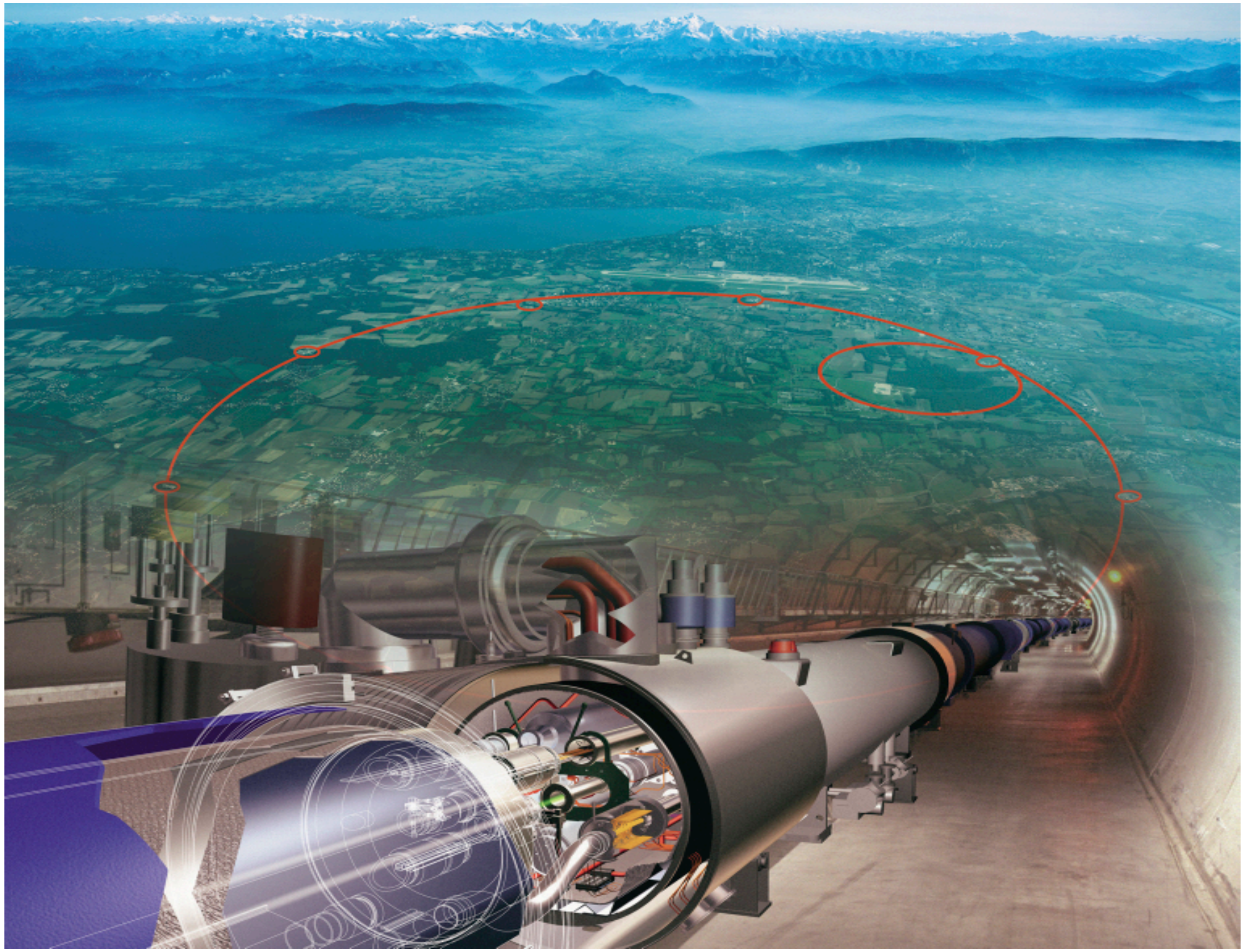

LHC Physics Prospects

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Rencontres de Physique des Particules 2010 - Lyon

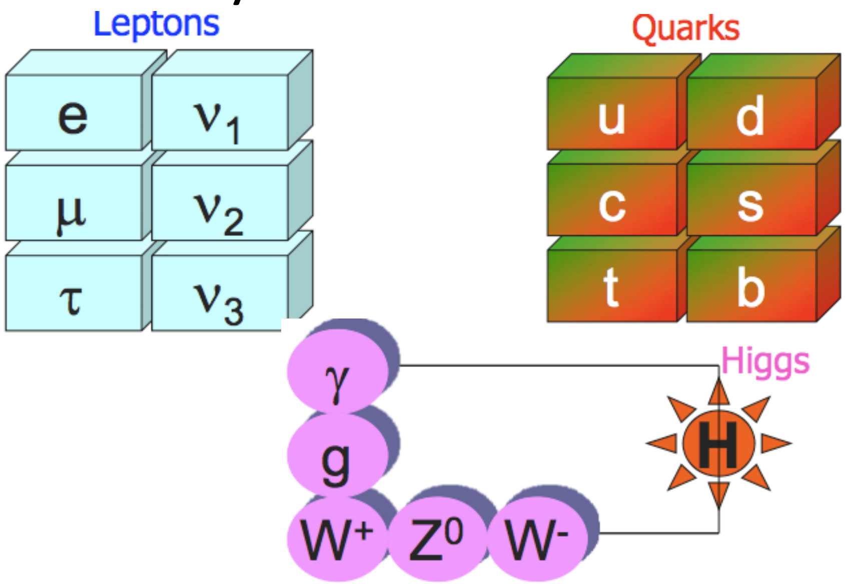
Contents

- Current view of particle physics
- The LHC and the experiments
- Early physics
- Selected topics of the long term program
- Conclusions

Current View of Particle Physics

The Standard Model

- A quantum field theory describing pointlike spin-1/2 constituents interacting by exchanging spin-1 particles.
- Remarkably complete and successful description of known phenomena in particle physics. Precisely overtested

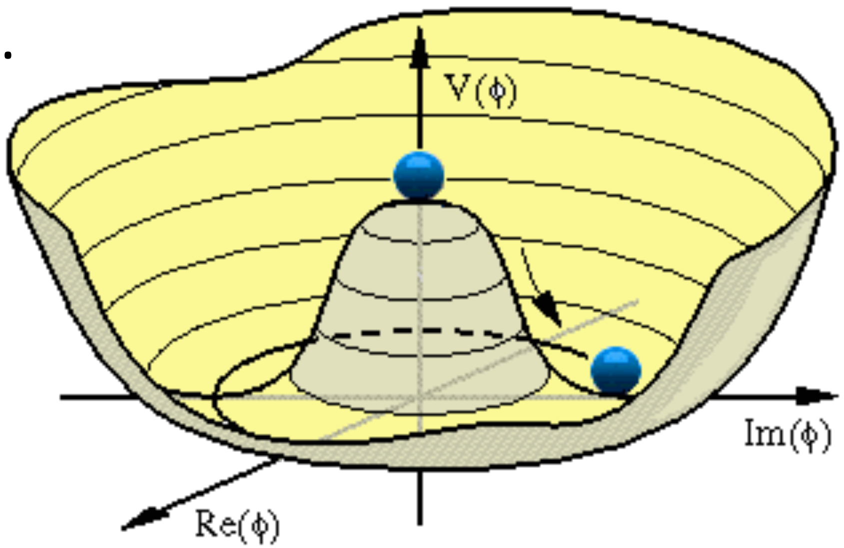


Quantity	Value PDG 2009	Standard Model	Pull	Dev.
m_t [GeV]	$170.9 \pm 1.8 \pm 0.6$	171.1 ± 1.9	-0.1	-0.8
M_W [GeV]	80.428 ± 0.039	80.375 ± 0.015	1.4	1.7
	80.376 ± 0.033		0.0	0.5
M_Z [GeV]	91.1876 ± 0.0021	91.1874 ± 0.0021	0.1	-0.1
Γ_Z [GeV]	2.4952 ± 0.0023	2.4968 ± 0.0010	-0.7	-0.5
$\Gamma(\text{had})$ [GeV]	1.7444 ± 0.0020	1.7434 ± 0.0010	–	–
$\Gamma(\text{inv})$ [MeV]	499.0 ± 1.5	501.59 ± 0.08	–	–
$\Gamma(\ell^+\ell^-)$ [MeV]	83.984 ± 0.086	83.988 ± 0.016	–	–
σ_{had} [nb]	41.541 ± 0.037	41.466 ± 0.009	2.0	2.0
R_e	20.804 ± 0.050	20.758 ± 0.011	0.9	1.0
R_μ	20.785 ± 0.033	20.758 ± 0.011	0.8	0.9
R_τ	20.764 ± 0.045	20.803 ± 0.011	-0.9	-0.8
R_b	0.21629 ± 0.00066	0.21584 ± 0.00006	0.7	0.7
R_c	0.1721 ± 0.0030	0.17228 ± 0.00004	-0.1	-0.1
$A_{FB}^{(0,e)}$	0.0145 ± 0.0025	0.01627 ± 0.00023	-0.7	-0.6
$A_{FB}^{(0,\mu)}$	0.0169 ± 0.0013		0.5	0.7
$A_{FB}^{(0,\tau)}$	0.0188 ± 0.0017		1.5	1.6
$A_{FB}^{(0,b)}$	0.0992 ± 0.0016	0.1033 ± 0.0007	-2.5	-2.0
$A_{FB}^{(0,c)}$	0.0707 ± 0.0035	0.0738 ± 0.0006	-0.9	-0.7
$A_{FB}^{(0,s)}$	0.0976 ± 0.0114	0.1034 ± 0.0007	-0.5	-0.4
$\bar{s}_\ell^2(A_{FB}^{(0,q)})$	0.2324 ± 0.0012	0.23149 ± 0.00013	0.8	0.6
	0.2238 ± 0.0050		-1.5	-1.6
A_e	0.15138 ± 0.00216	0.1473 ± 0.0011	1.9	2.4
	0.1544 ± 0.0060		1.2	1.4
	0.1498 ± 0.0049		0.5	0.7
A_μ	0.142 ± 0.015		-0.4	-0.3
A_τ	0.136 ± 0.015		-0.8	-0.7
	0.1439 ± 0.0043		-0.8	-0.5
A_b	0.923 ± 0.020	0.9348 ± 0.0001	-0.6	-0.6
A_c	0.670 ± 0.027	0.6679 ± 0.0005	0.1	0.1
A_s	0.895 ± 0.091	0.9357 ± 0.0001	-0.4	-0.4
g_L^2	0.3010 ± 0.0015	0.30386 ± 0.00018	-1.9	-1.8
g_R^2	0.0308 ± 0.0011	0.03001 ± 0.00003	0.7	0.7
$g_V^{\nu e}$	-0.040 ± 0.015	-0.0397 ± 0.0003	0.0	0.0
$g_A^{\nu e}$	-0.507 ± 0.014	-0.5064 ± 0.0001	0.0	0.0
A_{PV}	$(-1.31 \pm 0.17) \cdot 10^{-7}$	$(-1.54 \pm 0.02) \cdot 10^{-7}$	1.3	1.2
$Q_W(\text{Cs})$	-72.62 ± 0.46	-73.16 ± 0.03	1.2	1.2
$Q_W(\text{Tl})$	-116.4 ± 3.6	-116.76 ± 0.04	0.1	0.1
$\frac{\Gamma(b \to s\gamma)}{\Gamma(b \to X e \nu)}$	$\left(3.55^{+0.53}_{-0.46}\right) \cdot 10^{-3}$	$(3.19 \pm 0.08) \cdot 10^{-3}$	0.8	0.7
$\frac{1}{2}(g_\mu - 2 - \frac{\alpha}{\pi})$	$4511.07(74) \cdot 10^{-9}$	$4509.08(10) \cdot 10^{-9}$	2.7	2.7
τ_τ [fs]	290.93 ± 0.48	291.80 ± 1.76	-0.4	-0.4

July 24, 2008 18:04

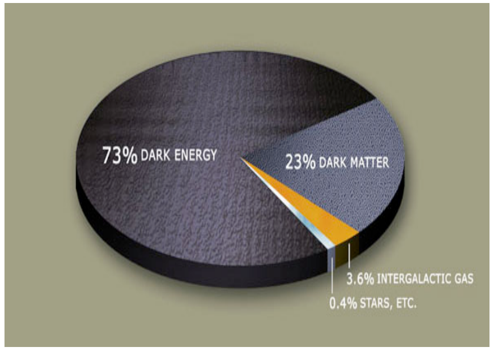
The EW Symmetry Breaking

- The *W* and *Z* bosons acquire mass via the spontaneous symmetry breaking mechanism:
  - The EWSB in the SM occurs by introducing a scalar field ϕ
  - ϕ has a finite vacuum expectation value: 246 GeV
  - this gives mass to the fermions as well.
- Is this the correct picture ? The prediction can be tested!
- Search for a scalar particle (the Higgs boson): its production and decay properties are fixed.
- The mass however remains a free parameter !
  - To be determined by the experiments.



… but

- … but the SM appears to be an incomplete theory.
- It can be viewed as a low-energy effective theory of a more general theory.
- Major basic questions remain to be answered:
  - What is the origin of mass ? Is the EW symmetry breaking mechanism of the SM the right description ?
  - What is dark matter ?



  - What is the source of the baryon asymmetry ? Why did antimatter disappear?
  - Why are there 3 generations ? Why are the masses of the elementary particles so different ?
  - How to reconcile gravity with the other forces ? Why 3+1 dimensions ?
- Many theories proposed along the years: the LHC will try to answer as many questions as possible
  - LHC designed as a discovery machine. Tried to take into account the widest range of scenarios

Supersymmetry

- All SM particles have a partner with spin differing by ±1/2
- SUSY describes all forces. Modifies the running of gauge couplings to provide grand unification at a single scale
- It offers solution to hierarchy problem.
  - Huge disparity between EW and M_{PL} scales
- … but so far no SUSY particles observed : SUSY must be broken.

