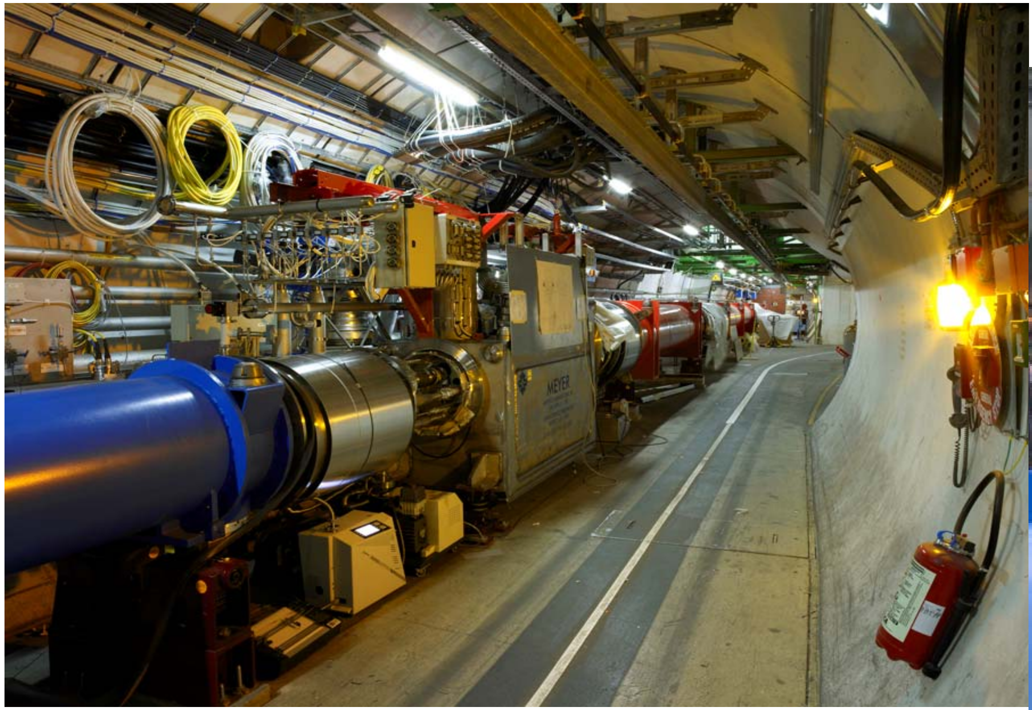
LHC Days in Split, October 2 - 7th, 2006

Physics potential of an upgraded LHC (SLHC at ~10^{35} cm^{-2} s^{-1}), demands to detectors and machine

D. Denegri,
CE Saclay/DAPNIA/SPP

- motivations to go to higher energies/luminosities
- SLHC and requirements on detectors
- Some physics motivations/perspectives

LHC construction/installation

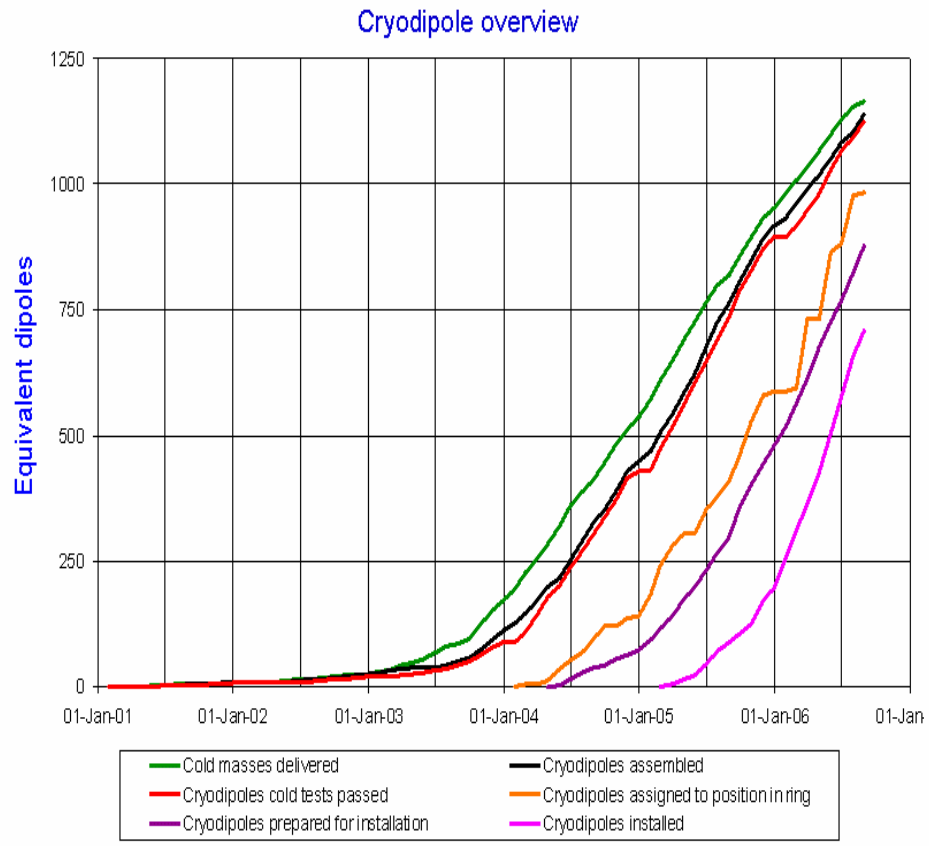


LHC tunnel - sector 81

September 06: ~ 750 dipoles and ~ 250 quads installed in the tunnel, ultimately they have to be aligned with 200µm precision

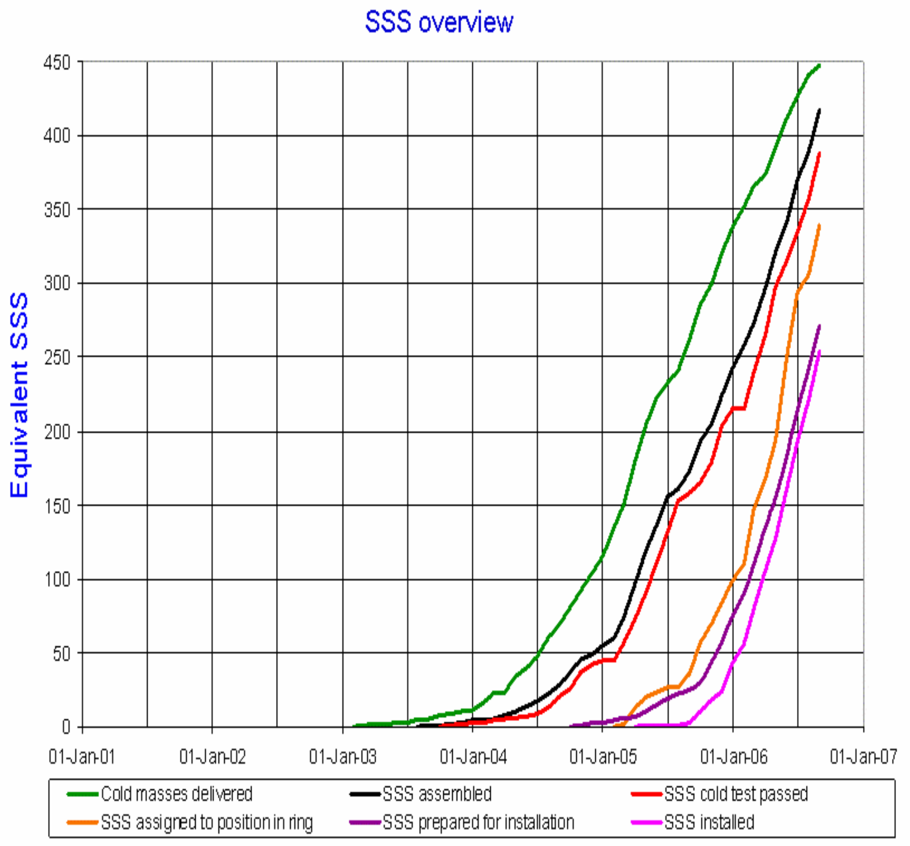
Progress on LHC construction
LHC dipoles and quadrupoles production/installation

LHC Progress Dashboard



Updated 31 Aug 2006 Data provided by D. Tommasini AT-MAS, L. Bottura

LHC Progress Dashboard

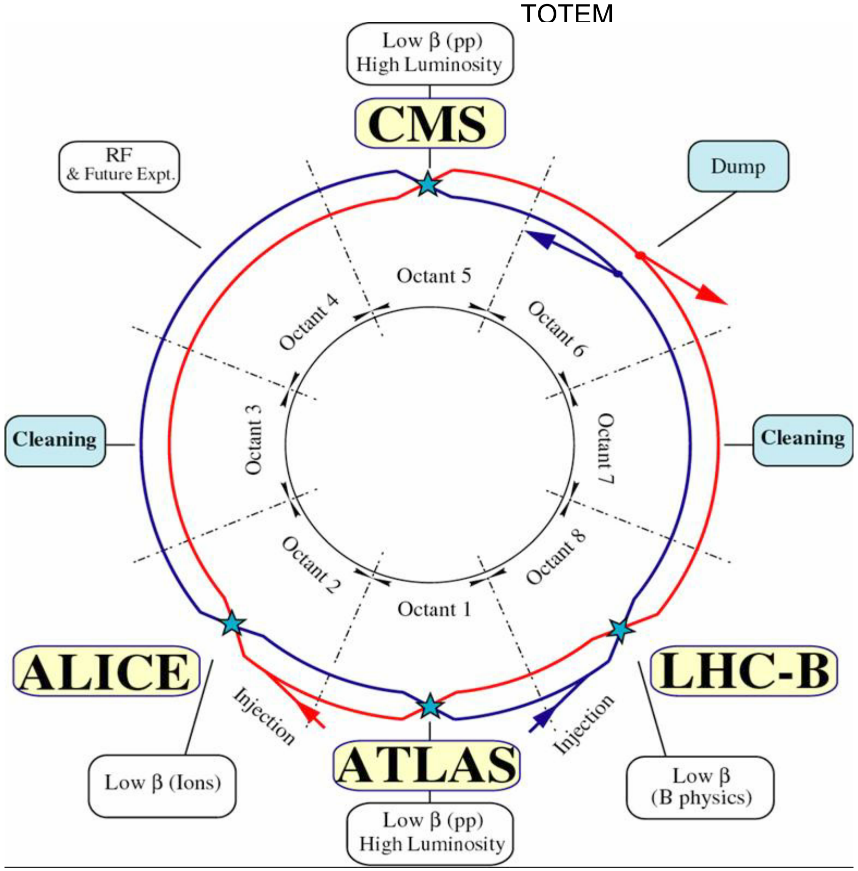


Updated 31 Aug 2006 Data provided by M. Modena AT-MAS, L. Bottura AT-MTM

LHC construction - milestones

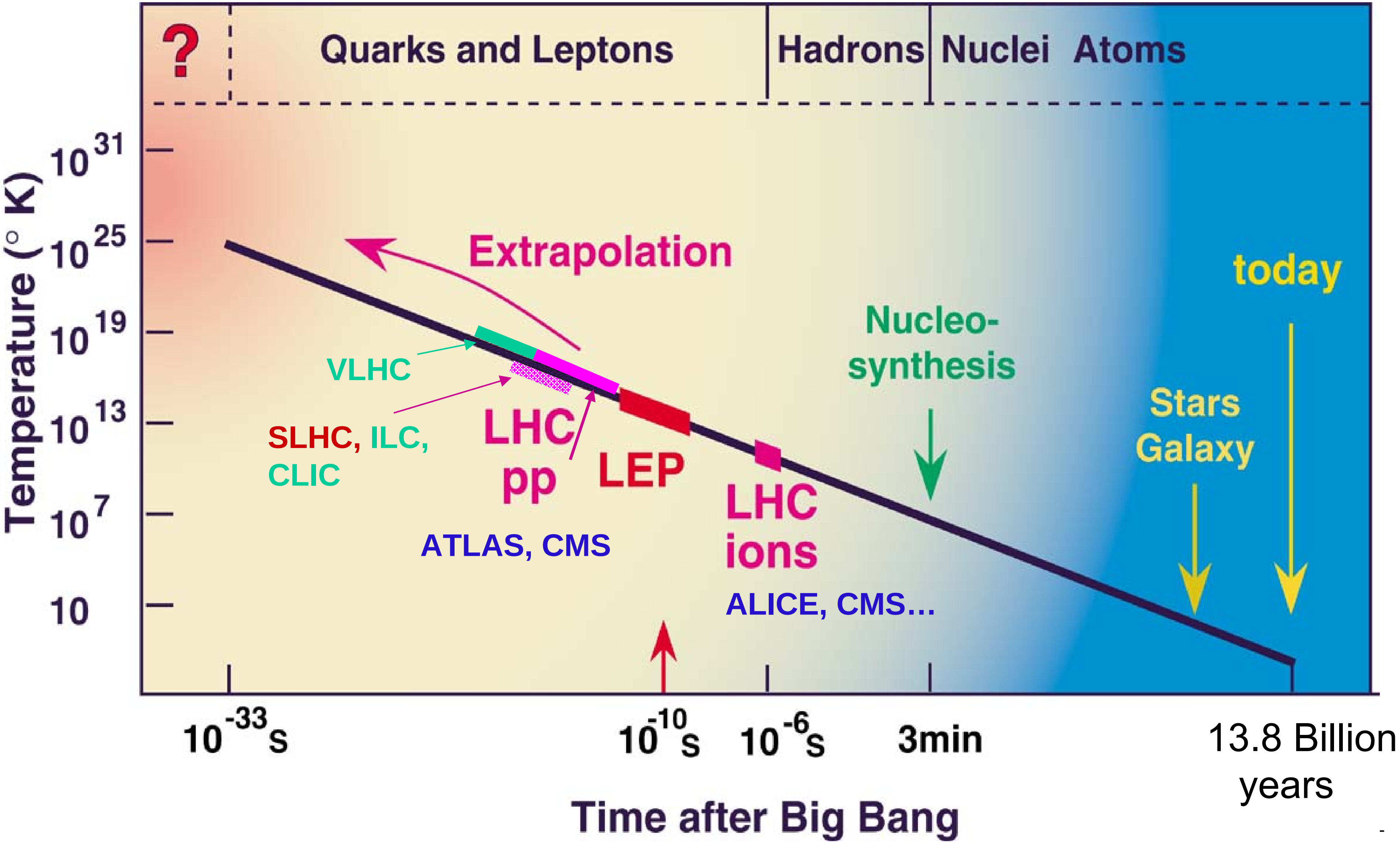
Last magnet delivered	October 2006
Last magnet tested	December 2006
Last magnet installed	March 2007
Machine closed	August 2007
First collisions	November 2007

