Group Studies - Particle Physics

Main Introductory Meeting

21st January 2014

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- Copy of Worksheet(at end of session!)
- Welcome
- Aims of Group Studies
- Organization
- Introduction to the elements of Group Studies
- Assessment
- Project

Group Studies

- Working within a *group* is an important aspect of research as a *particle physicist*.

- Work is done in large (international) *collaborations*. Sophisticated accelerators/detectors can take time to design/construct/commission. Need to start planning for next generation with present understanding/technology.

- For your Group Studies sub-division of work to ensure efficient working, sharing of knowledge and decision making. You assign group responsibilities.

- Remember Group studies is different to other teaching in that it is *student-led*. Staff are here as consultants.

- Students enjoy Group Studies – working with people as well as independently. A flavour of doing your own research.

- Particle Physics Group Studies is mainly a *design* project. Skills to find/understand/communicate info. Often required to calculate things yourself. Use computer simulation programs.

Organization

- Timetabled 10 hours per week (Tuesday/Thursday/Friday).
- 20 Credits.
- Rooms: Physics W125 booked for Tuesday/Thursday afternoons (Tuesdays best for staff). Nuffield G for Friday afternoons. You decide start time / meeting times / rooms. Physics West 2nd floor "open area" at any time.
- The dates for submission of material can be found on school web-site

https://intranet.birmingham.ac.uk/eps/eps-school-intranets/physics-astronomy/students/undergraduate/assessment-deadlines.aspx

Details/aims/contacts of project repeated on web site (plus these slides)

http://epweb2.ph.bham.ac.uk/user/thompson/gs/gs.html

You can find there also details about books in the particle physics library, loaning data projectors etc…

Elements of Group Study

- Organisational Plan How to organise yourselves. Subgroups: objectives, milestones, contingency (Wednesday 29th January)
- Worksheet Introductory. Fairly challenging. Collaborate, but not on numerical values. (Monday 10th February)
- Design work Design sub-groups. Project notebook.
- Weekly Group meetings Run entirely by you. Short reports from each team. Discuss and make main design decisions. Use a meeting half-way through for longer status presentations (invite staff).
- Final project seminar Organised by you. 1 or 2 speakers/group (Tuesday 18th March)
- Viva Near to end; mainly to assess what you have done.
- Final report Organised/written by you. One unified document from whole group. No more than 100 pages (Friday 28nd March)

Assessment

Since group studies is *student-led* we also rely on you to provide us with information about what you have worked on

Some elements of the assessment are common to the group or subgroup

- Organisational Plan (5%) – a common *group* mark
- Project seminar (10%) – a common *subgroup* mark

Other larger elements of the assessment are mainly individual

- Worksheet (15%)
- Project work/effort (20%)
- Viva (10%)
- Project Report (40%) +personal statement + ‘homogeneity’

Project work/effort

Project work/effort mark is set by:

Overall level per subgroup set by staff

Division of marks within subgroup via peer review

The qualities assessed in peer review decided by you. One peer review sheet for the whole group. Usually very good agreement between individuals in subgroup.

Clear that these individual marks are influenced by how well you all worked together: group work ***is*** important.

Advised to keep a logbook of all the work you do.

Feedback

Group studies is likely different to what you have done before:

First introduction to working in "real" environment

You have to work things out yourselves

Other people do exist – they can be a help as well as a hindrance!

If you are stuck then it is up to you to find out who can help – people in your subgroup, staff, …

To get feedback on how you are doing then you need to ask staff. Make use of the Tuesday afternoons and other Group Studies sessions.

If you don't ask us then you'll get no feedback!

Try to take on board the advice - for maximum marks

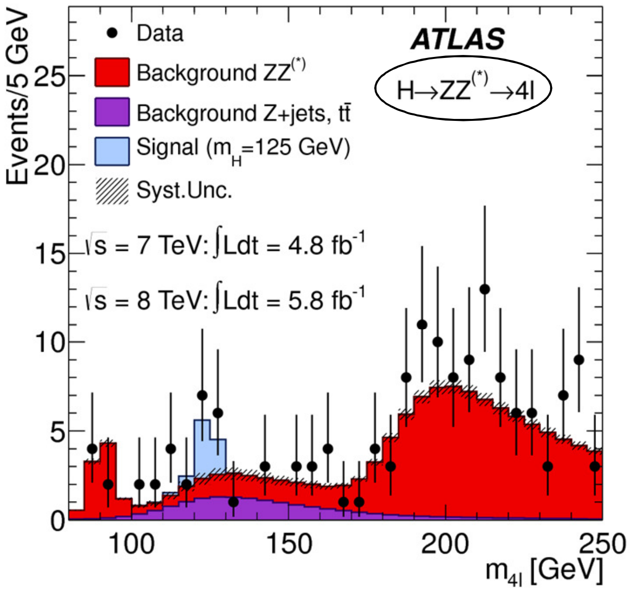
End of Part I

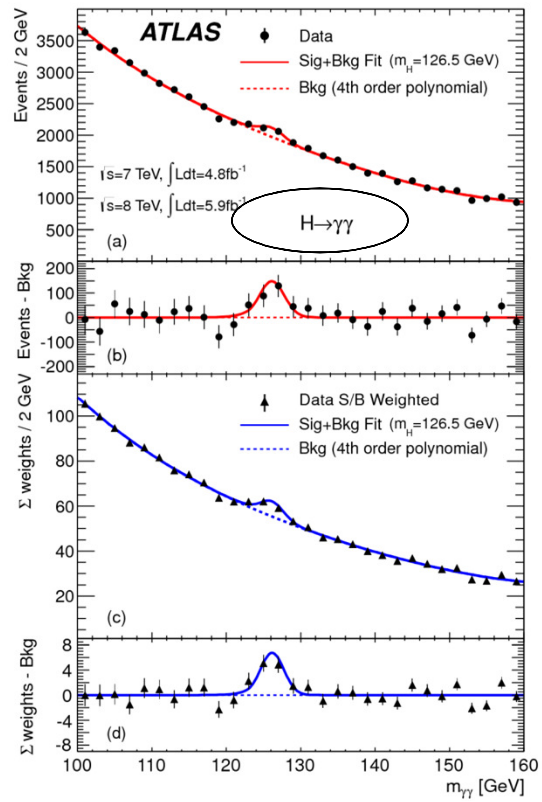
You will hear more about the project now