Spin 1/2	Spin 0	Spin 1	Spin 1/2
Quark	Squarks	W_3, B	$\tilde{W}_3$, $\tilde{B}$
Leptons	Sleptons	$W^{\pm}$	$\tilde{W}^{\pm}$
Higgsino $\tilde{H}_1$,$\tilde{H}_2$	Higgs H_1,H_2	gluon	gluino

+ graviton / gravitino

$\tilde{W}^{\pm}$, $\tilde{H}^{\pm}$ <-> charginos
$\tilde{W}_3$, $\tilde{B}$, $\tilde{H}_1$, $\tilde{H}_2$ <-> neutralinos

- > 100 free parameters….
- mSUGRA scenario: reduced to 5
  - m_0, $m_{1/2}$: common scalars and gauginos masses
  - A_0: common trilinear coupling
  - tanβ: ratio of vacuum expectation values of the two Higgs doublets
  - sign of Higgsino mixing parameter

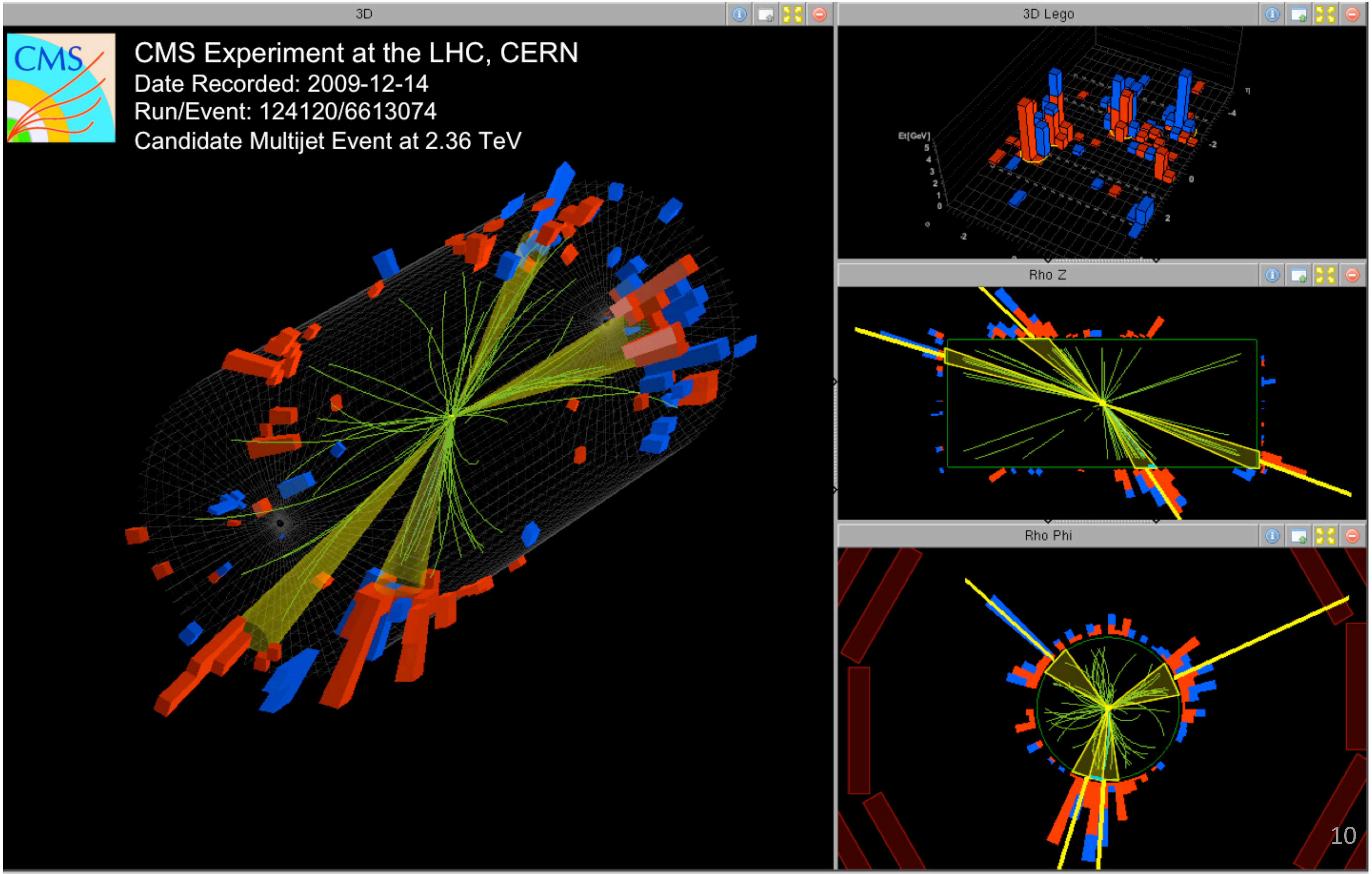
- If R-parity is conserved: $R=(-1)^{3(B-L)+2S}$
  - SUSY partners always produced in pairs
  - Lightest particle is stable: dark matter candidate!

String Theory and Extra Dimensions

- Fundamental particles are not pointlike, but rather small loops of vibrating strings.
- The theory implies additional spatial dimensions
  - The additional dimensions are compactified
- It explains why gravity appears so much weaker
- Standard particles would have heavier versions recurring at higher energies as they navigate smaller dimensions (Kaluza-Klein recurrences).
- Graviton may be not visible in the brane (ordinary dimensions), disappearing in the other dimensions: energy-momentum imbalance.

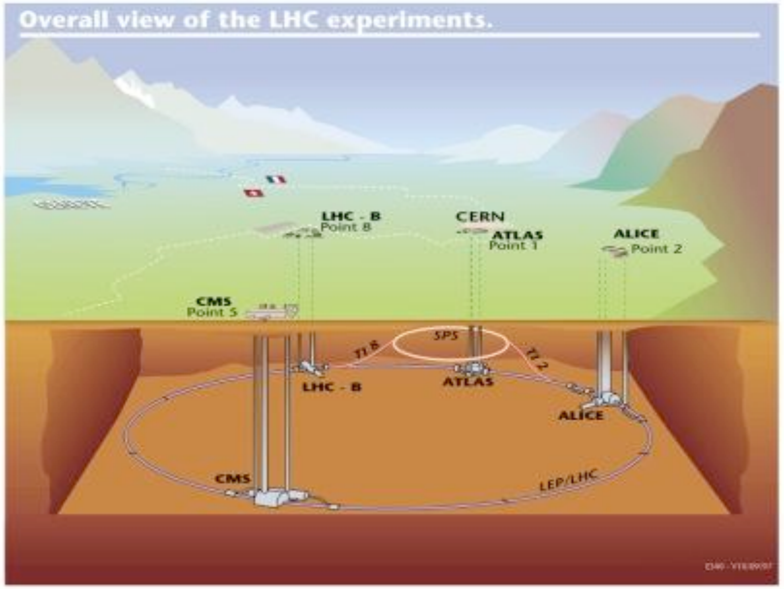
The Large Hadron Collider and the Experiments

- The LHC will try to shed as much light as possible: the adventure began !



The LHC: an Adventure Started Long Ago

- 80's: first proposals of a pp collider
- 1994: project approved
- 2000: end of LEP operations. LHC construction phase
- 2008: protons injected in the ring. Magnetic quench, investigation of the accident and repair.



- 20/11/2009: protons in the ring. First collisions at 900 GeV on 23/11!
- 30/11/2009: world record! 1.18 TeV/beam.
- 12/2009 collisions at c.o.m. energy 2.26 TeV, then winter shutdown.
- 02/2010: run restarts. Towards 7 TeV and later 10 TeV collisions.

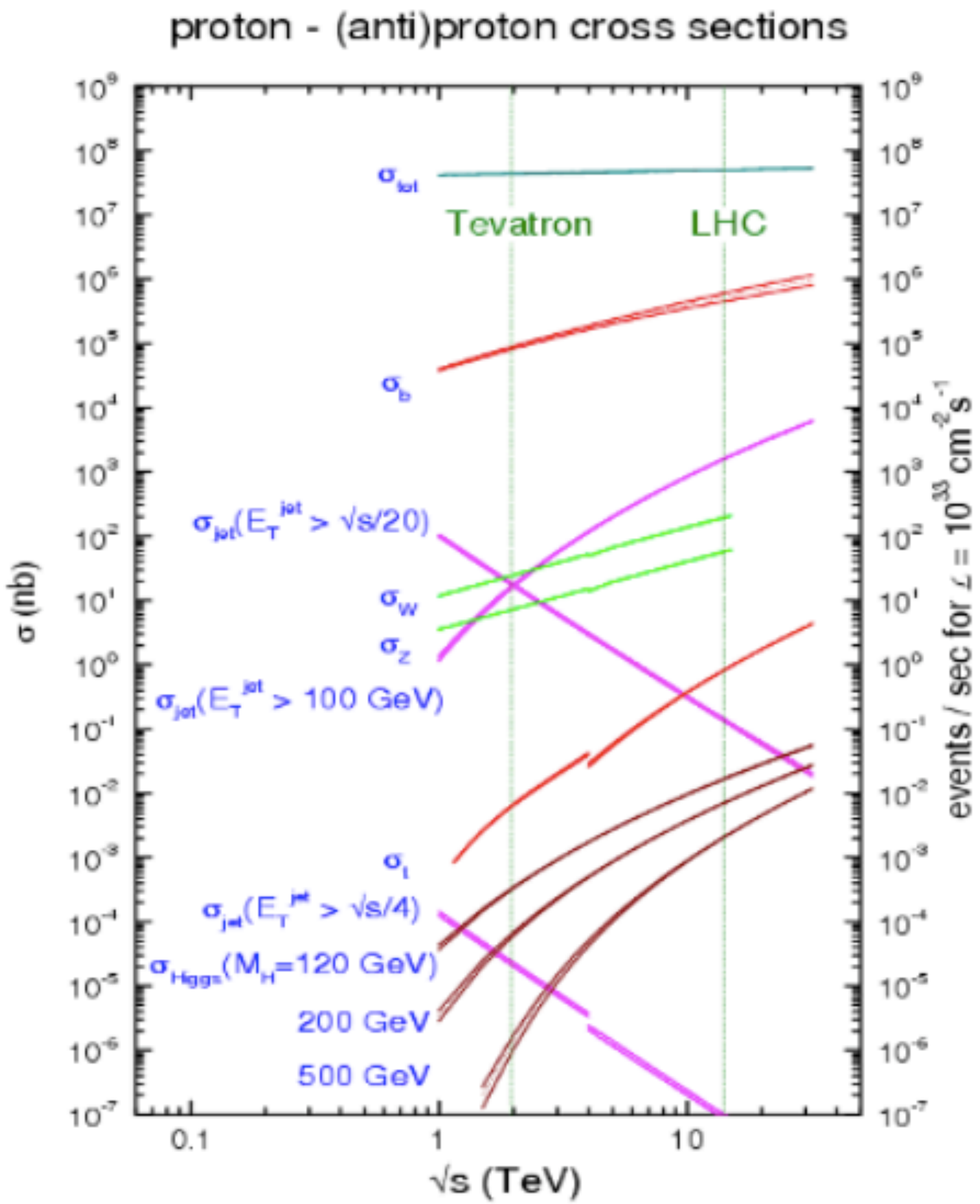
Nominal parameters
c.o.m. energy: 14 TeV
Lumi: 10^{34} cm^{-2} s^{-1}
Integrated lumi: 100 fb^{-1}/year

Collisions of protons and heavy ions too

Plans for 2010 Run

- Workshop in Chamonix this week
- Decisions on the plan for 2010 will be taken there
- Run resumed in February at 7 TeV and possibly later on at 10 TeV
  - At 7 TeV, σ(W), σ(Z), σ(tt) decrease by a factor 2-3 wrt 10 TeV
- After that sufficient experience will be collected, likely in June the maximal c.o.m. energy for 2010 will be decided
- Aiming at ~500 pb^{-1} of data in 2010
- Possibly a shutdown at the end of 2010: to be decided.

The Event Rate at the LHC

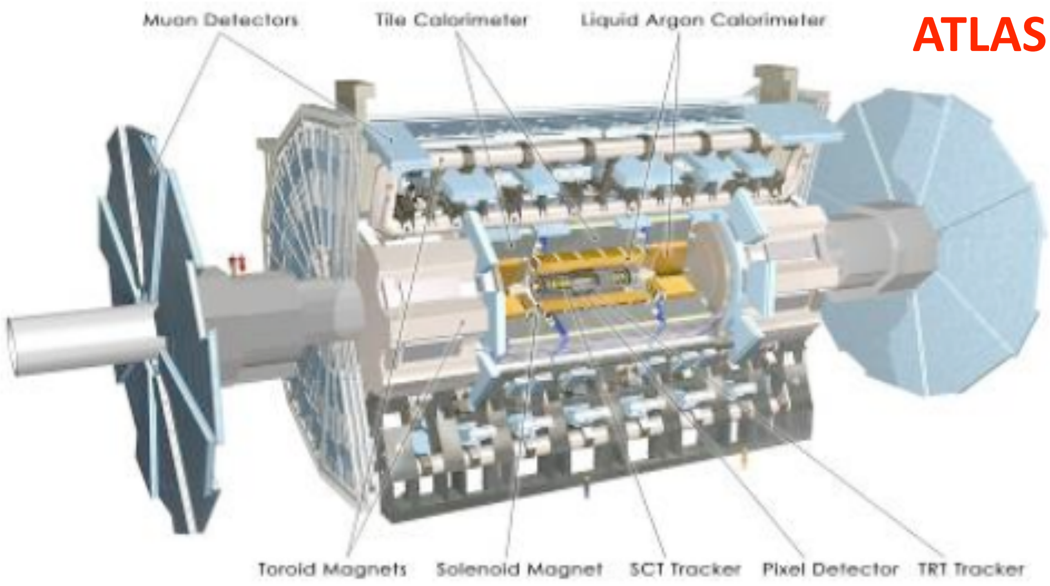


- Great physics potential.
- In fact, a *b*-, *Z*-, *W*-, top- … and more-factory !
- Assuming √s=10 TeV and 100 pb^{-1} of data:
  - 3M *W* to leptons
  - 300k *Z* to leptons
  - 30k top-pairs
  - ….
- A huge event rate !

Selecting the Events

- Rate for inelastic collisions: 10^9 Hz
- Aim at keeping 150-200 Hz
  - This corresponds to 25 GB/minute !
  - 4M of GB are needed per year !
- « Interesting » events occur at a 1 - 10 Hz frequency
- So, try to reject as much « noise » as possible while avoiding to kill physics and to bias the sample!
- Efficient triggers: hardware (typically objects from calorimeters and muon systems) and software
  - Simple: for commissioning, debugging and understanding
  - Inclusive: one trigger for many analyses; able to discover the unexpected!
  - Robust: can run on pathological events, can run on events with 10 times more hits than predicted by simulation
  - Redundant: if a trigger component has a problem, the event is not lost

Two General Purpose Detectors

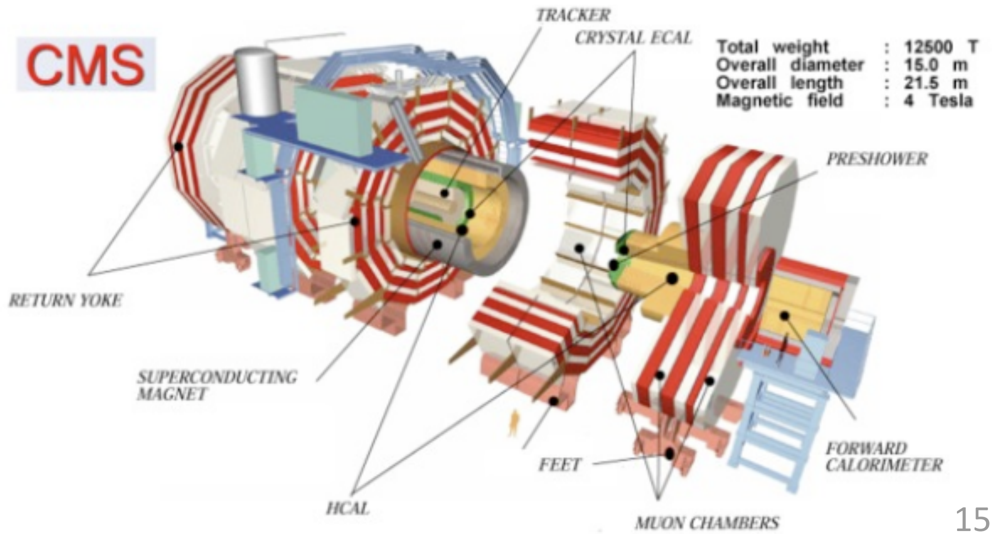


ATLAS

Detector	Resolution	Coverage
Tracker	$\sigma(p_T)/p_T$~5%p_T	$\|\eta\|<2.5$
Ecal	$\sigma(E)/E$~10%/√E +0.7%	$\|\eta\|<3.2$
Hcal	$\sigma(E)/E$~50%/√E +3%	$\|\eta\|<3.2$ (b) / 4.9 (f)
Muon	$\sigma(p_T)/p_T$~10%p_T	$\|\eta\|<2.7$

