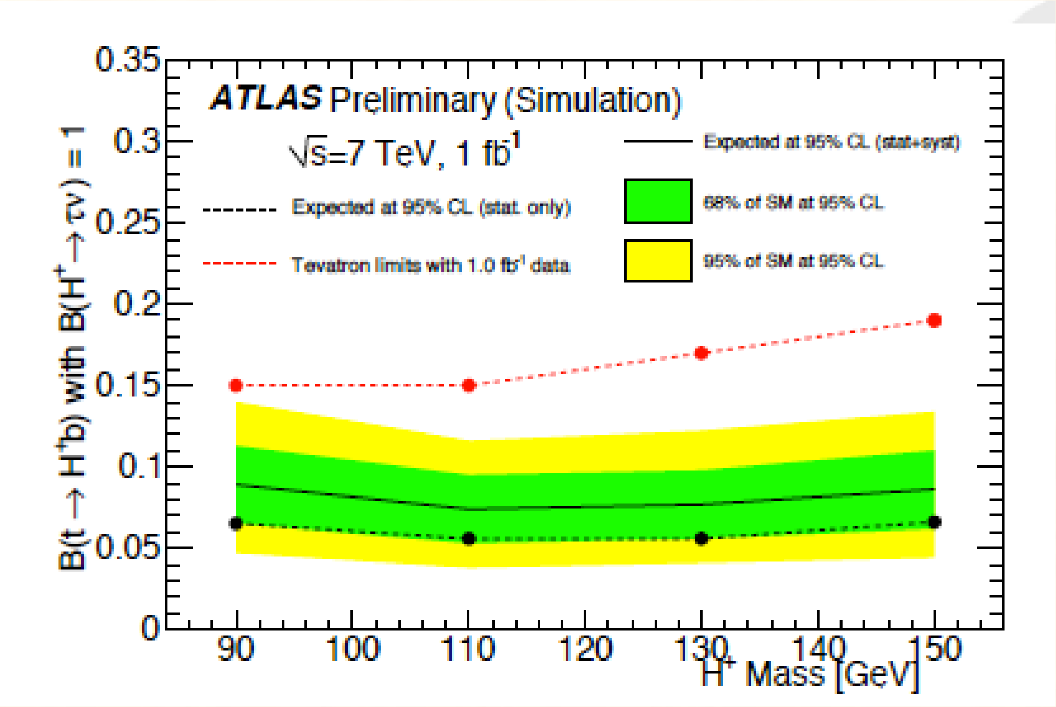
A. Ferrari

ATLAS / CMS Studies, $\sqrt{s}$ = 7 TeV

Two channels considered:

tt → bb W^-H^+ → bb $l\nu\ \tau_{lep}\nu$
tt → bb W^-H^+ → bb $l\nu$ cs

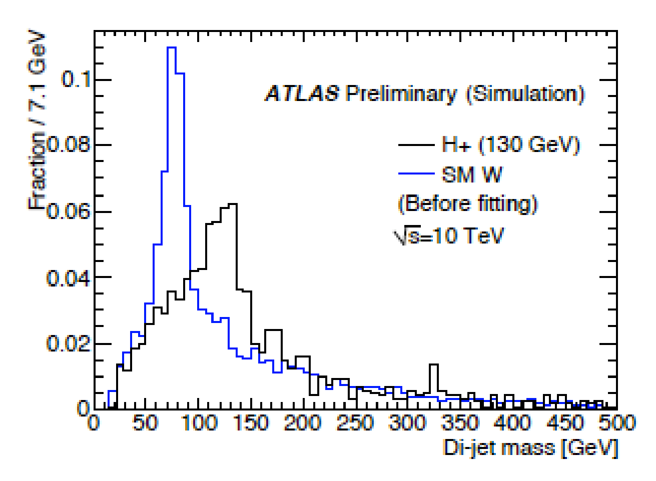




M. Klemetti

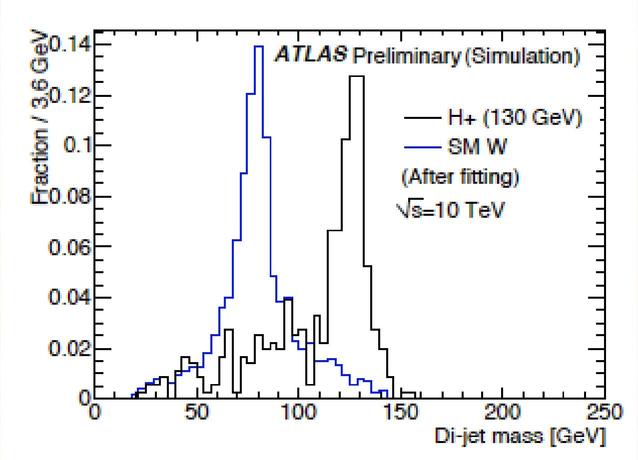
interesting approach to use kinematic fitting, generalized transverse mass