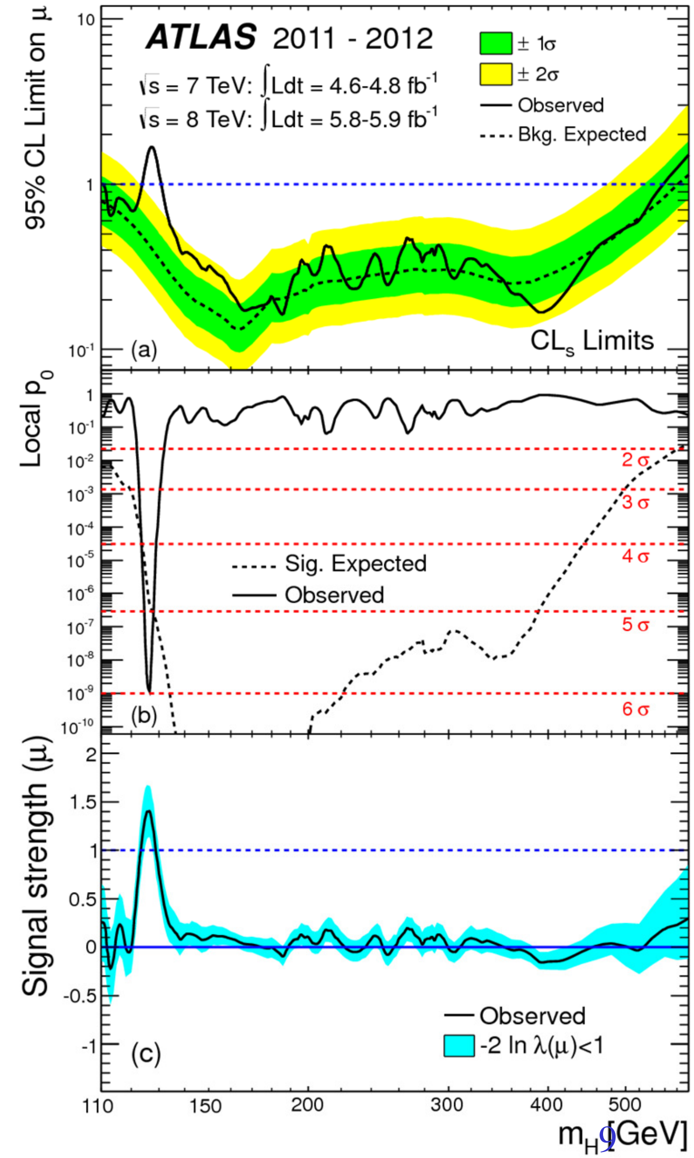
As an idea of what you are aiming for: see previous report

Any questions on organization/assessment?