The Large Hadron Collider



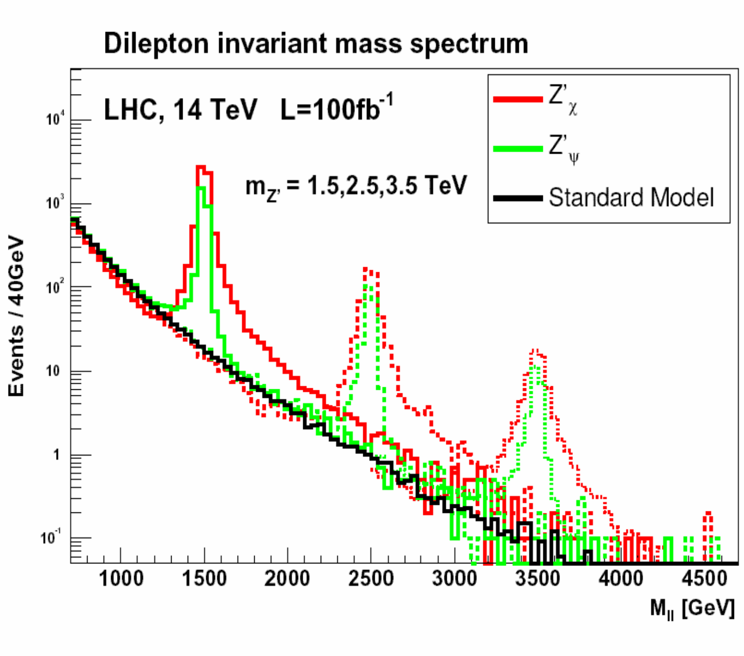
LEP	e^+e^-	200 GeV	10^{32} cm^{-2} s^{-1}
HERA	e p	300 GeV	$5*10^{31}$ cm^{-2} s^{-1}
Tevatron	p-p	2000 GeV	$3*10^{32}$ cm^{-2} s^{-1}
LHC	pp	14.000 GeV	10^{34} cm^{-2} s^{-1}
LHC	PbPb	1.312.000 GeV	10^{27} cm^{-2} s^{-1}
SLHC	pp	14.000 GeV	10^{35} cm^{-2} s^{-1}
VLHC	pp	30.000 GeV	10^{34} cm^{-2} s^{-1}

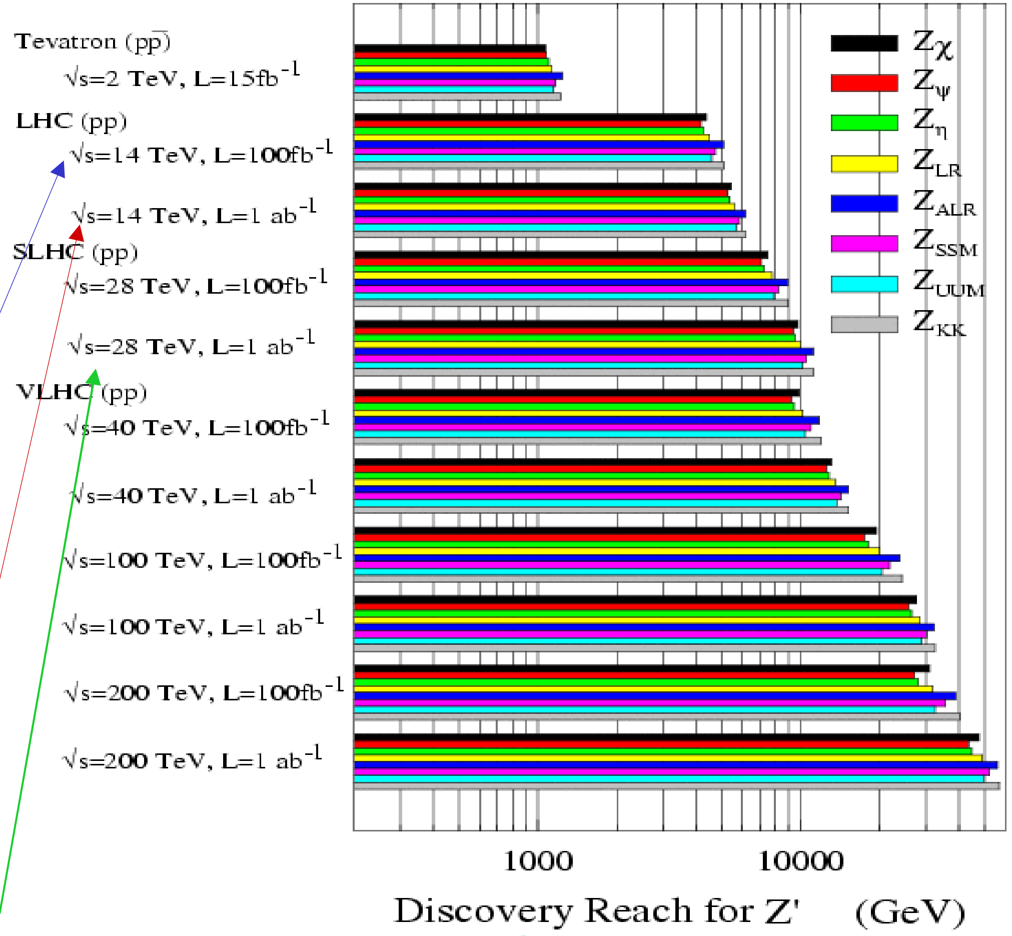
Connecting particle physics, the LHC and the Universe: towards the origin - the Big Bang



Need for higher energies and/or luminosities: new heavy bosons, extra dim. W, Z's, Gravitons…

For new heavy gauge bosons (Z'), mass reach at LHC, SLHC and VLHC





LHC reach ~ 4.0 TeV with 100 fb^{-1}

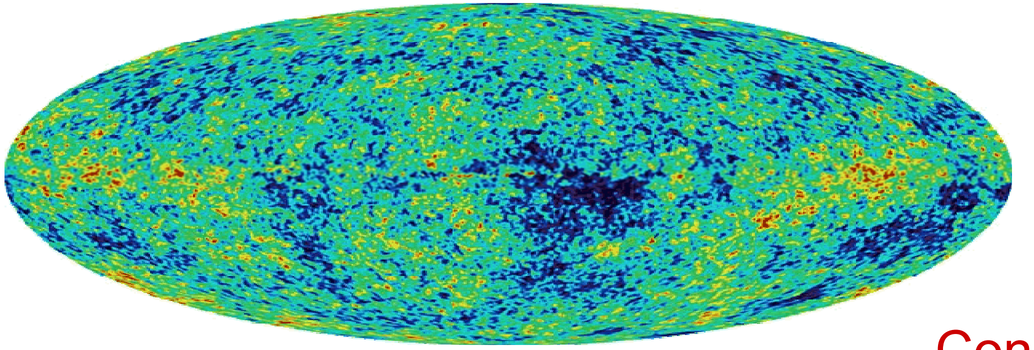
➡ gain in reach ~ 1.0 TeV i.e. 25-30% in going from LHC to SLHC

for massive objects larger center-of-mass energy is more profitable!

Need for a VLHC!!

D. Denegri, SLHC talk, LHC Days in Split, October, 2006

Dark Matter/Supersymmetry/LHC

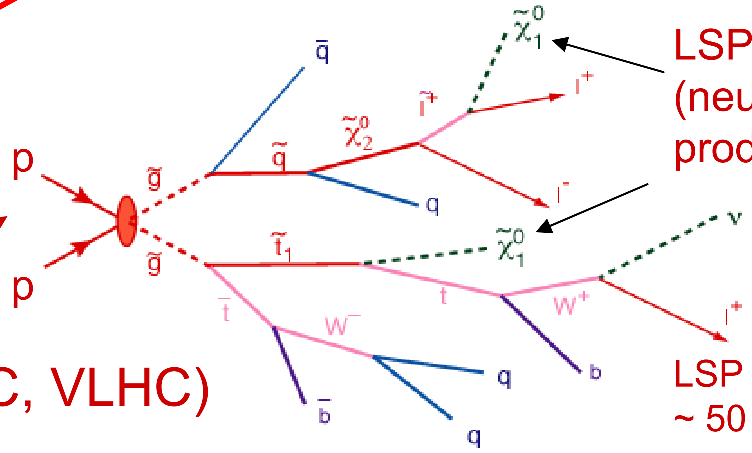


WMAP measurement of cosmic background anisotropies - evidence for density inhomogeneities seeding present day structures

Connection with SUSY and LHC

in terms of the critical density:

Baryon density : $\Omega_b = 0.044 \pm 0.004$
Dark Matter : $\Omega_m = 0.23 \pm 0.04$
Dark Energy : $\Omega_\Lambda = 0.73 \pm 0.04$



LSP-
(neutralino-1)
production

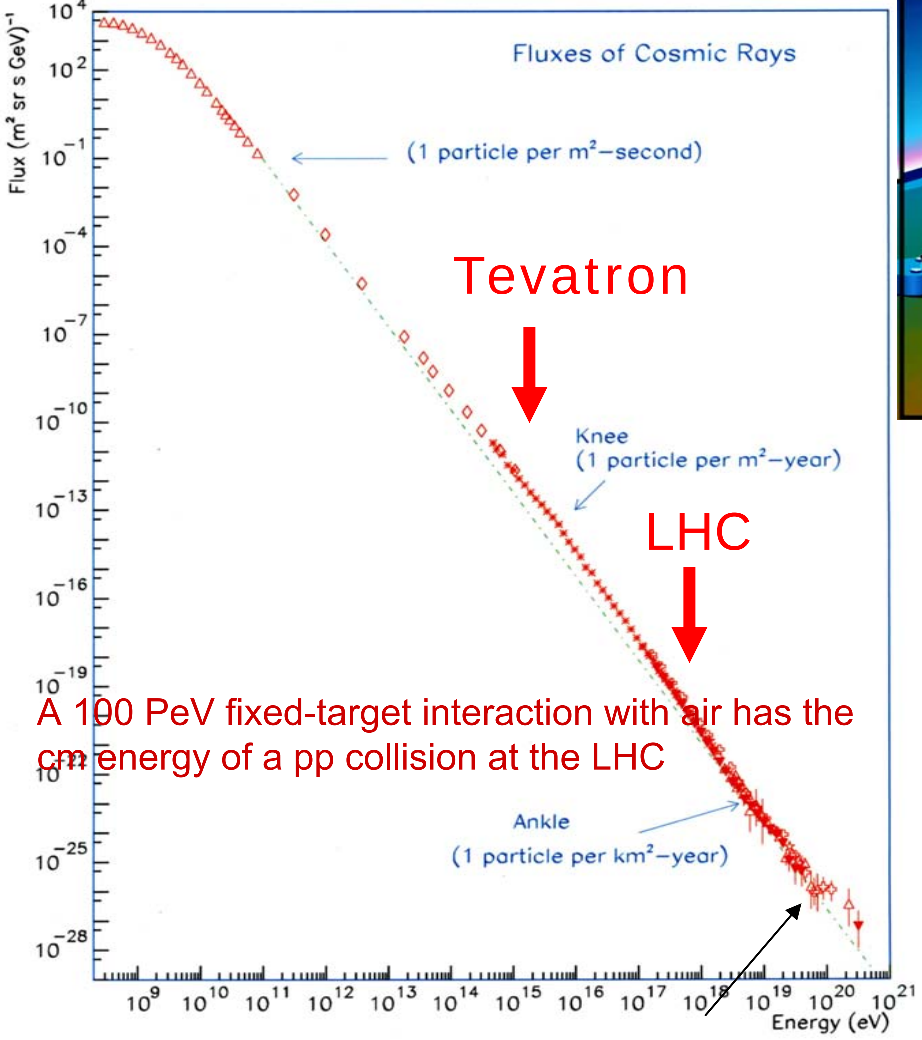
LSP mass:
~ 50 -1000 GeV

proton-proton collisions at LHC (SLHC, VLHC)

Data from WMAP significantly constrain the Dark Matter content of the Universe, this implies constraints on particle physics models, in particular on supersymmetry (< ~ few TeV mass scale) as the LSP, is a plausible particle-physics candidate for DM; this LSP could be aboundantly produced at the LHC, but not so any more if LSP mass ~ 1TeV…..