Un-ki Yang

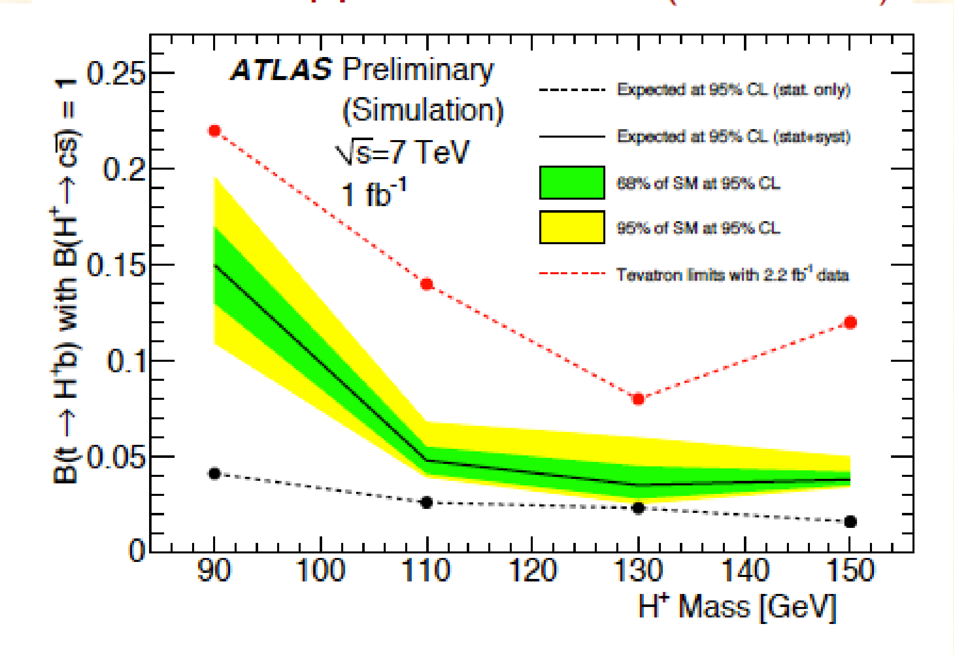


Hadronic mass spectrum,
difficult to separate
→large improvements using kinematical fits

QCD backgrounds to be checked / addressed with data



$H^+ \rightarrow c\bar{s}$: upper limits on $\mathcal{B}(t \rightarrow bH^+)$



Better sensitivity expected than at the Tevatron

Systematic effects are imported, detailed studies presented by ATLAS and CMS

S. Gentile

$\sqrt{s}$=7 TeV L_{int} =1fb^{-1} $\mathcal{B}(t \to bH^+)$ at 95%CL (with systematics) without systematics

m_{H^+} (GeV)	$H^+ \to \tau^+ \nu$ Tevatron	$H^+ \to \tau^+ \nu$ ATLAS expected (with systematics)	$H^+ \to \tau^+ \nu$ without systematics	$H^+ \to c\bar{s}$ Tevatron	$H^+ \to c\bar{s}$ ATLAS expected (with systematics)	$H^+ \to c\bar{s}$ without systematics
90	15%	9%	**6.5%**	22%	15%	**4.0%**
110	15%	7%	**5.6%**	15%	5%	**2.5%**
130	17%	8%	**5.6%**	8%	3.4%	**2.3%**
150	19%	9%	**6.6%**	13%	3.7%	**1.5%**

$\mathcal{B}(H^+ \to \tau^+ \nu) = 1$ $\mathcal{B}(H^+ \to c\bar{s}) = 1$

- Systematic uncertainties may lead to a degradation of the limits by factors of 2-3
- However, data will help enormously to constrain some of these uncertainties