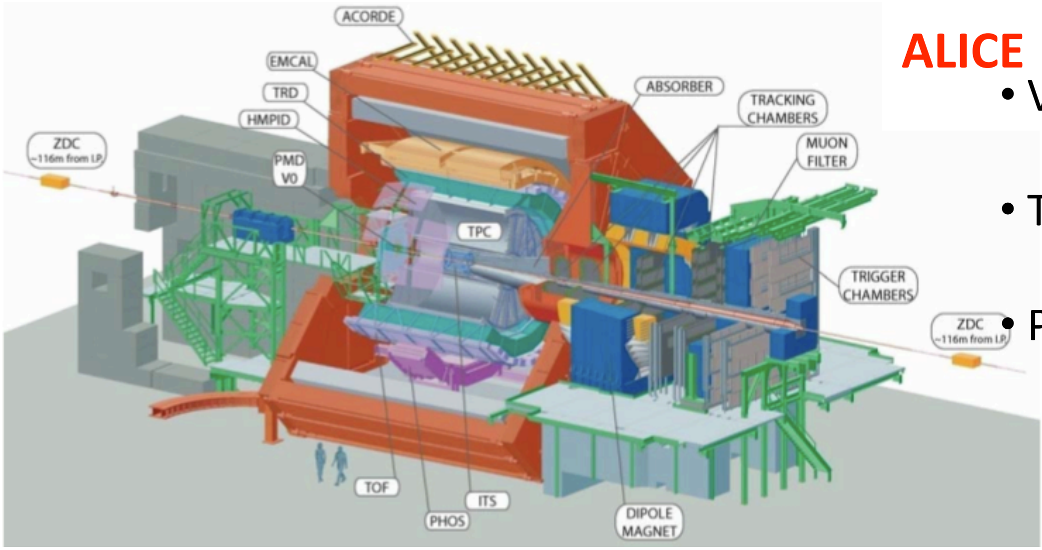
Detector	Resolution	Coverage
Tracker	$\sigma(p_T)/p_T$~1-5%p_T	$\|\eta\|<2.4$
Ecal	$\sigma(E)/E$~3%/√E +0.5%	$\|\eta\|<3$
Hcal	$\sigma(E)/E$~100%/√E +4%	$\|\eta\|<3$ (b) / 5 (f)
Muon	$\sigma(p_T)/p_T$~10%p_T	$\|\eta\|<2.4$

CMS



Two Specialized Experiments

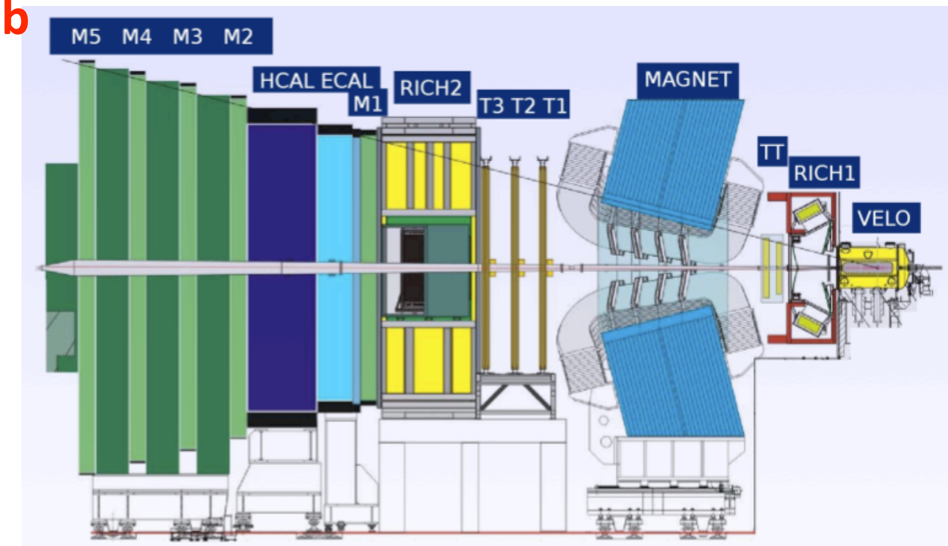
Also **TOTEM, LHCf**



ALICE

- Vertex:
  - σ_x, σ_y~15 μm; σ_z, 5 μm
- Tracking:
  - σ(p)/p ~ 1% p<10 GeV; 15% p~100 GeV
- Particle ID:
  - excellent PID using almost all known methods

LHCb

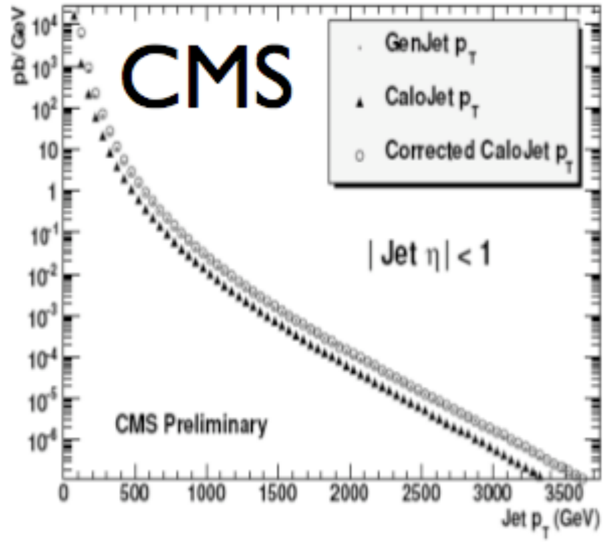


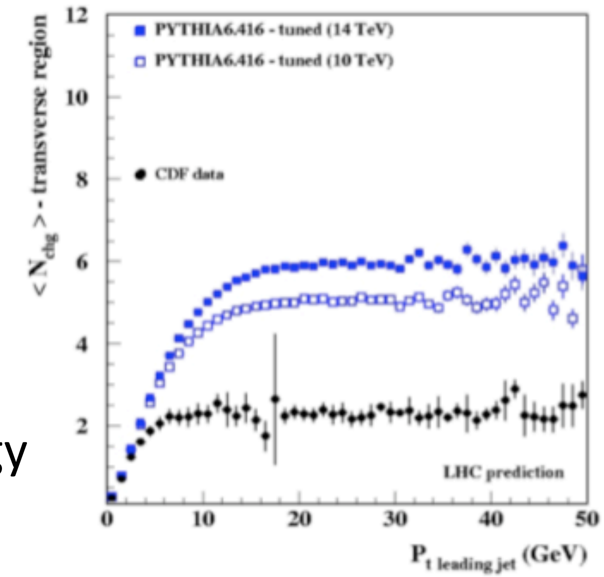
- Vertex:
  - σ(x)~50 (150) μm for primary (sec.) vertices; σ(t): 40 fs on *b*-hadron lifetimes
- Energy:
  - σ(E)/E~9%/√E + 0.8%(ECAL)
  - σ(E)/E~69%/√E + 9%(HCAL)
- Tracking:
  - eff ~ 95% for p > 5 GeV; σ(p)/p~0.4%
- Particle ID:
  - eff(K) ~ 88% w/3% misID; eff(μ) ~ 95% w/ 5% misID

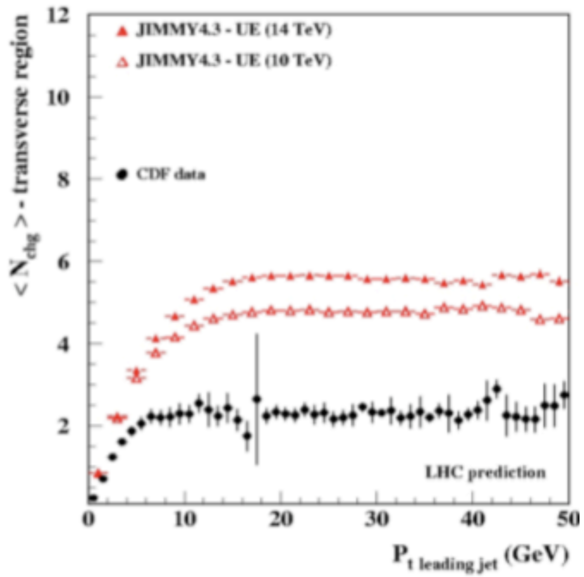
Making a Good Use of Known Particles

First Tasks: Understanding the Detectors

- A lot of QCD events:
  - hard interactions (high p_T): perturbative QCD
  - soft interactions (low p_T): minimum bias events
  - important background to many analyses
- Use these events to
  - Study the underline event (UE): initial and final state radiation (ISR/FSR); beam-beam remnants; multiple-parton interaction (MPI); spectators…
  - Improve the simulation and modelling of minimum bias.
  - Evaluate jet reconstruction performances: energy scale, resolution,…

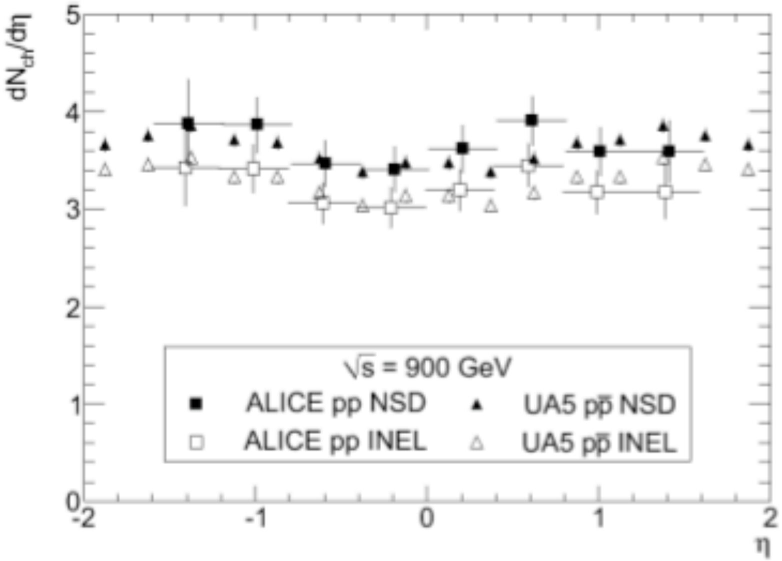


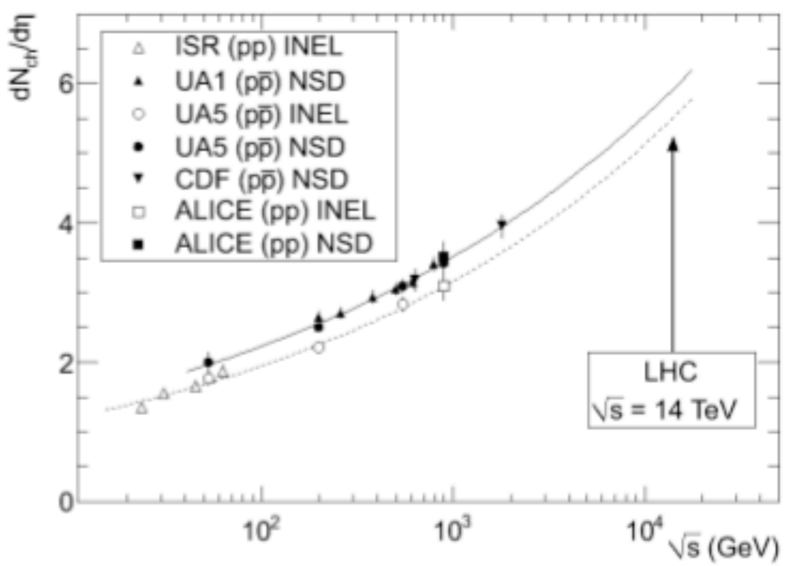




First Look at LHC Data!

- First paper by Alice appeared on the arXiv on November 29th!



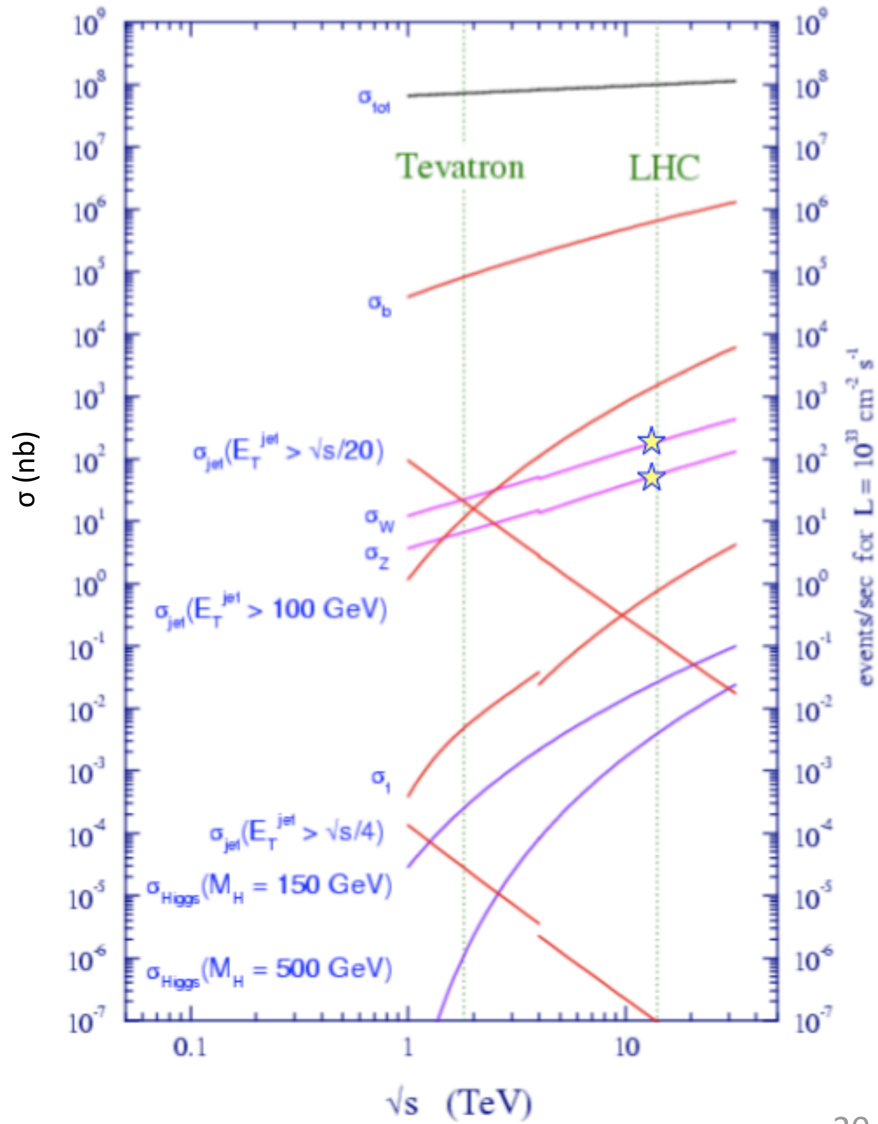


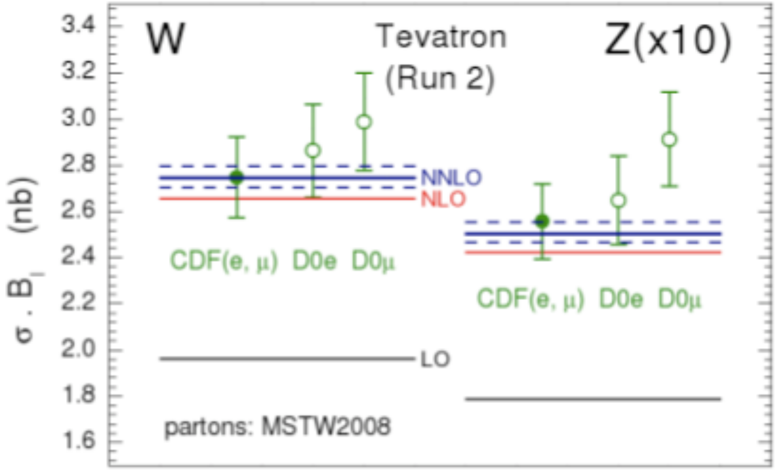
arXiv:0911.5430 [hep-ex]

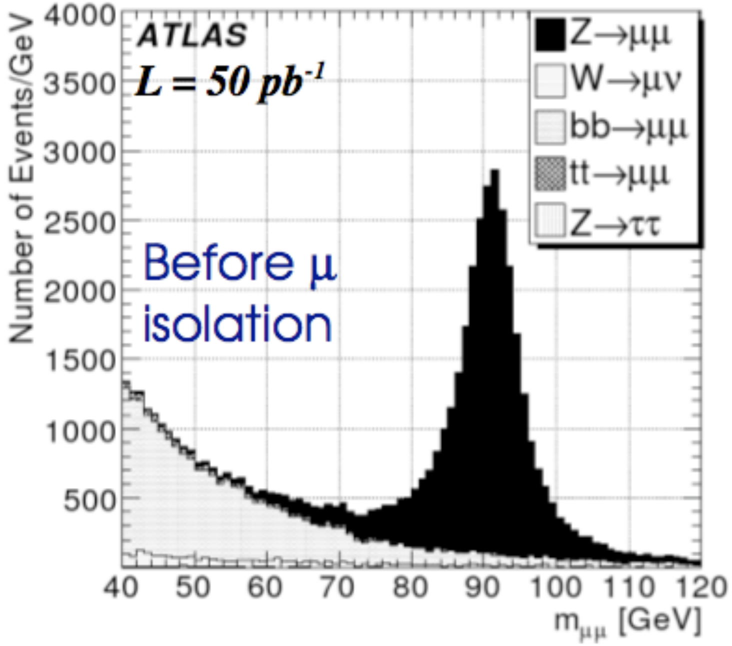
- First papers by the other experiments in preparation: to be submitted soon!

