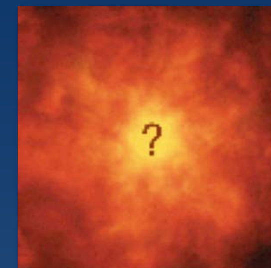
CERN and High Energy Physics

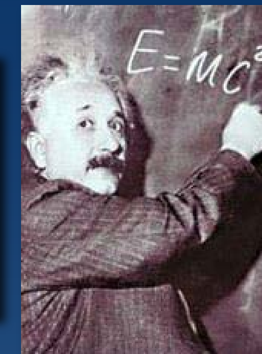
The Grand Picture

Rolf-Dieter Heuer
CERN Accelerator School
Varna
27 September 2010

Innovation
Education
CERN
uniting people
Research

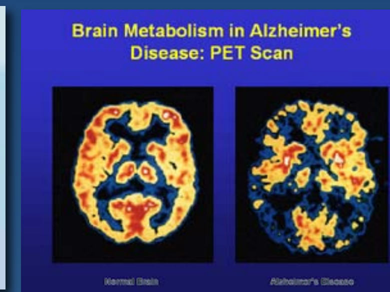
The Mission of CERN





- Push back the frontiers of knowledge

  E.g. the secrets of the Big Bang …what was the matter like within the first moments of the Universe’s existence?



- Develop new technologies for accelerators and detectors

  Information technology - the Web and the GRID

  Medicine - diagnosis and therapy

- Train scientists and engineers of tomorrow

- Unite people from different countries and cultures

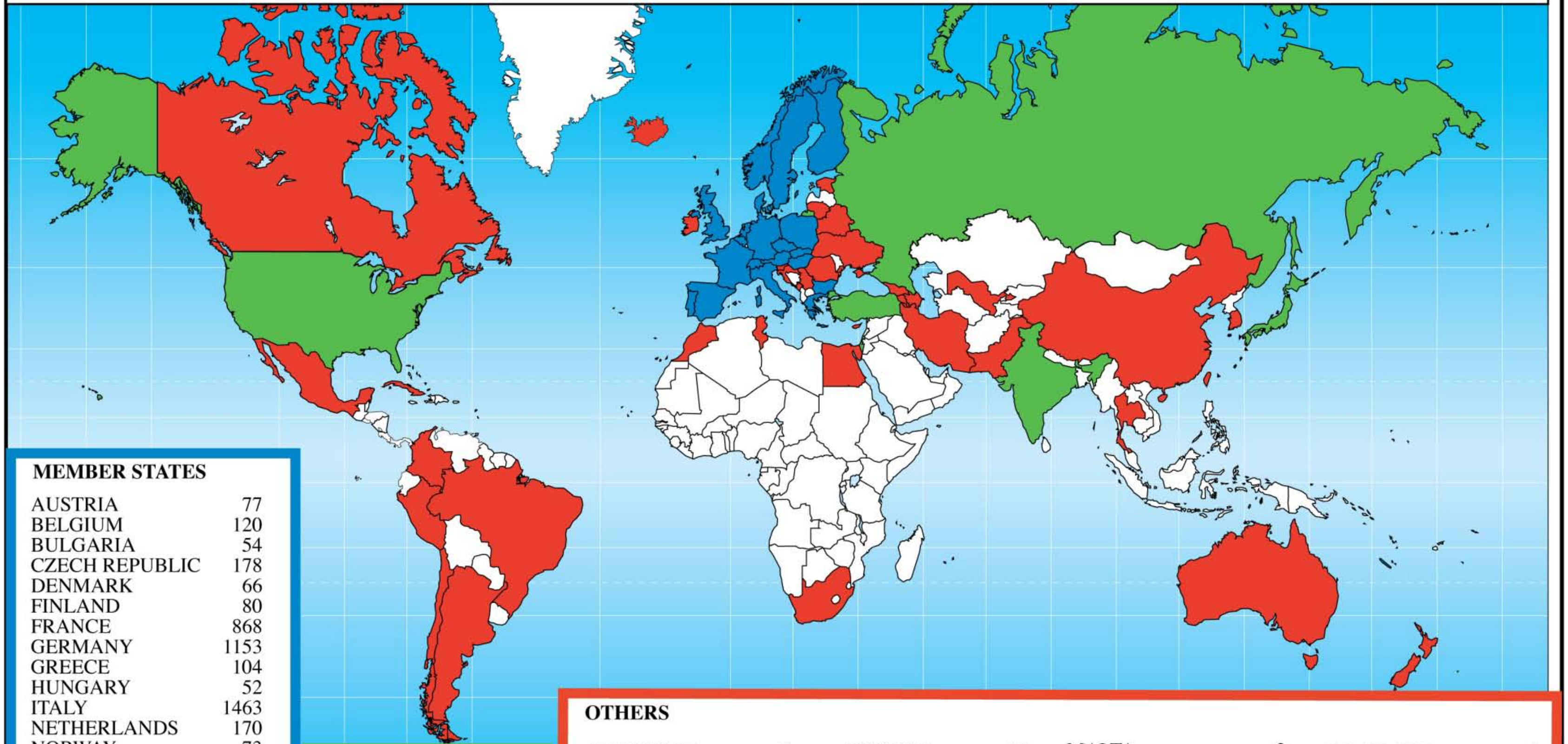
CERN was founded 1954: 12 European States
Today: 20 Member States

- ~ 2300 staff
- ~ 790 other paid personnel
- > 10000 users
- Budget (2010) ~1100 MCHF

- 20 Member States: Austria, Belgium, Bulgaria, the Czech Republic, Denmark, Finland, France, Germany, Greece, Hungary, Italy, Netherlands, Norway, Poland, Portugal, Slovakia, Spain, Sweden, Switzerland and the United Kingdom.
- 8 Observers to Council: India, Israel, Japan, the Russian Federation, the United States of America, Turkey, the European Commission and UNESCO

CERN in Numbers

Distribution of All CERN Users by Nation of Institute on 20 January 2010



MEMBER STATES

AUSTRIA	77
BELGIUM	120
BULGARIA	54
CZECH REPUBLIC	178
DENMARK	66
FINLAND	80
FRANCE	868
GERMANY	1153
GREECE	104
HUNGARY	52
ITALY	1463
NETHERLANDS	170
NORWAY	73
POLAND	191
PORTUGAL	122
SLOVAKIA	55
SPAIN	311
SWEDEN	71
SWITZERLAND	362
UNITED KINGDOM	732

6302

OBSERVER STATES

INDIA	91
ISRAEL	49
JAPAN	204
RUSSIA	901
TURKEY	60
USA	1618

2923

OTHERS

ARGENTINA	8
ARMENIA	16
AUSTRALIA	17
AZERBAIJAN	1
BELARUS	19
BRAZIL	77
CANADA	141
CHILE	2
CHINA	78
CHINA (TAIPEI)	53
COLOMBIA	9
CROATIA	18
CUBA	4
CYPRUS	8
EGYPT	3
ESTONIA	9
GEORGIA	10
ICELAND	1
IRAN	15
IRELAND	14
KOREA	64
LITHUANIA	5
MALTA	2
MEXICO	33
MONTENEGRO	1
MOROCCO	6
NEW ZEALAND	8
PAKISTAN	15
PERU	1
ROMANIA	59
SERBIA	20
SLOVENIA	17
SOUTH AFRICA	8
THAILAND	1
TUNISIA	1
UKRAINE	17
UZBEKISTAN	1

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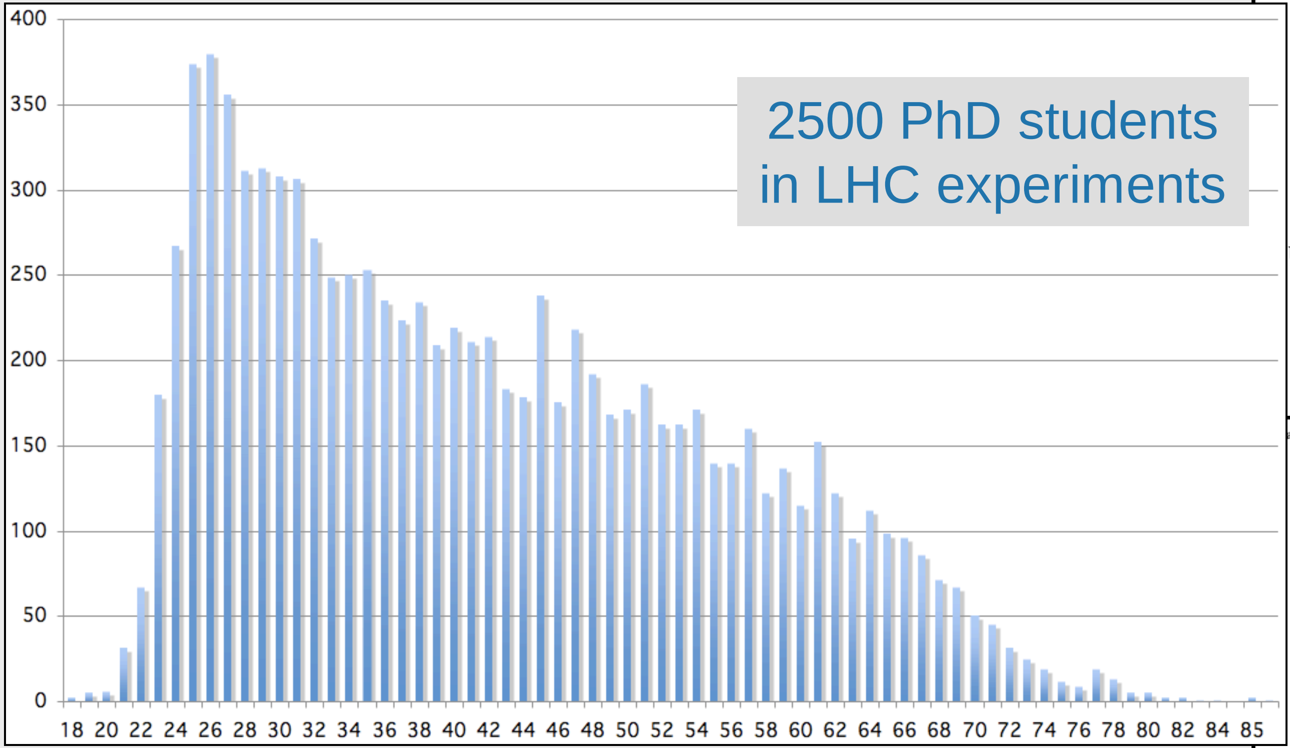
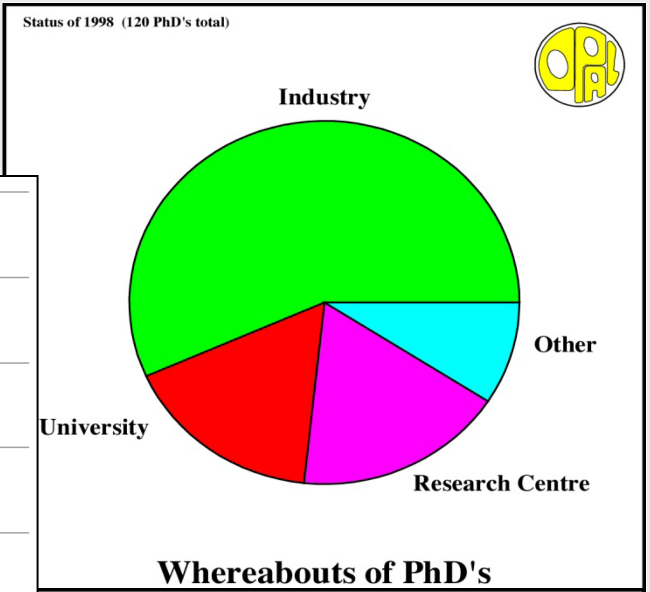
Age Distribution of Scientists

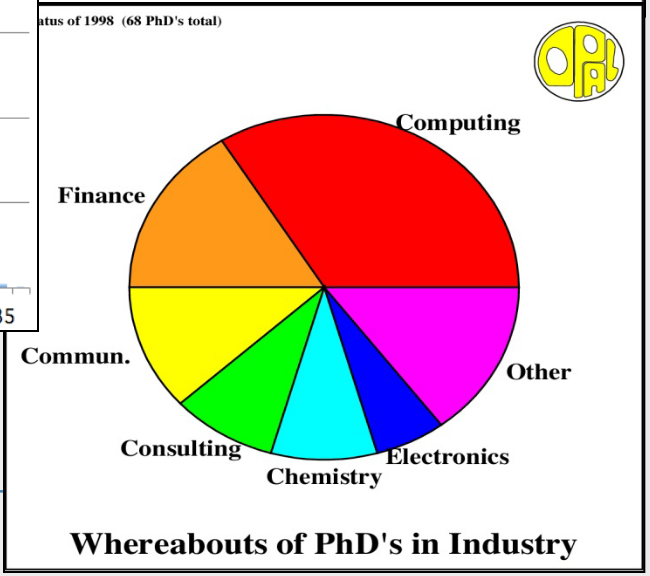
- and where they go afterwards

Survey in March 2009



2500 PhD students in LHC experiments





They do not all stay: where do they go?