Systematic effects are imported, detailed studies presented by ATLAS and CMS

L. Wendland

Summary

• Cross-section uncertainties		
– ttbar cross-section	16 %	
– W/Z + jets cross-sections	100 %	estimate
– QCD multi-jet cross-sections	100 %	estimate
• Luminosity measurement	11 %	EWK-10-004
• Underlying event	10 %	QCD-10-010
• Electrons		
– reconstruction and identification efficiency	~3 %	ICHEP, 198 nb^{-1}
– fake rate	~5 %	ICHEP, 78 nb^{-1}
• Muons		
– reconstruction and identification efficiency	~3 %	EWK-10-002, 198 nb^{-1}
– fake rate	negligible	MUO-10-002, 0.47 nb^{-1}
• Electromagnetic calorimeter energy scale	0.9/2.2 %	EGM-10-003, 123 nb^{-1}
• Jet energy scale	5-10 %	JME-10-003, 73 nb^{-1}
• Missing E_T	~10 %	JME-10-004, 11.7 nb^{-1}
• tau-jets energy scale	n.a.	to be determined
• tau-jet reconstruction and identification efficiency	~10 %	estimate
• jet→tau fake-rate	20-40 %	PFT-10-004, 8.4 nb^{-1}
• b-tagging		
– b-tagging efficiency	19 %	BTV-10-001, 8 nb^{-1}
– b-mistag rate	3-60 %	BTV-10-001, 12 nb^{-1}
• Work ongoing on background measurements from data		

Where do we stand today ?

The important issues are:

1. Tau Identification

1. $Z \rightarrow \tau\tau$ is an important milestone

1. b-tagging, missing E_T

1. Understanding of the backgrounds

   - W + jets
   - tt
   - QCD

M. Kortelmainen

A. Attikis

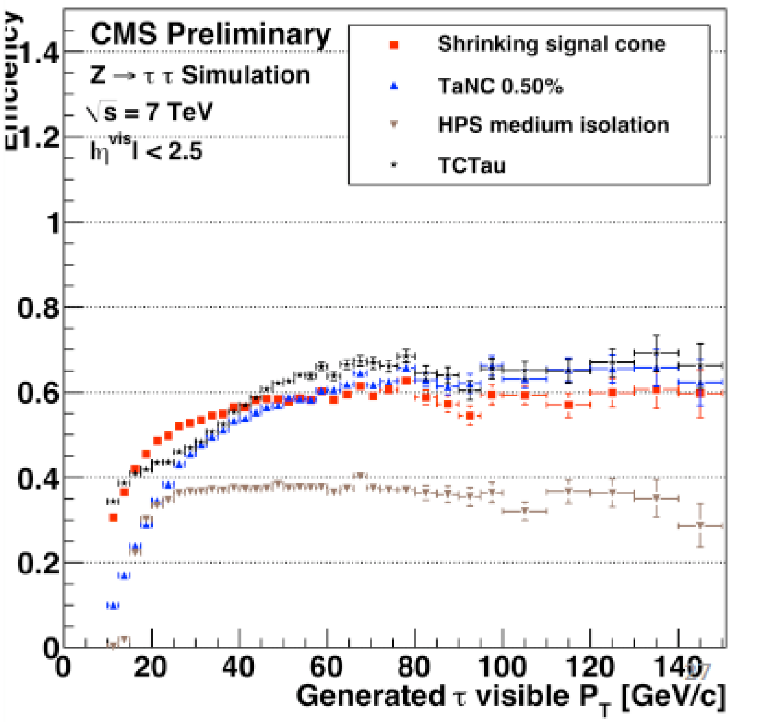
F. Terrade

M. Flechl

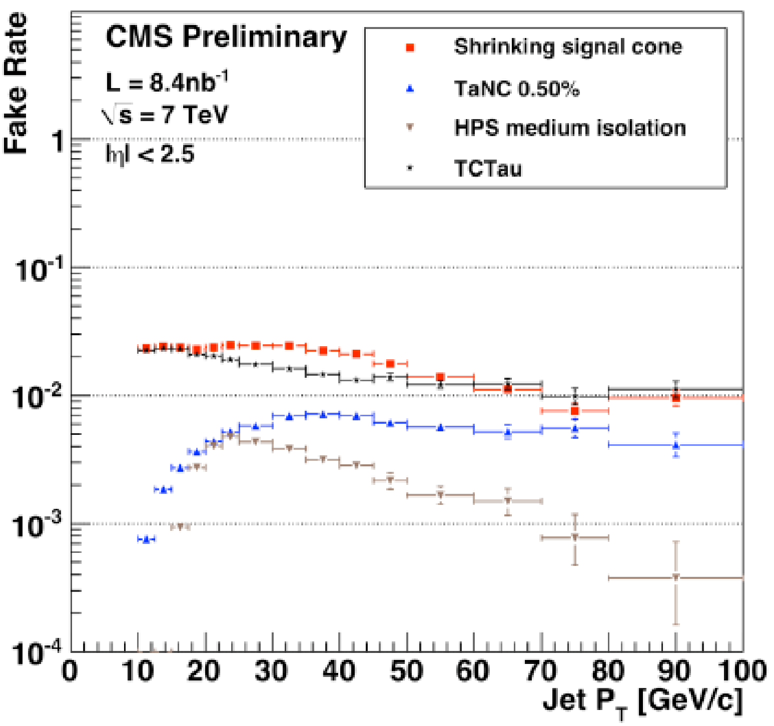
Tau ID and fake rates (CMS)