The *Z* and *W* Bosons

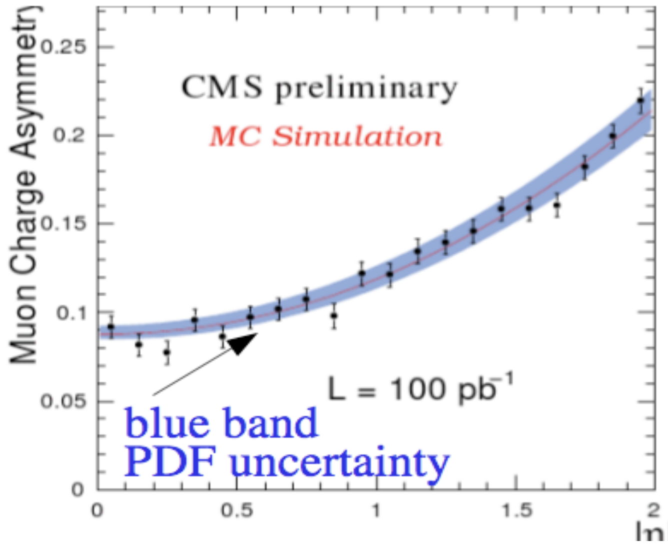
- Large cross section for *Z* and *W* production
  - σ(*Z->ll*) ~ 1.4 nb (@ 10 TeV)
  - σ(*W->lν*) ~ 14 nb (@ 10 TeV)
- Isolated leptons provide a clear experimental signature.
- Measuring *Z* and *W* properties will help understanding the detectors.
  - Calibration/alignement
  - Trigger and lepton ID efficiencies
  - Luminosity
- Many interesting measurements using *W* and *Z*







- Cross sections
  - Known at the <1% level at the NNLO
  - Negligible stat errors above 10 pb^{-1}
  - Systematics of some % (improving with L)
  - --> Precise test of perturbative QCD
- Lepton charge asymmetry
  - With ~100 pb^{-1}, the uncertainty will be comparable to that of the PDFs.



- *W* mass
  - Precision test of the SM
  - Constraints on the Higgs mass
  - Aim:15 MeV uncertainty (now ~25 MeV)
- VV

	WZ	WW	ZZ	Wγ	Zγ
σ (SM)	51.5 pb	117 pb	18 pb	74 pb	140 pb

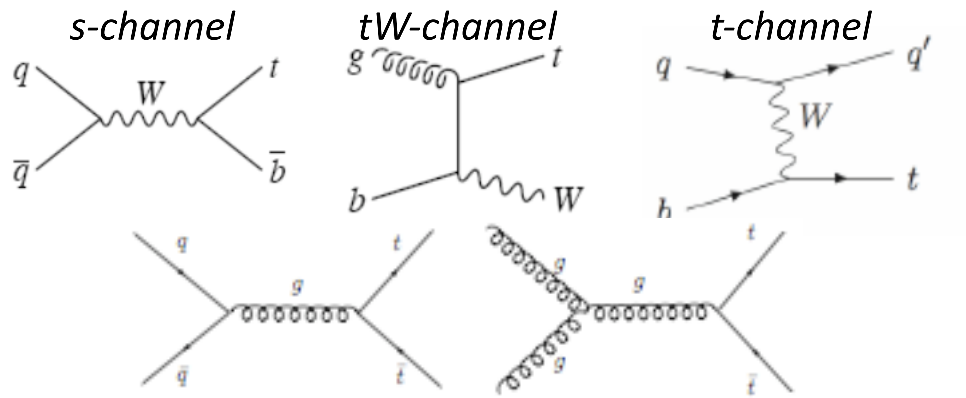
  - Test of the SM.
  - Observation with 0.1 – 1 fb^{-1}

The Top Quark

- The top quark is the heaviest elementary particle known to date
  - m = (173.1±1.3) GeV*; τ < 10^{-25} s
  - It decays before hadronizing.
  - BR(*t*->*Wb*) ~ 100%

- The top quark can be produced either alone (single top) or in pairs.
  - Single top: via weak interaction
  - $t\bar{t}$ pairs: via strong interaction.

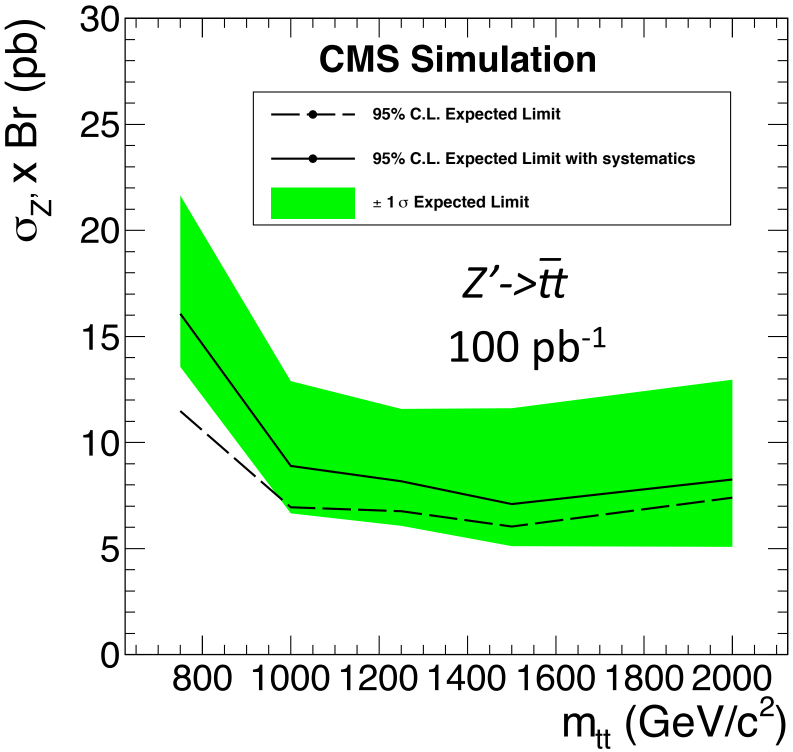
  3 decay channels: leptonic, semileptonic, hadronic.



- Important tests of the SM
  - Deviations may indicate NP
- Important tool to test the detector performances
  - Many subsystems are involved (leptons, jets, missing energy)
- Background to many processes

** Tevatron, March 2009: arXiv:0903:2503 [hep-ex]*

- At the Tevatron, $\sigma(t\bar{t})$ is measured with an uncertainity of ~9%, comparable to the theoretical one.
- At the LHC (10 TeV) the cross section will be more than 50 times larger.
  - With ~100 pb^{-1}, uncertainty of 5-10%
- NP can manifest itself in the top quark sector in many ways:
  - NP expected to have a priviledged coupling to tops: resonances decaying to $t\bar{t}$, *b'->Wt*, Higgs, stop.
- *W* polarization and spin correlation
  - A few % uncertainty with 10 fb^{-1}
  - Test coupling to fermions and SM pattern
  - Deviations may indicate anomalous couplings or new particles (including a $H^{\pm}$)
- Top mass
  - Precision below 1 GeV with 10 fb^{-1}



- Single top was discovered at the Tevatron with ~3 fb^{-1} of data *.
- At the LHC, σ is 120 to 500 times larger (at 14 TeV, varying w/channel)
  - Observation with 700 pb^{-1} (10 TeV)
- FCNC and anomalous couplings
- Direct constraints on V_{tb}
  - 10% uncertainty on *R* with 250 pb^{-1}

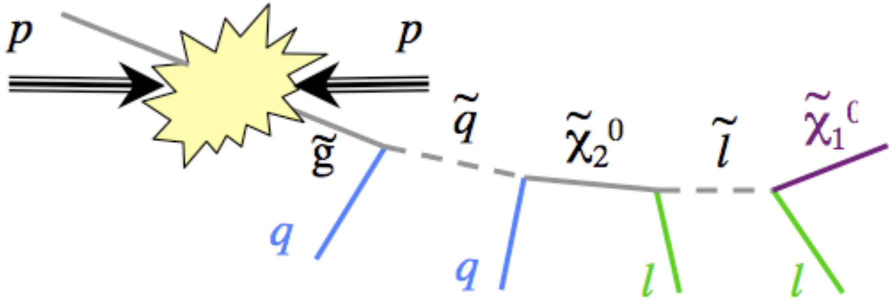
$$R = \frac{\Gamma(t \to Wb)}{\Gamma(t \to Wq(=d,s,b))} = \frac{|V_{tb}|^2}{|V_{td}|^2 + |V_{ts}|^2 + |V_{tb}|^2}$$

* Phys.Rev.Lett.103:092001
Phys.Rev.Lett.103:092002

Searching for Beyond the Standard Model Physics

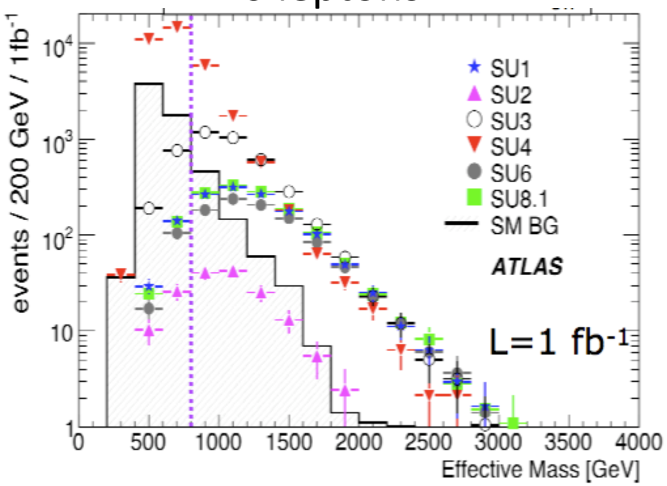
Hunting for SUSY

- Strongly interacting sparticles dominate the production
- Long cascades into the lightest stable particle:
  - Large missing E_T
  - Large multiplicity of high p_T jets
  - Leptons

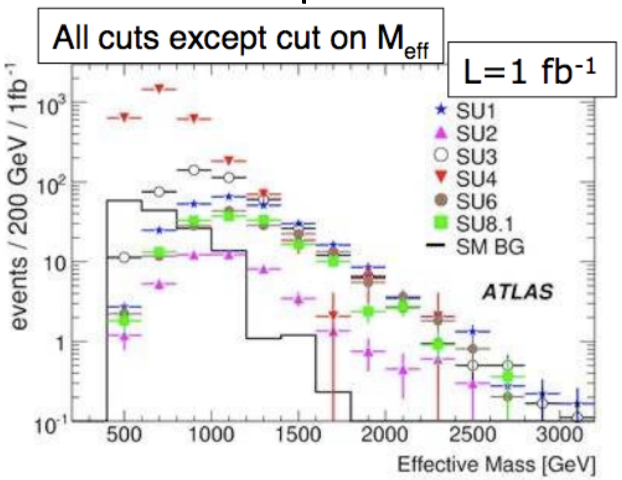


- Look for excess of events in a phase-space region where SUSY is expected

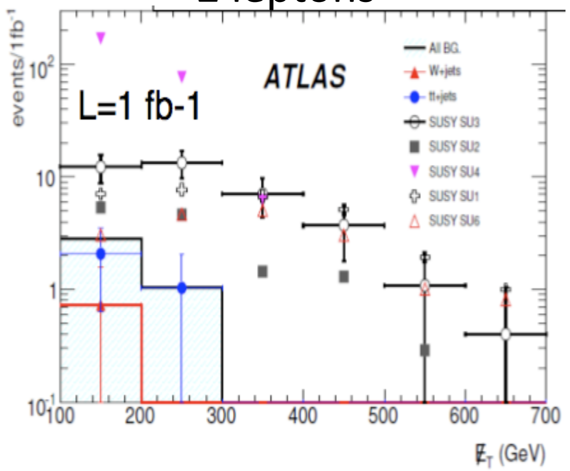
0 leptons



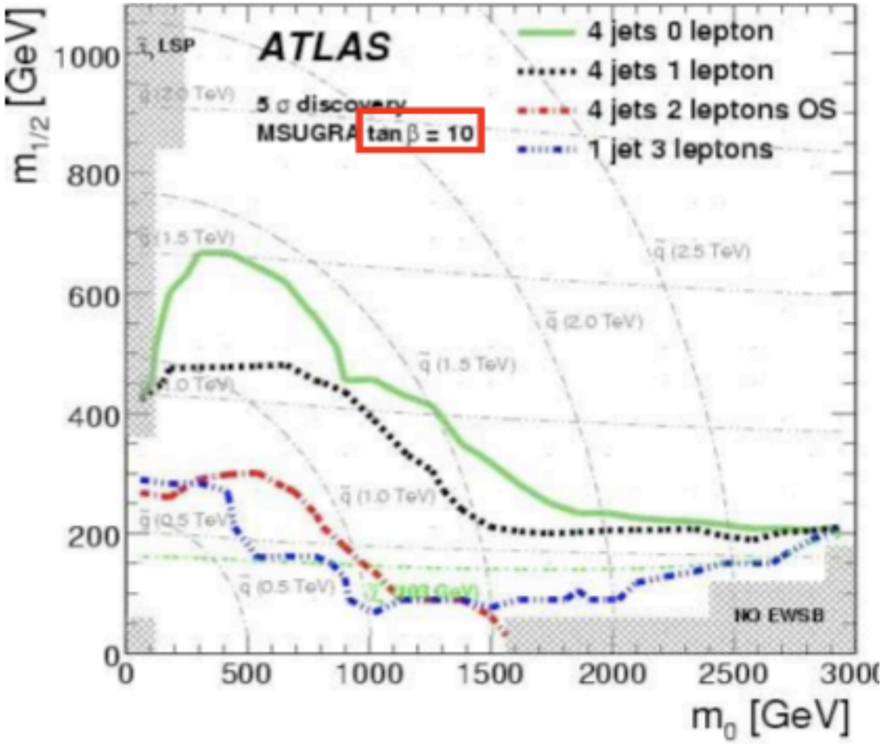
1 leptons

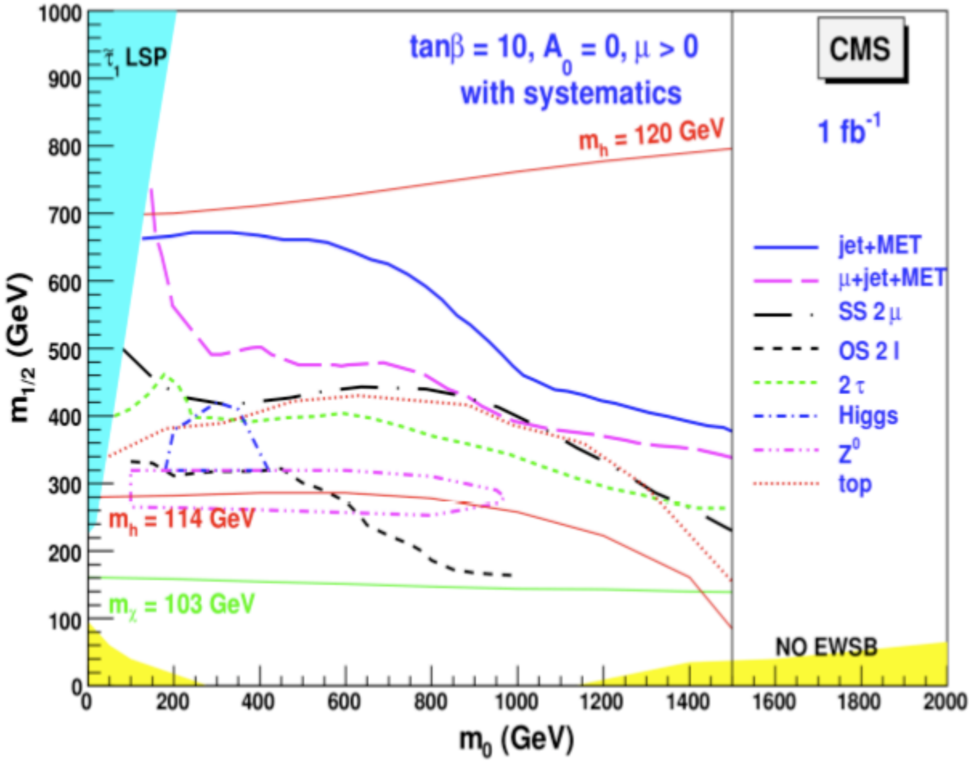


2 leptons

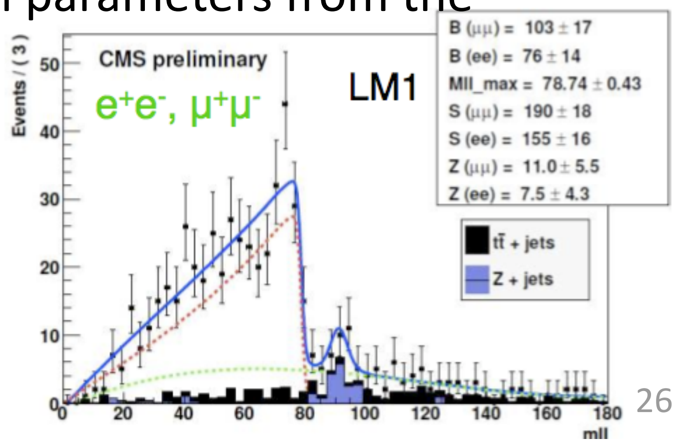


- Excess due to SUSY clearly visible !