Past few decades

"Discovery" of Standard Model

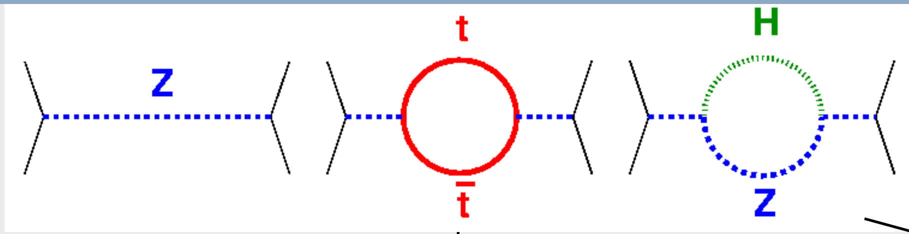
through synergy of

hadron - hadron colliders (e.g. Tevatron, SPS)

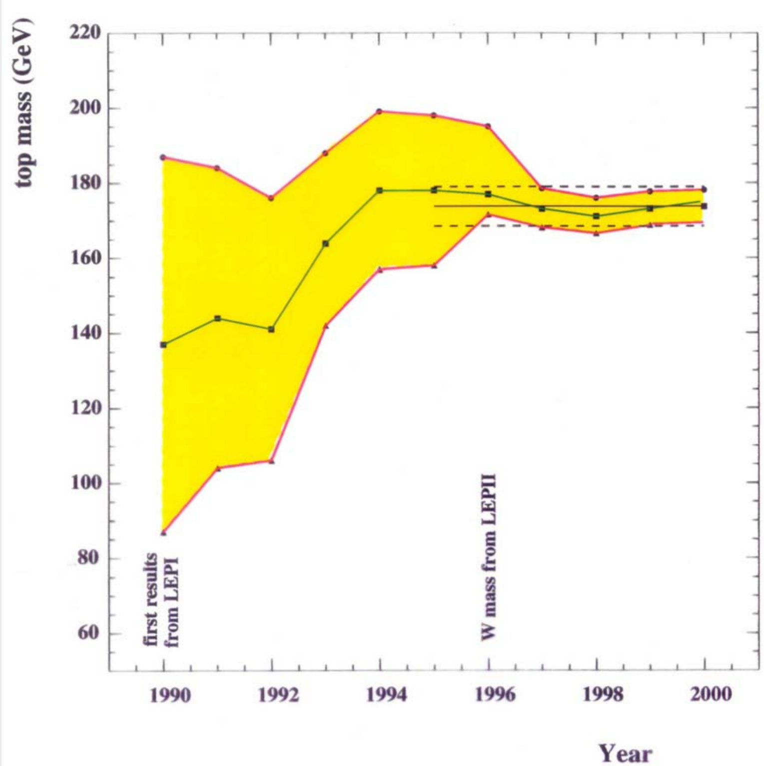
lepton - hadron colliders (HERA)

lepton - lepton colliders (e.g. LEP)

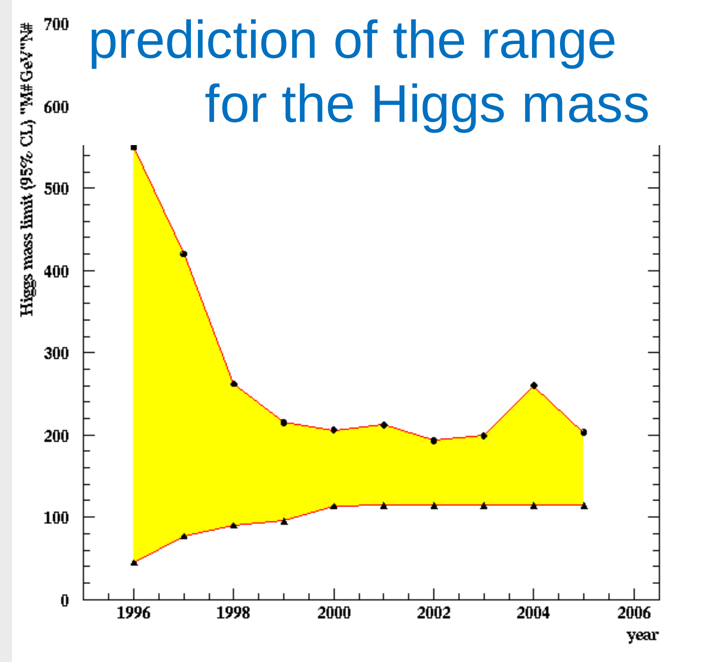
Test of the SM at the Level of Quantum Fluctuations



indirect determination of the top mass



prediction of the range for the Higgs mass



possible due to

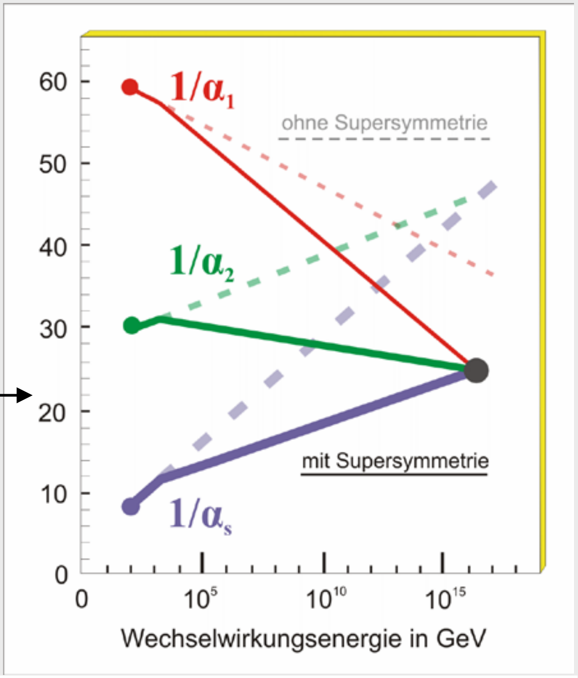
- precision measurements
- known higher order electroweak corrections

$$\propto \left(\frac{M_t}{M_W}\right)^2, \ln\left(\frac{M_h}{M_W}\right)$$

Key Questions of Particle Physics

origin of mass/matter or
origin of electroweak symmetry breaking

unification of forces →



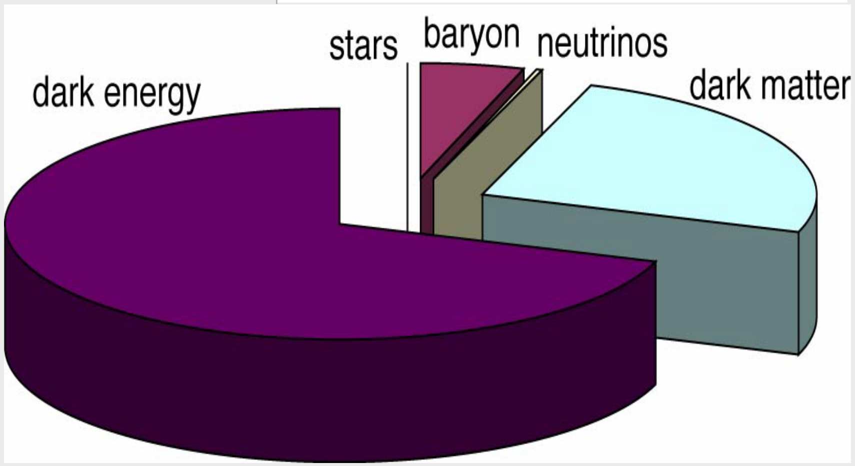
fundamental symmetry of forces and matter

unification of quantum physics and general relativity

number of space/time dimensions

what is dark matter

what is dark energy



Scientific Strategy

- Full exploitation of LHC physics potential
  - Reliable operation (including consolidation and LINAC 4)
  - Remove bottlenecks to benefit from nominal luminosity for both machine and detectors
  - Focused R&D and prototyping for High-Luminosity LHC
  - Re-establish standards for technical and general infrastructure
- Preparation for the long-term future (>2015)
  - Energy frontier
    - CLIC/ILC collaboration and R&D (for detectors and machine)
    - Generic R&D for High-Energy LHC (i.e. high field magnets)
  - R&D for high-power proton sources (HP-SPL) e.g for v-physics
- World-class fixed-target physics programme

Accelerating Science and Innovation

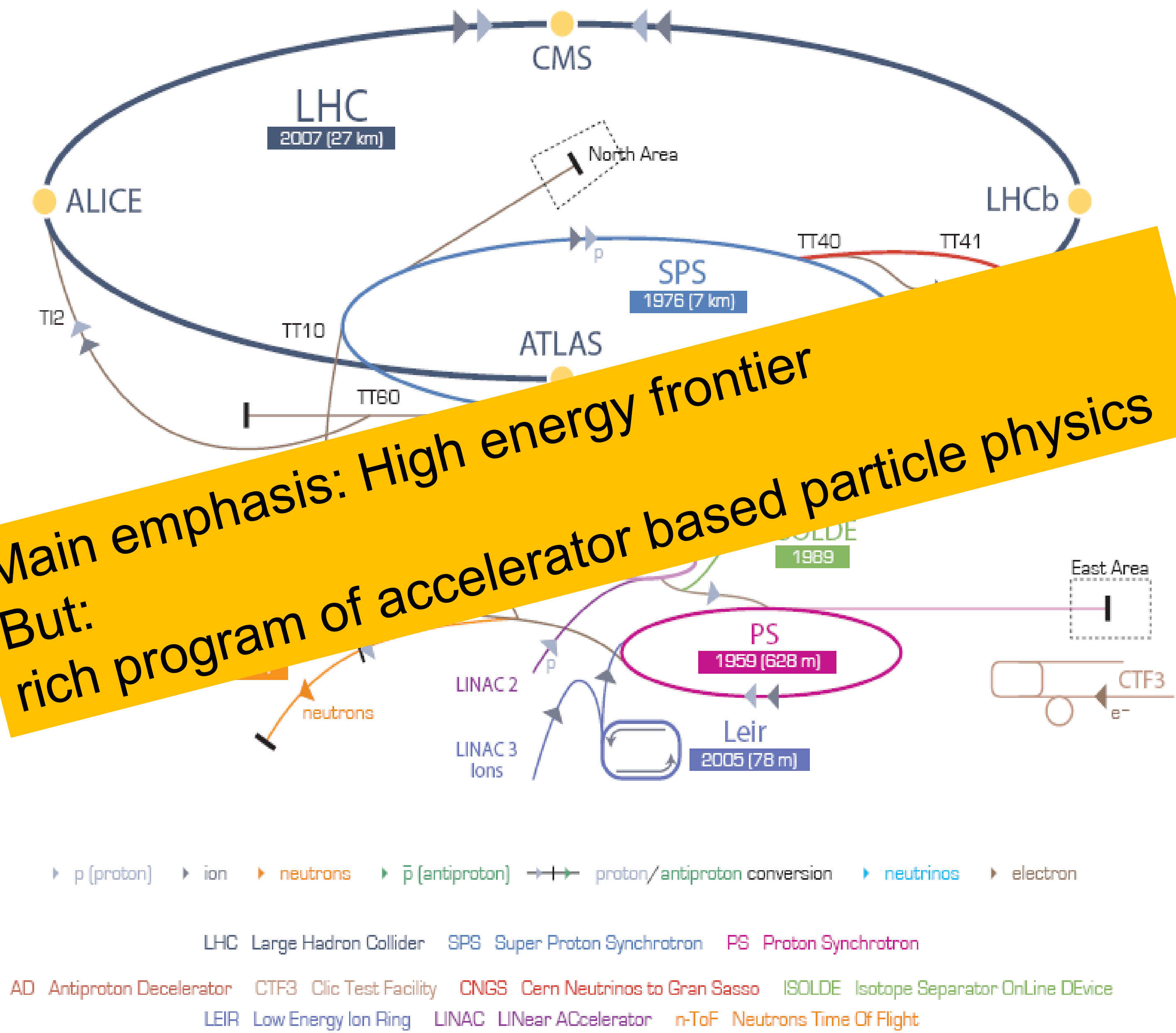
Science

Particle Physics at CERN: Experiments and Theory

Main emphasis: High energy frontier

But:

rich program of accelerator based particle physics



Fixed Target Physics

Antiproton Physics

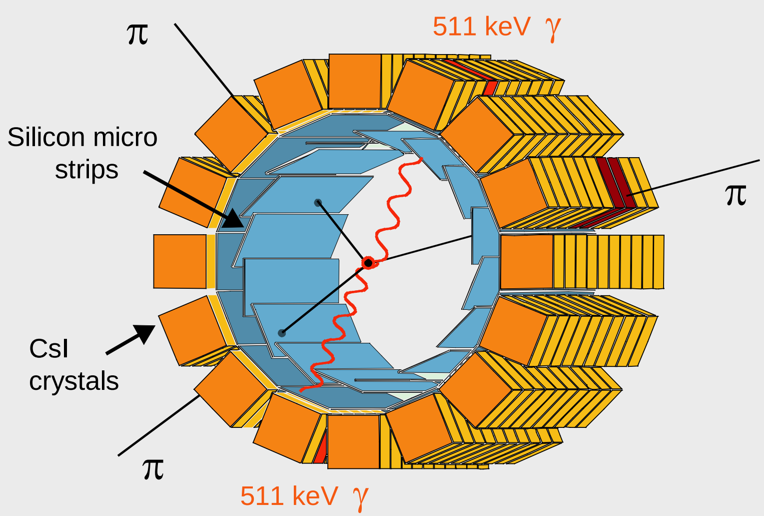
Cold antiprotons
("manufacturing anti-matter")

1. PS $p \rightarrow p\bar{p}$ 10^{-6}/collision
2. AD deceleration + cooling
   stochastic + electron
3. Extraction @ ~ 0.1*c*
4. Produce thousands of *anti-H*