A. Nikitenko

τ_{had} efficiency: Monte-Carlo



Jet->τ_{had} fake rate: data

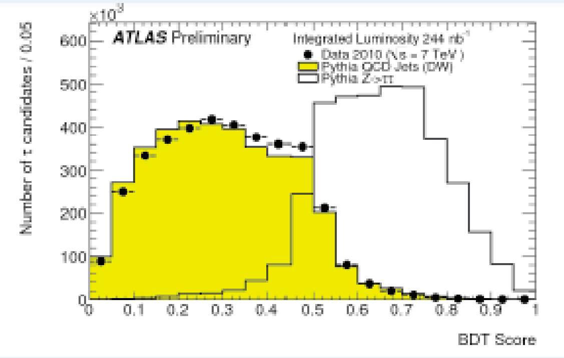


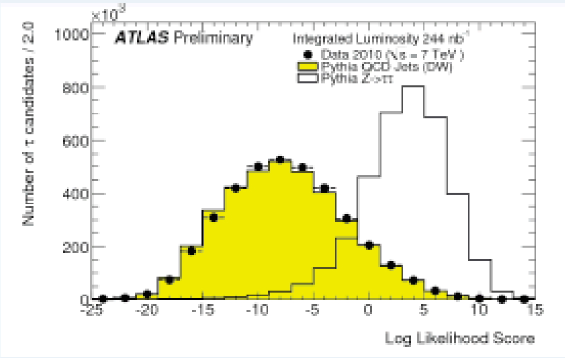
Tau ID and fake rates (ATLAS)

Y. Coadou

Discriminant output

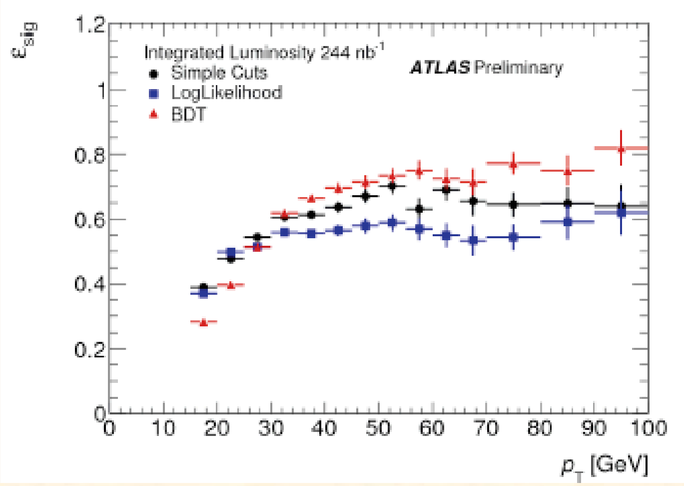
- Boosted decision trees (BDT) use all seven variables
- Log likelihood (LL) excludes core energy fraction (correlations)



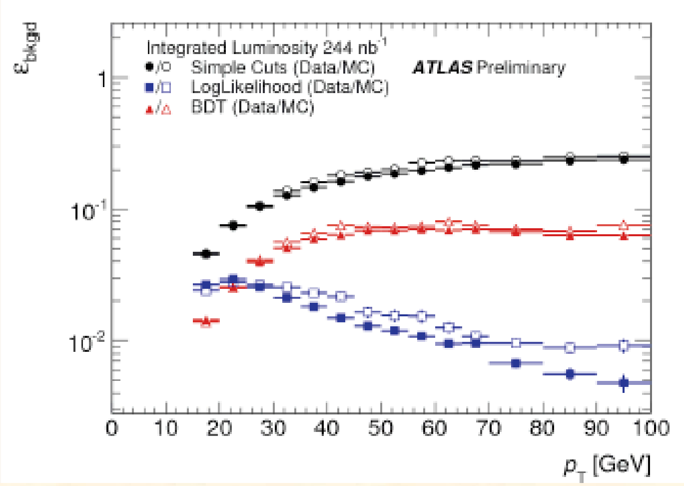


- Output well described by MC, quite discriminating

Signal efficiency ($Z \to \tau\tau$ MC)