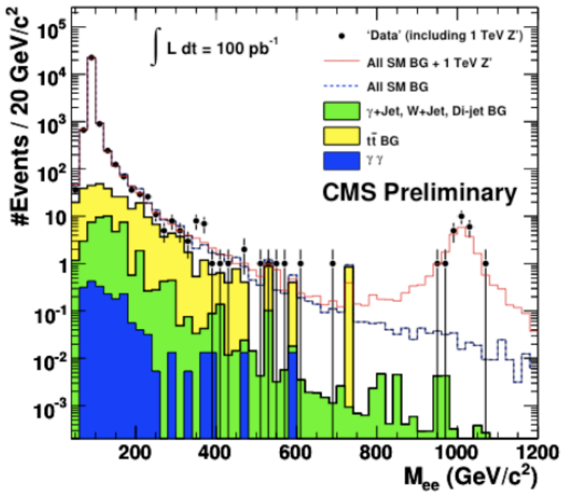


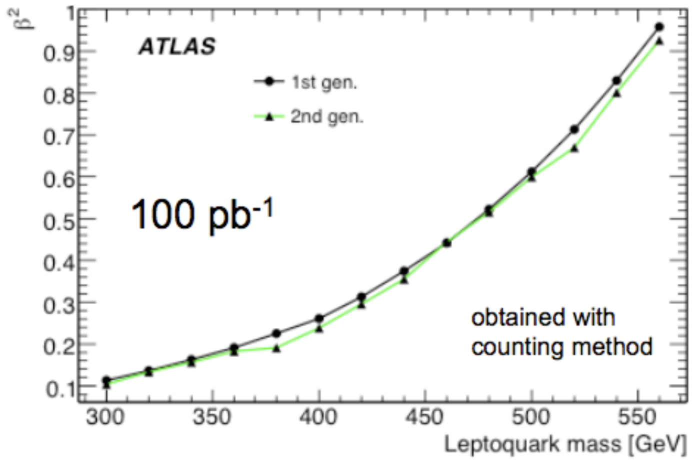
- SUSY particles with masses ≈TeV are observable with ~ 1 fb^{-1}
- Typically 2 LSP in the final state: large missing energy
  - Rough determination of SUSY masses and model parameters from the endpoints.
  - Apply kinematical constraints on the chain.
  - Endpoints are function of the particles in the chain
  - Expect to measure m_0, $m_{1/2}$ at the 1-3 %
  - tanβ, A_0 only order of magnitude (but tanβ from Higgs width too !)



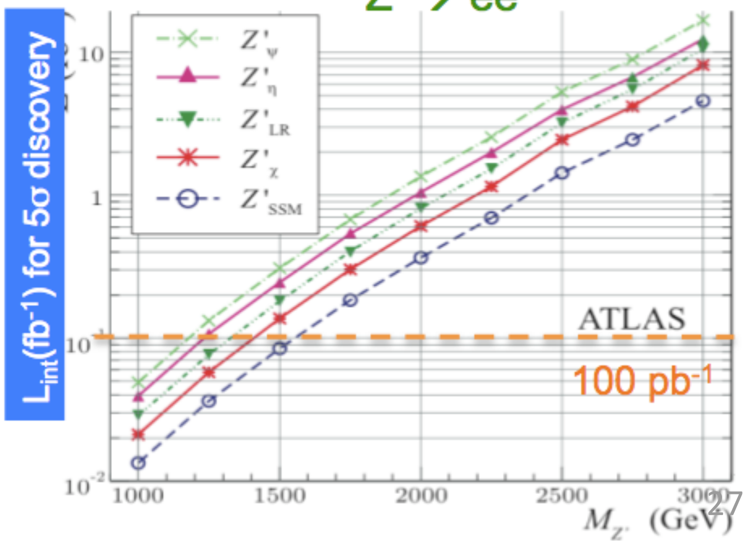
Searches for « Exotica »

- Exotica usually refers to beyond SM physics except SUSY.
  - A large number of models. LHC experiments actively try to explore all possibilities. Only a few examples here
- Dilepton resonances: a channel historically important for discoveries
  - Foreseen in many models: grand unification theories (GUT), technicolors, extra dimensions, little Higgs….
- Leptoquarks (GUT): carry both lepton and quark quantum numbers. Striking signature!



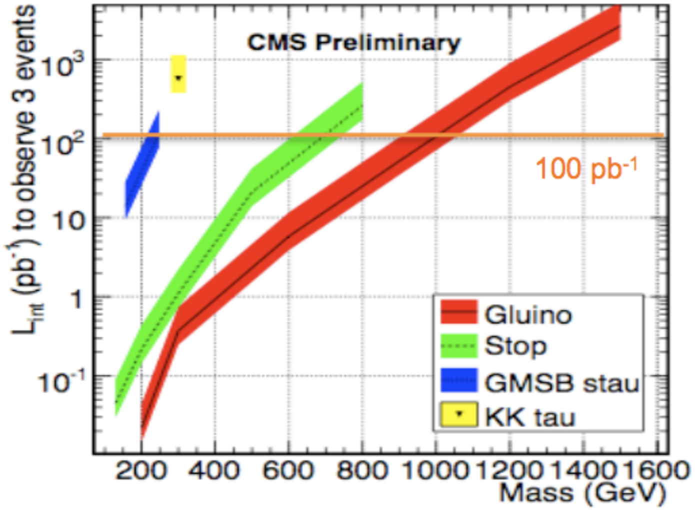


Z' → ee

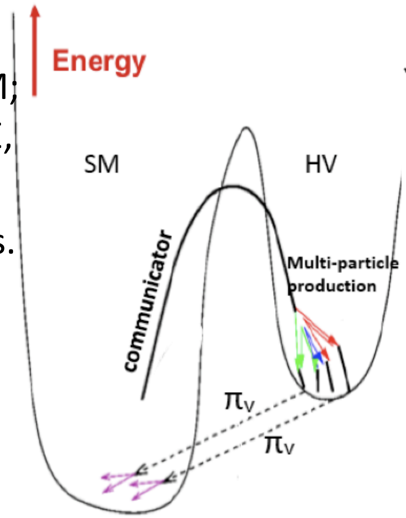


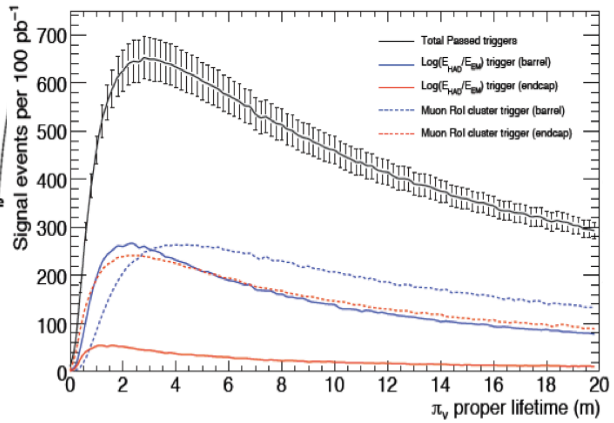
- Care has been taken in order not to miss exotic events
  - Good trigger efficiency also for peculiar signatures
- Examples:
  - Heavy stable charged particles (HSCP): foreseen in many models
    - High p_T, heavy mass, very low β
    - Muon trigger has good efficiency except for too slow particles (wrong bunch crossing assignment) and for R-hadrons (charge flipped)

      Dedicated trigger ←
    - MET, $\Sigma(E_T)$ triggers: efficient but model dependent



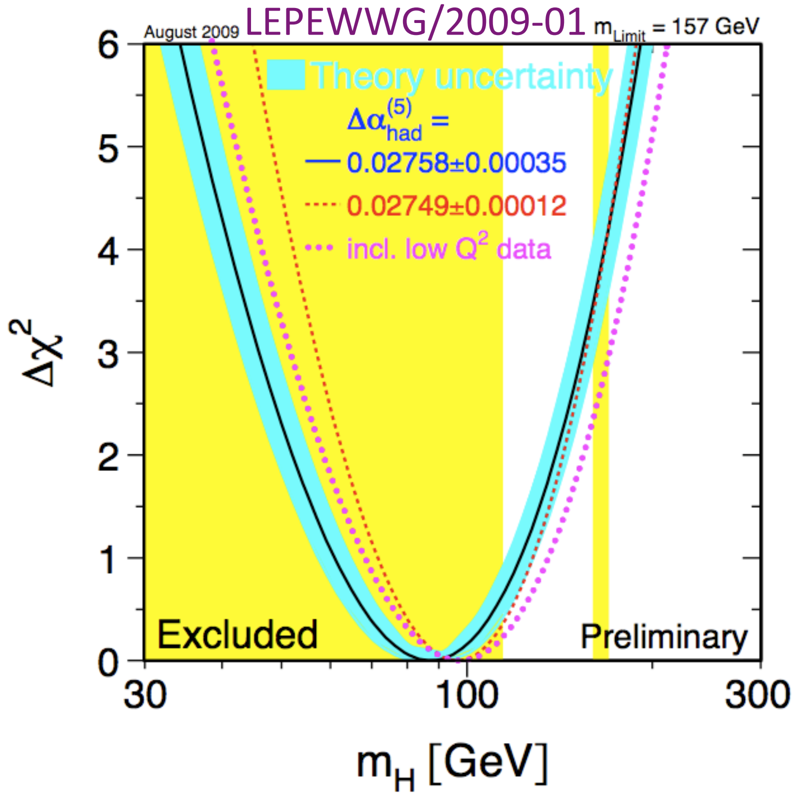
  - In some models, particles exist that can be trapped in the detector and decay much later
    - Search for particles in no-beam periods or in gaps between bunches.
  - Hidden valley:
    - A hidded sector (v) appended to the SM; a barrier makes v-particles rare at low E, but possible at LHC.
    - Some long-lived or even stable particles. Typical decay to *b* pairs.
    - Highly displaced neutral vertices
    - Search for trackless jets with high log(Ehad/Eem), trackless jets with associated muon, muon clusters