Cosmic rays, the LHC and beyond

Cosmic ray spectrum

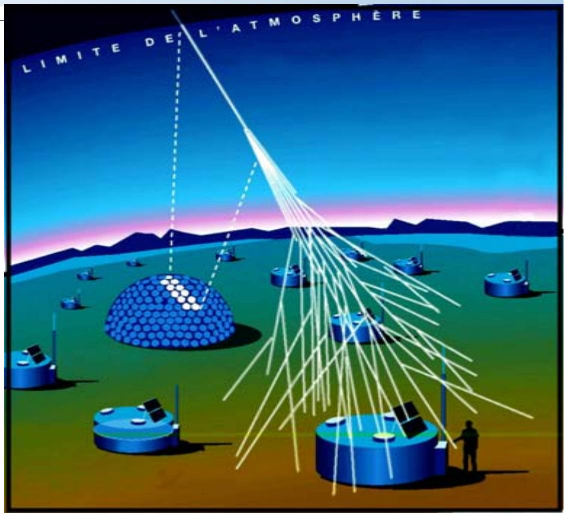


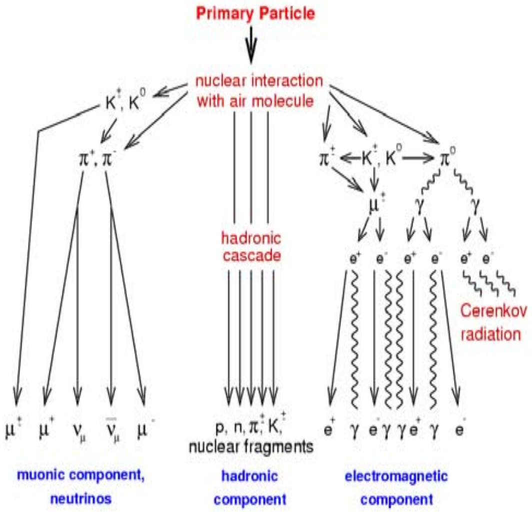
Tevatron

LHC

A 100 PeV fixed-target interaction with air has the cm energy of a pp collision at the LHC

AUGER

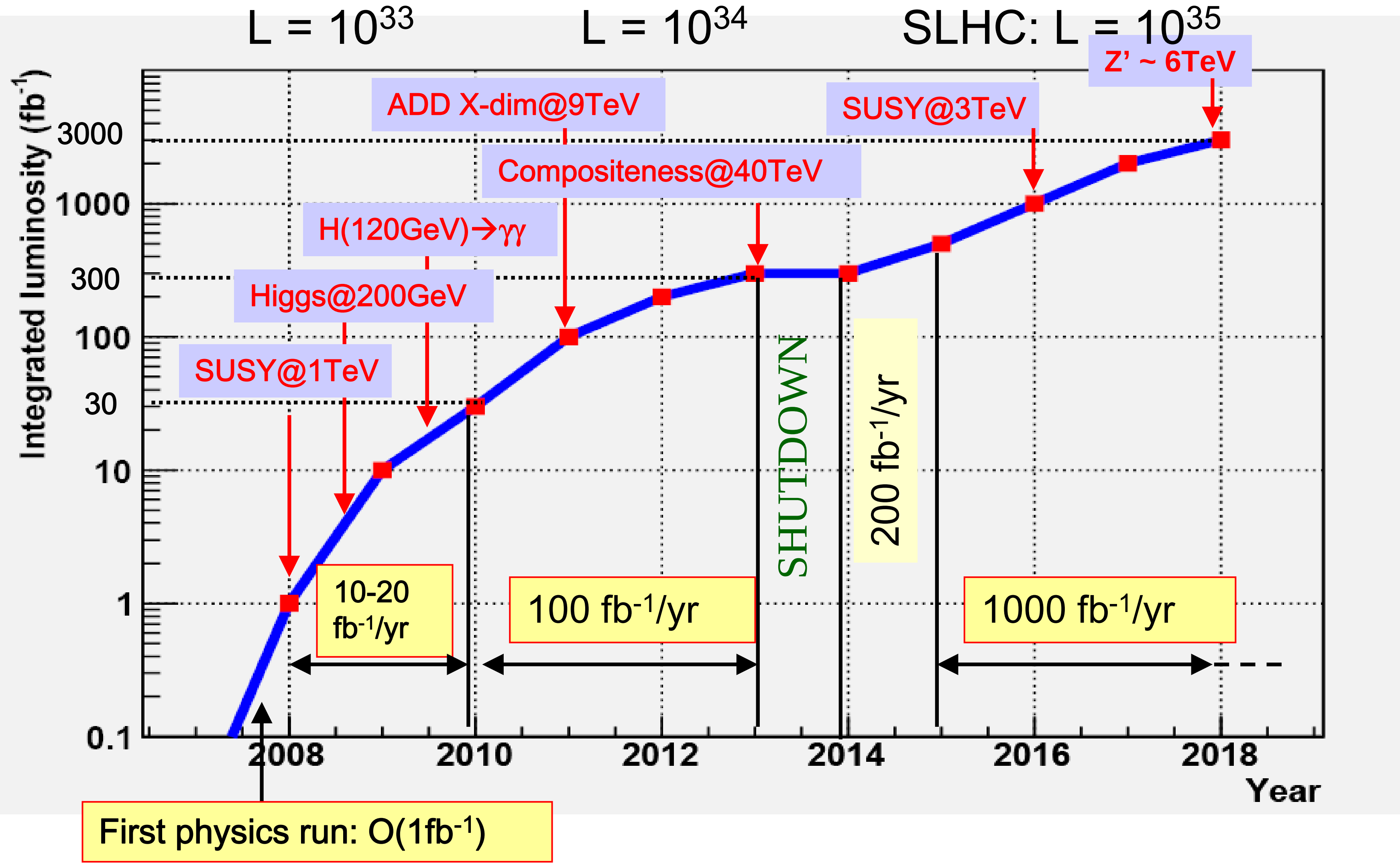




Correct simulation of interactions of primary cosmic rays with the atmosphere is essential to cosmic ray studies

LHC detectors (CMS +TOTEM in particular) with large acceptance/very large rapidity coverage will allow to understand and model pp, pA, A'A interactions giving rise to air-showers in the $10^{17\text{-}18}$ eV range. But the AUGER experiment is already testing the $10^{19\text{-}20}$ eV range range! One day we are going to need a VLHC/VVLHC!

Probable/possible LHC luminosity profile - need for L-upgrade in a longer term



First physics run: O($1fb^{-1}$)

for the 2008 run likely to get from $100pb^{-1}$ to $1fb^{-1}$

Upgrades considered, physics potential of the LHC at 10^{35} cm^{-2} s^{-1} (SLHC)

What improvements in the physics reach operating the LHC at a luminosity of ~ 10^{35} cm^{-2} s^{-1} with an integrated luminosity ~ 500 - 1000 fb^{-1}per year at $\sqrt{s} \approx$ 14 TeV i.e. retaining present LHC magnets/dipoles -

→ an upgrade at a relatively modest cost for machine (IR) + experiments (< ~ 0.5 GSF) for ~ 2013-15

a more ambitious upgrade (but ~ 2-3 GSF!) would be to go for a $\sqrt{s} \approx$ 25 - 30 TeV machine (~ 2020) changing LHC dipoles (~15T, Nb_3Sn?)

For the 10^{35}cm^{-2} sec^{-1} case:
- expected modifications/adaptations of LHC and experiments/CMS,
- improvements in some basic SM measurements and in SM/MSSM Higgs reach
- improvements in reach at high mass scales

Nominal LHC and possible upgrades - overview

Nominal LHC: 7 TeV beams,
- injection energy: 450 GeV, ~ 2800 bunches, spacing 7.5 m (25ns)
- 1.1 $*10^{11}$ protons per bunch, β^* at IP : 0.5 m ⇒ 10^{34} cm^{-2} s^{-1} (lumi-lifetime ~10h)

Possible upgrades/steps considered:

-increase up to 1.7 $*10^{11}$ protons per bunch (beam-beam limit) ⇒ 2$*10^{34}$ cm^{-2} s^{-1}
- increase operating field from 8.3T to 9T (ultimate field) ⇒ $\sqrt{s} \approx 15$ TeV

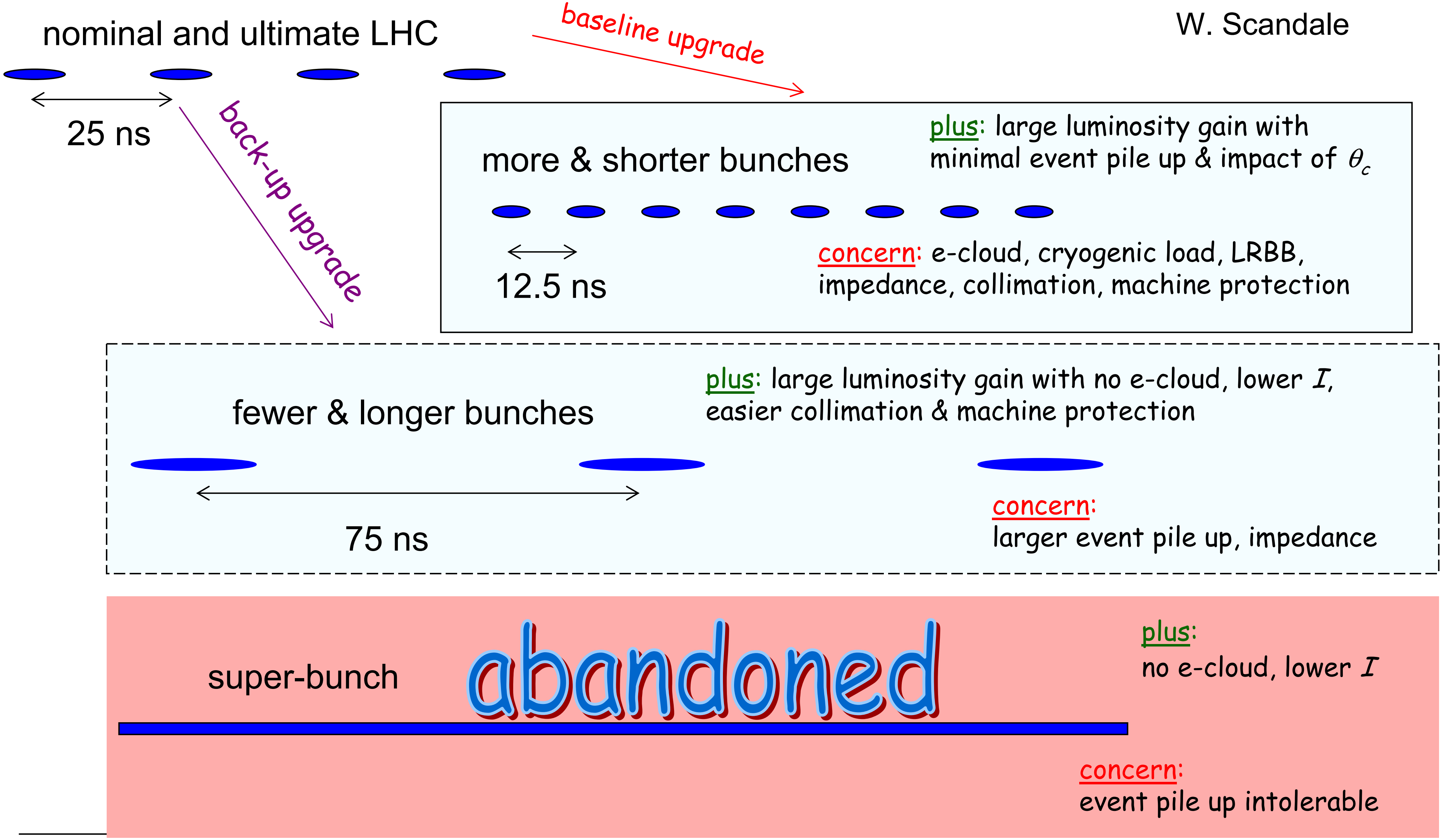
minor hardware changes to LHC insertions or injectors:
- modify insertion quadrupoles (larger aperture) for $\beta^* = 0.5 \rightarrow 0.25$ m new quads!
- increase crossing angle 300 μrad → 424 μrad new IR dipoles!
- halving bunch spacing (12.5 nsec), with new RF system new electronics!

⇒ $L \approx 5 * 10^{34}$ cm^{-2} s^{-1}

major hardware changes in arcs or injectors:
- SPS equipped with superconducting magnets to inject at ≈ 1 TeV ⇒ $L \approx 10^{35}$ cm^{-2} s^{-1}
- new superconducting dipoles at B ≈ 15 Tesla for beam energy ≈ 12.5TeV i.e. $\sqrt{s} \approx 25$ TeV for ~ 2020

Bunch schemes considered

W. Scandale



nominal and ultimate LHC

25 ns

baseline upgrade

back-up upgrade

more & shorter bunches

12.5 ns

plus: large luminosity gain with minimal event pile up & impact of θ_c

concern: e-cloud, cryogenic load, LRBB, impedance, collimation, machine protection

fewer & longer bunches

75 ns

plus: large luminosity gain with no e-cloud, lower I, easier collimation & machine protection

concern: larger event pile up, impedance

super-bunch

abandoned

plus: no e-cloud, lower I

concern: event pile up intolerable

LHC performance and parameters in different schemes

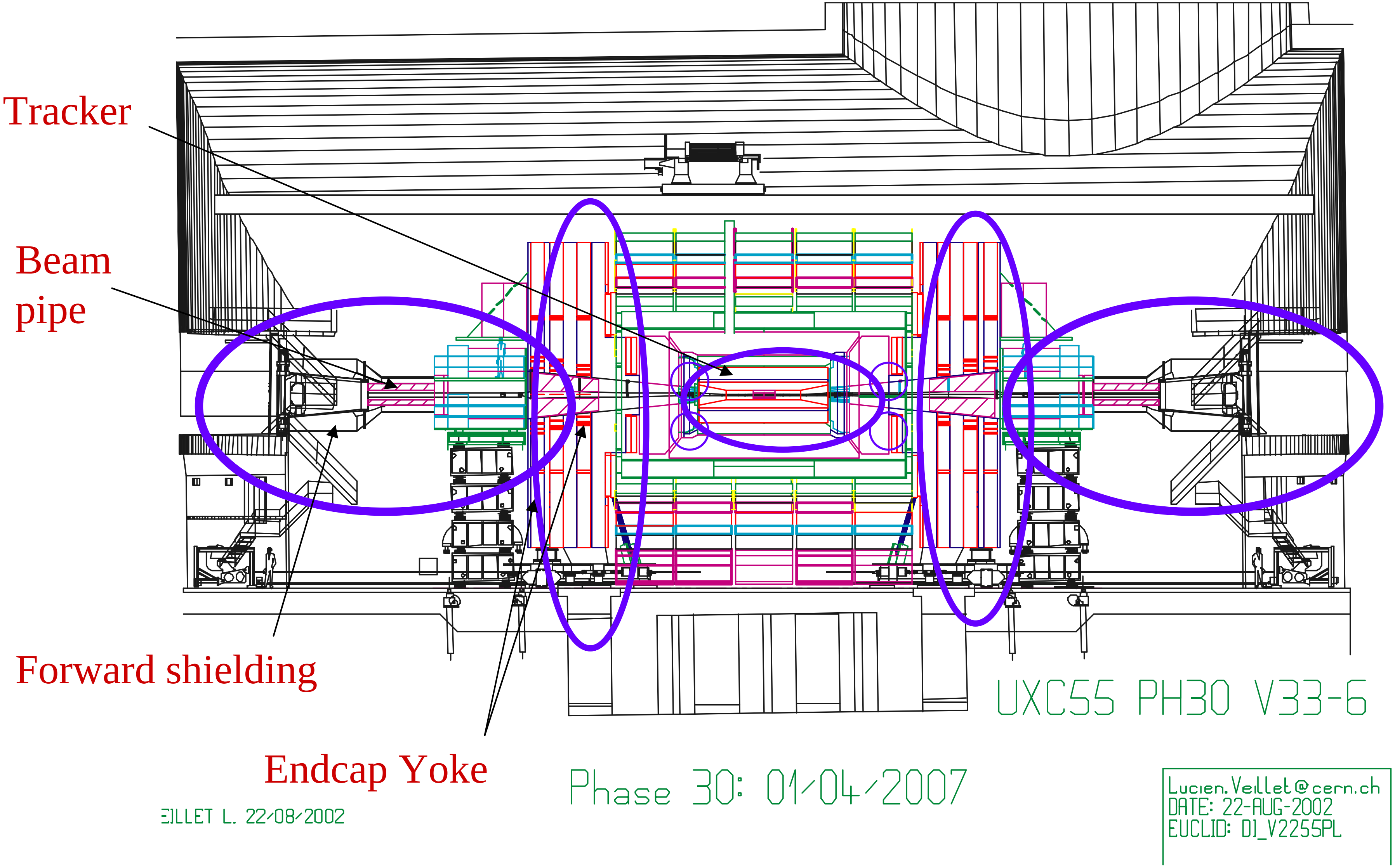
Parameter [units]	Nominal	Ultimate	Short bunch	Long bunch
No. of bunches n_b	2808	2808	5616	936
p$^+$ 5 bunch N_b [10^{11}]	1.15	1.7	1.7	6.0
Bunch spacing Δt_{sep} [ns]	25	25	12.5	75
Beam current [A]	0.58	0.86	1.72	1.0
E_{beam} [MJ]	366	541	1085	631
Beta at IP β^* [m]	0.55	0.50	0.25	0.25
Xing angle θ_c [μrad]	285	315	445	430
Bunch length [cm]	7.55	7.55	3.78	14.4
Piwinski ratio $\theta_c\,\sigma_s/(2\sigma^*)$	0.64	0.75	0.75	2.8
L lifetime τ_L [h]	15	10	6.5	4.5
L_{peak} [10^{34}cm^{-2}s^{-1}]	1.0	2.3	9.2	8.9
$T_{turnaround}$ [h]	10	10	5	5
Events per Xing	19.2	44.2	88	510
$\int_{\text{one year}} L\,dt$ [fb^{-1}]	66.2	131	560	410