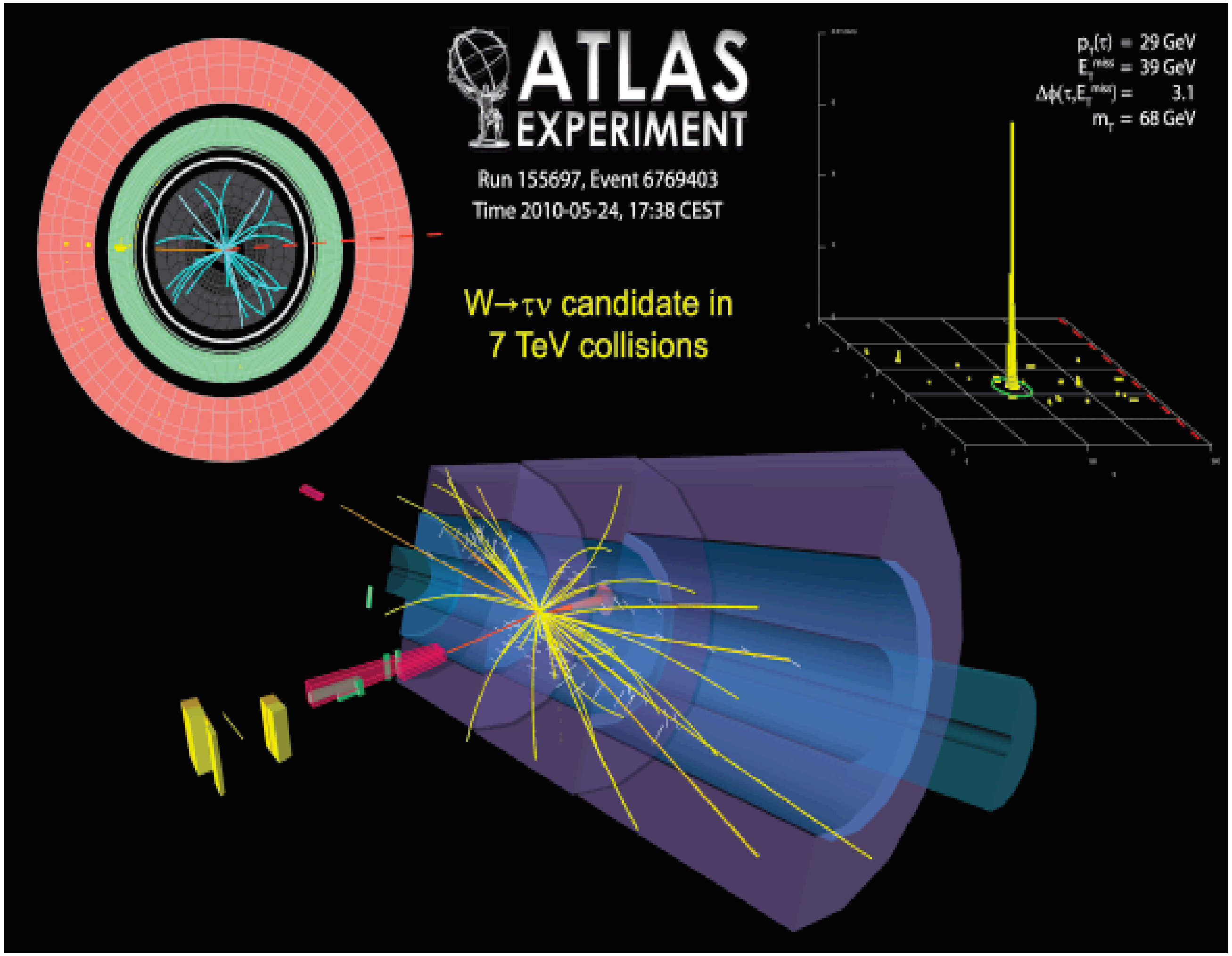
Background efficiency (medium)