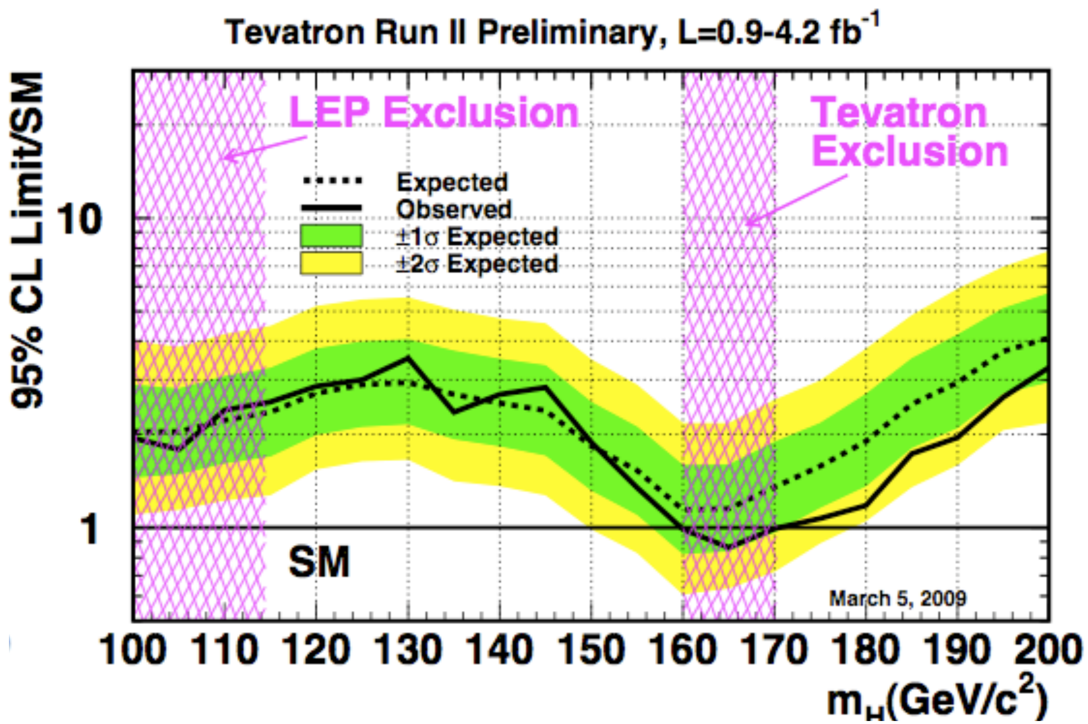




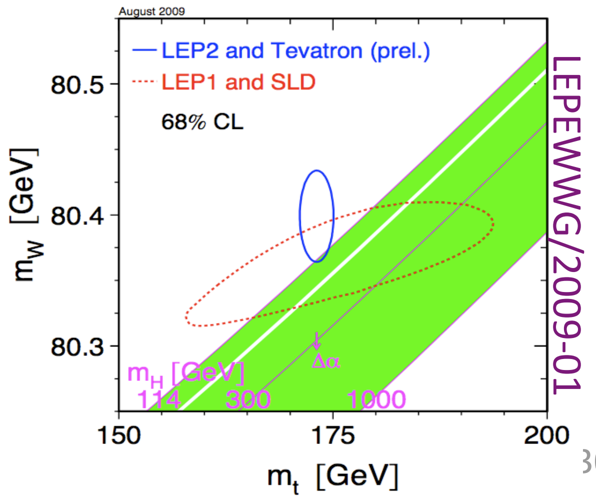
The Higgs Boson

Searching for the Higgs Boson

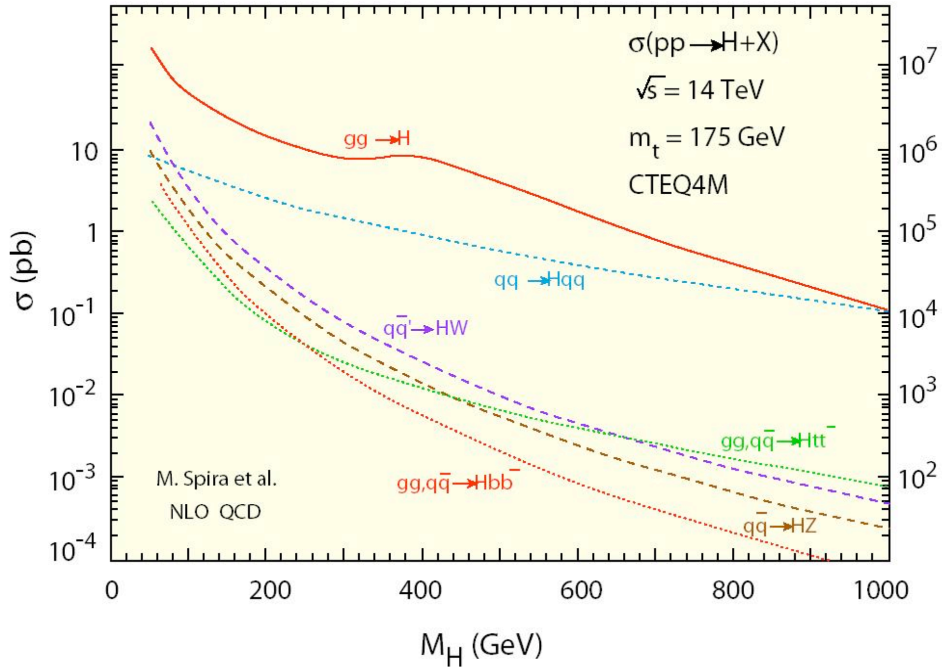


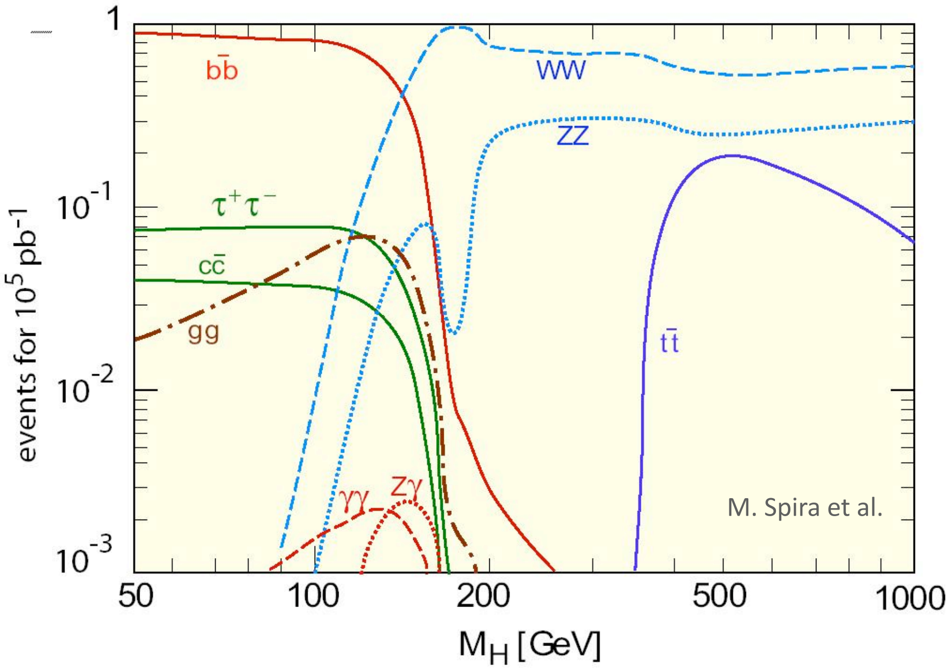


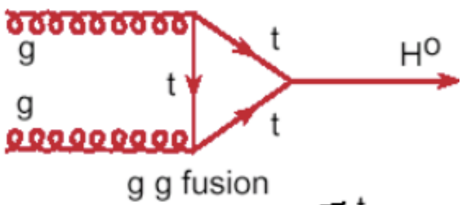
- Direct searches at LEP: m(*H*)>114 GeV at the 95% C.L.
- Tevatron excluded the range 160-170 GeV
- Precision EW constraints: < 157 GeV (< 186 when adding LEP2 data)

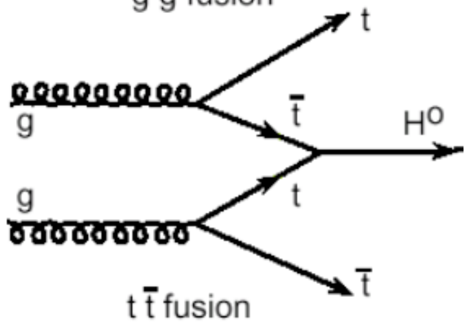


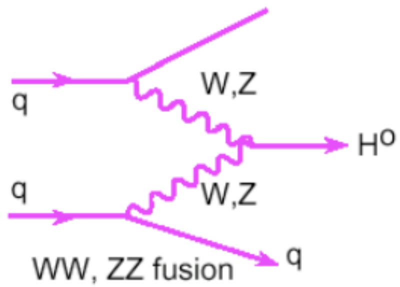
SM Higgs at the LHC





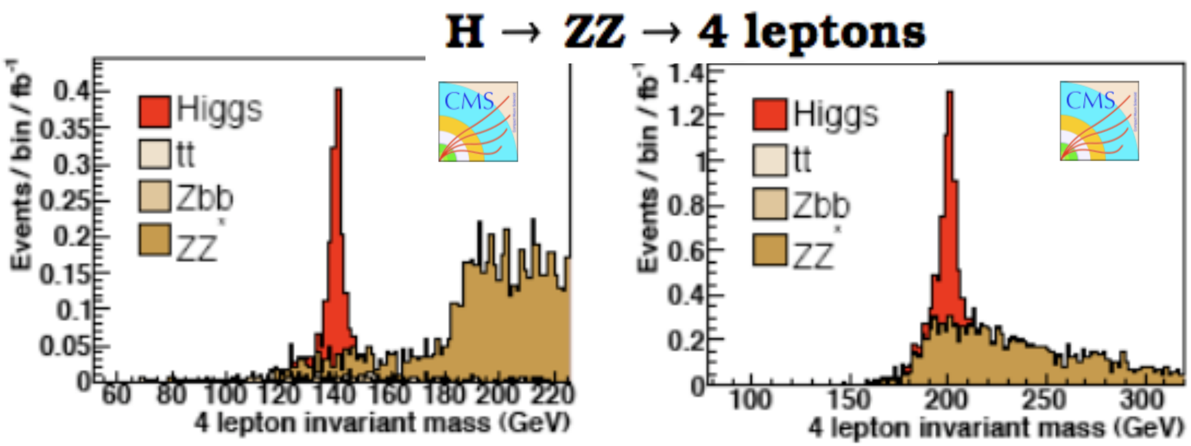


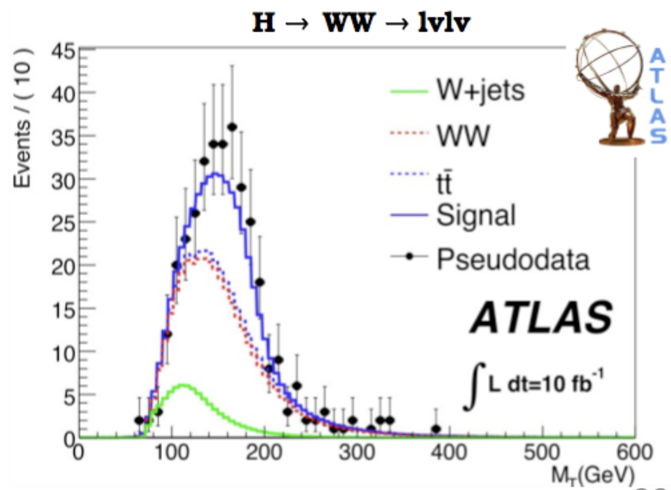




Higgs: High Mass Region

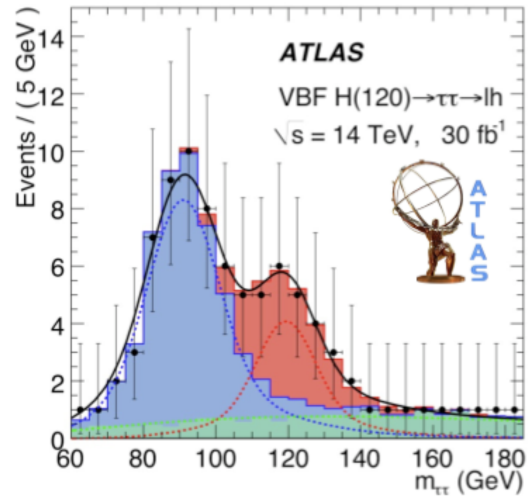
- *H->ZZ ->* 4 leptons:
  - « golden mode » for masses above ~ 130 GeV
  - CMS and ATLAS have a very good resolution and efficiency
- *H->WW ->lvlv*:
  - Dominant rate for masses above ~130 GeV
  - But missing energy spoils Higgs mass: use transverse mass

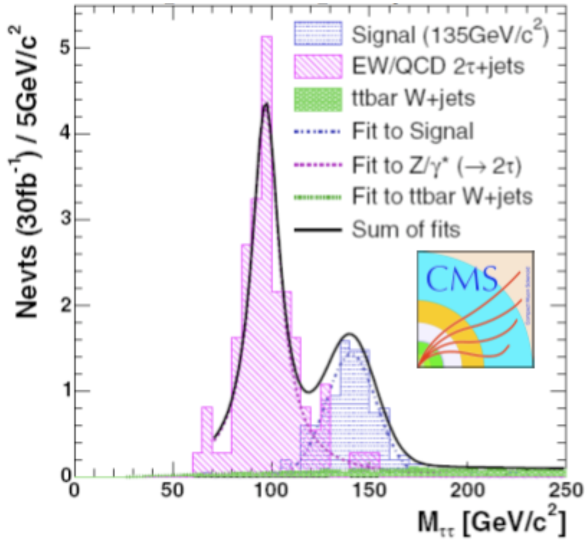


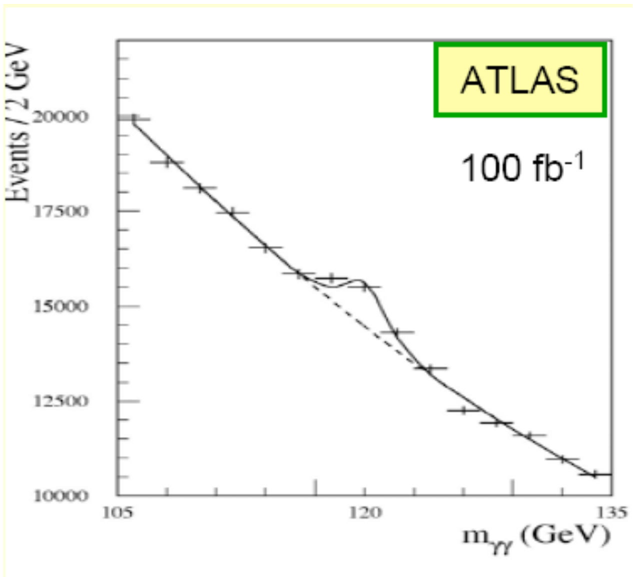


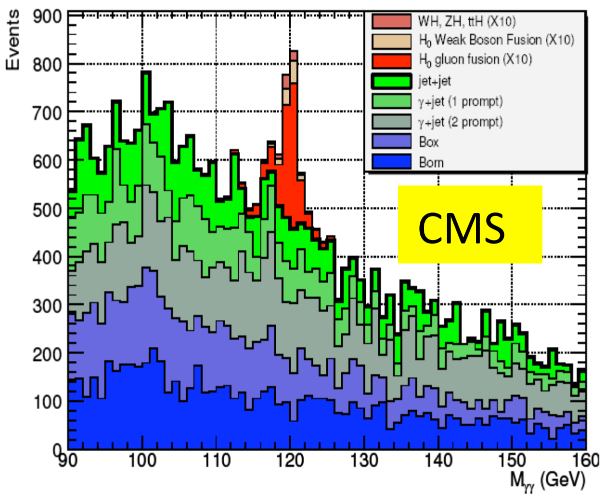
Higgs: Low Mass Region

- *H->ττ* dominant rate (after $b\bar{b}$) below ~130 GeV
  - Production via vector boson fusion provides unique signature to reduce backgrounds.
- *H->γγ* most powerful mode for low masses
  - CMS and ATLAS have a very good diphoton mass resolution
  - Important backgrounds to reject:γ+jets and jet+jet.



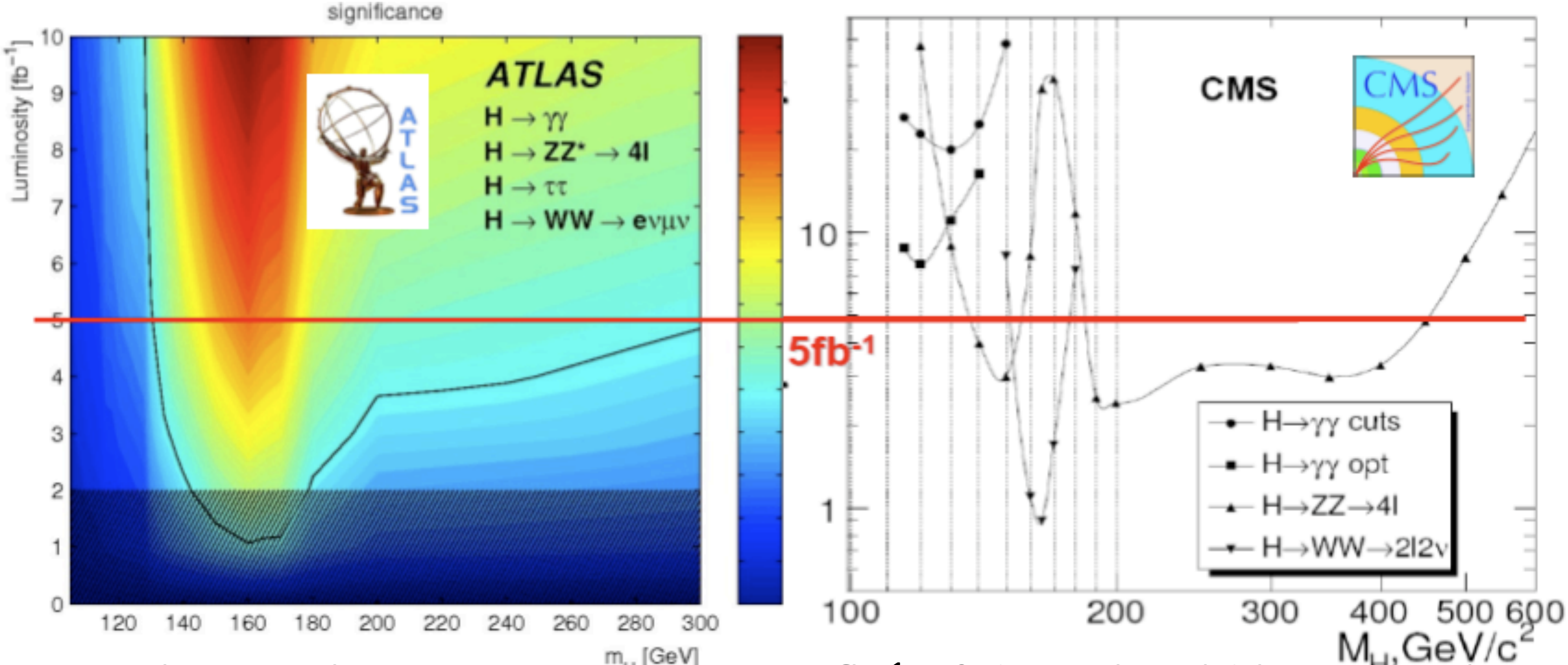






Higgs: Discovery Potential

- Broad discovery potentials especially above ~130 GeV
- More data needed for masses below 130 GeV
- If Higgs is not there, exclusion requires lower statitics in general.