New particle: 4^{th} July 2012

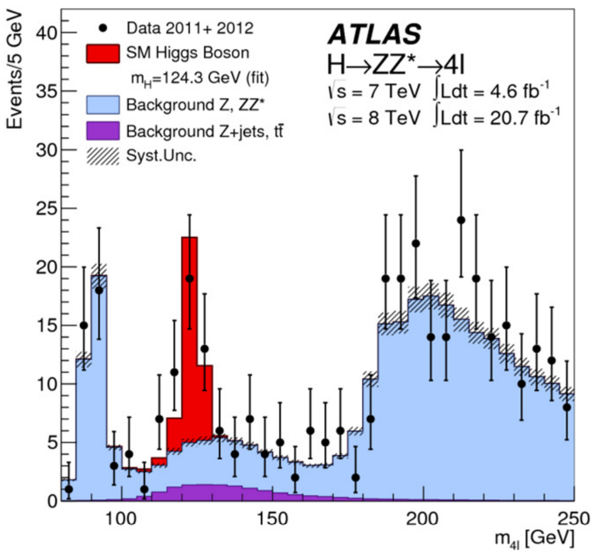


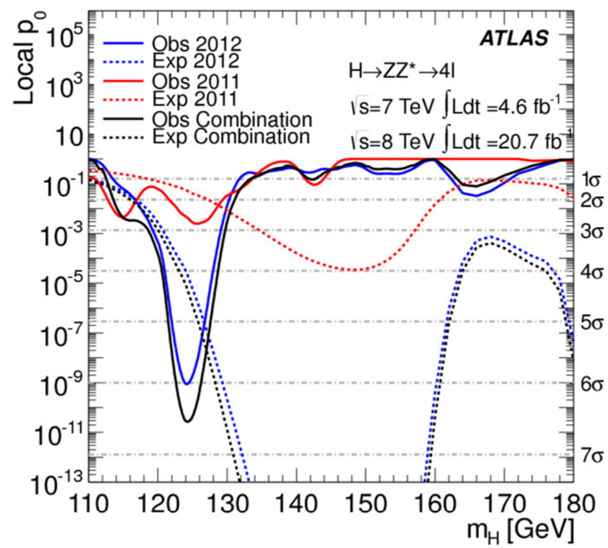


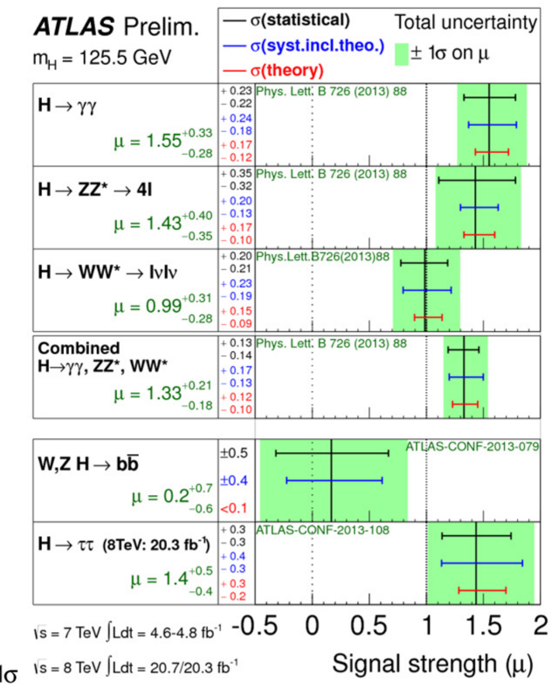


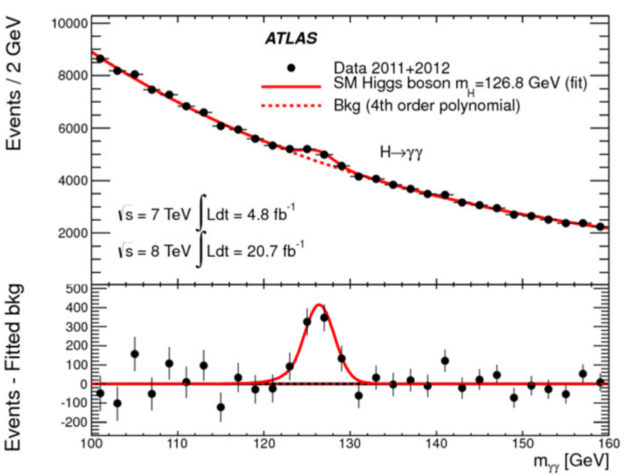
Production rate of new particle was consistent with Standard Model Higgs – Higgs mechanism responsible for electroweak symmetry breaking giving W, Z gauge bosons mass

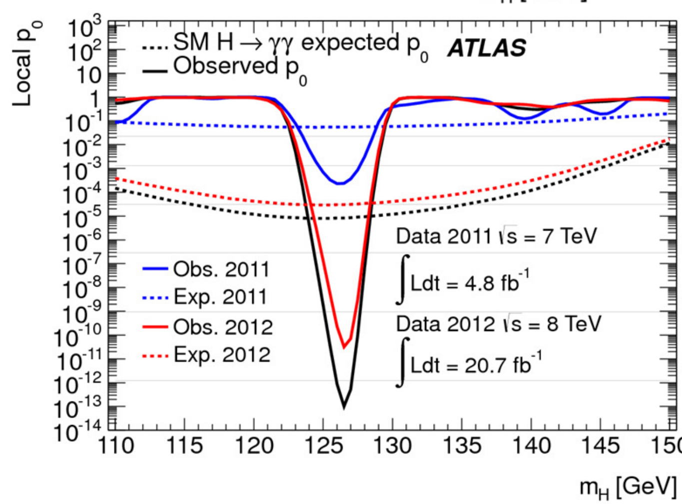
Latest Status (SM Higgs)

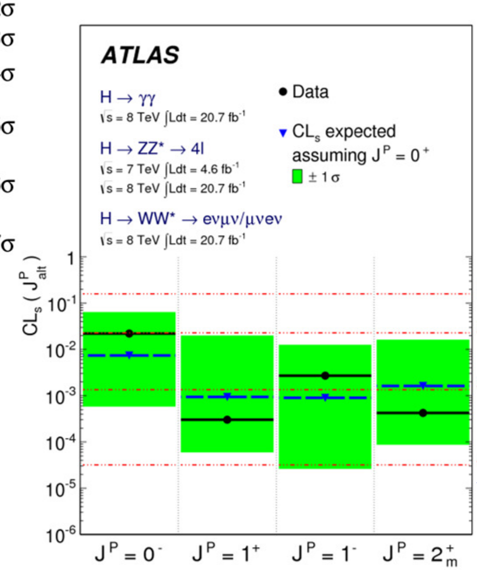








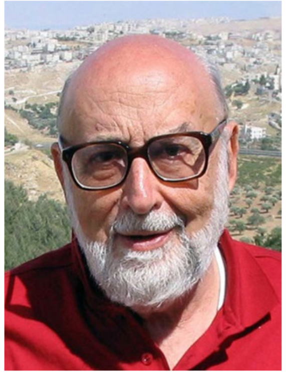




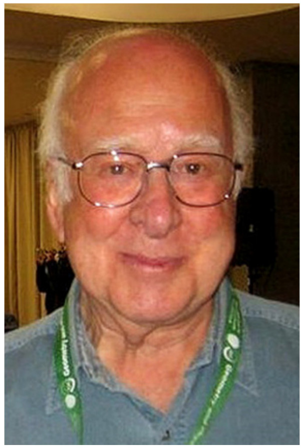
Discovered in individual bosonic channels, spin-parity 0+, looks like Higgs also decays to fermions

2013 Nobel Prize in Physics

Brout-Englert-Higgs mechanism



"for the theoretical discovery of a mechanism that contributes to our understanding of the origin of mass of subatomic particles, and which recently was confirmed through the discovery of the predicted fundamental particle, by the ATLAS and CMS experiments at CERN's Large Hadron Collider"



What's Next?

New particle observed at the LHC - need to measure its properties precisely e.g. mass, production cross section, decays, spin etc..

If not a Standard Model Higgs – then how to measure the new physics? How to determine what we see is super-symmetry, technicolour etc.?