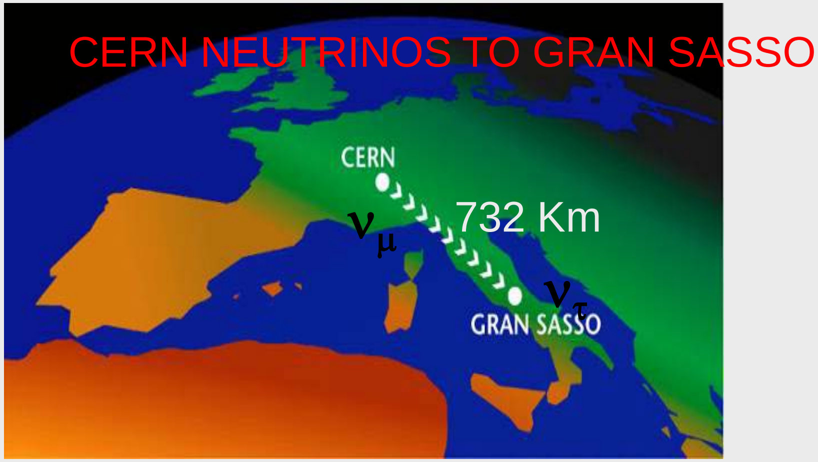
Anti-H annihilations detected

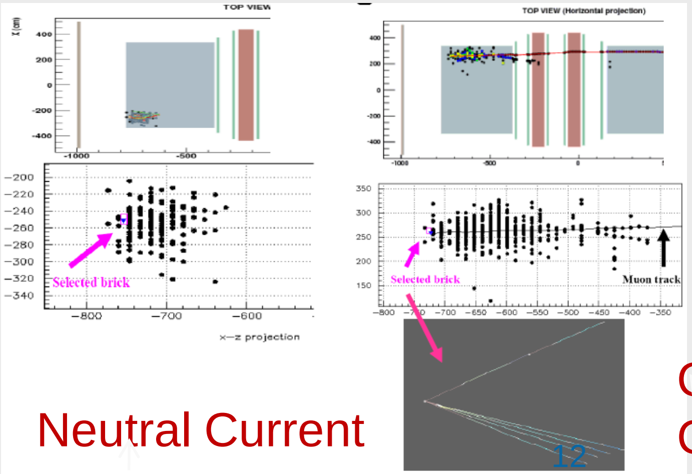
ATHENA (→ ALPHA)

anti-H ($\bar{p}e^{+}$) + matter → $\pi^{+}\pi^{-}$ + $\gamma\gamma$



Neutrino Physics



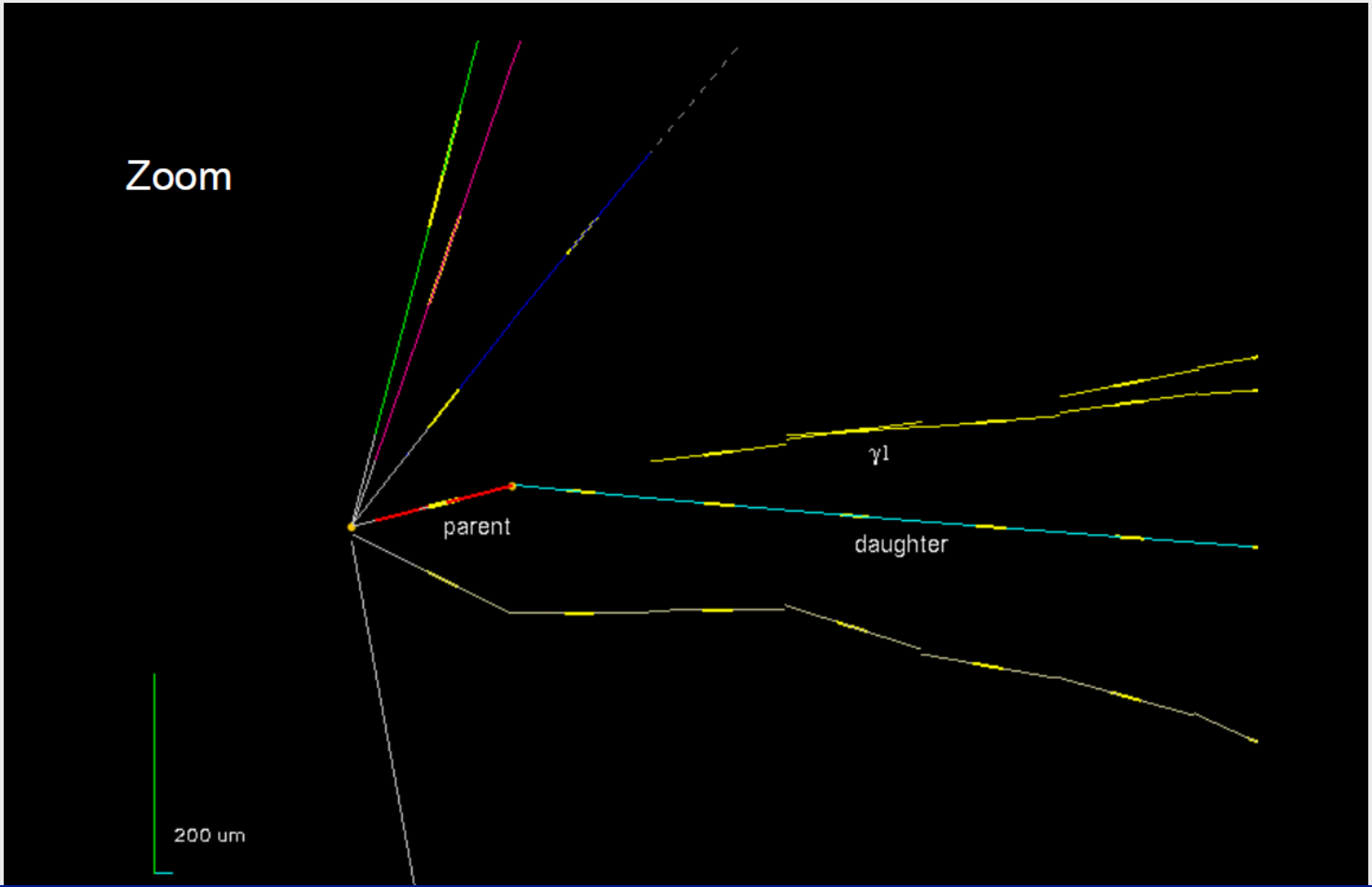


OPERA

Charge Current

CNGS - OPERA

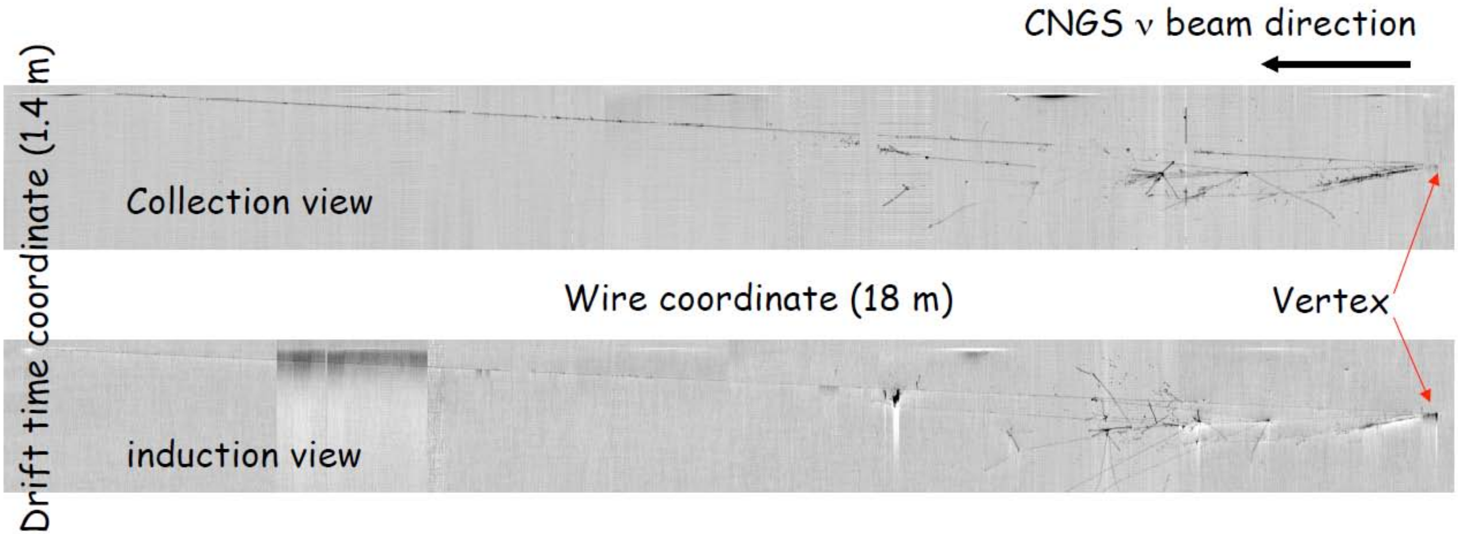
First υ_{τ} Candidate



Muonless event 9234119599, taken on 22 August 2009, 19:27 (UTC)
(as seen by the electronic detectors)

CNGS - ICARUS

The first CNGS neutrino interaction in ICARUS T600



- Leading muon (crossing horizontally the whole cryostat)
- Two charged particle tracks undergoing hadronic interactions
- Two γ converting at 14 and 16 cm from vertex (π^0?)
- Vertex not fully visible in collection view, due to locally wrong wire biasing

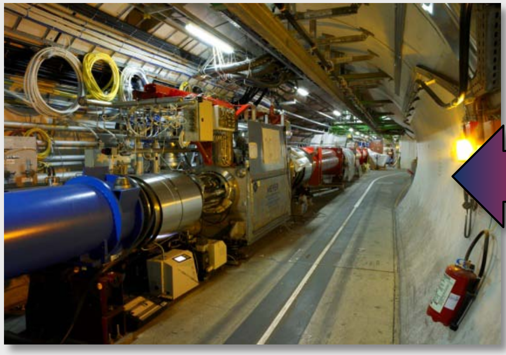
The CLOUD Experiment

- Experiment using cloud chamber to study possible link between cosmic-rays and cloud formation.
  - Studies suggest that cosmic-rays may have an influence on the amount of cloud cover through the formation of new aerosols (tiny particles suspended in the air that seed cloud droplets).
- Understanding the underlying microphysics in controlled laboratory conditions is a key to unraveling the connection between cosmic-rays, clouds and climate.
- First time high-energy physics accelerator used to study atmospheric and climate science.

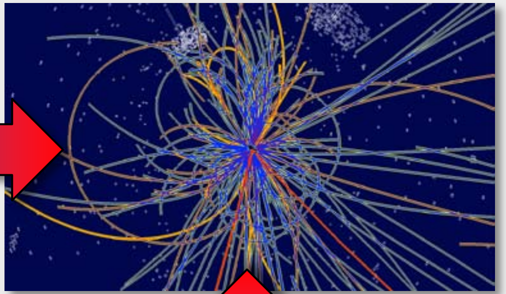
CERN Technologies - Innovation

Three key technology areas at CERN

Accelerating particle beams



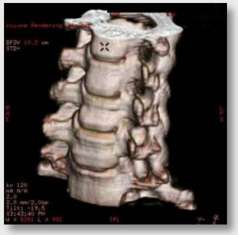
Detecting particles



Large-scale **computing** (Grid)