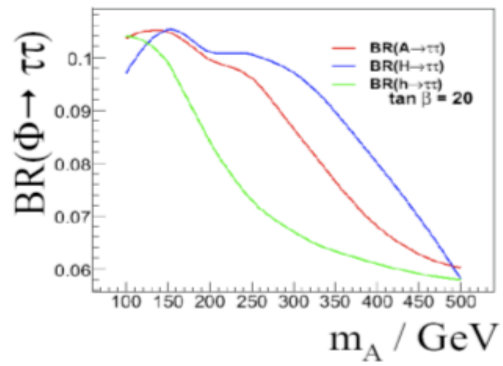


- Combining the two experiments, 1fb^{-1} of data should be enough for a discovery above ~140 GeV

MSSM Higgs Bosons

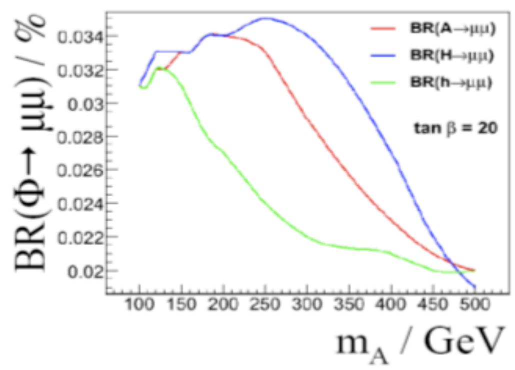
- In minimal extensions of the SM, there are two Higgs doublets:
  - 5 physical states: h^0, H^0 (CP +), A^0 (CP-), H^+, H^-
- At tree level, description using two parameters: m(A) and tanβ.
- h^0, H^0 and A^0 mostly decay to $b\bar{b}$
  - $\tau\tau$ and $\mu\mu$ are more rare, but easier.
- $H^\pm$ mainly produced by $t\to Hb$; dominat decay $\tau\nu$

BR h/A/H → ττ

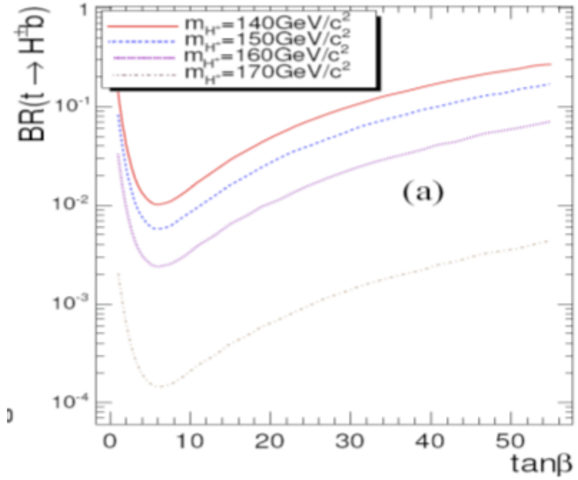


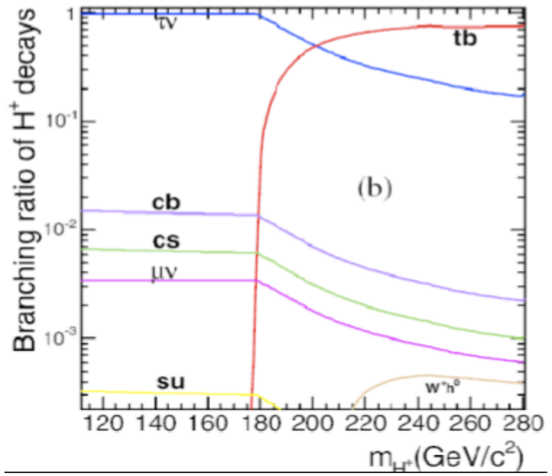
≈ 10 % for low m_A

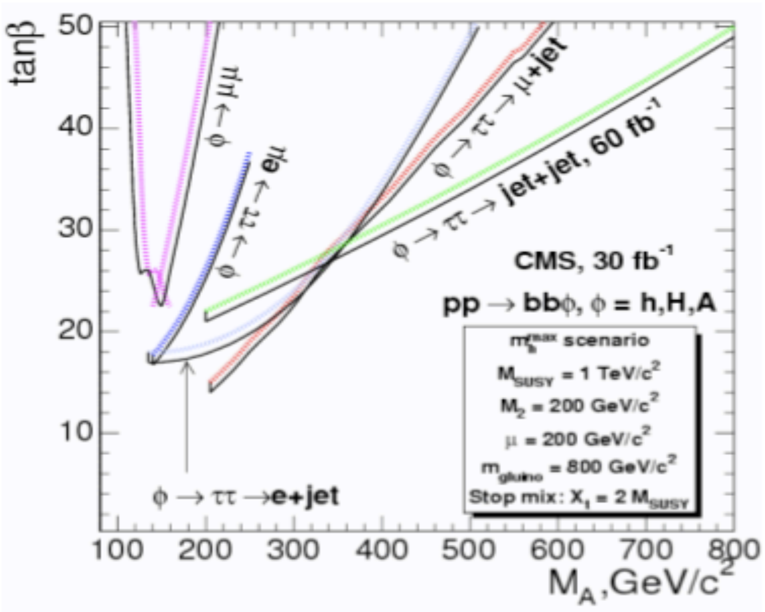
BR h/A/H → μμ

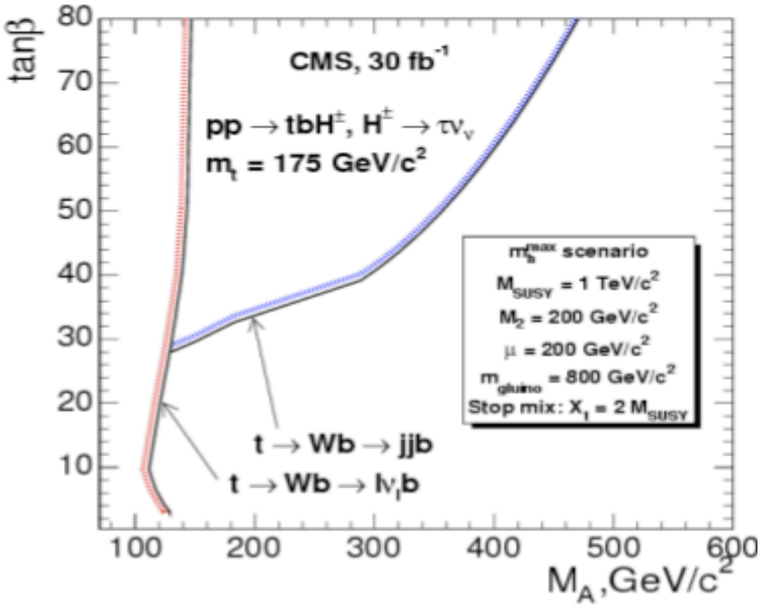


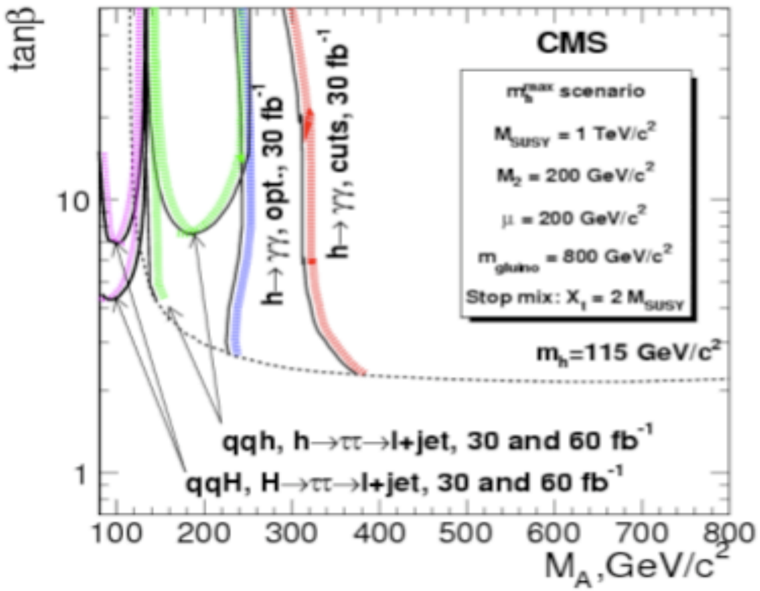
≈ 0.03 % for low m_A

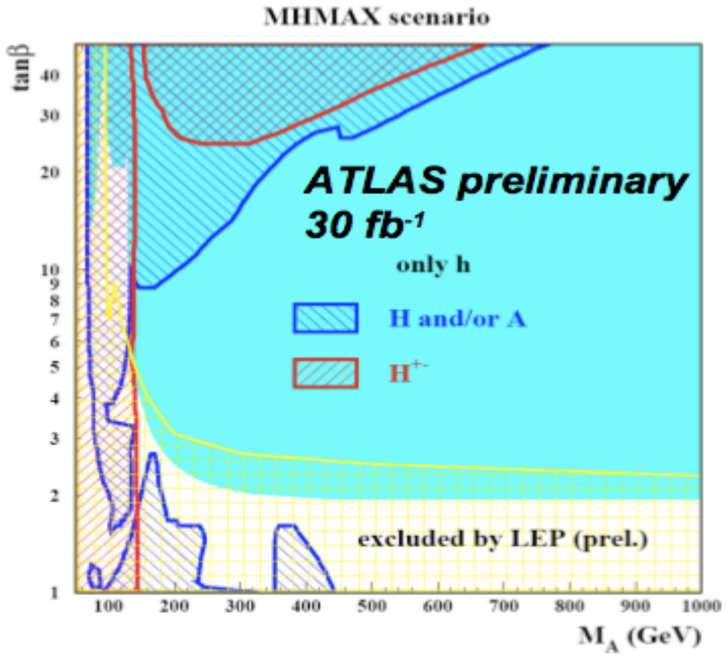












- At least one Higgs boson can be observed at ATLAS and CMS, possibly more than one...

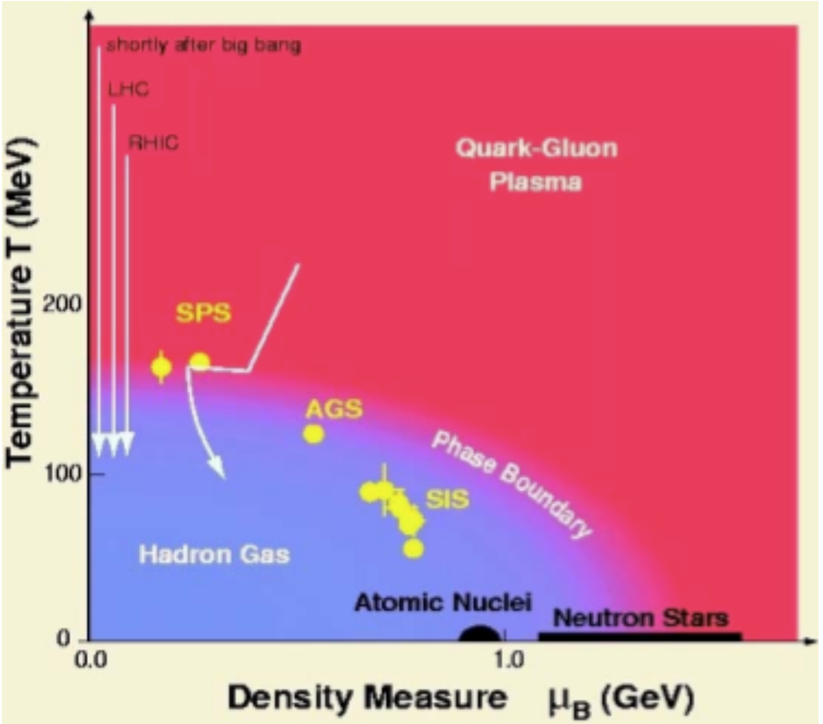
Heavy-Ion Collisions

Heavy Ion Collisions

- The LHC will collide not only protons but heavy ions too
  - ~ 1 month per year dedicated to heavy ion runs
- ALICE experiment specialized for heavy ion physics

Beam	√s (TeV)	Lumi ($cm^{-2} s^{-1}$)
proton	14	10^{34}
Light nuclei	7	10^{30} - 10^{31}
Lead	5.5	10^{27}

	Protons	Pb
N. Bunches / ring	2835	608
Distance between bunches	25	125
N. Particles / bunch	10^{11}	$6\ 10^{7}$
N. particles/ ring	$3\ 10^{14}$	$3\ 10^{10}$
Beam current (mA)	530	5
Lumi lifetime (h)	10	10

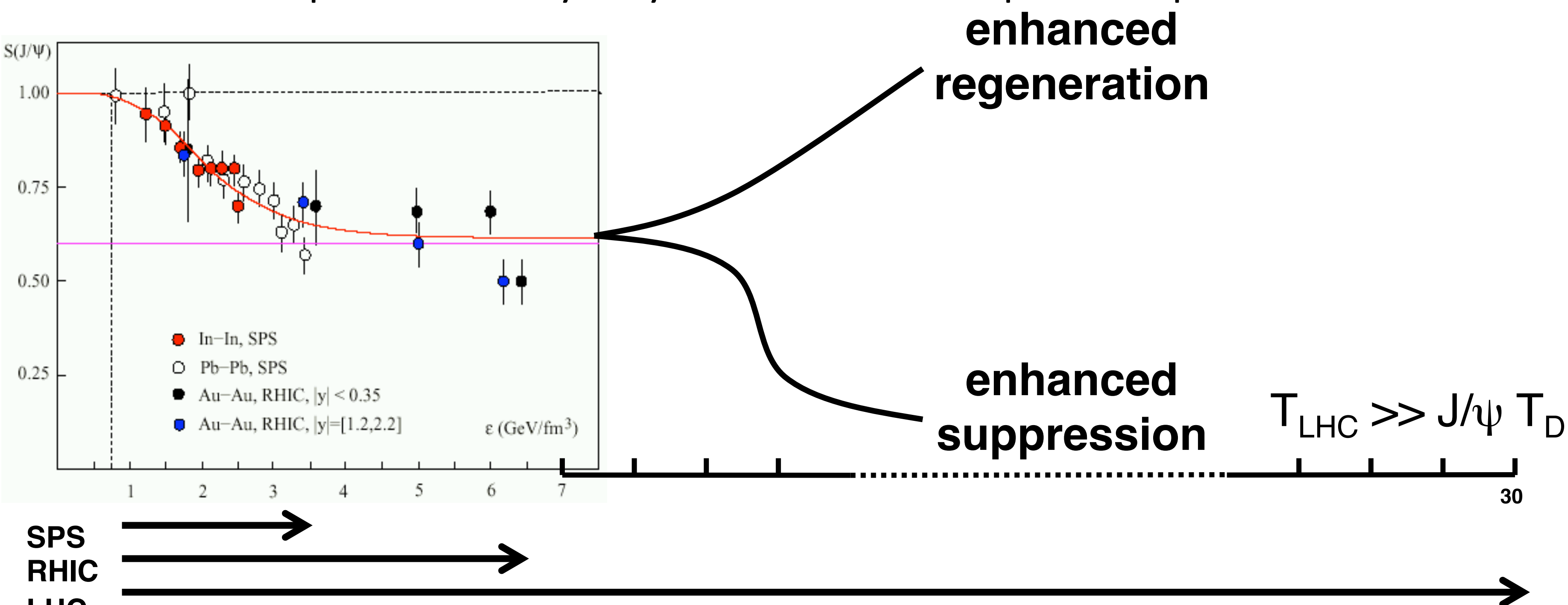


- At very high temperatures and densities, quarks and gluons are not confined inside composite particles: quark-gluon plasma