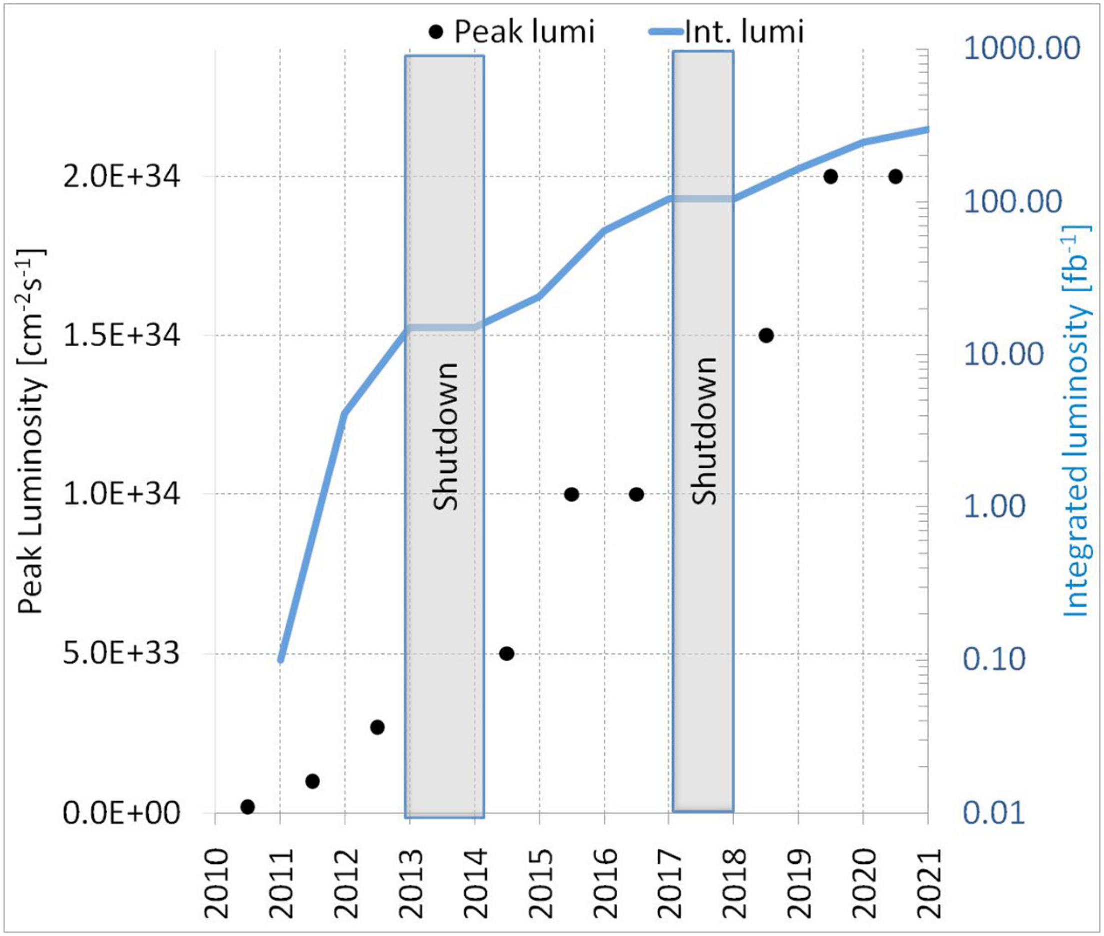
Many possibilities such as upgrade LHC luminosity/energy (HL-LHC, HE-LHC), collide electrons with LHC protons (LHeC), build a precise electron-positron linear collider (ILC) or extend energy frontier e.g. muon collider or larger electron-positron circular collider (TLEP).

The project this year is to evaluate what can be done with a new LHC (Very High Energy LHC – VHE-LHC – see later)?

You have to evaluate the physics potential of this future facility

The timeline for the next 10 years is 'known' but beyond that still to be evaluated….

LHC upgrade



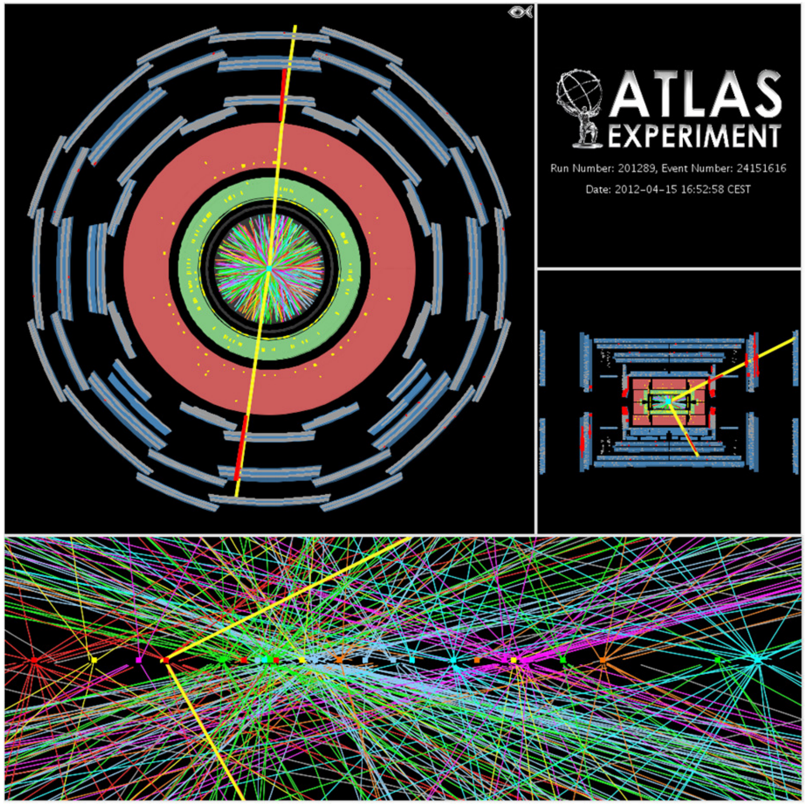
Phase 0: Restart 2015 at 13-14 TeV ($50\text{-}100\ fb^{-1}$)