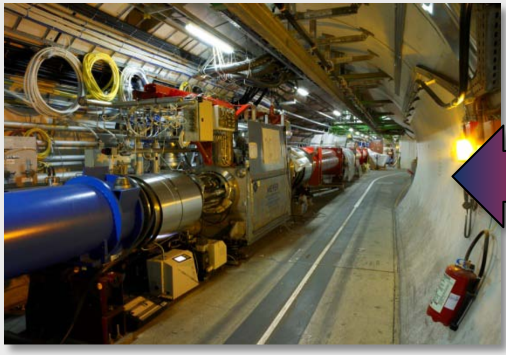
CERN Technologies - Innovation

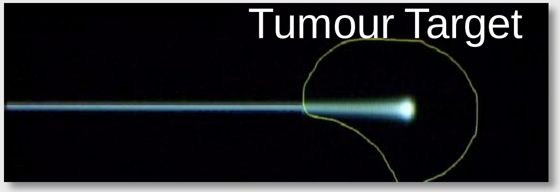
Medical imaging



Example: medical application

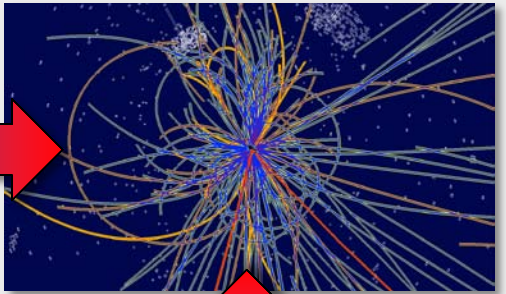
Accelerating particle beams

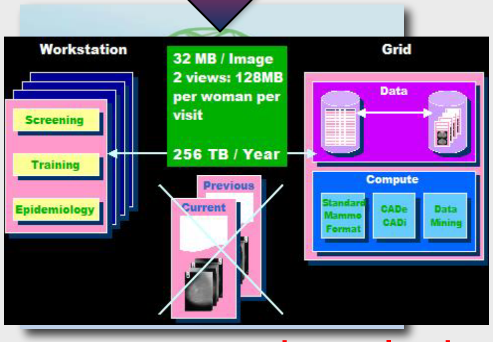




Charged hadron beam that loses energy in matter

Detecting particles

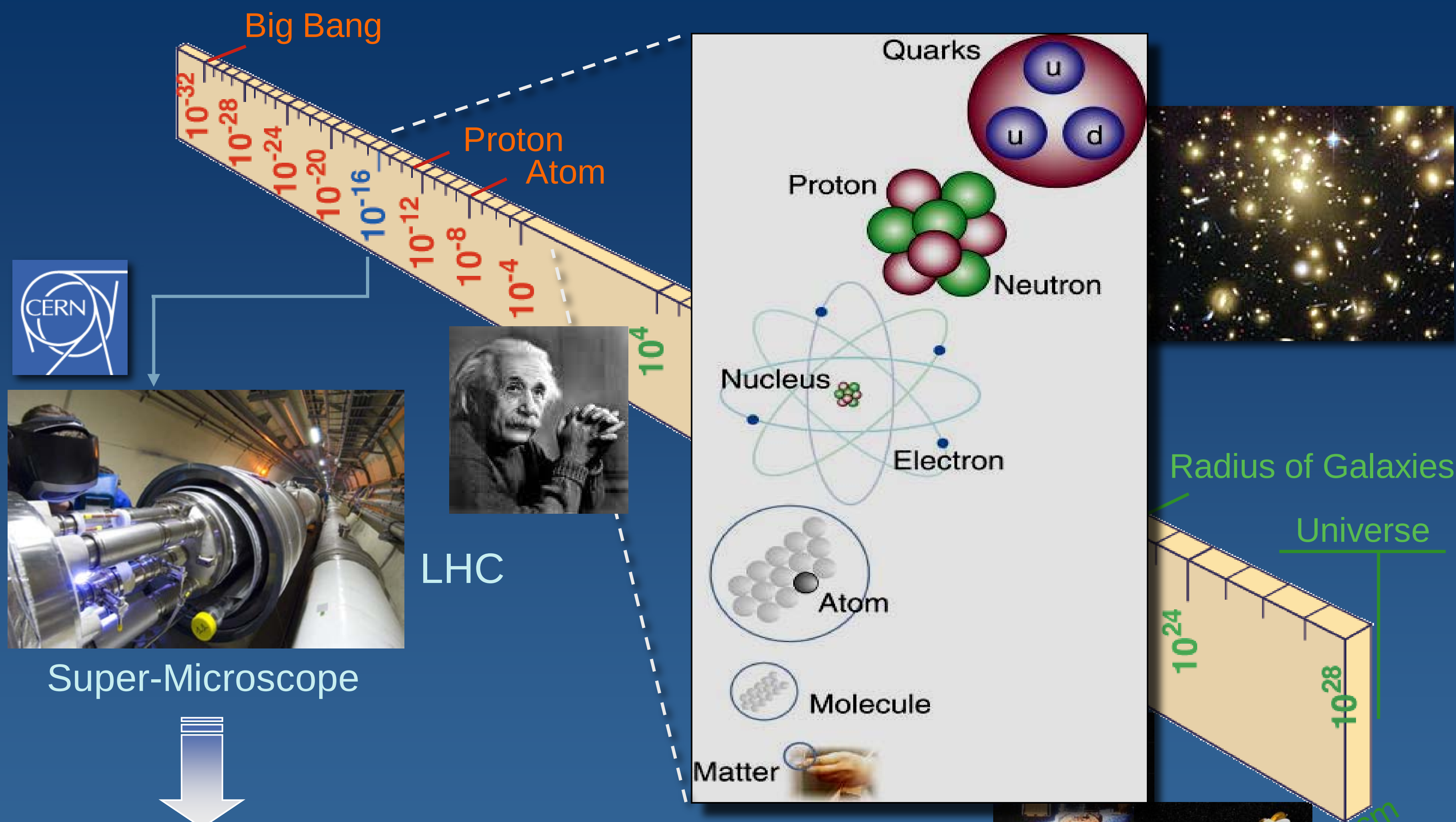




Large-scale **computing** (Grid)

Grid computing for medical data management and analysis

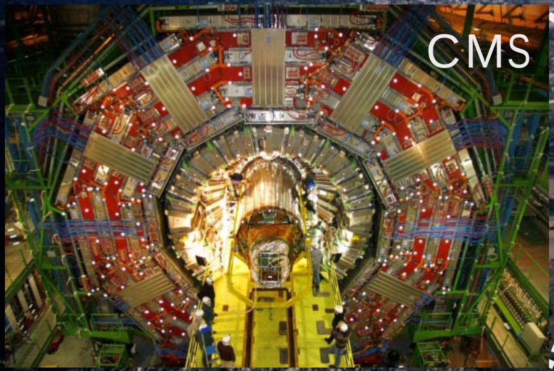
Accelerating Science and Innovation



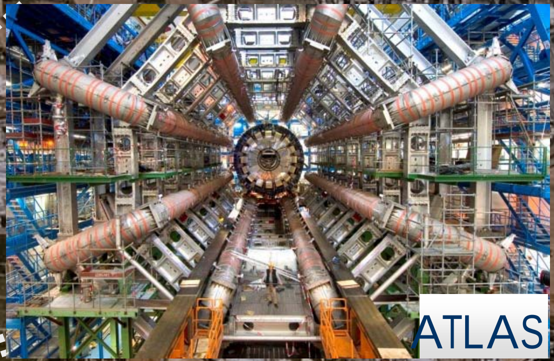
Study physics laws of first moments after Big Bang increasing Symbiosis between Particle Physics, Astrophysics and Cosmology

Enter a New Era in Fundamental Science

Start-up of the Large Hadron Collider (LHC), one of the largest and truly global scientific projects ever, is the most exciting turning point in particle physics.



Exploration of a new energy frontier



The Large Hadron Collider - Experiments

Two 'general purpose' 4π
detectors for pp collisions
at high L; some capabilities for PbPb
ATLAS and CMS

$$\int_0^{2\pi} d\phi \int_{-1}^{1} d\cos\theta = 4\pi$$

One dedicated PbPb detector with some capabilities
for pp
ALICE

One dedicated detector for studying B mesons
(CP violation; rare decays), produced
in the forward (backward) hemisphere
LHCb

$$gg \rightarrow b\bar{b}$$

Precision (1%) measurement of total cross section (and more) **TOTEM**
Study of forward π^0 production **LHCf**
Search for magnetic monopoles **MoEDAL**

Experimental Challenge

High Interaction Rate: $N = L\sigma = 10^{34}$ x 100 x 10^{-27}

pp interaction rate 10^9 interactions/s
data for only ~100 out of the 40 million crossings can be recorded per sec (100 – 150 MB/sec)
need fast, pipelined, intelligent electronics and sophisticated data-acquisition

High Energy and Large Particle Multiplicity

~ <20> superposed events in each crossing
~ 1000 tracks stream into the detector every 25 ns
need highly granular detectors with good time resolution for low occupancy
large detectors, a large number of channels

High Radiation Levels

radiation hard (tolerant) detectors and electronics

Physics Requirements

Follow from requirements to observe Higgs boson whether it is heavy or light, to observe Supersymmetry if it is there (missing energy), to find other new physics if it is there; all this in the presence of a huge background of standard processes (QCD)

Very good muon identification and momentum measurement

trigger efficiently and measure charge of a few TeV muons

High energy resolution electromagnetic calorimetry

~ 0.5% @ E_T~50 GeV

Powerful inner tracking systems

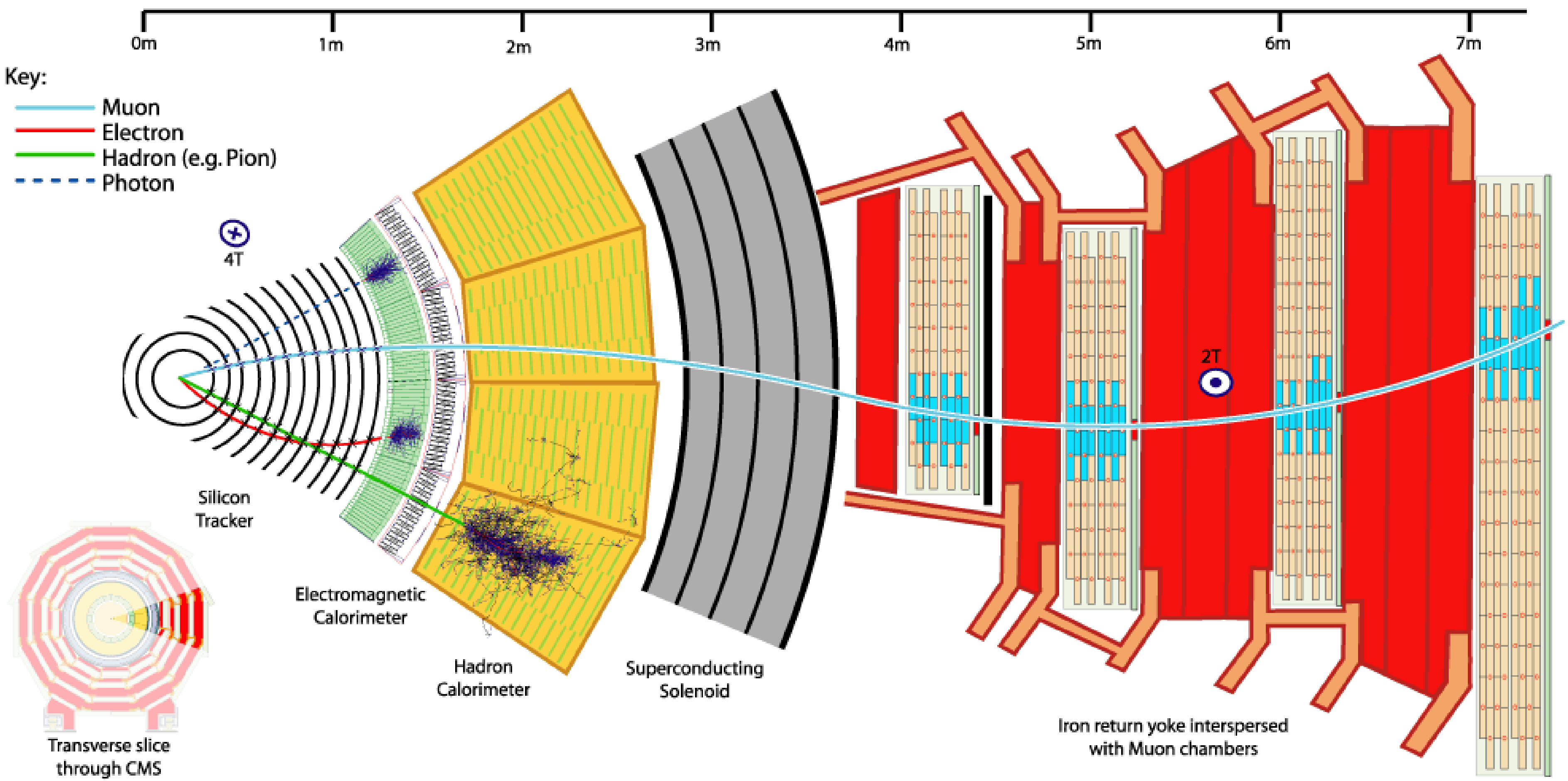
factor 10 better momentum resolution than at LEP

Hermetic calorimetry

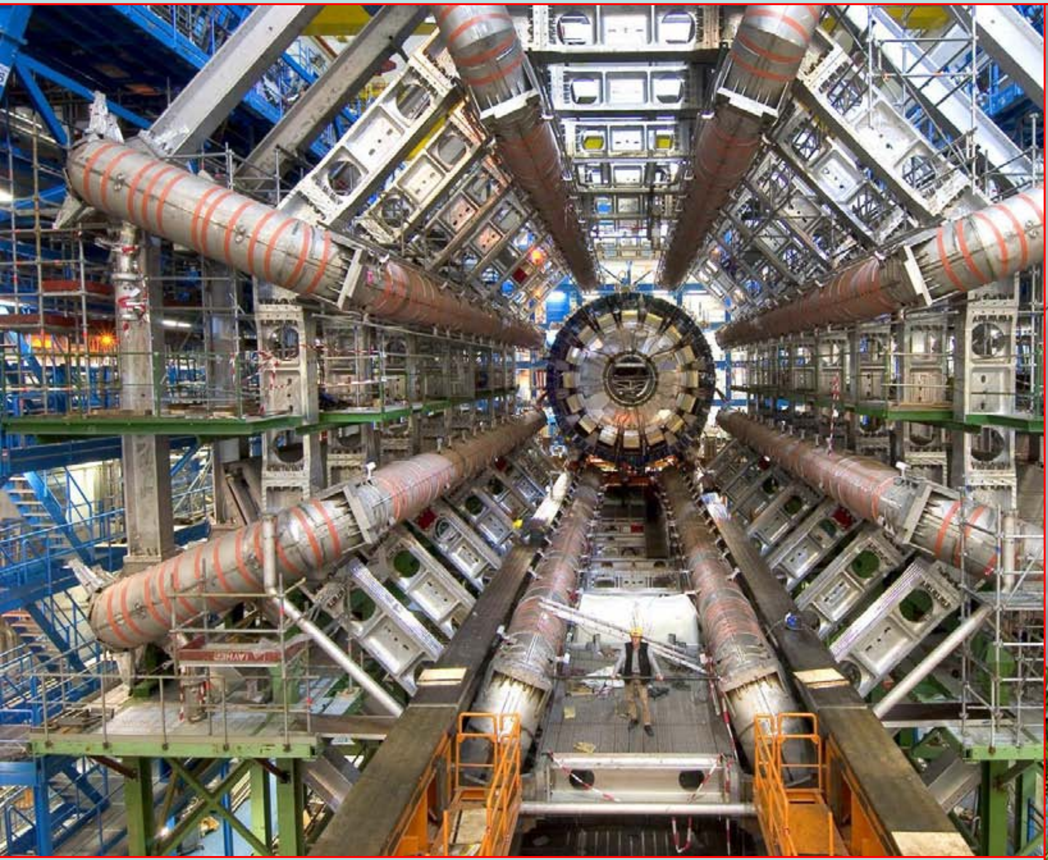
good missing E_T resolution

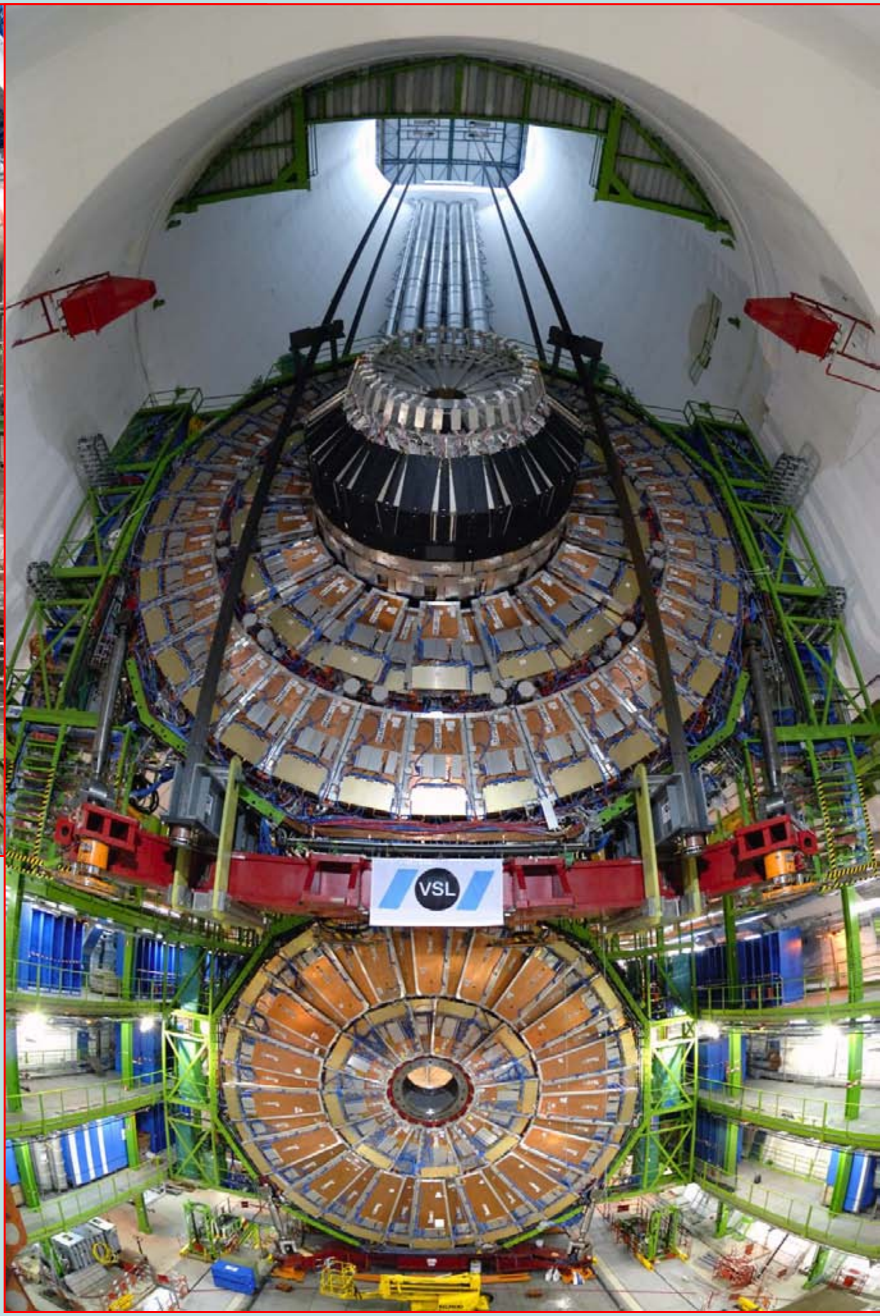
(Affordable detector)