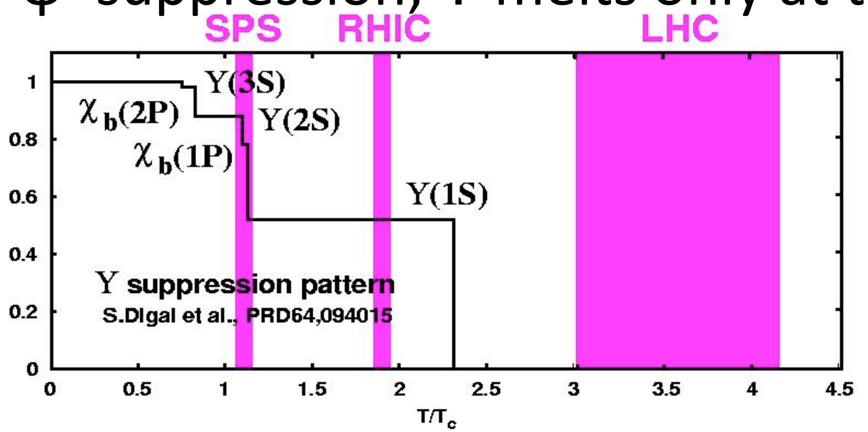
Heavy Quarks

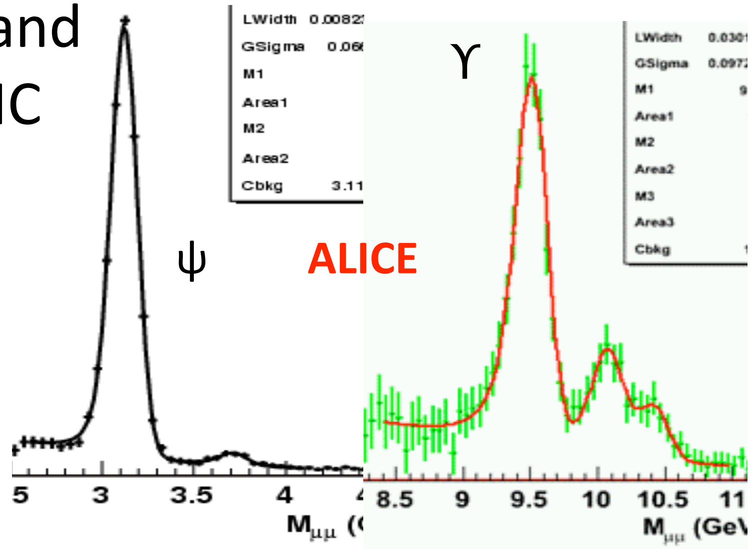
- Heavy quarks (*c* and *b*) probe QCD in extreme conditions
  - Production time scale shorter than medium, and lifetime larger.
  - Low p_T: probe small Bjorken-x structure of *p* and nuclei
    - Low-momentum gluons close to saturation
  - Intermediate p_T: medium thermalisation
  - High p_T: medium density via energy loss
- Calculable in pQCD; calibration from *pp* and *pA*.
- Essentially produced in initial impact: probe of the high density phase
- An example: secondary J/ψ from *B* decays
  - Yield reduced and η distribution significantly narrower as a result of *b* quenching

- Charmonium and bottomonium are probes of QCD phase transition
  – If QGP is produced they may dissolve into the quark soup



- J/ψ suppression and regeneration; χ_c and ψ' suppression; Υ melts only at the LHC



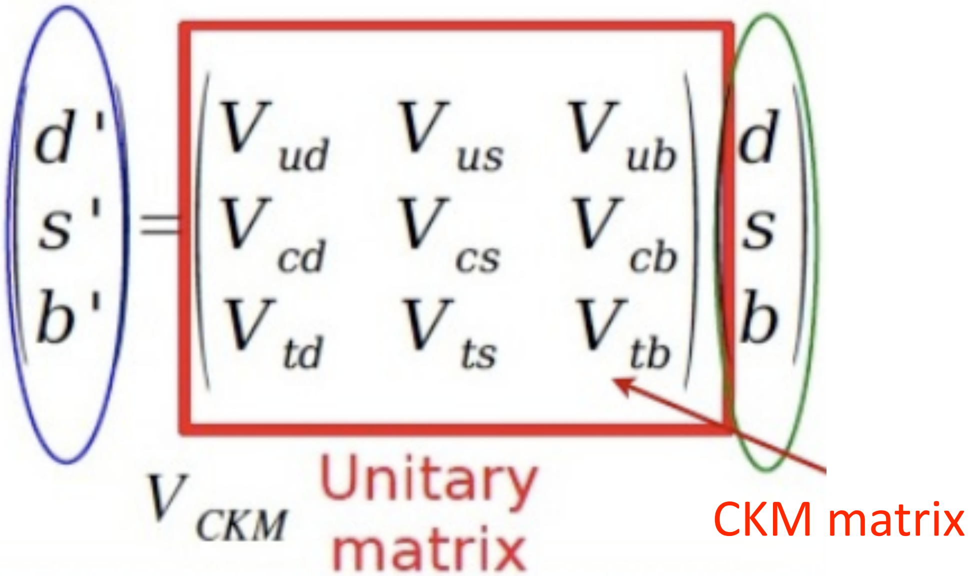


Flavour Physics

b Physics

- A very large number of *b* hadrons produced at the LHC: σ(*b*)~mb
- LHCb specialized experiment for *b* physics.
- *b*-hadron physics allows to test SM prediction of CP violation and search for indirect NP effects in asymmetries and decay rates.

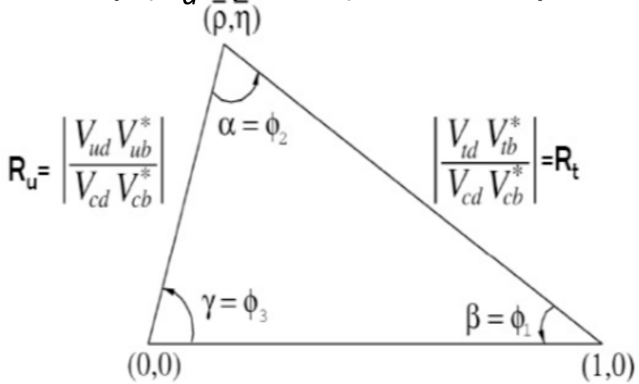
Quark mixing matrix



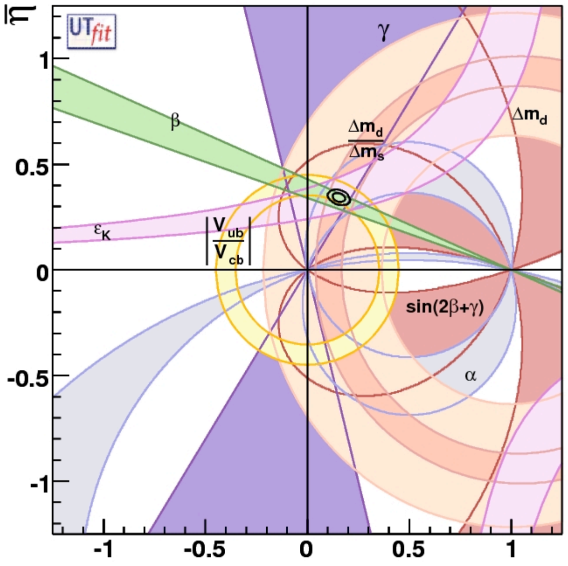
Unitarity condition:

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

Graphically (B_d system): Unitarity Triangle



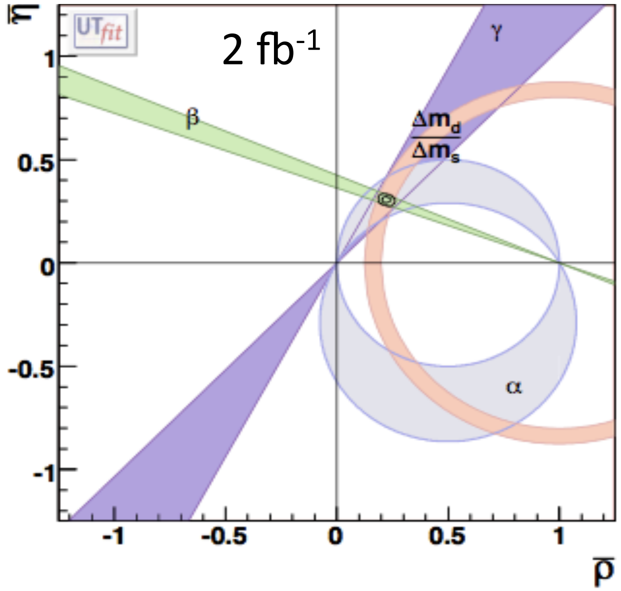
- In the SM, one irremovable phase in the matrix: CP violation. Asymmetry between matter and antimatter



Today: $\sigma(\bar{\rho})/\bar{\rho} = 14\%$

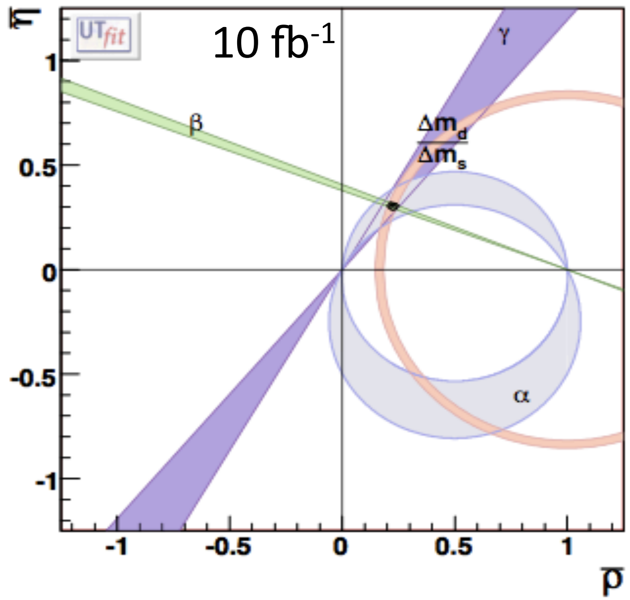
$\sigma(\bar{\eta})/\bar{\eta} = 4\%$

UTfit: http://www.utfit.org/



$\sigma(\bar{\rho})/\bar{\rho} = 7.1\%$

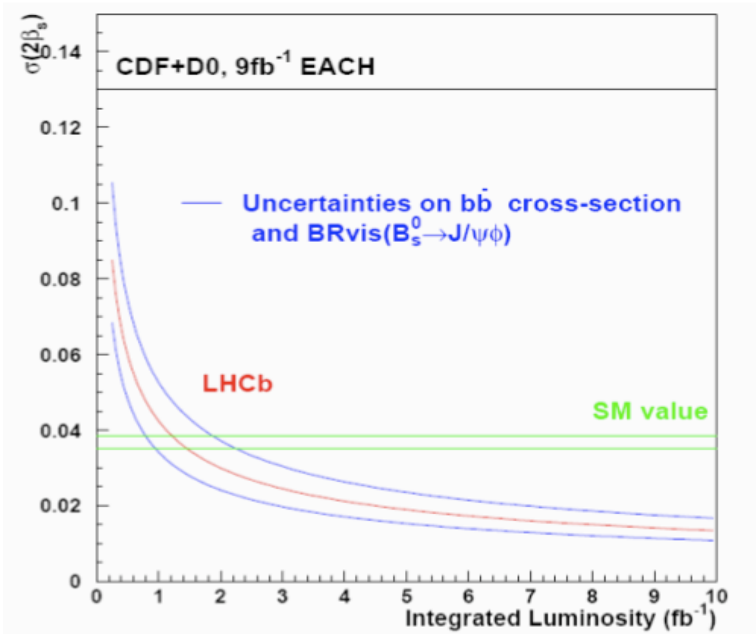
$\sigma(\bar{\eta})/\bar{\eta} = 3.9\%$



$\sigma(\bar{\rho})/\bar{\rho} = 3.6\%$

$\sigma(\bar{\eta})/\bar{\eta} = 1.8\%$

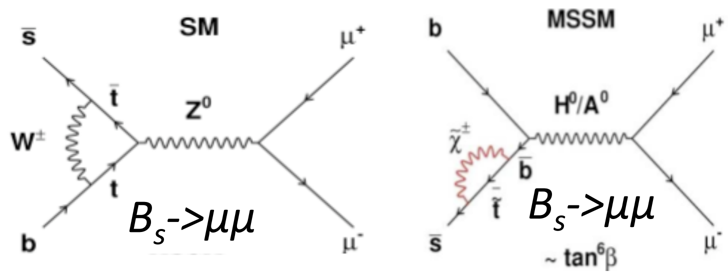
with LHCb alone

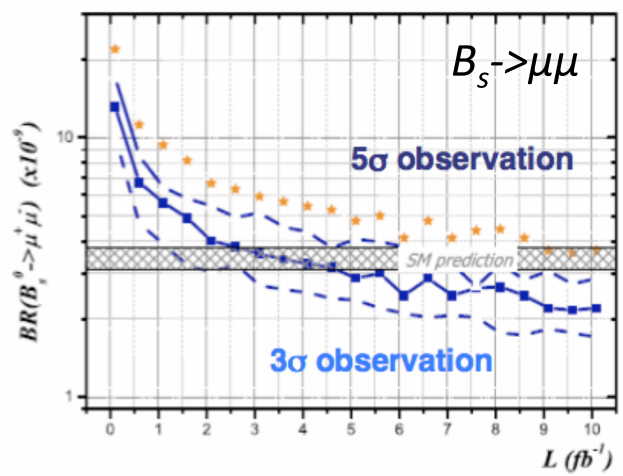


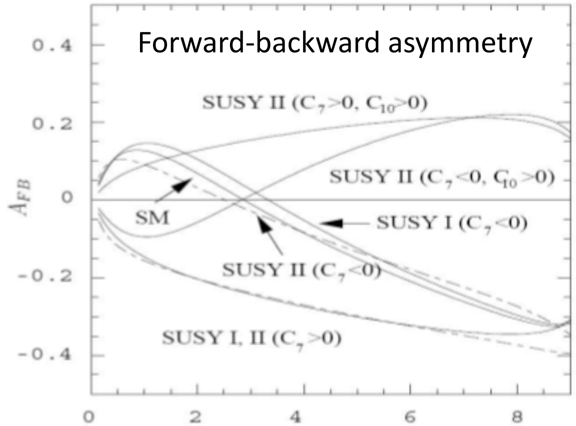
- Currently *B*-Factories only have access to B_d and B_u.
- All *b*-hadrons accessible at the LHC.
- At the Tevatron, tension with the SM predictions in the B_s system: 2.2σ from the SM. In the SM $\beta_s=(1.05\pm0.04)^o$

Rare *b*-hadron decays

- Rare decays can probe SM.
  - Indirect evidence of NP
- $B_s \to \mu\mu$ is very rare in the SM ~3.4×10^{-9}
  - BR enhanced in NP scenarios (models with extended Higgs sector)
  - Current Tevatron limit: < 47×10^{-9}
  - With 9 fb^{-1}, LHCb can reach 20×10^{-9}
- *b->sll*
  - NP can modify BR and angular distributions
  - Sensitive to SUSY, extra dimension.
  - With $2fb^{-1}$, A_{fb} spectrum

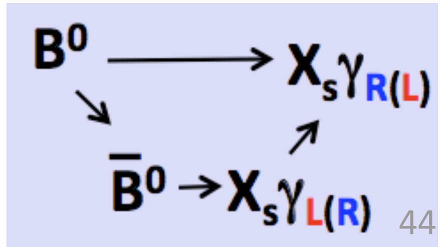






- *b->sγ*
  - With $2fb^{-1}$, $\sigma(\psi)/\psi$~10%

$$\tan\psi \equiv \left| \frac{\mathcal{A}(\bar{B}_{(s)} \to \Phi^{CP}\gamma_R)}{\mathcal{A}(\bar{B}_{(s)} \to \Phi^{CP}\gamma_L)} \right|$$



Conclusions

- Many open questions in particle physics
- The LHC is a powerful tool to try and answer as many questions as possible.
- The LHC started to deliver *p-p* collisions: a new era in particle physics has began
- Detectors are ready to collect and analyse data !
- First papers on collision data already coming out !
- … stay tuned !