Phase 1: Peak lumi $2.5x10^{34}$ ($>300\ fb^{-1}$)

Phase 2: Less decided. Upgrade to $5x10^{35}$, $3000\ fb^{-1}$ over 10 years. Increase energy? Number of different scenarios

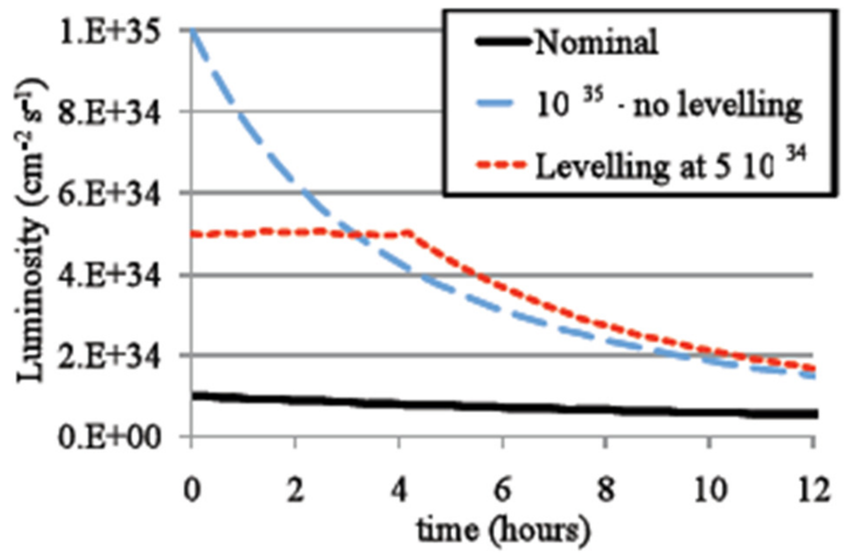
LS1 - phase 0 – LS2 – phase 1 – LS3 – phase 2

Experimental Challenges



High 'pileup' event in 2012 with 25 vertices

At 10^{35} around 200pp collisions per bunch. Lumi levelling to reduce this ~100pp



-High radiation doses for detectors (need 'hard' detectors)

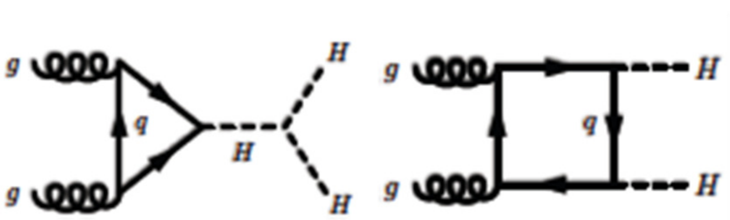
-Challenging high interaction rate and large backgrounds to 'trigger' events of interest

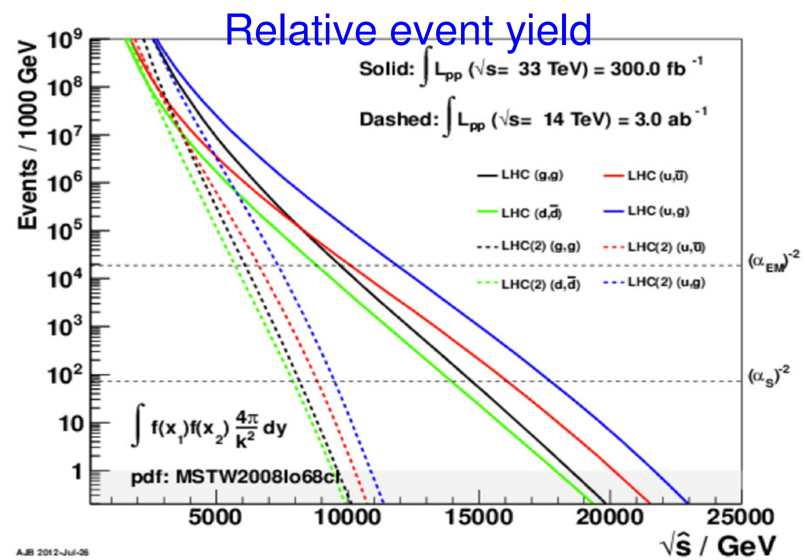
Physics Goals

With data taken in coming years at or near to the design energy of 14 TeV, a broader picture of physics at the TeV scale will emerge.

Amongst the essential inputs:

- **Precision measurements of the properties of the Higgs boson**
  - Spin/CP nature
  - Higgs couplings and self-couplings
  - VV scattering : understanding electroweak symmetry breaking
- **Direct searches for new physics up to multi-TeV scale**
  - SUSY particles
  - High mass resonances (Z’, KK ...)
  - Their properties, if found





circular *pp* Higgs factories

LHC: **1st circular Higgs factory!**

E_{CM}=8-14 TeV, $\hat{L}\sim 10^{34}$cm^{-2}s^{-1}

1 M Higgs produced so far – more to come!

15 H bosons / min – and more to come

HL-LHC: planned (~2022-2035):

E_{CM}=14 TeV, $L\sim 5\mathrm{x}10^{34}$cm^{-2}s^{-1} (leveled)

10x more Higgs

HE-LHC: **proposed** in LHC tunnel (2038-?)