ε_n = 3.75 mm in all the options

W. Scandale

Luminosity upgraded LHC

Main CMS areas affected by luminosity upgrade



Tracker

Beam pipe

Forward shielding

Endcap Yoke

Shielding between machine and HF

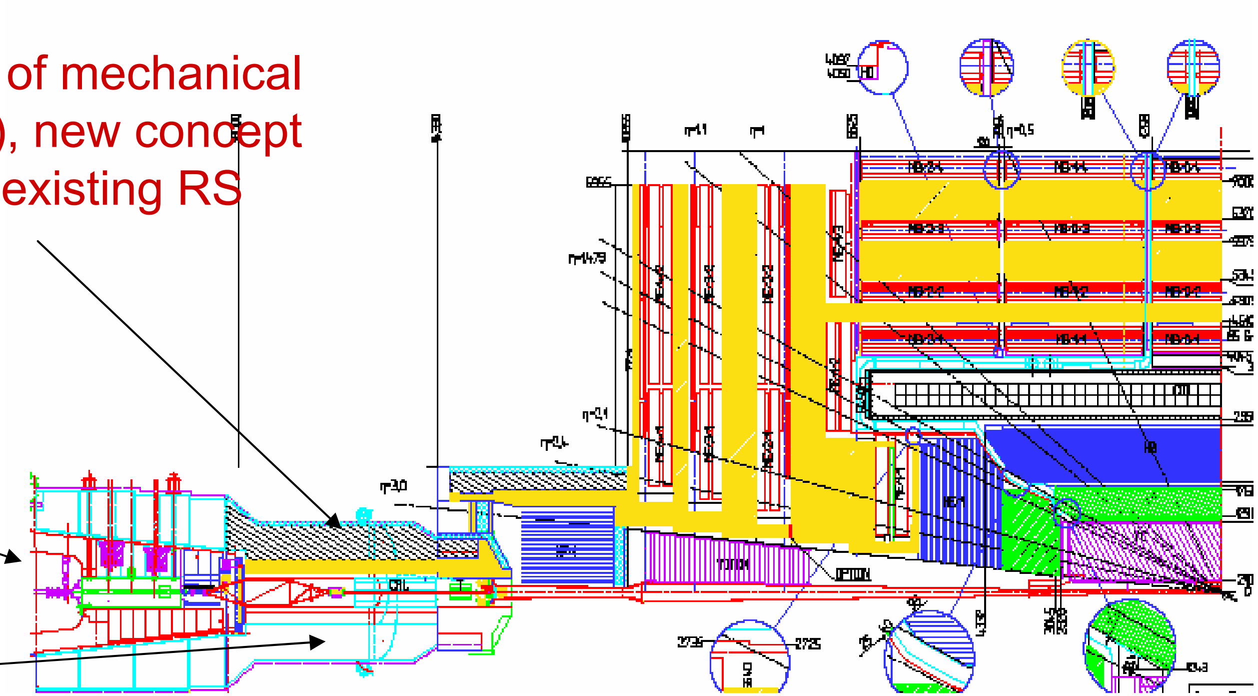
Basic functions of the shielding elements between the machine area and HF are:

-reduce the neutron flux in the cavern by 3 orders of magnitude

-reduce the background rate in the outer muon spectrometer (MB4, ME3,ME4) by 3 orders of magnitude

-reduce the radiation level at the HF readout boxes to a tolerable level

Rotating system is near the limits of mechanical strength (doubly hinged structure), new concept or supplementary system around existing RS needed for SLHC running,

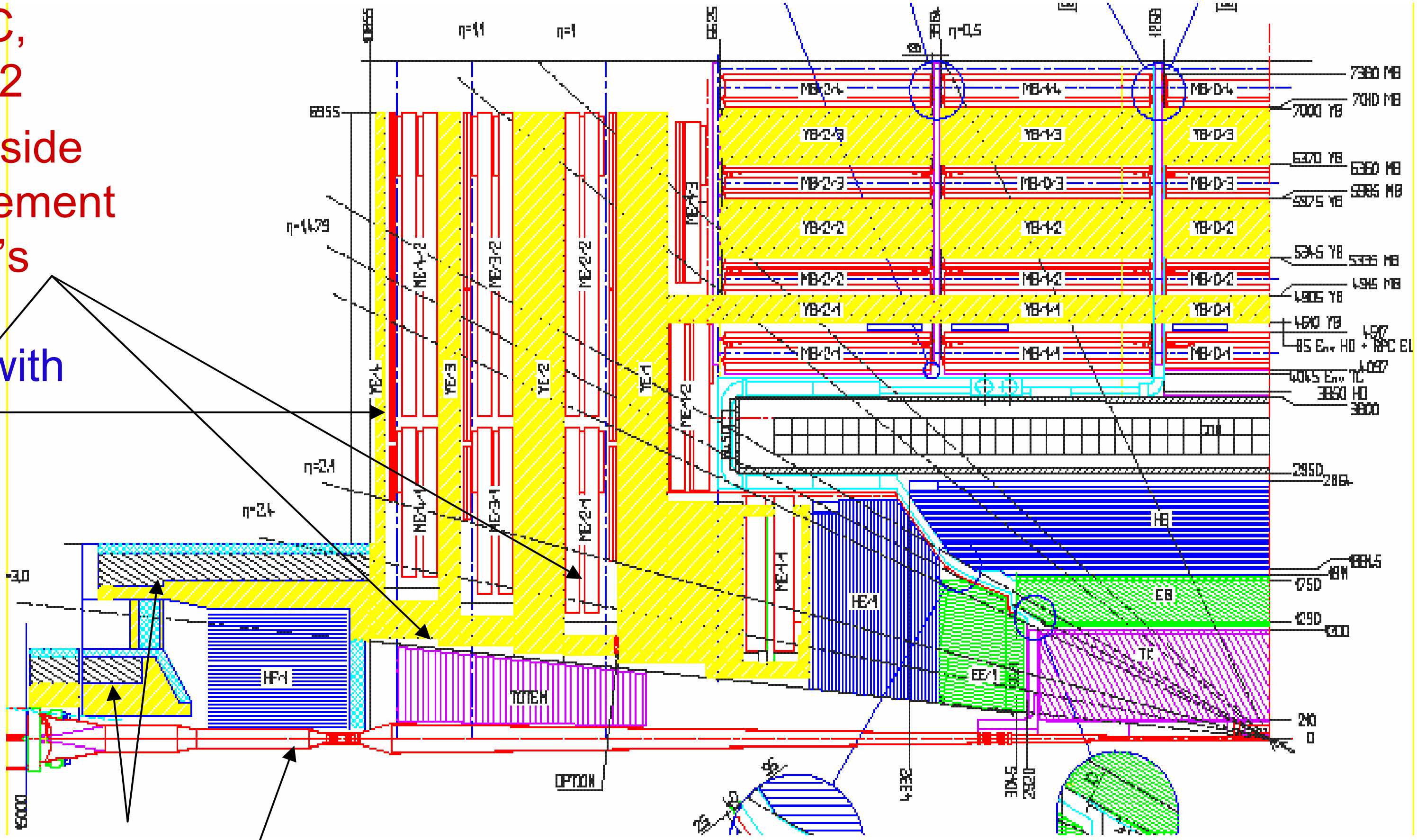


inner quadrupole triplet

new quadrupoles !

forward shielding

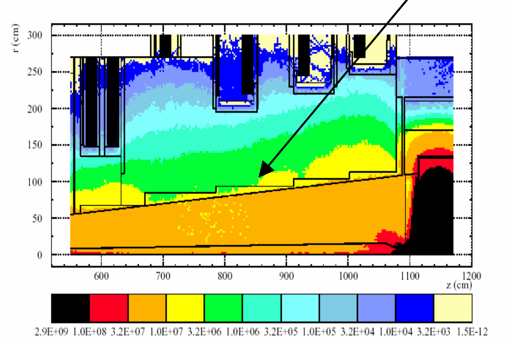
CMS yoke and forward detectors- modifications considered for SLHC



End cap yoke for SLHC, acceptance up to |η| ~ 2

Reinforced shielding inside forward muons, replacement of inner CSC and RPC's

Supplement YE4 wall with borated polythene



Improve shielding of HF PMT's

Quadrupoles here?

Free space in radius in the HF calo is : 14cm beam-pipe radius + 5cm clearance, the issue - if quads were to be located there or in the "TOTEM part", is the neutron albedo into CMS acceptable?

Experimental conditions at 10^{35} cm^{-2} s^{-1} (12.5ns) - considerations for tracker and calorimetry

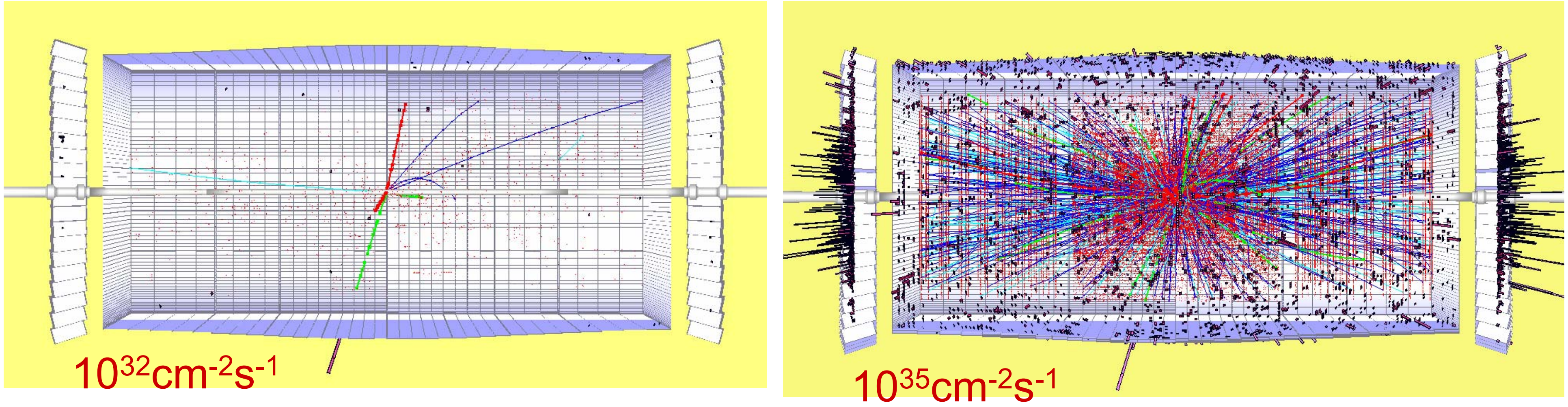
~ 100 pile-up events per bunch crossing - if 12.5 nsec bunch spacing (with adequate/faster electronics, reduced integration time) - compared to ~ 20 for operation at 10^{34}cm^{-2}s^{-1} and 25 nsec (nominal LHC regime),

➡ $dn^{ch}/d\eta$/crossing ≈ 600 and ≈ 3000 tracks in tracker acceptance

$H \rightarrow ZZ \rightarrow ee\mu\mu$, $m_H = 300$ GeV, in CMS

Generated tracks, $p_t > 1$ GeV/c cut, i.e. all soft tracks removed!

I. Osborne



10^{32}cm^{-2}s^{-1}

10^{35}cm^{-2}s^{-1}

➡ If same granularity and integration time as now: tracker occupancy and radiation dose in central detectors increases by factor ~10, pile-up noise in calorimeters by ~ 3 relative to 10^{34}

CMS inner tracking for SLHC

From R.Horisberger

Pixels to be used to much larger radius, from ~10 cm up to ~ 60 cm

Technology and pixel size vary with radius, not too large an extrapolation in sensor technology, cost geometry optimization:

3 pixel systems proposed:

- system 1 - for maximal fluence and rate, two layers between ~ 10 -15 cm
.   ~ 400 CHF/cm^2

- system 2 -large pixel system, two layers between ~ 15 - 30 cm
.   ~ 100 CHF/cm^2

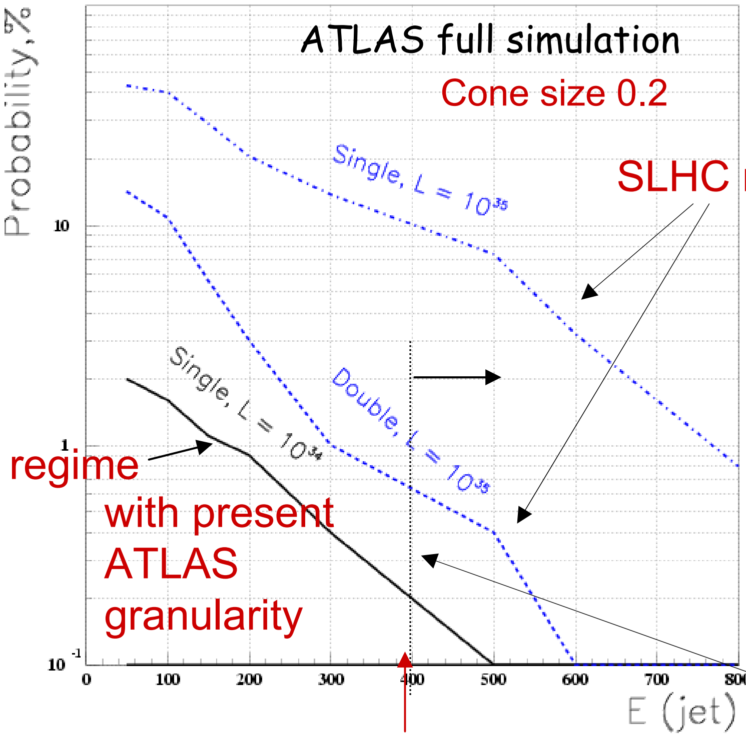
- system 3 -large area macro-pixel system,~four layers between ~ 30 - 60 cm
.   ~ 40 CHF/cm^2

This 8 -layer system could eventually deal with up to 1200 tracks per unit of rapidity i.e. 10^{35} luminosity with 25 nsec bunch spacing.