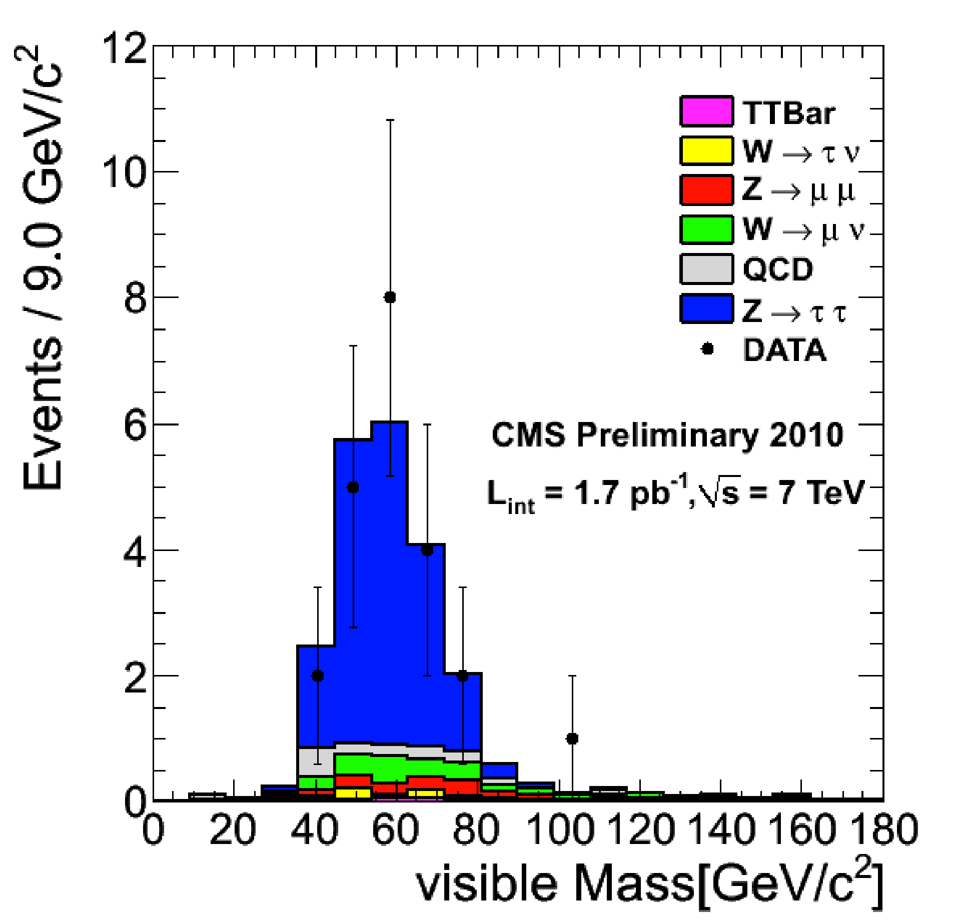
Performance of ATLAS and CMS comparable for the best methods (log likelihood, ...)

First $W \to \tau\nu$ candidate observed in ATLAS

- Hadronically decaying tau (1-prong), $p_T = 29$ GeV, $\not{E}_{\mathrm{T}} = 39$ GeV, $\Delta\phi(\tau, \not{E}_{\mathrm{T}}) = 3.1$, transverse mass $m_T = 68$ GeV