E_{CM}=33 TeV, $L \geq$ 5x10^{34}cm^{-2}s^{-1}

6x higher cross section for *H* self coupling

or

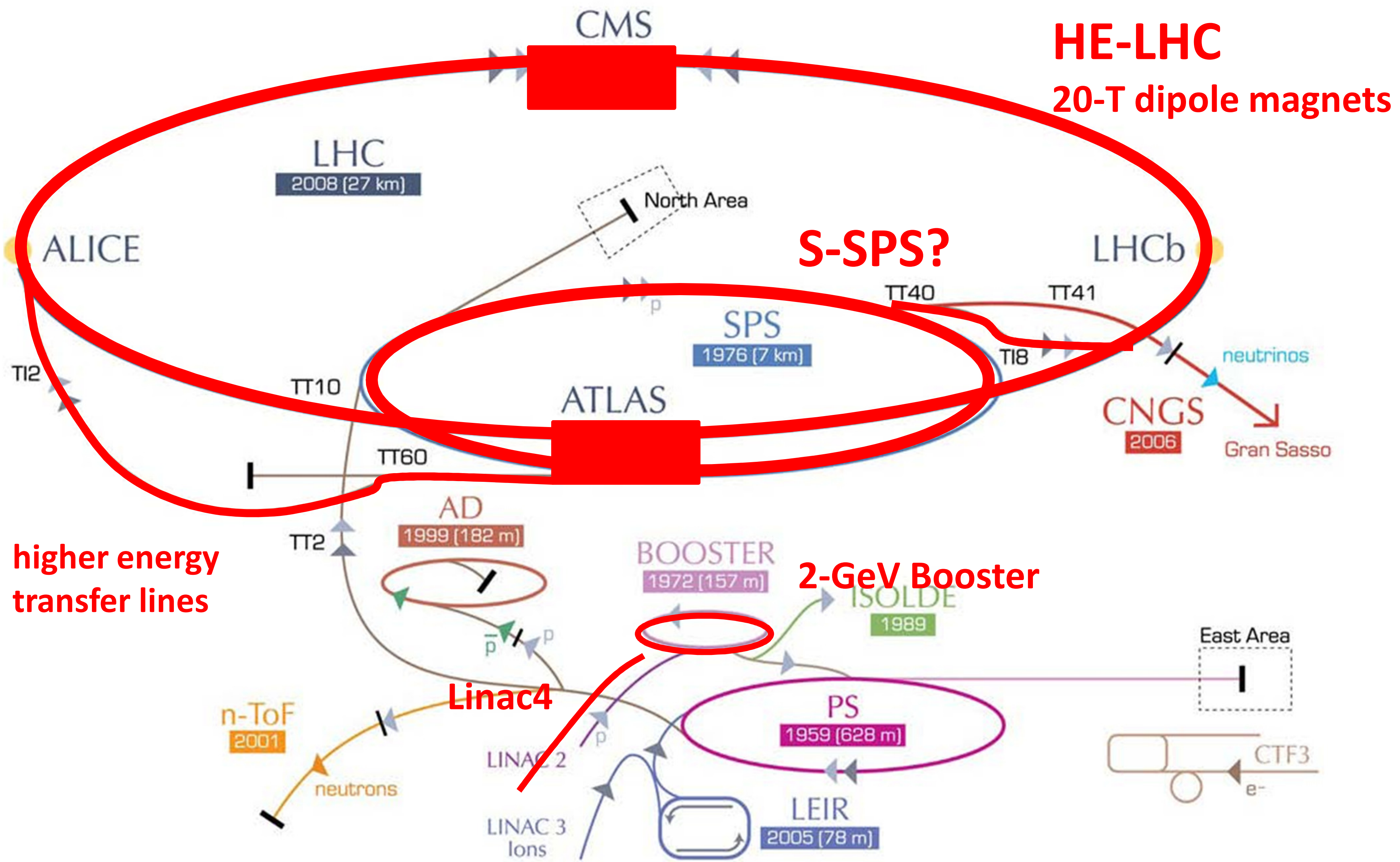
VHE-LHC: **proposed** in new 80-100 km tunnel (2040?)

E_{CM}=84-104 TeV, $L \geq$ 5x10^{34}cm^{-2}s^{-1}

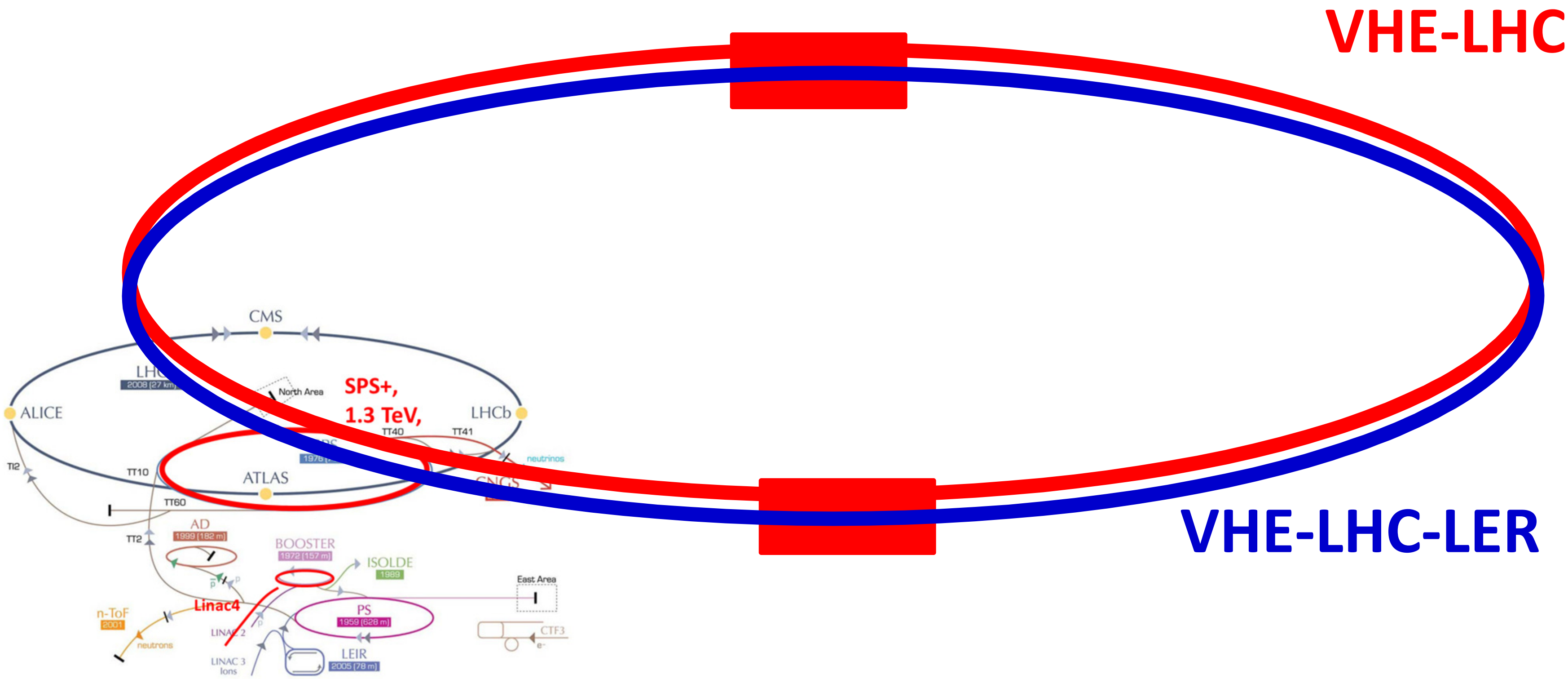
42x higher cross section for *H* self coupling