Importance of VFCAL/feasability of forward jet tagging at 10^{35} cm^{-2} s^{-1}

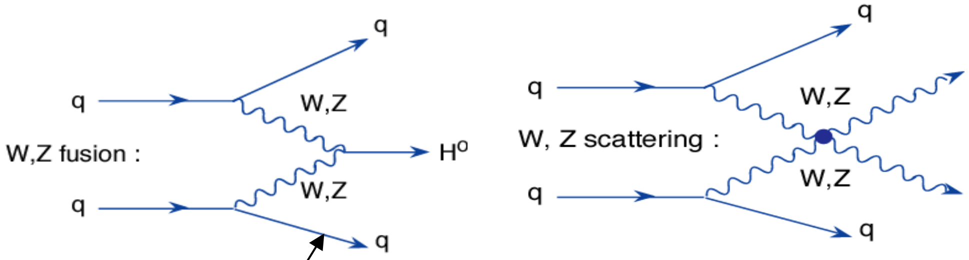
Forward jet tagging needed to improve S/B in VB fusion/scattering processes pp → qqH, qqVV ….if still of interest in ~ 2015 , but could also be crucial if no Higgs found by then!

Fake fwd jet tag ($|\eta| > 2$) probability from pile-up (preliminary ...)

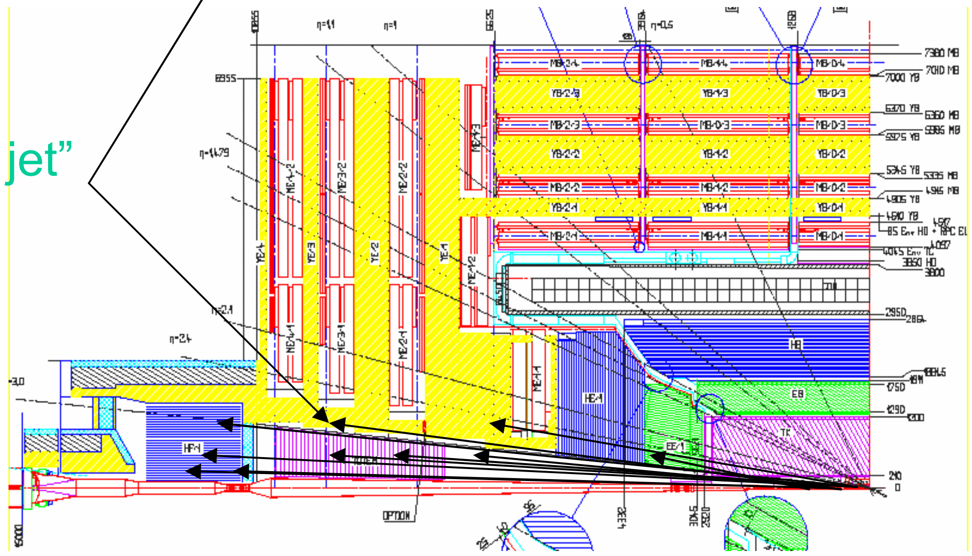


SLHC regime

LHC regime
with present ATLAS granularity



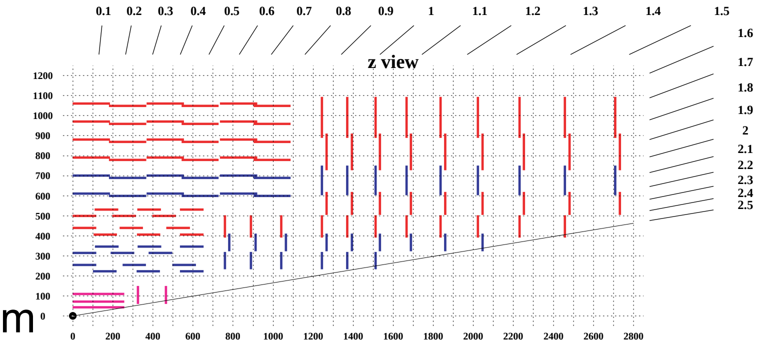
“tagging jet”



cut at > ~ 400 GeV

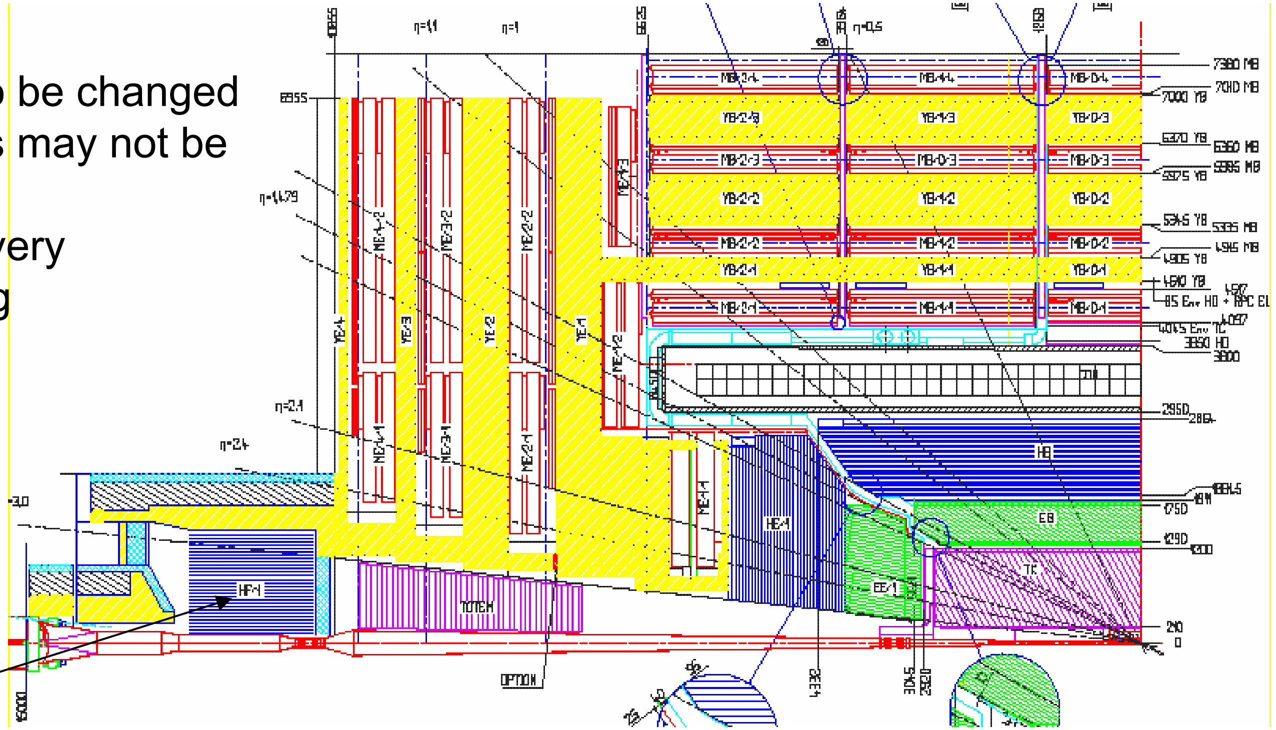
➡ Method should still work at 10^{35}: increase forward calo granularity, reduce jet reconstruction cone from 0.4 to ~ 0.2, optimise jet algorithms to minimize false jets

Foreseeable changes to detectors for 10^{35}cm^{-2}s^{-1} overview



changes to CMS and ATLAS :

- Trackers, to be replaced due to increased occupancy to maintain performance, need improved radiation hardness for sensors and electronics
  - present Si-strip technology is OK at R > 60 cm
  - present pixel technology is OK for the region ~ 20 < R < 60 cm
  - at smaller radii(<~10 cm) new techniques required
- Calorimeters: ~ OK
  - endcap HCAL scintillators in CMS to be changed
  - endcap ECAL VPT's and electronics may not be enough radiation hard
  - desirable to improve granularity of very forward calorimeters - for jet tagging
- Muon systems: ~ OK
  - acceptance reduced to $|\eta| <\sim 2.0$ to reinforce forward shielding
- Trigger(L1), to be replaced, L1(trig.elec. and processor) for 80 MHz data sampling



➡ VF calorimeter for "jet tagging"

Cost expectations for CMS upgrade for SLHC

from J.Nash

Inner Tracker	25 - 30 MCHF
Outer Tracker	90 MCHF
Level 1 Trigger	15 MCHF
DAQ	10 MCHF
Other Front Ends	5 -10 MCHF
Additional Costs 10ns/15ns	20 - 30 MCHF
Infrastructure	15 MCHF

Physics motivations for a luminosity upgraded LHC, expected performances

Expectations for detector performances at 10^{35} cm^{-2} s^{-1} - overview

- Electron identification and rejections against jets, $E_t = 40$ GeV, ATLAS full simulation

L (cm^{-2} s^{-1})	Electron efficiency	Jet rejection
10^{34}	81%	10600±2200
10^{35}	78%	6600±1130

- Electron resolution degradation due to pile-up, at 30 GeV: 2.5% (LHC) → 3.5% (SLHC)
- b-jet tagging performance: rejection against u-jets for a 50% b-tagging efficiency

p_T (GeV)	R_u at 10^{34} cm^{-2}s^{-1}	R_u at 10^{35} cm^{-2}s^{-1}
30-45	33	3.7
45-60	140	23
60-100	190	27
100-200	300	113
200-350	90	42

Preliminary study, ATLAS

$\Rightarrow$performance degradation at 10^{35} factor of ~ 8 - 2 depending on E_t

$\Rightarrow$ increase (pixel) granularity!

- Forward jet tagging and central jet vetoing still possible - albeit at reduced efficiencies reducing the cone size to ≈ 0.2

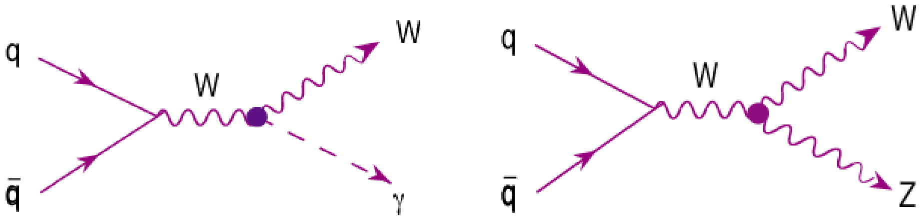
probability of fake double forward tag is ~ 1% for $E_{jet} > 300$ GeV ($|\eta| > 2$)

probability of ~ 5% for additional central jet for $E_t > 50$ GeV ($|\eta| < 2$)

ew physics, triple gauge boson couplings

In the SM TGC uniquely fixed, extensions to SM induce deviations

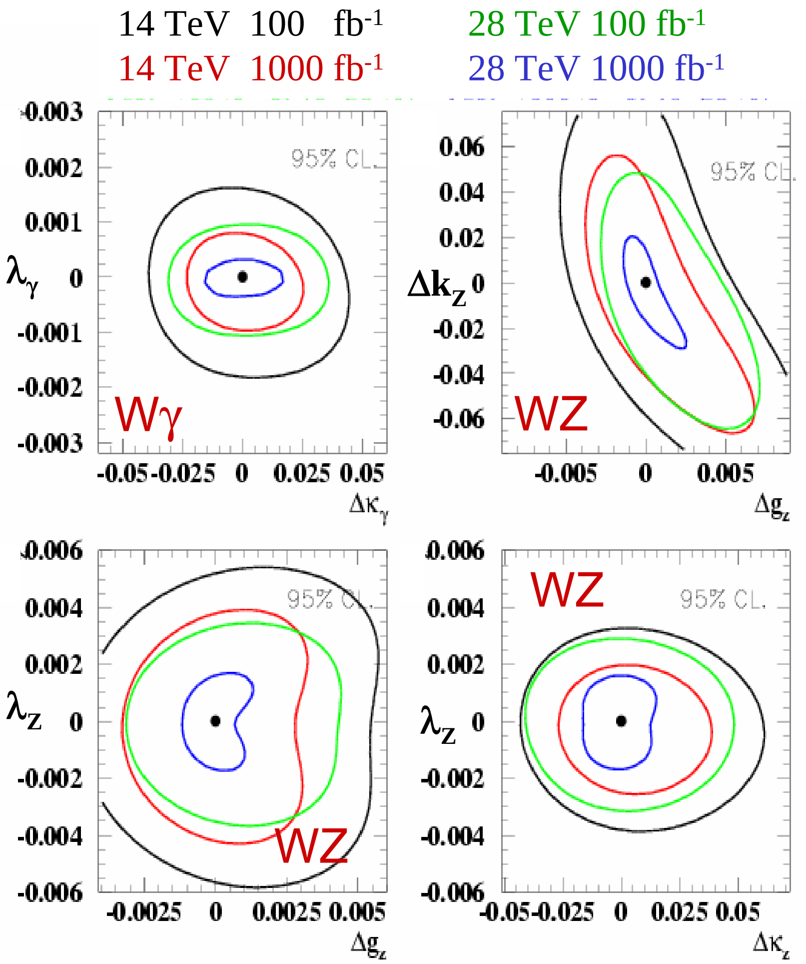
- At LHC the best channels are: $W\gamma \to l\nu\gamma$ and $WZ \to l\nu ll$



5 parameters describe these TGCs:
g_1^Z (1 in SM), $\Delta\kappa_Z$, $\Delta\kappa_\gamma$, λ_γ, λ_Z (all 0 in SM)
$W\gamma$ final state probes $\Delta\kappa_\gamma$, λ_γ and WZ probes g_1^Z, $\Delta\kappa_Z$, λ_Z

- TGCs: a case where a luminosity increase by a factor ~10 is better than a center-of-mass energy increase by a factor ~ 2

Correlations among parameters



➡ SLHC can bring sensitivity to λ_γ, λ_Z and g_1^Z to the ~ 0.001 level (of SM rad.corrections)

Higgs physics - new modes/larger reach

Increased statistics would allow:

- to look for modes not observable at the LHC for example:

$H_{SM} \to Z\gamma$ (BR ~ 10^{-3}), $H_{SM} \to \mu^+\mu^-$ (BR ~ 10^{-4}) - the muon collider mode!
$H^\pm \to \mu\nu$

to check couplings; H_{SM}, $H^\pm$ etc masses well known by this time!