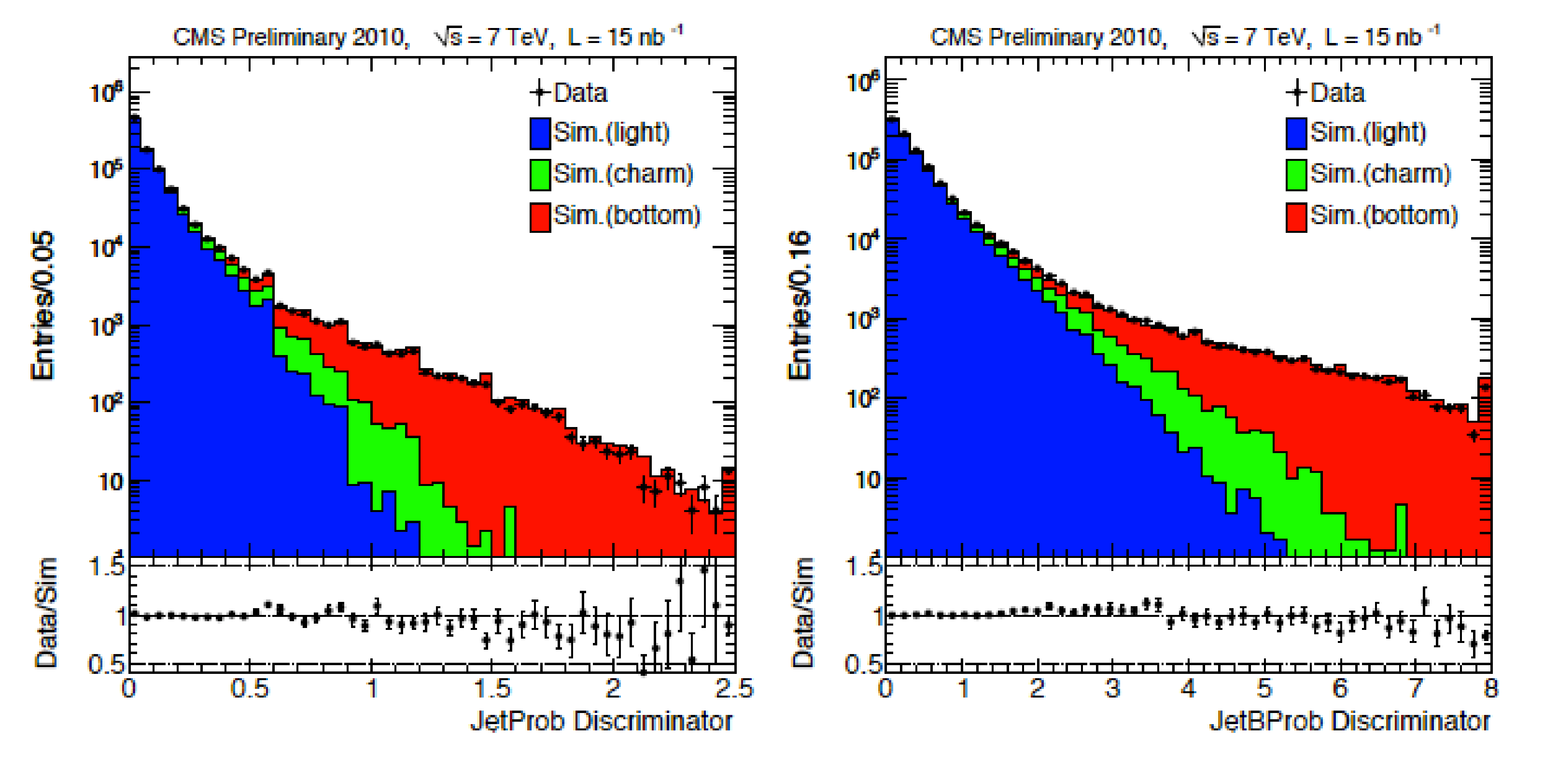
Z → τ τ on the horizon



.... an important benchmark towards charged Higgs physics

b-tagging

J. Komaragiri



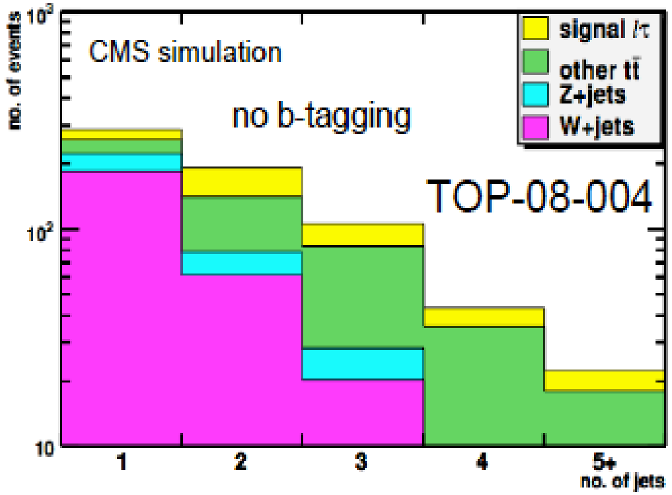
- Very good agreement between data and Monte Carlo
- Good performance, given that we are at that early stage of data taking
- Efficiencies and mistag rates already estimated from data