'Generic' experimental set-up

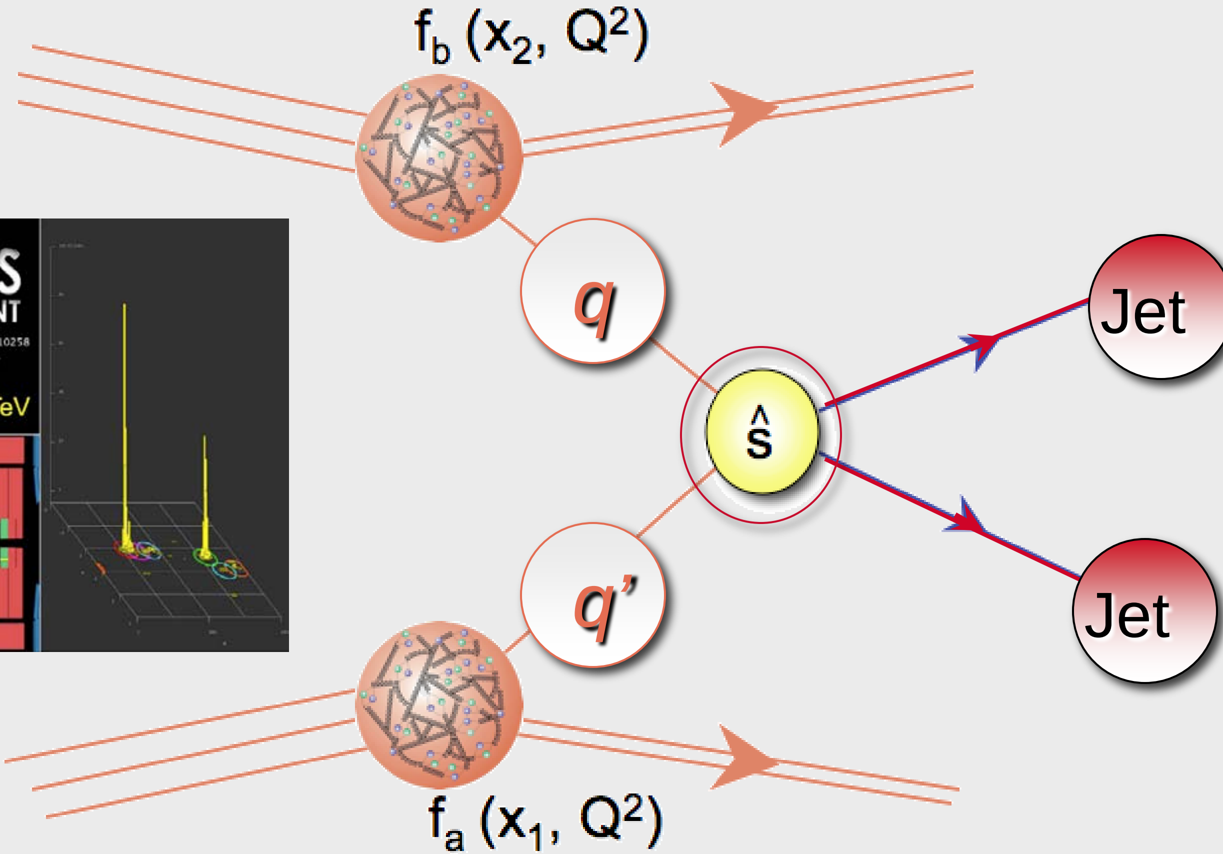


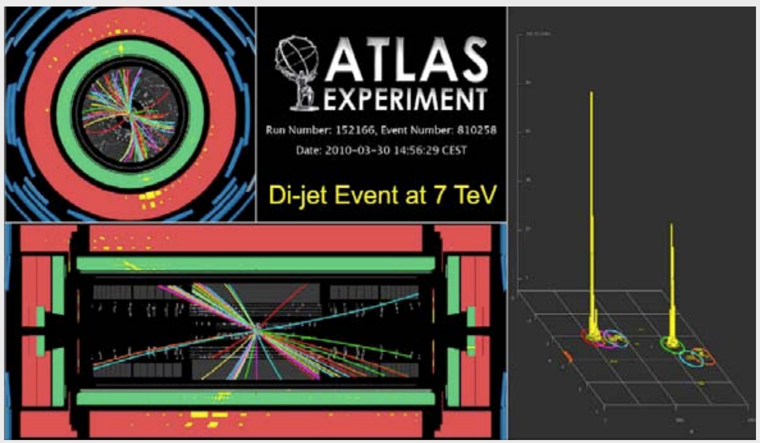
Deflection ~ BL^2/p → need high B (s.c.) and large magnets; need high resolution position measurements (10 -100μ) at large p; also energy and position measurement through total absorption (photon, electron, hadron)




VSL

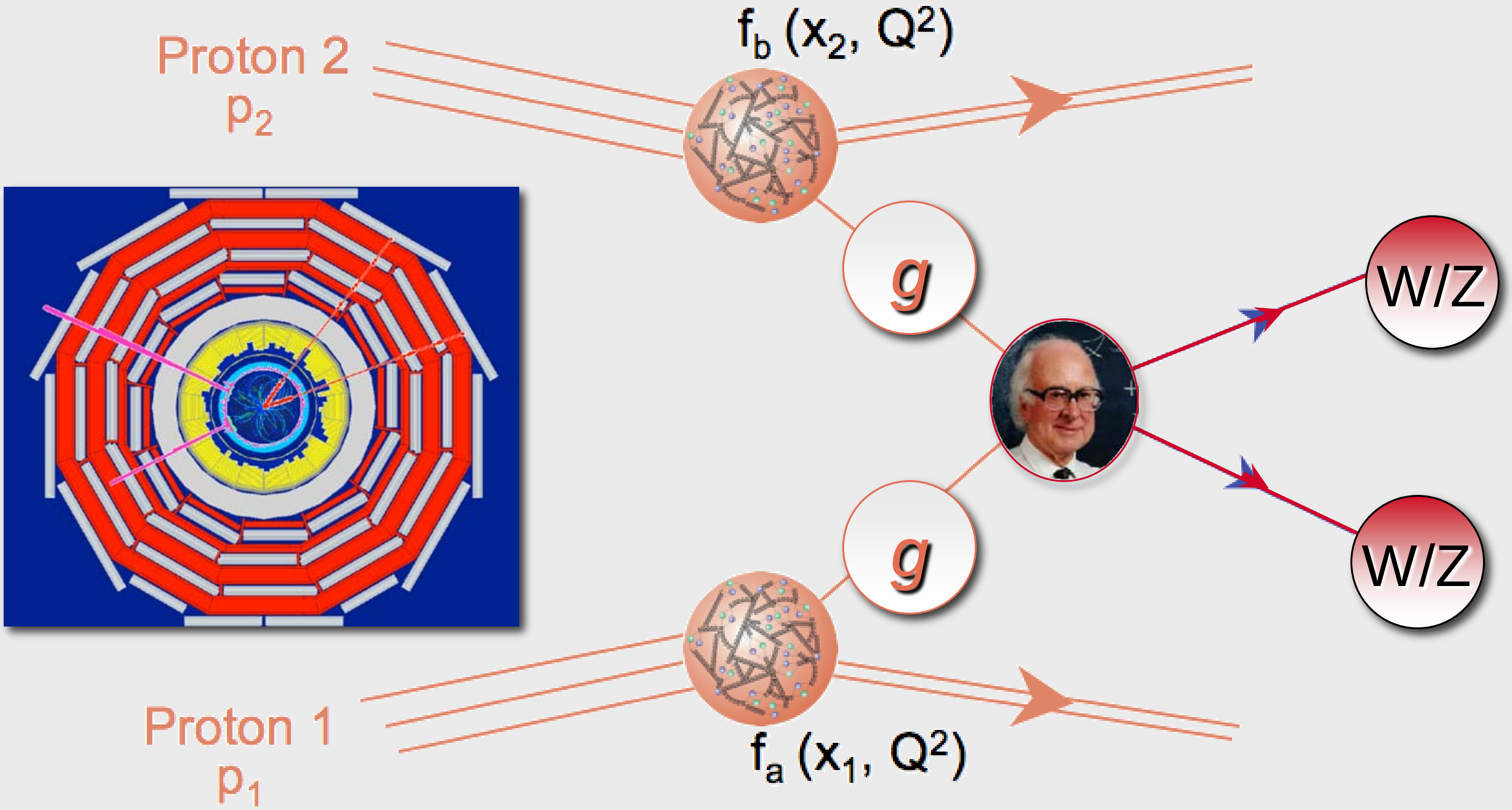
Basic processes at LHC



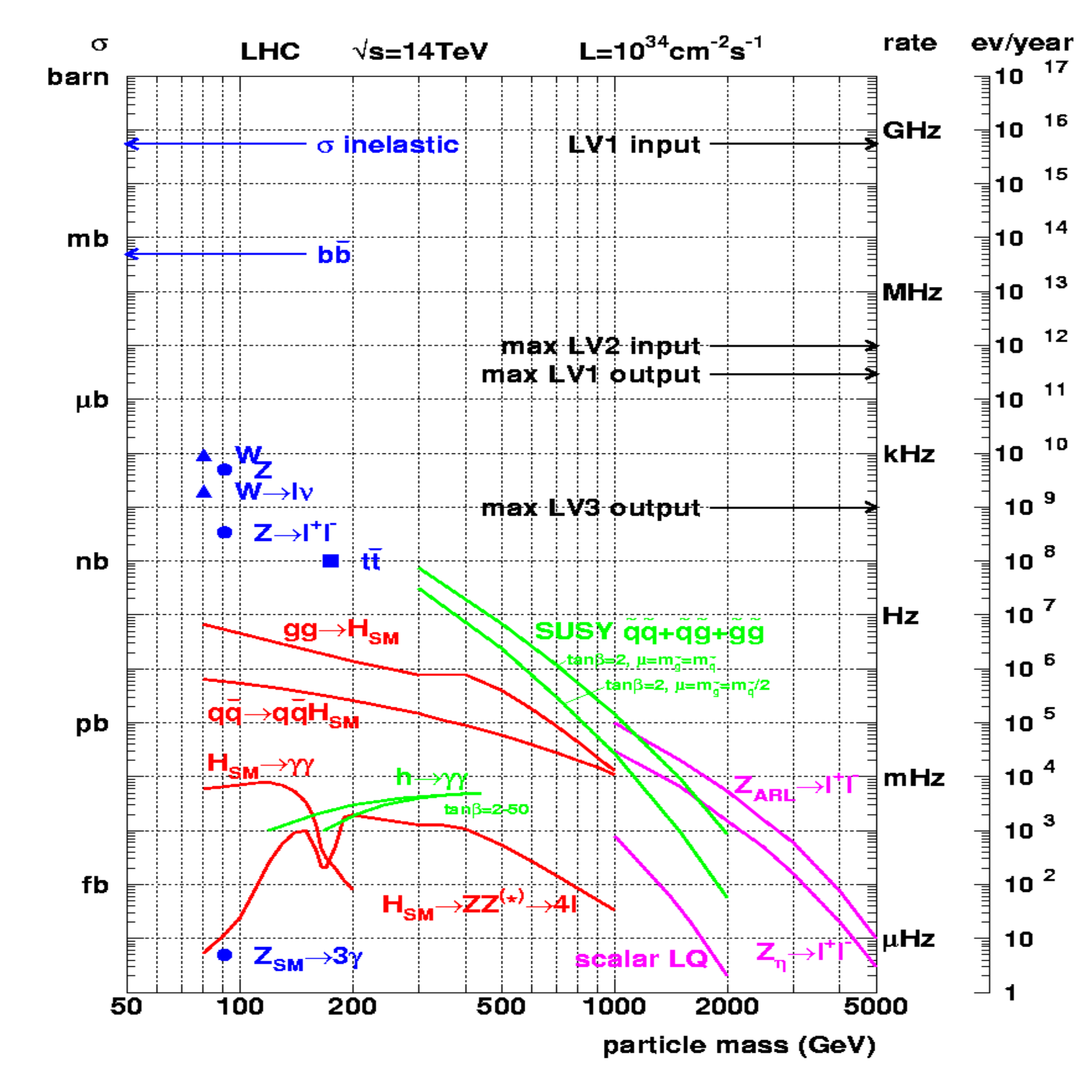


$$d\sigma(p_1 p_2 \rightarrow c\ d) = \int_0^1 dx_1 dx_2 \sum_{a,b} \left(f_a(x_1, Q^2)\, f_b(x_2, Q^2)\, d\hat{\sigma}^{ab \rightarrow cd}\right)$$