- extend significantly coverage of the MSSM parameter space, for example in:

$A/H \to \mu^+\mu^-$, $A/H \to \tau^+\tau^- \to \mu e$, $A/H \to \tau^+\tau^- \to \mu/e + \tau\ (\tau \to \text{jet})$, $H^\pm \to \tau\nu$
$A/H \to \chi\chi \to \mu\mu ee$

Specific example for a new mode:

.

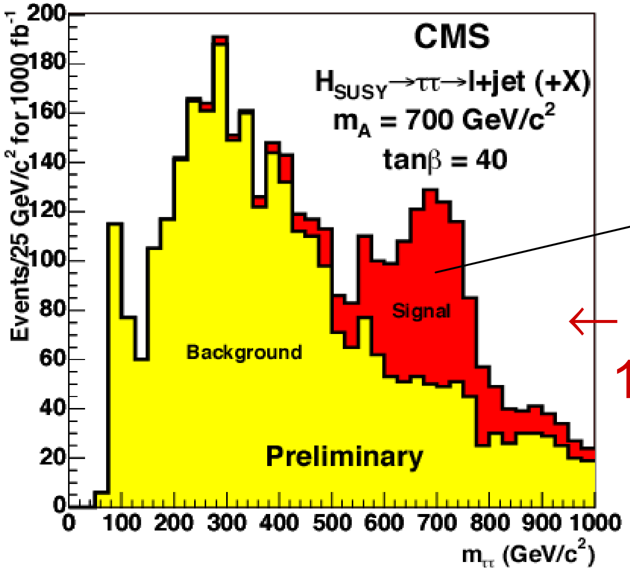
$H_{SM} \to \mu^+\mu^-$ $120 < M_H < 140$ GeV, LHC (600 fb^{-1}) significance: $< 3.5\sigma$,
SLHC (two exps, 3000 fb^{-1} each) ~ 7σ

SLHC: improved reach for heavy MSSM Higgs bosons

The order of magnitude increase in statistics with the SLHC should allow to extend the discovery domain for massive MSSM Higgs bosons A,H,H±

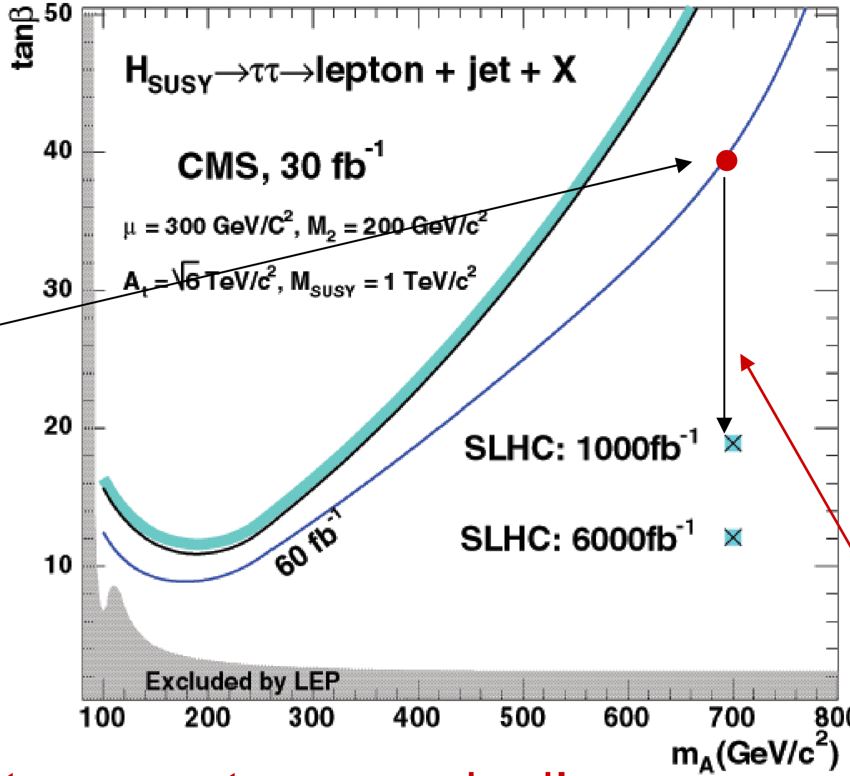
example: A/H → ττ → lepton + τ-jet, produced in bbA/H

Peak at the 5σ limit of observability at the LHC greatly improved at SLHC, fast simulation, preliminary:



S. Lehti

← SLHC 1000 fb^{-1}



←LHC 60 fb^{-1}

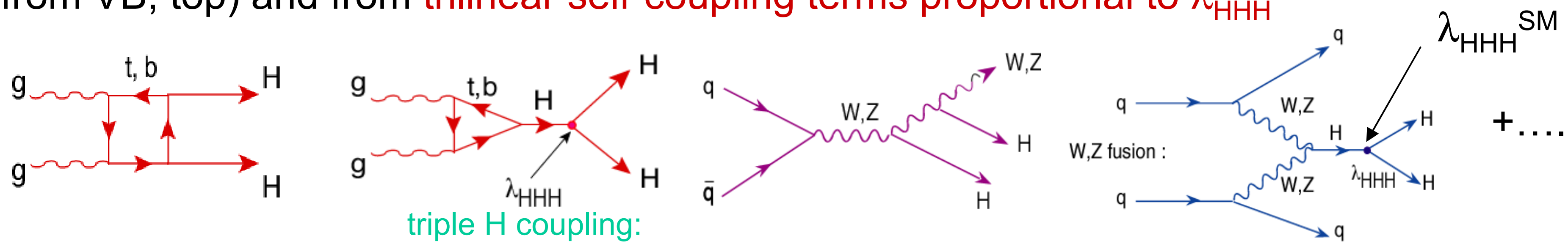
←SLHC 1000 fb^{-1}

gain in reach

b-tagging performance comparable to present one required!

Higgs pair production and Higgs self coupling

Higgs pair production can proceed through two Higgs bosons radiated independently (from VB, top) and from trilinear self-coupling terms proportional to λ_{HHH}^{SM}



triple H coupling:
$\lambda_{HHH}^{SM} = 3m_H^2/v$

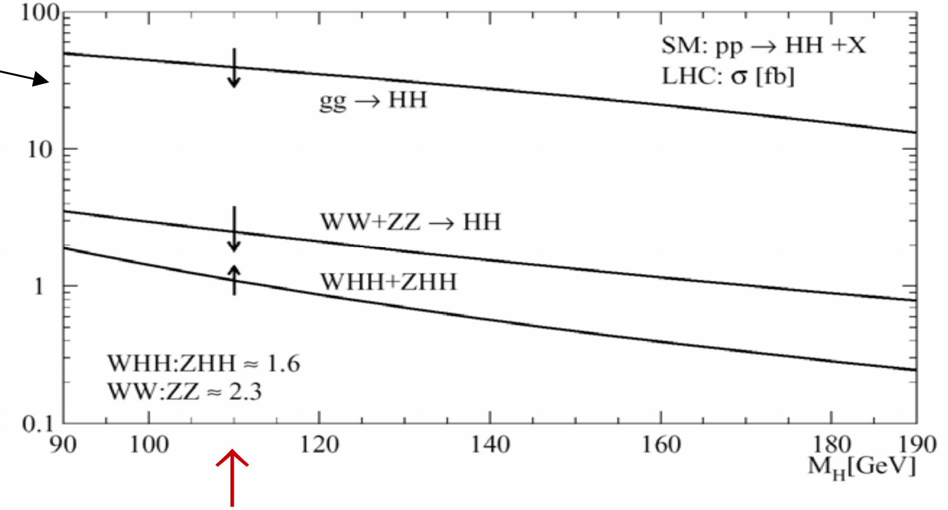
very small cross sections, hopeless at LHC (10^{34}), some hope at SLHC

channel investigated, $170 < m_H < 200$ GeV (ATLAS):

$gg \to HH \to W^+ W^- W^+ W^- \to l^\pm \nu jj\ l^\pm \nu jj$
with same-sign dileptons - very difficult!

➡ total cross section and λ_{HHH} determined with ~ 25% statistical error for 6000 fb^{-1} provided detector performances are comparable to present LHC detectors

cross sections for Higgs boson pair production in various production mechanisms and sensitivity to λ_{HHH} variations



↑

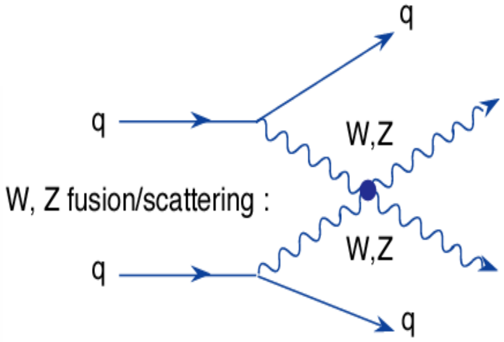
arrows correspond to variations of λ_{HHH} from 1/2 to 3/2 of its SM value

WZ vector resonance in VB scattering

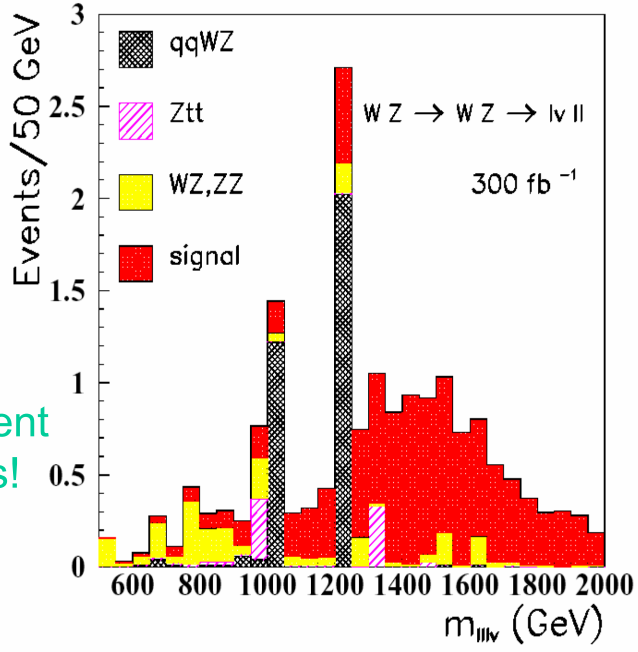
If no Higgs found, possibly a new strong interaction regime in $V_L V_L$ scattering, this could become the central issue at the SLHC! For ex.:

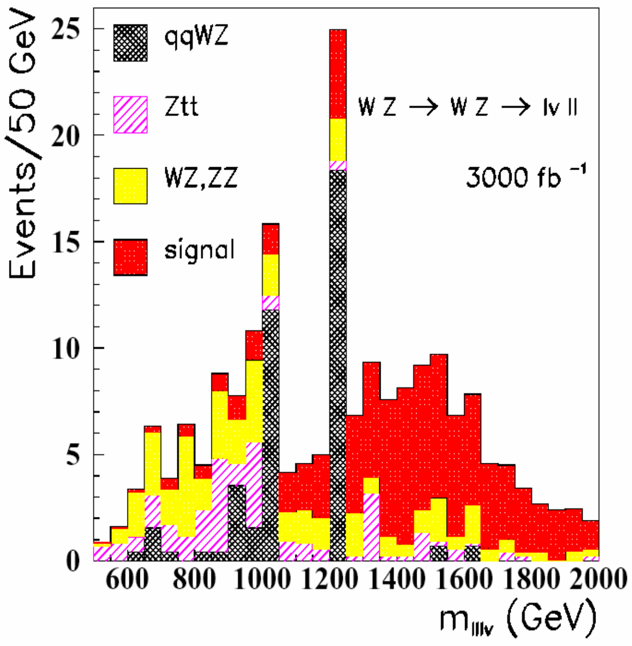
Vector resonance (ρ-like) in $W_L Z_L$ scattering from Chiral Lagrangian model
M = 1.5 TeV, leptonic final states, 300 fb^{-1} (LHC) vs 3000 fb^{-1} (SLHC)

lepton cuts: p_{t1} > 150 GeV, p_{t2} > 100 GeV, p_{t3} > 50 GeV; E_t^{miss} > 75 GeV



Note event numbers!





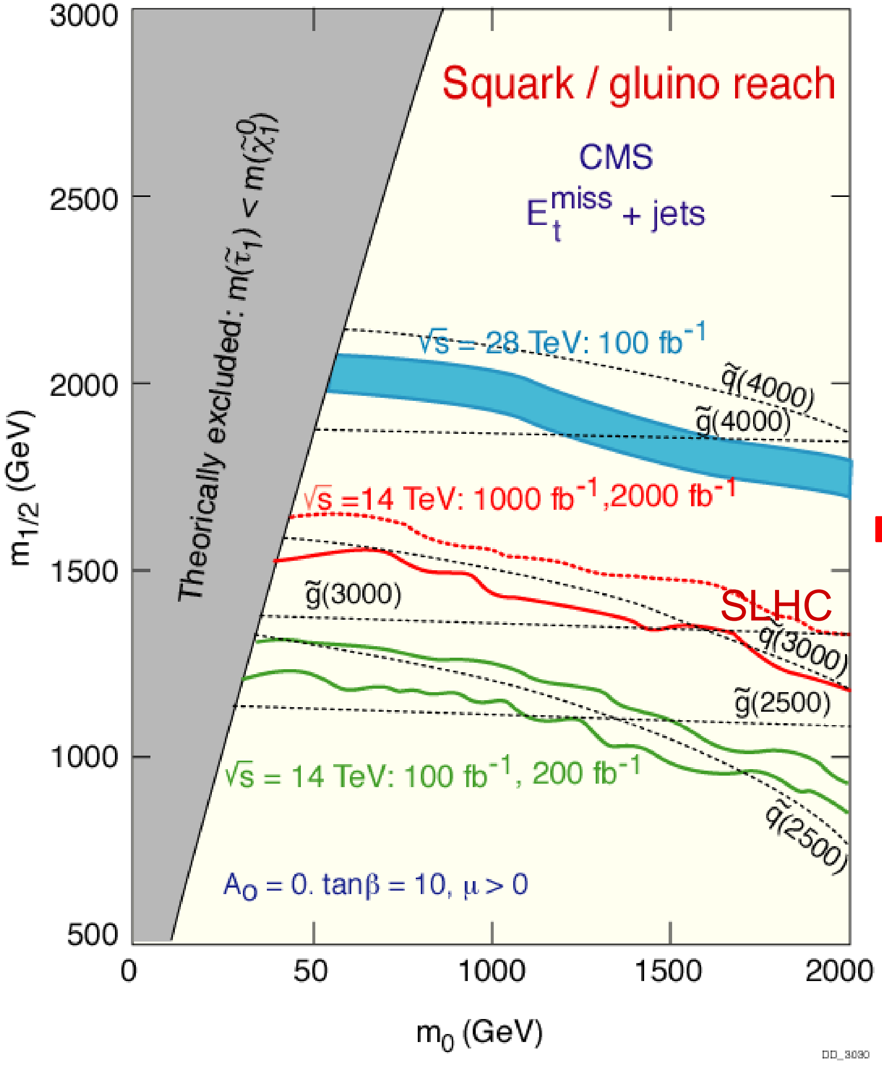
These studies require both forward jet tagging and central jet vetoing! Expected (degraded) SLHC performance is included

increased cm energy/ VLHC even better!!

at LHC: S = 6.6 events, B = 2.2 events

at SLHC: $S/\sqrt{B}$ ~ 10

SUSY at SLHC/VLHC - mass reach



Notice advantage of a 28 TeV machine….