THE ultimate Higgs factory!

High-Energy LHC



VHE-LHC

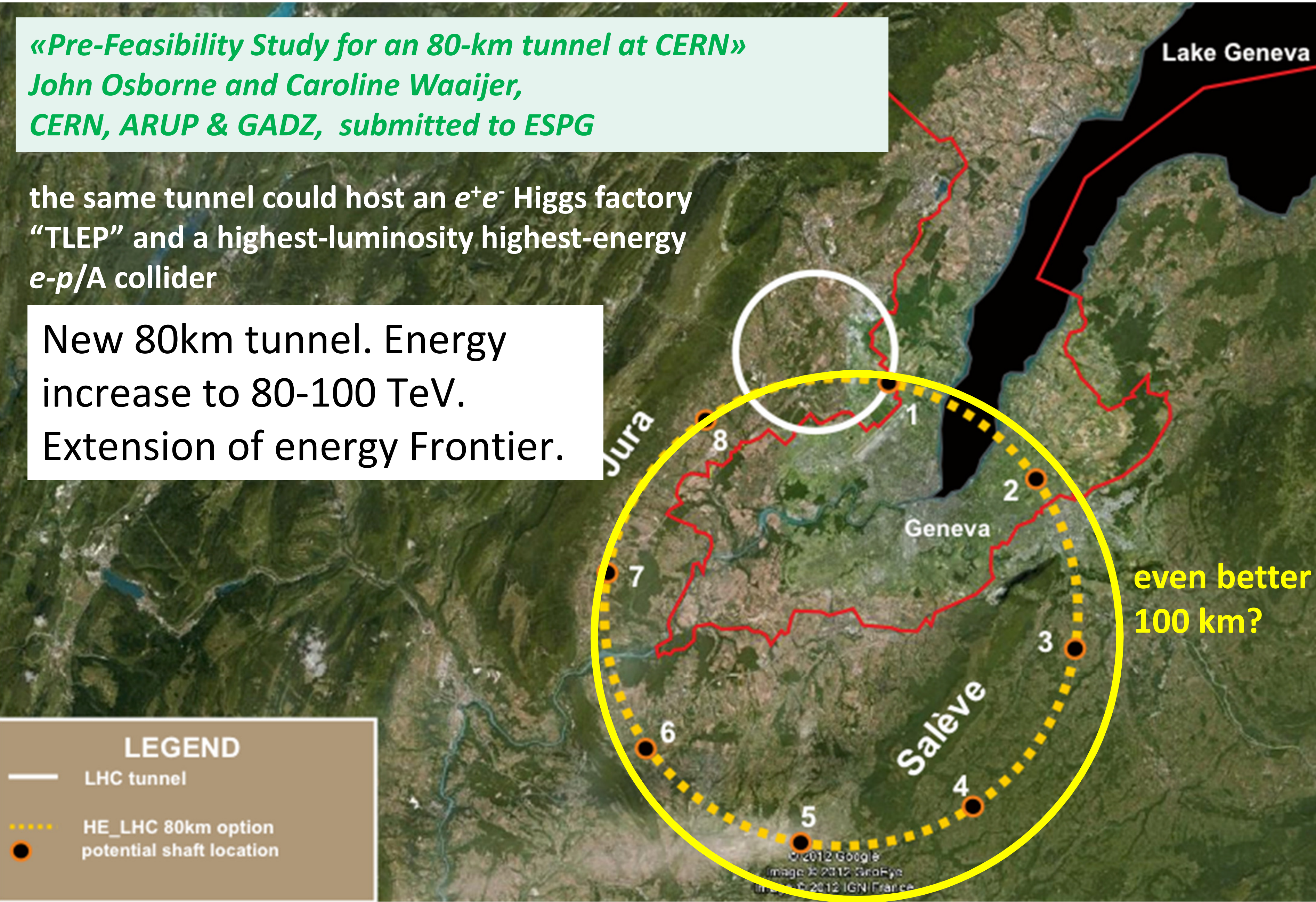

VHE-LHC
VHE-LHC-LER
CMS
2008 (27 km)
North Area
SPS+,
1.3 TeV,
ALICE
LHCb
TT40
TT41
1976
neutrinos
TI2
TT10
ATLAS
TT60
AD
1999 (182 m)
TT2
BOOSTER
1972 (157 m)
ISOLDE
1989
East Area
Linac4
n-ToF
2001
PS
1959 (628 m)
LINAC 2
CTF3
e-
neutrons
LINAC 3
Ions
LEIR
2005 (78 m)

80-km tunnel for VHE-LHC – "best" option

«Pre-Feasibility Study for an 80-km tunnel at CERN»
John Osborne and Caroline Waaijer,
CERN, ARUP & GADZ, submitted to ESPG

the same tunnel could host an e^+e^- Higgs factory "TLEP" and a highest-luminosity highest-energy *e-p*/A collider

New 80km tunnel. Energy increase to 80-100 TeV. Extension of energy Frontier.



even better 100 km?