Basic processes at LHC



Cross sections at the LHC

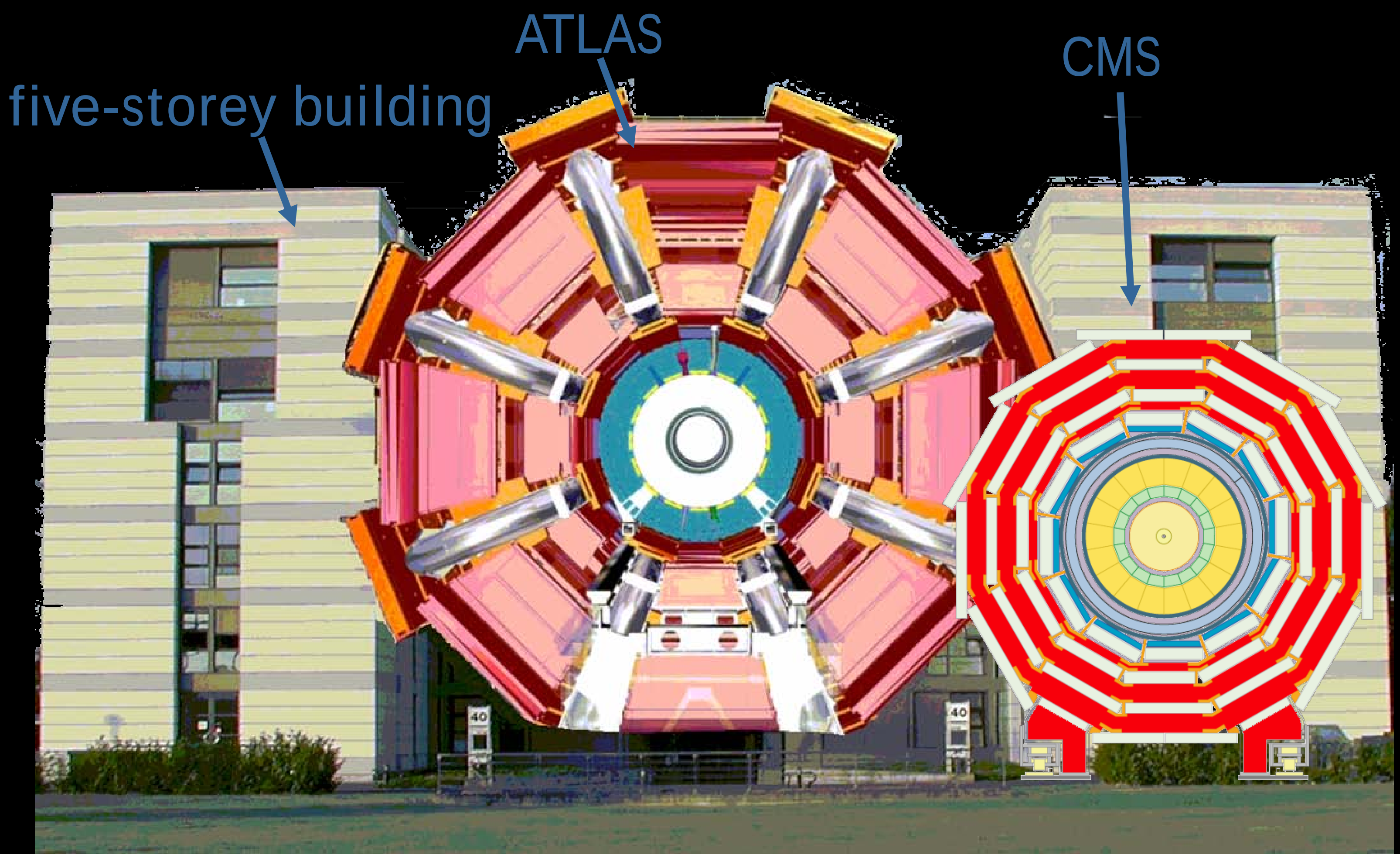


"Well known" processes. Don't need to keep all of them …

New Physics!!

We want to keep!!

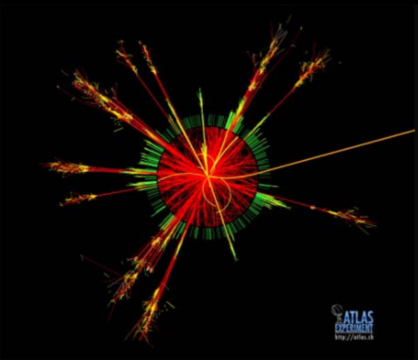
The LHC experiments: about 100 million “sensors” each [think your 6MP digital camera… …taking 40 million pictures a second]

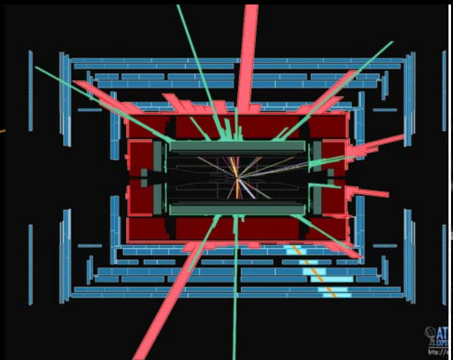


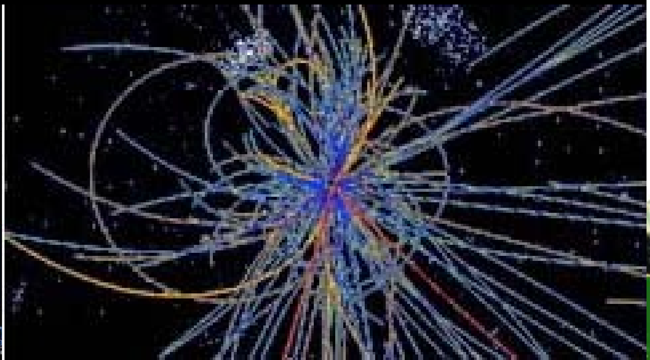
The LHC data

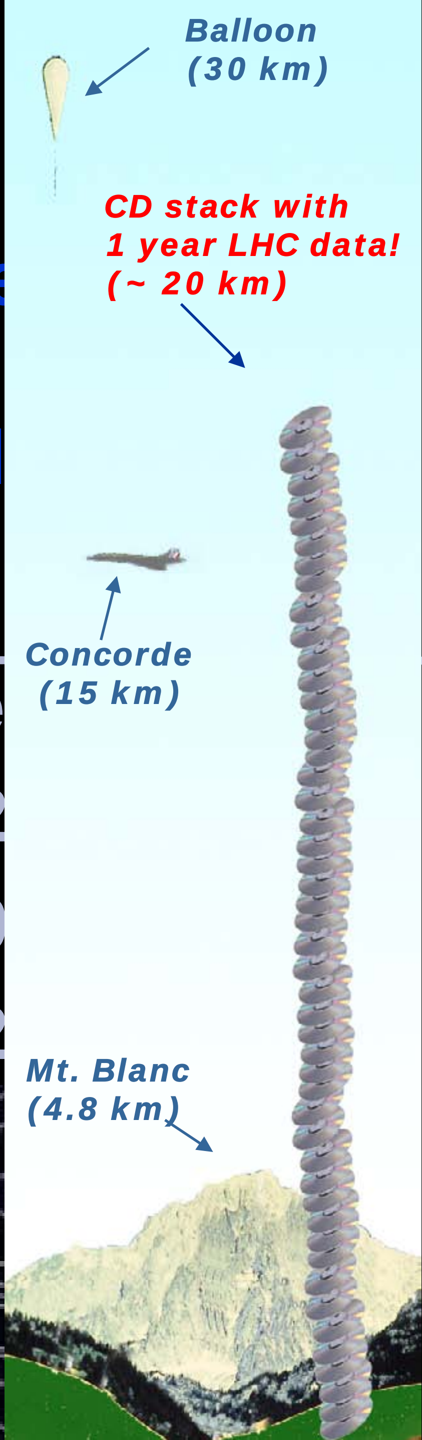
- **40 million events (pictures) per second**
- **Select (on the fly) the ~200 interesting e second to write on tape**
- **"Reconstruct" data and convert for anal "physics data" [→ the grid…]**

(x4 experiments x15 years)	Per event	Pe
Raw data	1.6 MB	32
Reconstructed data	1.0 MB	20
Physics data	0.1 MB	2

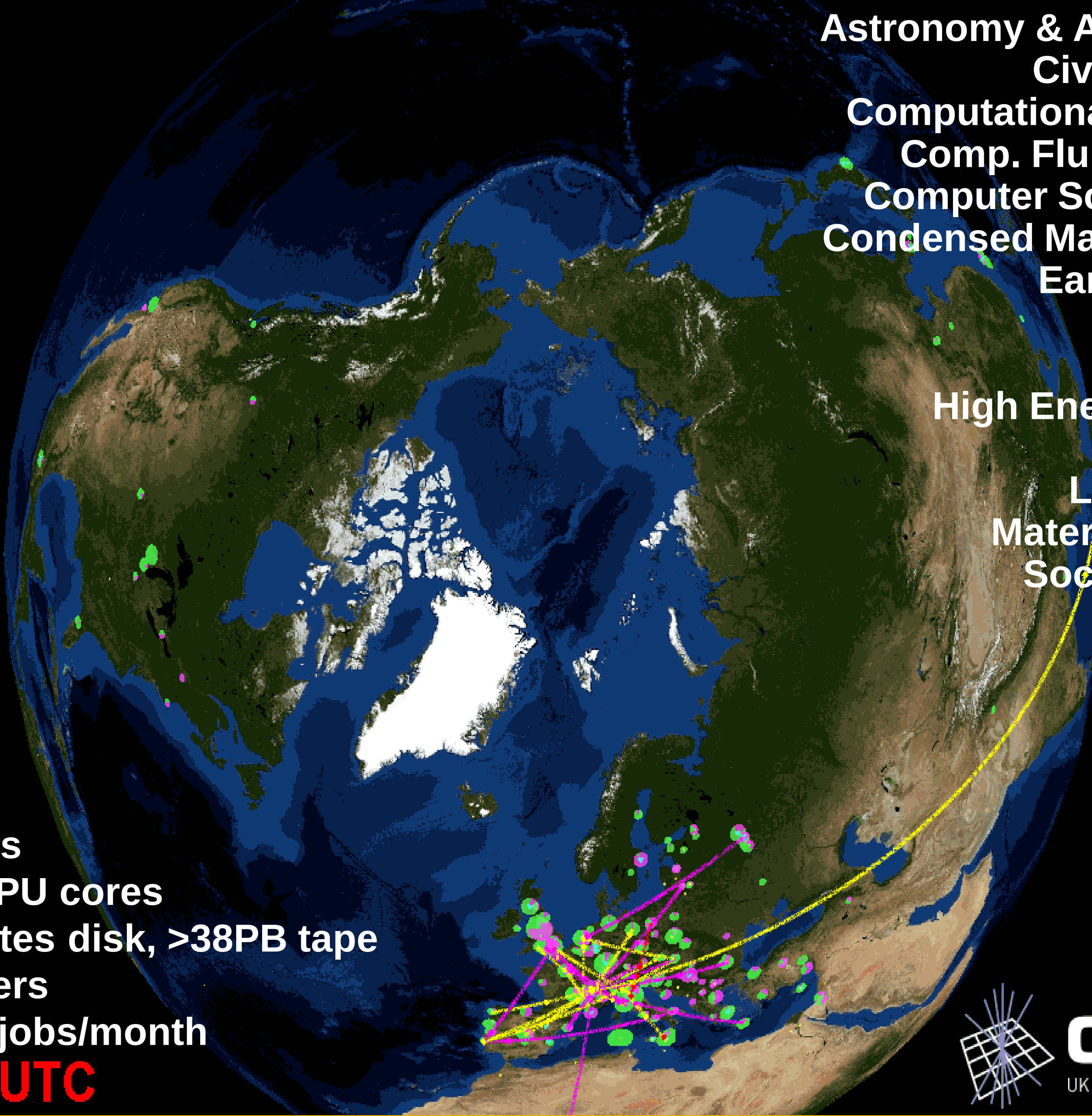








Enabling Grids for E-sciencE



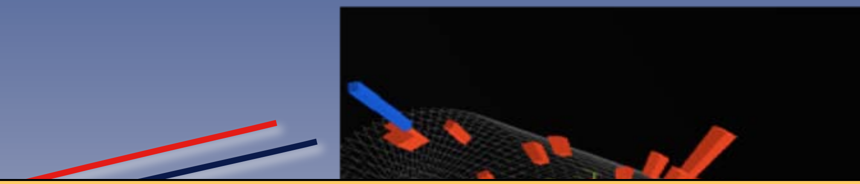
Astronomy & Astrophysics
Civil Protection
Computational Chemistry
Comp. Fluid Dynamics
Computer Science/Tools
Condensed Matter Physics
Earth Sciences
Finance
Fusion
High Energy Physics
Humanities
Life Sciences
Material Sciences
Social Sciences

~285 sites
48 countries
>140,000 CPU cores
>20 PetaBytes disk, >38PB tape
>13,000 users
>12 Million jobs/month

21:13:50 UTC

GridPP
UK Computing for Particle Physics

First Collisions at LHC on 23 November 2009 at E_{CM} = 900 GeV



<u>Chronology of a fantastic escalation of events:</u>

2009

- 20 November: first beams circulating in the LHC
- 23 November: first collisions at $\sqrt{s}$ = 900 GeV
- 8, 14, 16 December: few hours of collisions at $\sqrt{s}$ = 2.36 TeV (the world record !)
- 16 December- 26 February: technical stop