- Higher integrated luminosity brings increase in mass reach in squark, gluino searches, i.e. in SUSY discovery potential;
not too demanding on detectors as very high E_t jets, E_t^{miss} are involved, large pile-up not so detrimental

→ with SLHC the SUSY reach is increased by ~ 500 GeV, up to ~ 3 TeV in squark and gluino masses
(and up to ~ 4 TeV for 30 TeV VLHC)

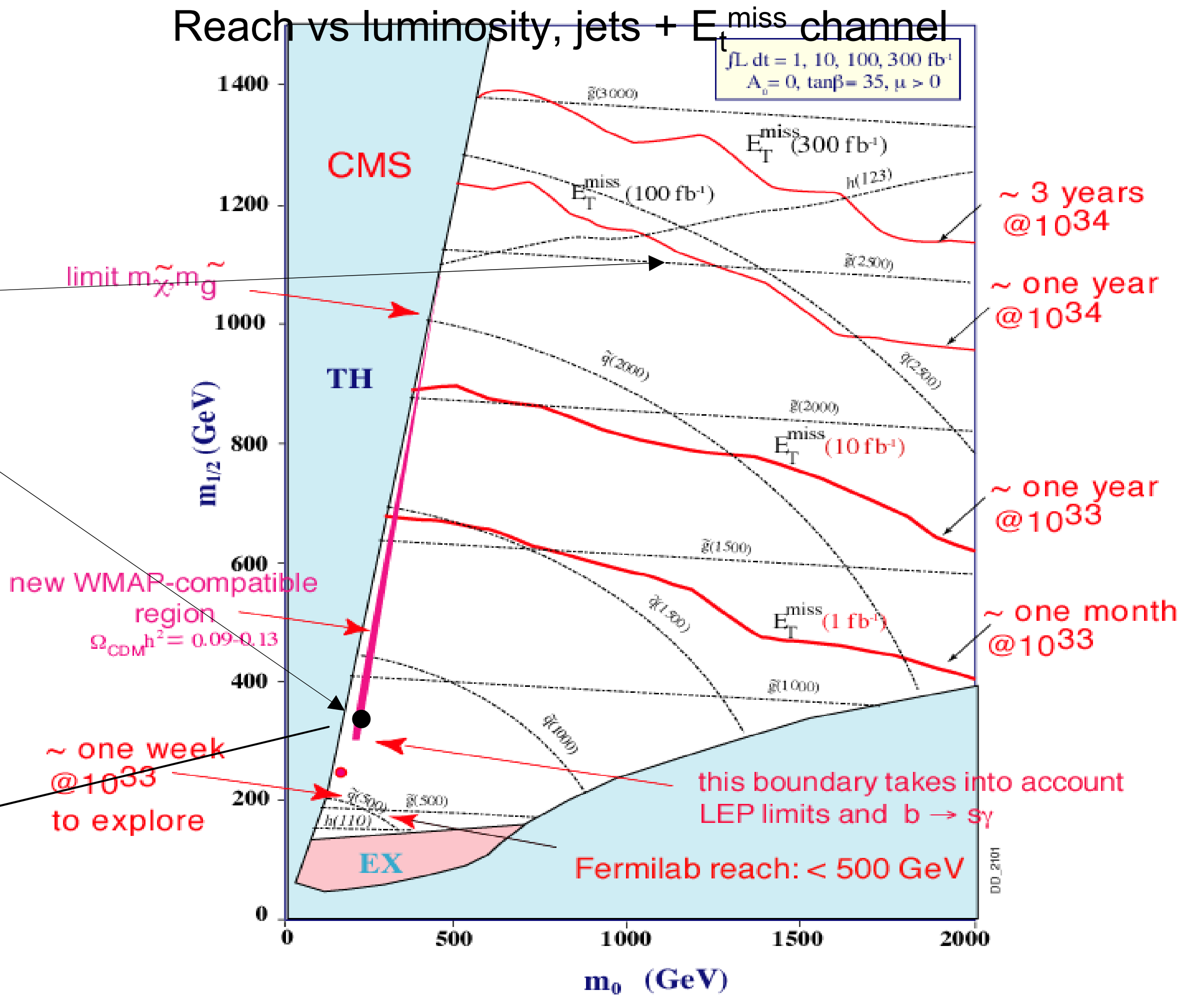
- the advantage of increased statistics should be in the sparticle spectrum reconstruction possibilities, larger fraction of spectrum, requires detectors of comparable performance to “present ones”

SUSY at SLHC - importance of statistics

Discovering SUSY is one thing, understanding what is seen requires much more statistics!

Compare for ex. 100 fb^{-1} reach and sparticle reconstruction stat limited at 100 fb^{-1} at “point G” (tgβ = 20), as many topologies required, leptons, b-tagging…

Reach vs luminosity, jets + E_t^{miss} channel



~ 3 years @10^{34}

~ one year @10^{34}

~ one year @10^{33}

~ one month @10^{33}

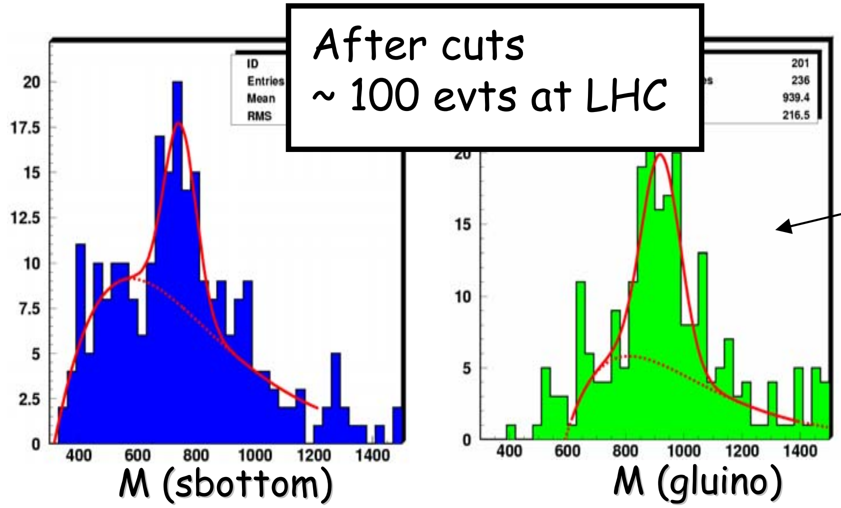
limit $m_{\tilde\chi}$,$m_{\tilde g}$

new WMAP-compatible region $\Omega_{CDM}h^2 = 0.09\text{-}0.13$

~ one week @10^{33} to explore

this boundary takes into account LEP limits and b → sγ

Fermilab reach: < 500 GeV



After cuts
~ 100 evts at LHC

This is domain where SLHC statistics may be decisive!
but LHC-type detector performance needed

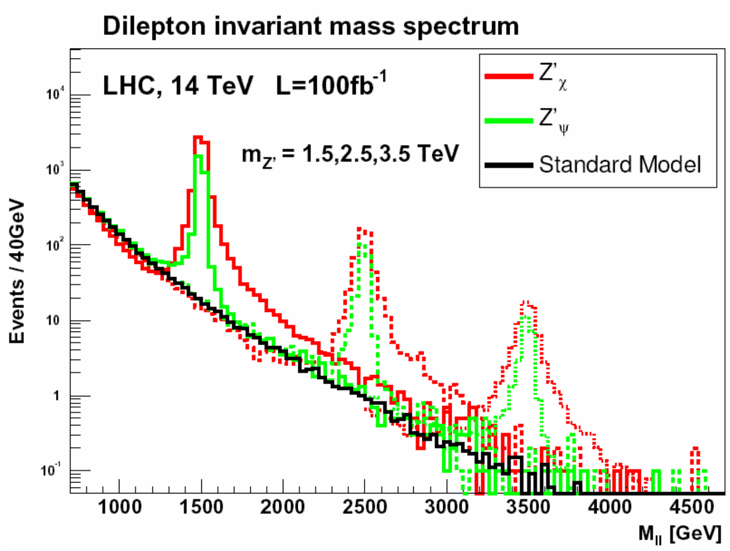
LHC and extra dimensions

New Gauge Bosons,
γ, Z, W recurencies, R-S Gravitons,
Mini Black Holes

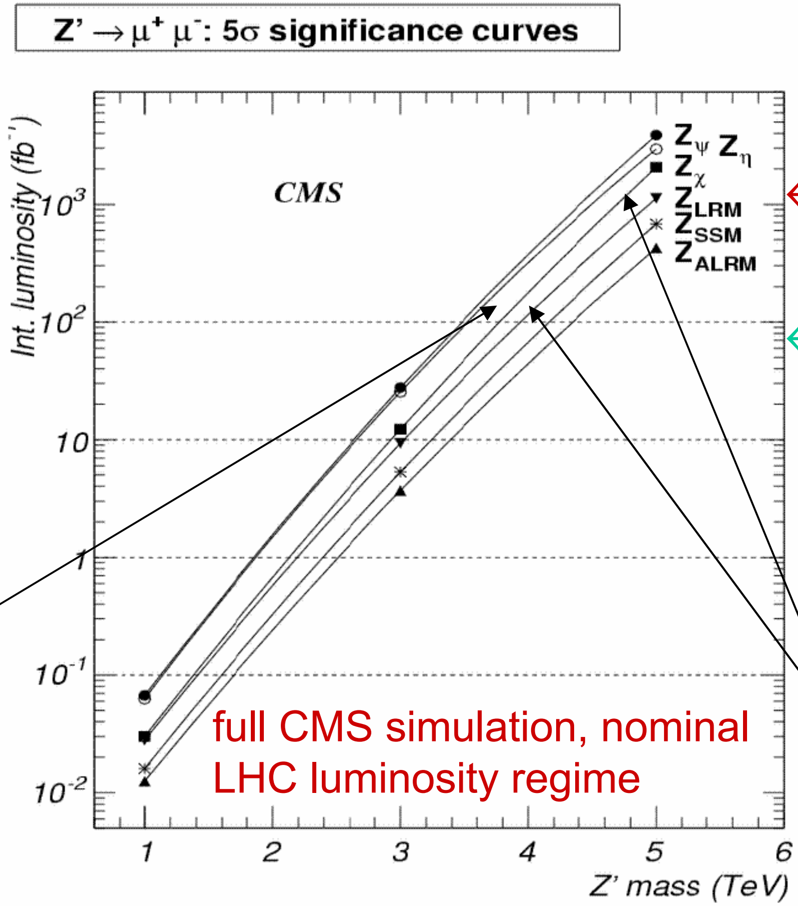
New gauge bosons, Z' → *ll* reach at SLHC

Additional heavy gauge bosons (W, Z-like) are expected in various extensions of the SM symmetry group (LR, ALR, E_6, SO(10)…..),

Examples of Z' peaks in some models:



LHC discovery potential for Z' → μμ



full CMS simulation, nominal LHC luminosity regime

← SLHC 1000 fb^{-1}

← LHC 100 fb^{-1}

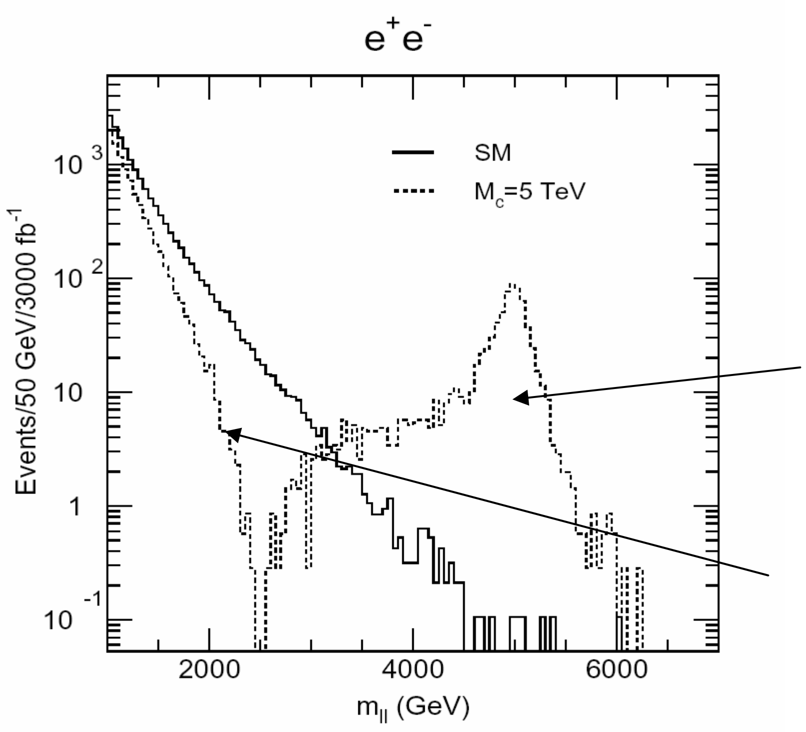
~ 1.0 TeV

LHC reach ~ 4.0 TeV with 100 fb^{-1}

➡ gain in reach ~ 1.0 TeV i.e. 25-30% in going from LHC to SLHC

Extra dimensions, TeV^{-1} scale model

Theories with extra dimensions - with gravity scale ~ ew scale - lead to expect characteristic new signatures/signals at LHC/SLHC; various models: ADD, ABQ, RS…