HE-LHC & VHE-LHC parameters

O. Dominguez,
L. Rossi, F. Zimmermann

parameter	LHC	HL-LHC	HE-LHC	VHE-LHC
c.m. energy [TeV]	14	14	**33**	**100**
circumference [km]	26.7	26.7	**26.7**	**80 (or 100)**
dipole field [T]	8.33	8.33	**20**	**20 (or 16)**
beam current [A]	0.58	1.12	**0.48**	**0.49**
rms IP spot size [μm]	16/7	7.1 (min)	5.2	6.7
stored beam energy [MJ]	362	694	701	**6610**
SR power per ring [kW]	3.6	7.3	96.2	2900
arc SR heat load [W/m/apert.]	0.17	0.33	**4.35**	**43.4**
energy loss per turn [keV]	6.7	6.7	**201**	**5857**
critical photon energy [eV]	44	44	575	5474
longit. SR emit. damping time [h]	12.9	12.9	**1.03**	**0.32**
peak events / crossing	27	135 (lev.)	**147**	**171**
peak luminosity [10^{34} cm^{-2}s^{-1}]	1.0	5.0	**≥5.0**	**≥5.0**
beam lifetime due to burn off [h]	45	15.4	5.7	14.8
optimum av. luminosity / day [fb^{-1}]	**0.5**	**2.8**	**1.4**	**2.1**

The Design Project

Evaluate the physics potential of a future VHE-LHC experiment in view of the discovery of the Higgs particle

-Focus on the design of the experiment. Can be based on existing detector or a hybrid or completely new.

-There are a range of possible machine parameters concerning luminosity/energy but base them on the values given before i.e. 100 TeV COM energy.

-What physics can you study at these rates/energies? Higgs? New particles?

-What performance do you need from your detector?

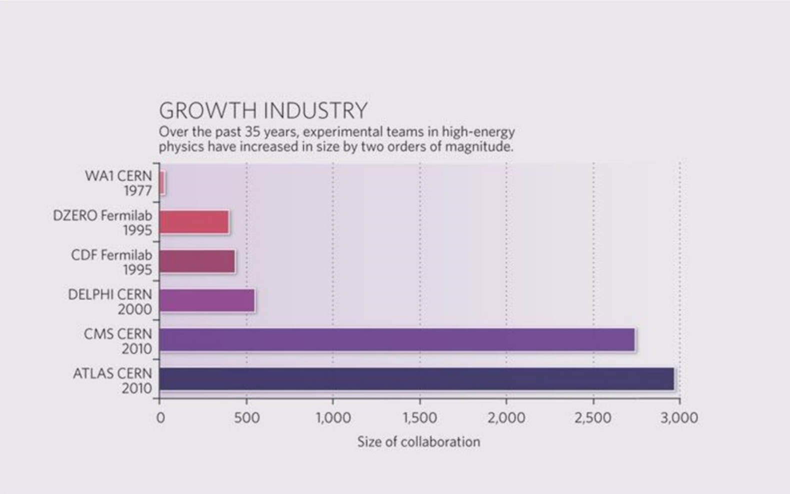
Come up with your own detector design. Focus on the critical aspects. No marks for blindly copying existing proposals!

Examples of Problems to consider

- What is the physics behind the Standard Model Higgs, likely theories to describe new physics?
- How do we detect and measure Higgs properties?
- How to detect new physics beyond Standard Model?
- Detector design choice? What is important for precision measurements? Will the detectors survive high radiation environment? Can we trigger on all events of interest?
- Conflicting design aims – accuracy/flexibility. Don't want to be blind to any other new particles!
- What are the main costs? Engineering? Equipment? Power?

How will you do it?

- Work together! Particle physics experiments are expensive
- You will work as one collaboration (ATLAS 3000 authors!)
- Particle physicists usually are experts in one area of detector AND physics. We want you to do the same.
- You will need team leaders



(Birmingham)

How will you do it?

- Identify quickly the most important points
- Evaluate existing studies and try to build on them
- Calculate yourselves, from first principles, the crucial parameters
- Also chance to use physics simulation software to e.g. calculate particle production rates, or track passage of particles through matter
- One example is the Monte Carlo simulation program PYTHIA
- http://home.thep.lu.se/~torbjorn/Pythia.html
- Particle physicists use a tool called ROOT, to loop over particle data, to fill histograms, analyse the results etc.
- http://root.cern.ch/drupal/
- Can be used on particle physics linux systems or download executable for Windows etc.
- Written in C++. But libraries can be accesses using python (PyRoot)
- Recommend that final report is written using latex http://www.latex-project.org/

Getting Started I

Suggested subgroups

Physics: Higgs Properties, SUSY/Exotics/BSM, Standard Model

Detector: Calorimeter, Tracking, Muons

Everyone is a member of a Physics and a Detector group. We don't want a 1-1 correspondence (in fact we want maximum 2 people in the same groups for both)! Usually a physics group will have representatives in all detector groups.

A realistic scenario – you have to know about the physics and also the detector you are using to make the measurement . Useful "real world" skill to be able to manage two things at once.

Getting Started II

Divide yourselves into subgroups (today!)

Identify sub-group leaders? For both physics and detector groups? Keep liaising between all groups. Remember you are producing one coherent report!

An overall group leader? Other roles (Collaborative tools/web-site, minuting, staff-student liason, report editor, meetings organiser)?

Remember the management plan is for next week (please include subgroup membership)

Good luck!
…any questions?