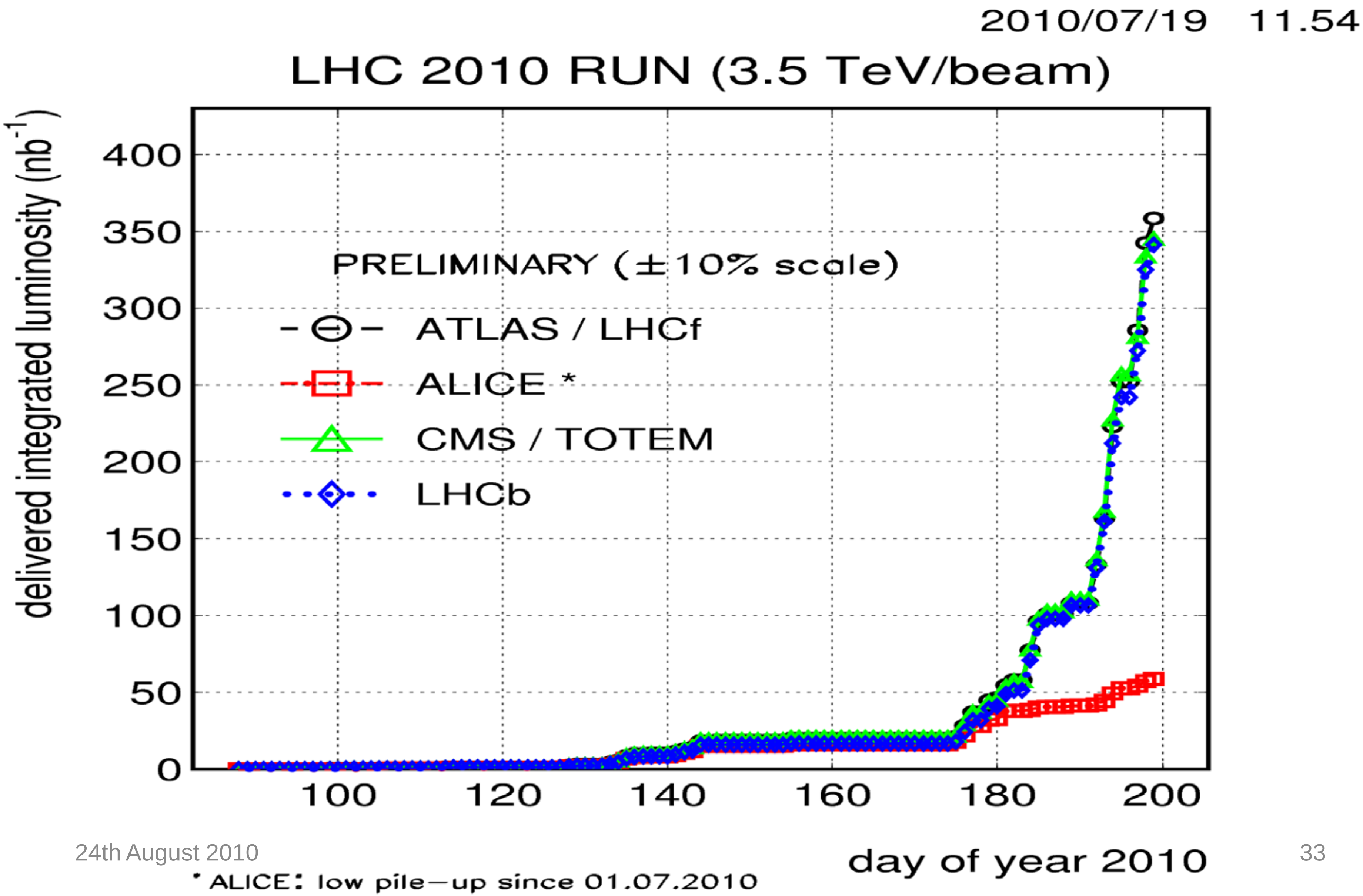
2010

- 27 February : machine operation started again
- 19 March   : first (single) beams ramped up to 3.5 TeV
- 30 March   : first collisions at 3.5+3.5 TeV

- immediate data taking by all experiments with high efficiency
- end July: first results presented at the international High Energy Conference
- since then, tenfold statistics increase

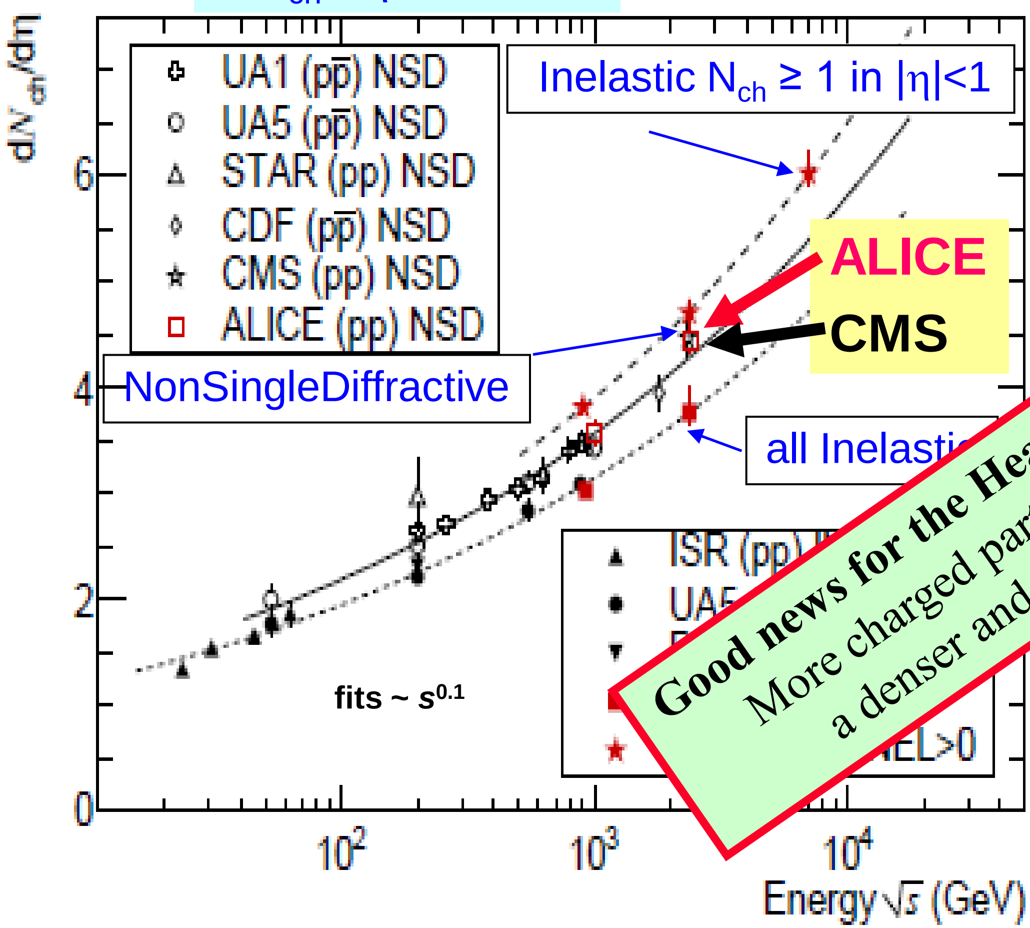
… after more than a year of repairs and improvements

Integrated Luminosity ICHEP10 (350nb-1)

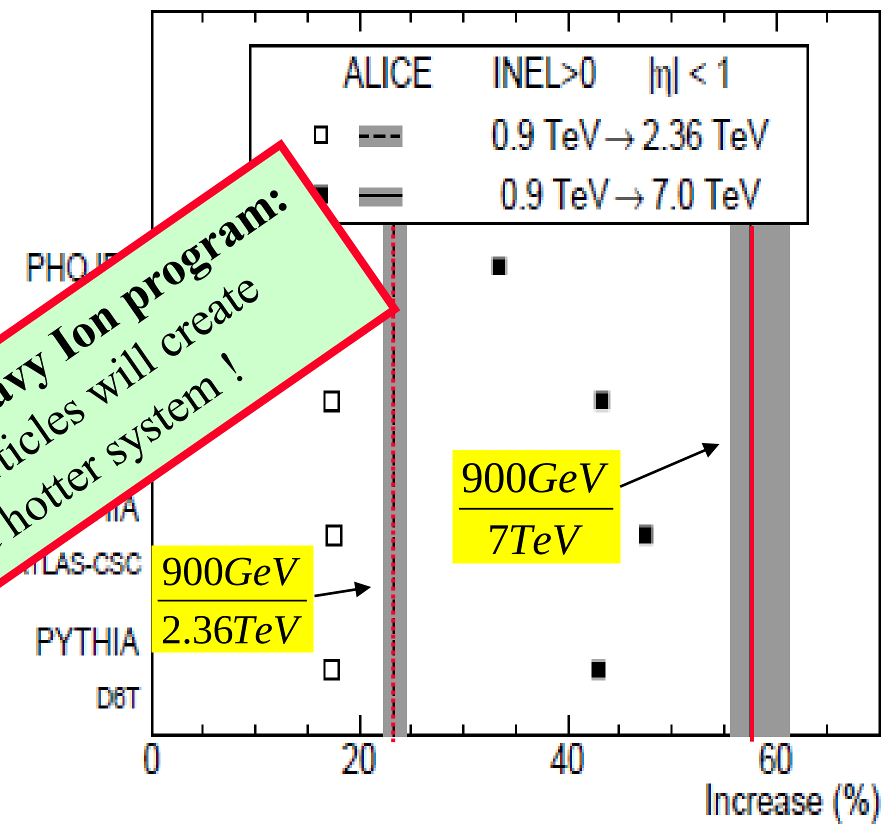


$dN_{ch}/d\eta$ versus $\sqrt{(s)}$

$dN_{ch}/d\eta$ versus $\sqrt{s}$



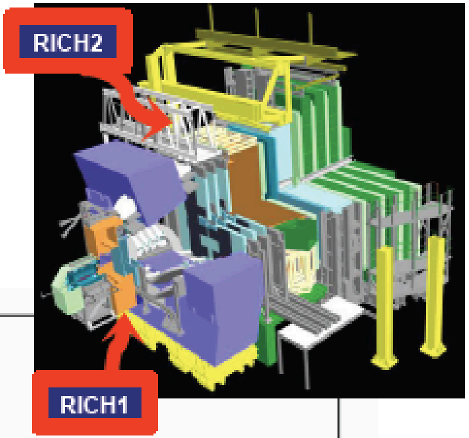
Relative increase in $dN_{ch}/d\eta$



Results:

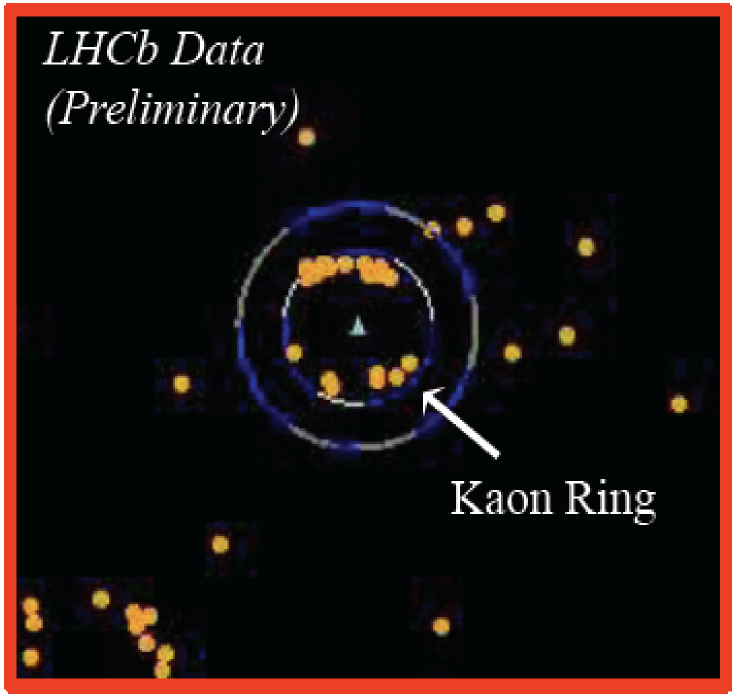
- $dN_{ch}/d\eta$ well described by power law $(\sqrt{s})^{0.2}$
- increase with energy significantly stronger in data than MC's
- Alice & CMS agree to within 1 σ (< 3%)