Example: two-lepton invariant mass

TeV^{-1} scale extra dim model (ABQ-type, one "small" extra dim. $R_c = 1/M_c$) with M_c = 5 TeV, 3000 fb^{-1}

peak due to first γ, Z excitation at ~ M_c ;

note interference between γ, Z and KK excitations $\gamma^{(n)}$, $Z^{(n)}$, thus sensitivity well beyond direct peak observation from dσ/dM (background control!) and from angular distributions/ F-B asymmetry

➡ reach ~ 6 TeV for 300 fb^{-1} (LHC), ~ 7.7 TeV for 3000 fb^{-1} from direct observation

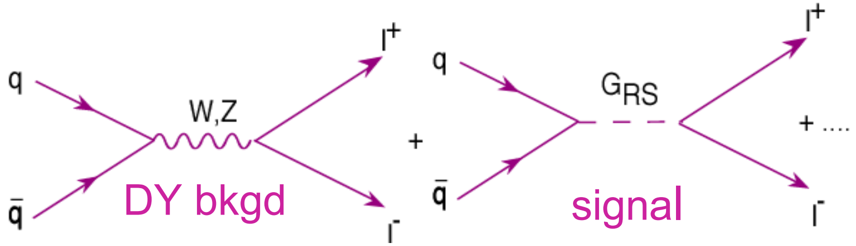
indirect reach (from interference) up to ~ 10 TeV at LHC, 100 fb^{-1}

~ 14 TeV for SLHC, 3000 fb^{-1}, e + μ

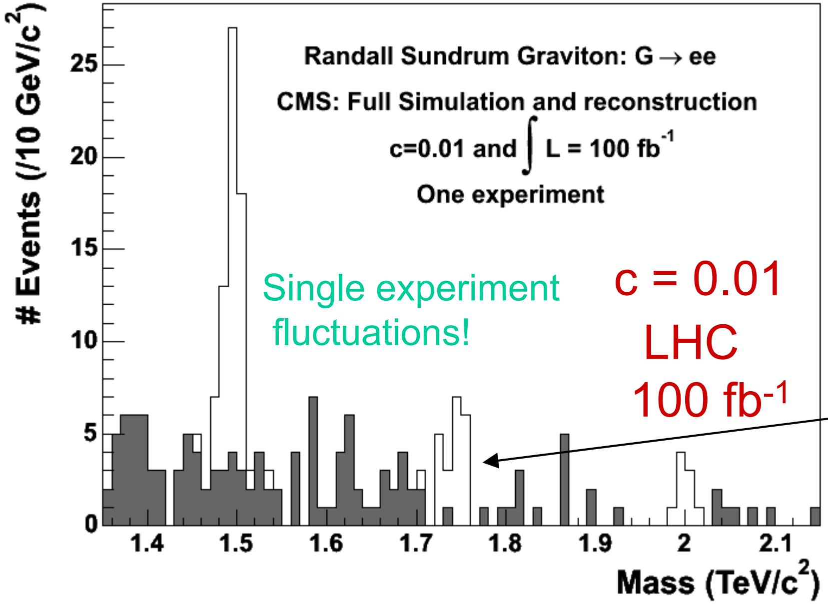
10σ

Extra dimensions, Randall-Sundrum model (II)

pp → G_{RS} → ee   full simulation and reconstruction chain in CMS,



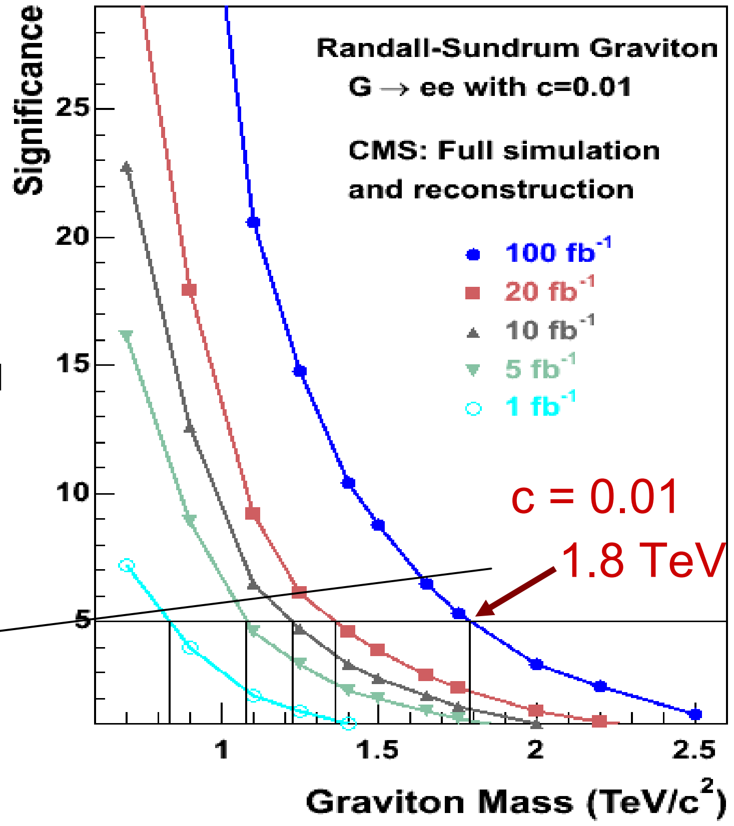
$$S = 2(\sqrt{N_S + N_B} - \sqrt{N_B}).$$



Single experiment fluctuations!

c = 0.01
LHC
100 fb^{-1}

C. Collard



c = 0.01
1.8 TeV

LHC stat limited! A factor ~ 10 increase in luminosity obviously beneficial (SLHC!) for mass reach - increased by 30% - and to differentiate a Z’ (spin = 1) from G_{RS} (spin = 2)

If Planck scale in TeV range

- Schwarzschild radius

4-dim., $M_{gravity} = M_{Planck}$ $$R_S \sim \frac{2}{M_{Pl}^2}\frac{M_{BH}}{c^2}$$

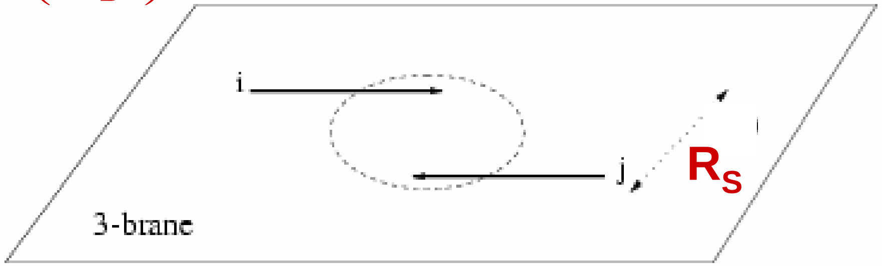
$R_s \rightarrow << 10^{-35}$ m

$R_s \rightarrow \sim 10^{-19}$ m

4 + n-dim., $M_{gravity} = M_D \sim$ TeV $$R_S \sim \frac{1}{M_D}\left(\frac{M_{BH}}{M_D}\right)^{\frac{1}{n+1}}$$

⬇

Since M_D is low, tiny black holes of M_{BH} ~ TeV can be produced if partons ij with $\sqrt{s_{ij}} = M_{BH}$ pass at a distance smaller than R_S



- Large partonic cross-section : $\sigma(ij \rightarrow BH) \sim \pi R_S^2$
- $\sigma(pp \rightarrow BH)$ is in the range of 1 nb – 1 fb

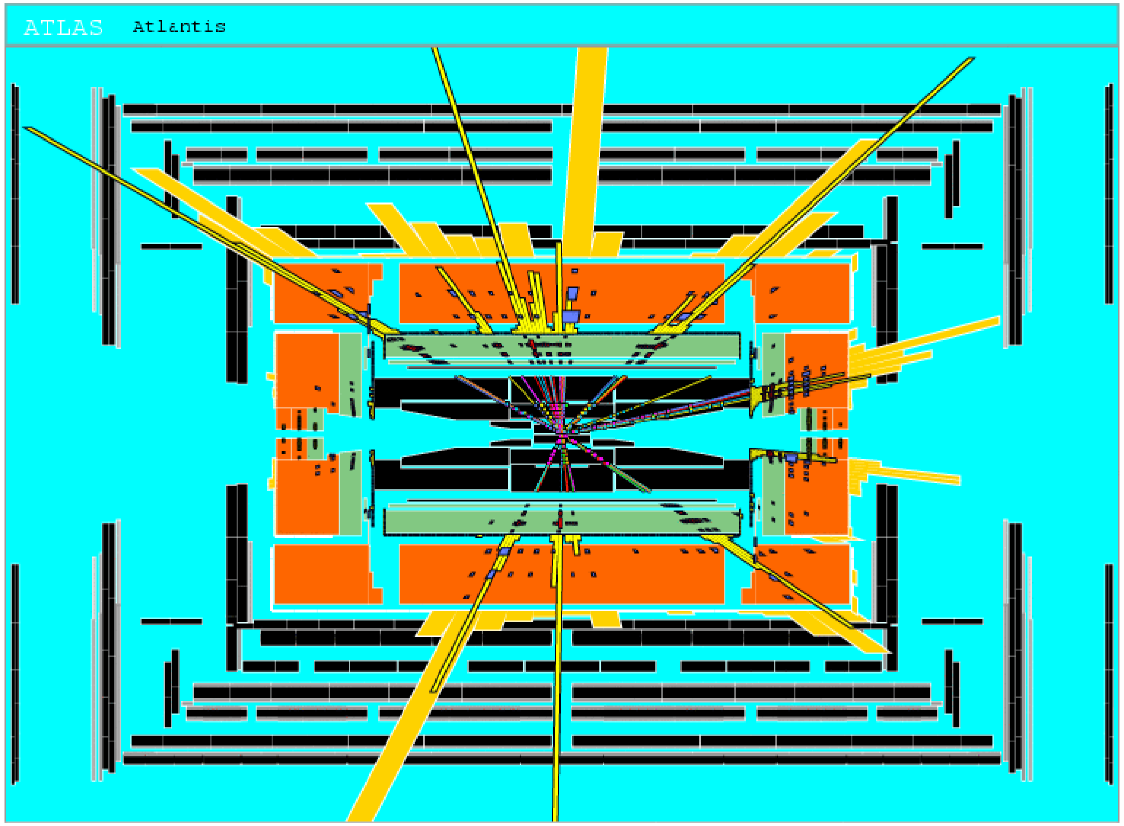
e.g. For M_D ~1 TeV and n = 3, produce 1 event/second at the LHC!!

- Black holes decay immediately by Hawking radiation (democratic evaporation)

expected signature (quite spectacular …)

Extra dimensions/ Black Holes production

If the Planck scale is in ~ TeV region: possible quantum mini Black Hole production, mass of order few TeV, rate at LHC ~1/sec !



Simulation of a black hole event with M_{BH} ~ 8 TeV in ATLAS

M_D ~ 1 TeV n=6

BH decay BR's

Particle	Branching Ratio
Photons	~2% (lower for n=0)
Charged Leptons	~10%
Neutrinos	~5%
Quarks/Gluons	~70%

Signature: Spherical events many high energy jets, leptons, photons, little missing Et ("democratic decays")

BH's decay within ~10^{-27} secs

Possible physics situation after 3-5 years of LHC running/ conceivable scenarios for SLHC

(view of D.Denegri)	I	II	III	IV	V
Detector (CMS) or machine requirements	Heavy bosons Extra dims, W',Z',KK recs. no SUSY	no Higgs no SUSY W,Z scat., BESS, TC	very massive SUSY, gluino,squark at 2 - 3 TeV	SUSY at ~ 0.5 - 1TeV A,H ~ 0.5 TeV	SM-Higgs, TGC ,QGC, SM tests, Triple-Higgs cpl.
Tracker: patt. rec; p	Excel. p-resol.	high perform.	high perform.	max.requirement	high perform.
Tracker: IP;b, τ-tag.	less need for b,τ	No effort	b, τ-tag. desirab.	optimal b, τ-tag	excel. b, τ-tag
Muons ($|\eta|$ < ~2.0?) (now $|\eta|$ < 2.4)	reduced acceptance OK	red. acc. OK	red. acc. OK	Largest acceptance possible.	Largest accept. possible.
ECAL ($|\eta|$ < ~ 2.0?)	red. accept for precis. meas.OK	red. acc ~ OK	OK	Largest accept possible	Largest accept. possible.
HCAL ($|\eta|$< ~ 3) Et^{miss}	Some red. acc .OK	Full acceptance needed, f-jet-tag	Full accept.needed	Full accept .and perf. needed,Et^{miss}	Full accept. and perf. needed, Et^{miss}
VFCAL ($|\eta|$ from < 5 to < ~ 4.0 - 4.5?)	Reduc. accept. OK	Full acc.required Improve granular.	Not essential, Red. accept	Not so essential, Red. Acc. if need	Not so essential, Red. acc. if needed
Trigger/electronics bunch crossing	25 nsec ~ OK, minimal changes	25 nsec or 12.5 nsec	25 nsec or 12.5 nsec	Track. at L1, ~12.5 nsec needed minimize pile-up	Track. at L1, ~12.5 nsec needed minimize pile-up
Comments/Machine/ IR/bunch crossing	Max. int. Lumi. Max cm Energy Pile-up <~ 200	Max. int. Lumi Max cmEnergy Pile-up < 200	Max. int Lumi. Max cm Energy Pile-up < 200	Minimize pile-up <~100, stable run conditions Optimize b/τ tag eff.*Int luminosity	Minimize pile-up <~100, stable run conditions Optimize b/τ tag eff.*Int luminosity

Conclusions on SLHC

In conclusion the SLHC ($\sqrt{s} \approx 14$ TeV, $L \approx 10^{35}$ cm^{-2} s^{-1}) would allow to extend significantly the LHC physics reach - whilst keeping the same tunnel, machine dipoles and a large part of “existing” detectors, however to exploit fully its potential inner/forward parts of detectors must be changed/hardened/upgraded, trackers in particular, to maintain performances similar to “present ones”; forward calorimetry of higher granularity would be highly desirable for jet tagging, especially if no Higgs found in the meantime!
Changes to the machine: only near-experiment optics

For a VLHC (~ 30 TeV) - more desirable from the physics point of view, but much more expensive ~ 3 GCHF - complete change of machine elements, dipoles in particular