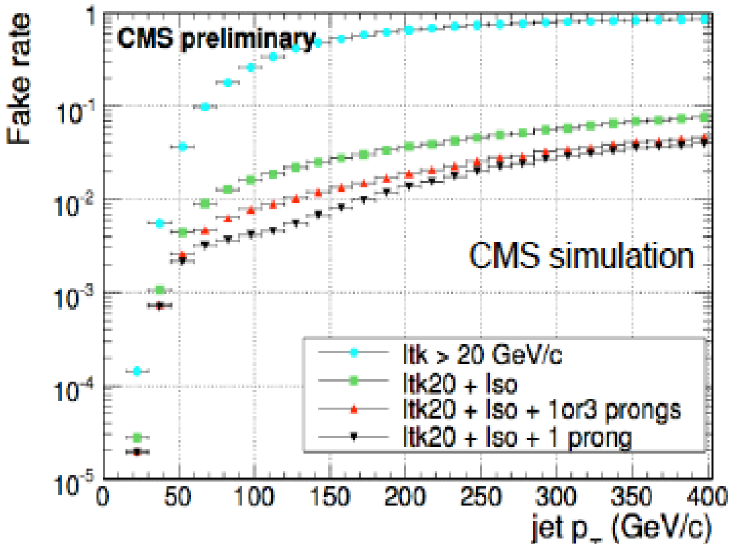
QCD background

- Jets may "fake" hadronic tau decays
  - from `W+jets' and from `ttbar→l+jets'
- It is a large background
- Estimate background from data
  - inclusive jet pT distribution
  - jet identified as a tau
  - estimate "fake" probability from ratio
- Apply to W+≥3 jet distribution
- Estimates within 10-15% of expectations

<u>Early data:</u>

- look at low/high pT tracks
- Tau ID/PF
- validate bkg studies (fake rates, etc)





Summary on Charged Higgs potential in 2010/11

- Direct / indirect charged Higgs boson limits so far from Tevatron and B-factories

- LHC enters the game now...

- First data used to study the performance of the detectors
  Look very promising (both ATLAS and CMS)

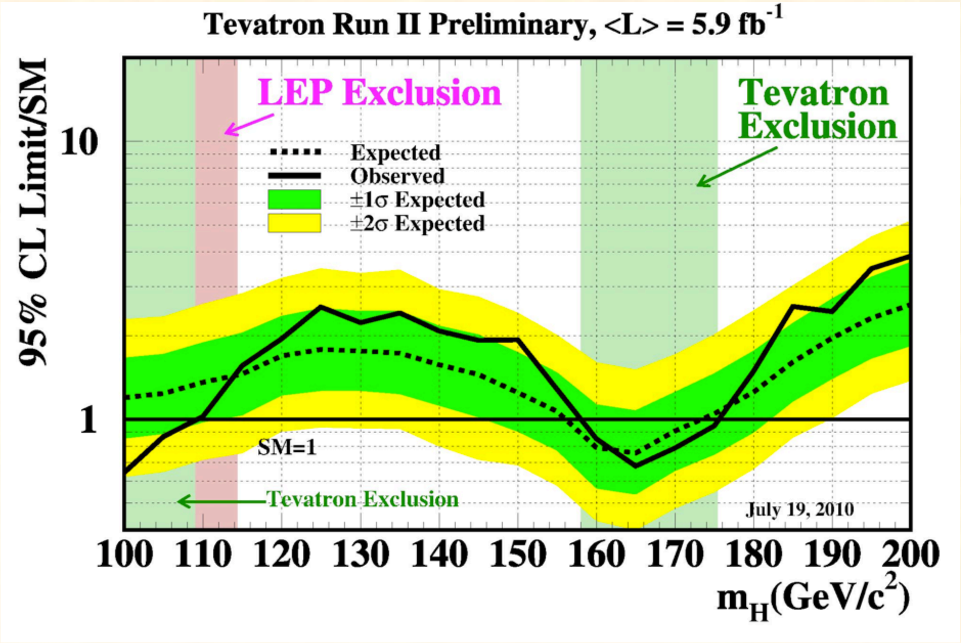
- Search for low mass charged Higgs boson looks promising with present tools and detector performance

- Present studies indicate that existing limits on branching ratios from the Tevatron can be superseded

- ….however, still challenges ahead of us
  (understanding of the backgrounds, but also there, a lot of activity is going on…)

LHC vs. Tevatron

- Tevatron has reached sensitivity to SM Higgs bosons



- Tevatron does / will add complementary information on the H → bb decay mode which is difficult –and not for the early days- at the LHC.

- However, present sensitivity studies in low mass region assume improvements on the analysis

- On Charged Higgs: so far only a small fraction of the data analyzed; Factor four in Branching ratio sensitivity...can be reached with 17 fb^{-1}

- LHC is very competitive ! already with 1 fb^{-1}
  → concentrate on the New LHC Data (Monte Carlo scan times are over)
  ……

...and help theorists to find the right model

Conclusions (cont.)

From 2006 summary

Uppsala is a nice place to be, looking forward to forthcoming workshops

Possible Roadmap:

→ 2008: work on tooling (tau, btags, methods to get efficiencies from first data)

→ 2010: first results from data ….

→ 2012: I hope that we know whether a Charged Higgs exists or not

regardless of the outcome: we could continue to get lectures on how to drink the "Uppsala Schnaps"

A big Thanks to the Organizers (Tord, Johan, ….) for the perfect organization