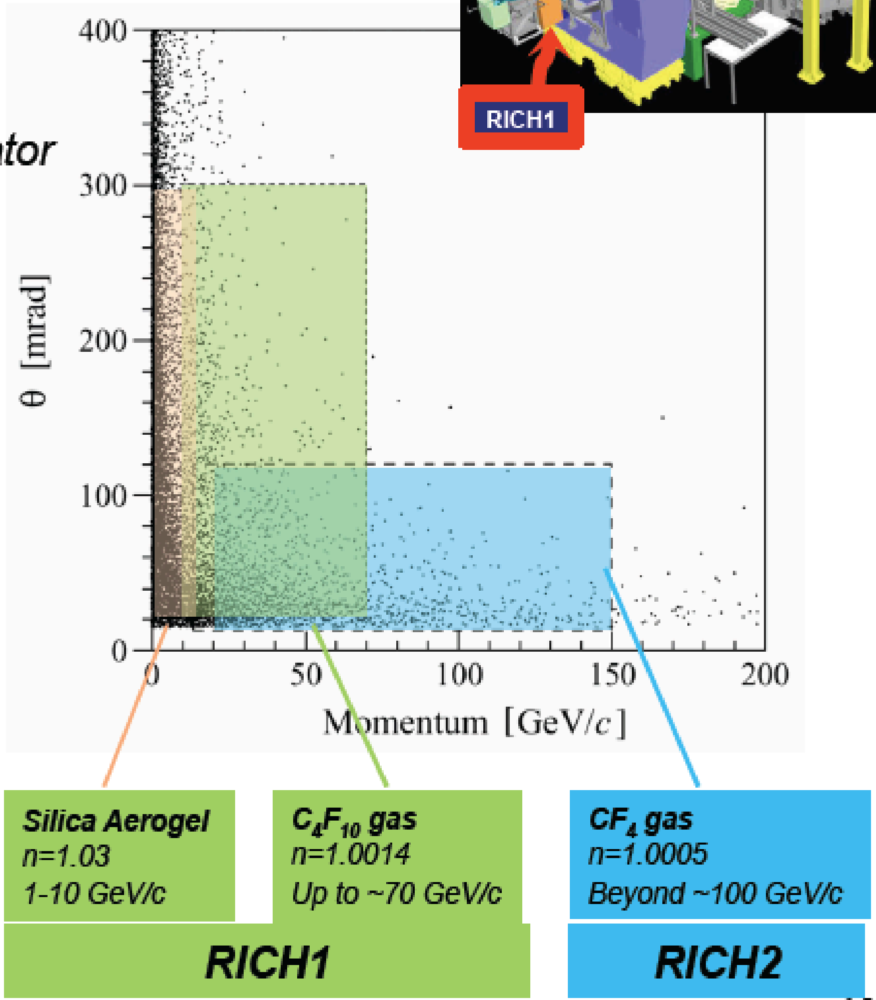
Particle Identification



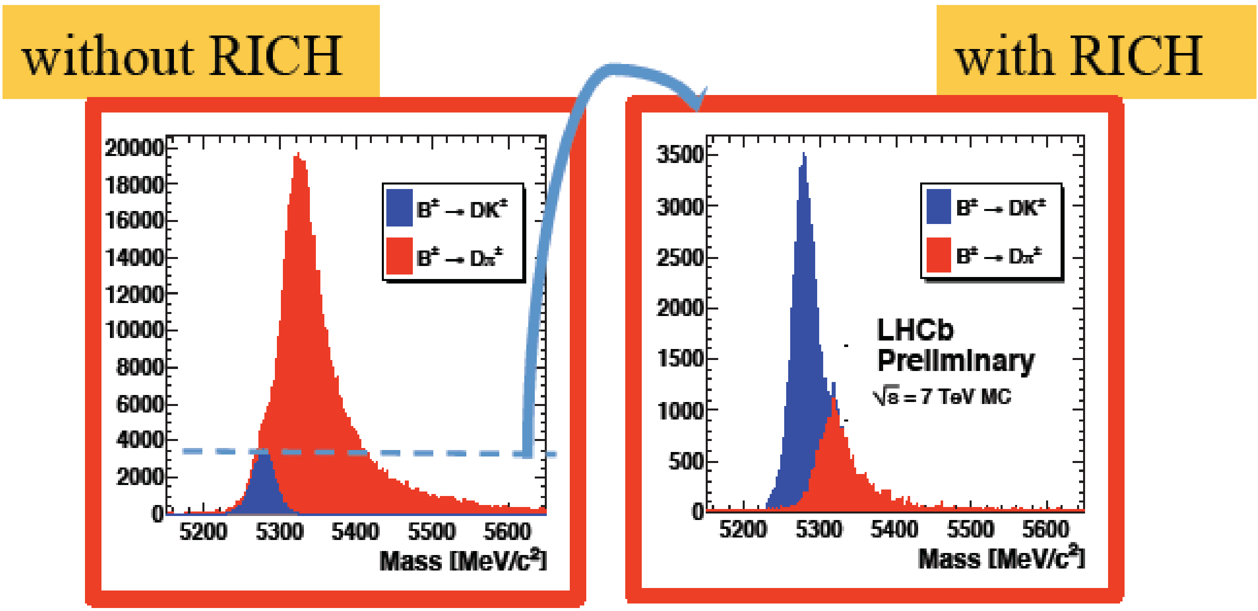
RICH:

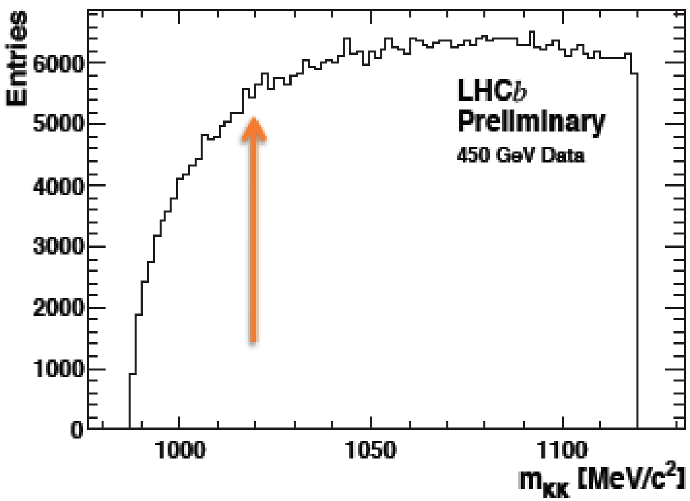
- π / K / p separation
- 2 – 100 GeV/c
- two gaseous and one aerogel radiator

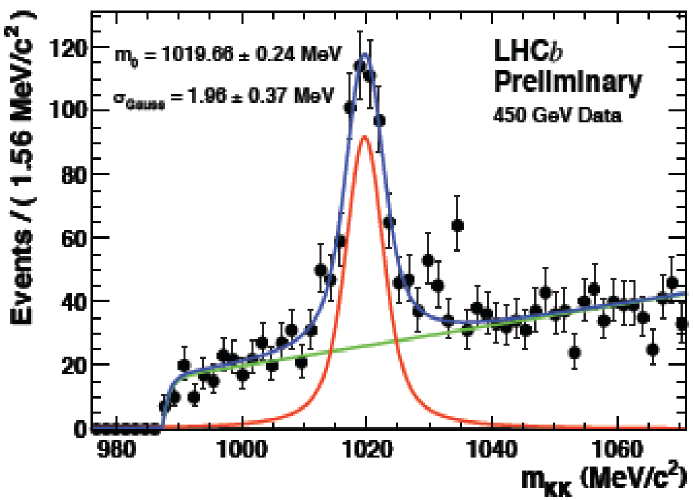




PID with RICH



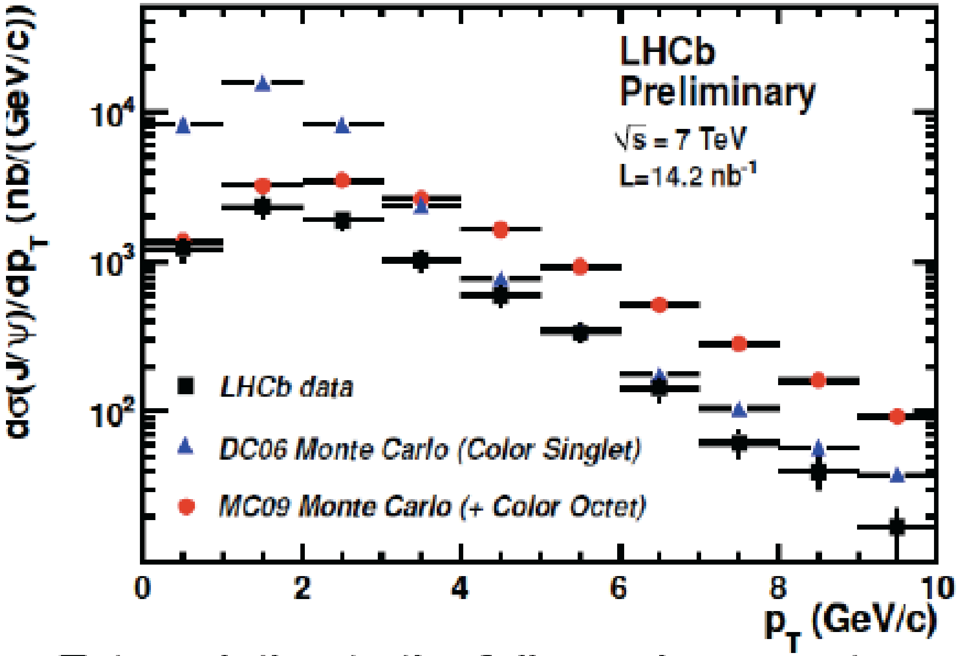




Prompt J/ψ and $b\bar{b}$ cross-sections @ $\sqrt{s}$ = 7 TeV

σ(inclusive J/ψ, $p_T < 10$ GeV/c, $2.5 < y < 4$) = $7.65 \pm 0.19 \pm 1.10^{+0.87}_{-1.27}$ μb,
where the third error is due to unknown J/ψ polarization; will be measured in 2nd pass.

σ(J/ψ from b $p_T < 10$ GeV/c, $2.5 < y < 4$) = $0.81 \pm 0.06 \pm 0.13$ μb

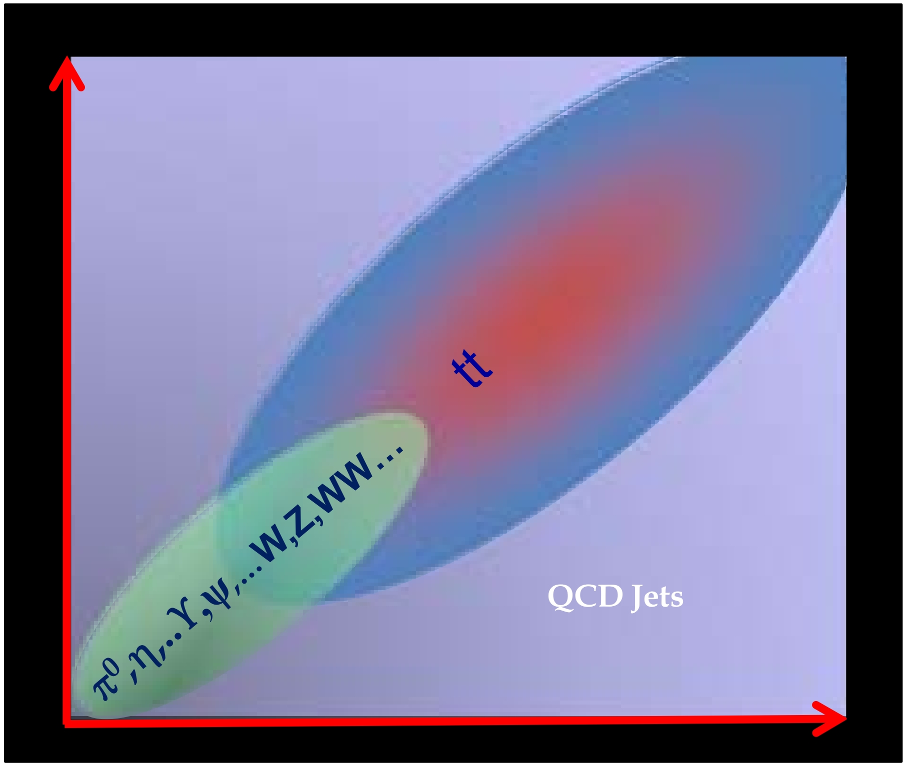


Data favour neither color singlet nor color octet model !!!

Extrapolation to the full angular acceptance using PYTHIA 6.4 and EvtGen:

$$\sigma (pp \rightarrow b\bar{b}X) = 319 \pm 24 \pm 59 \ \mu b$$

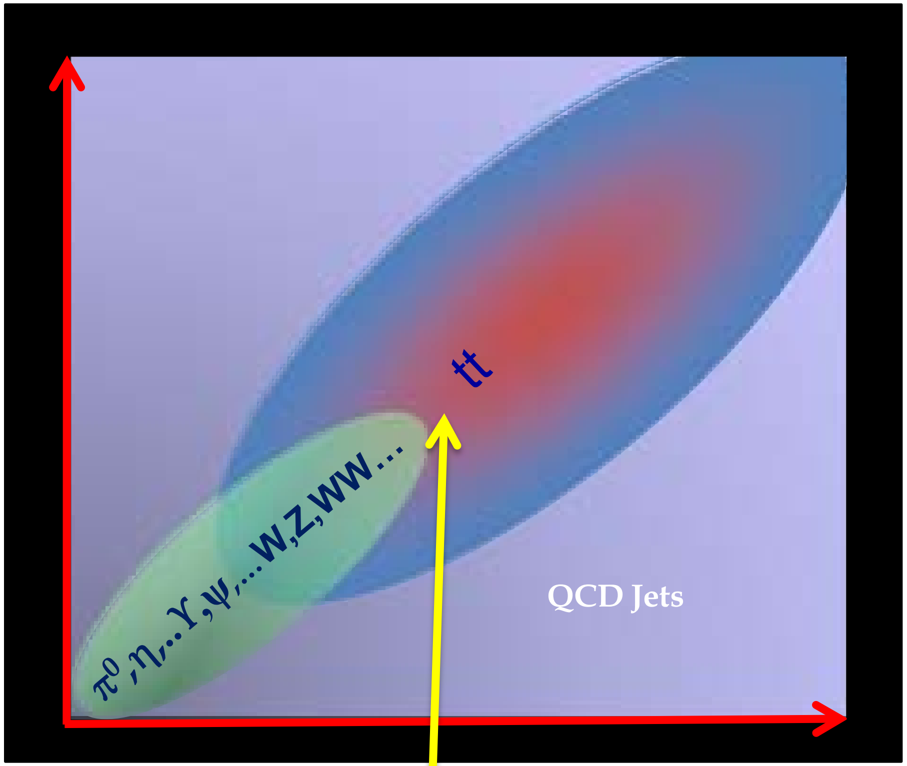
SM at 7-14 TeV



- Low initial luminosity
  - Min Bias data
    - Study dN/dη and Underlying Event
    - Define better tunes, PDFs etc..
  - Jets & MET
    - Refine noise filters, cleaning algo's
    - Optimization of jet algorithms for resolution, scale, lepton and γ fakes, etc.
  - Commission higher level algo's
    - B tagging
    - Particle Flow

Also calibrate with known objects
  - Study candles for leptons and photons*
    - π^0,η,..ϒ,ψ,... initially to understand the detector, tracking, object id's
    - Extend to W, Z →leptons
- Compare to MC V+Jets
- Next comes the tt core region and
- Then we have to deal with the tails of tt production...

SM at 7-14 TeV

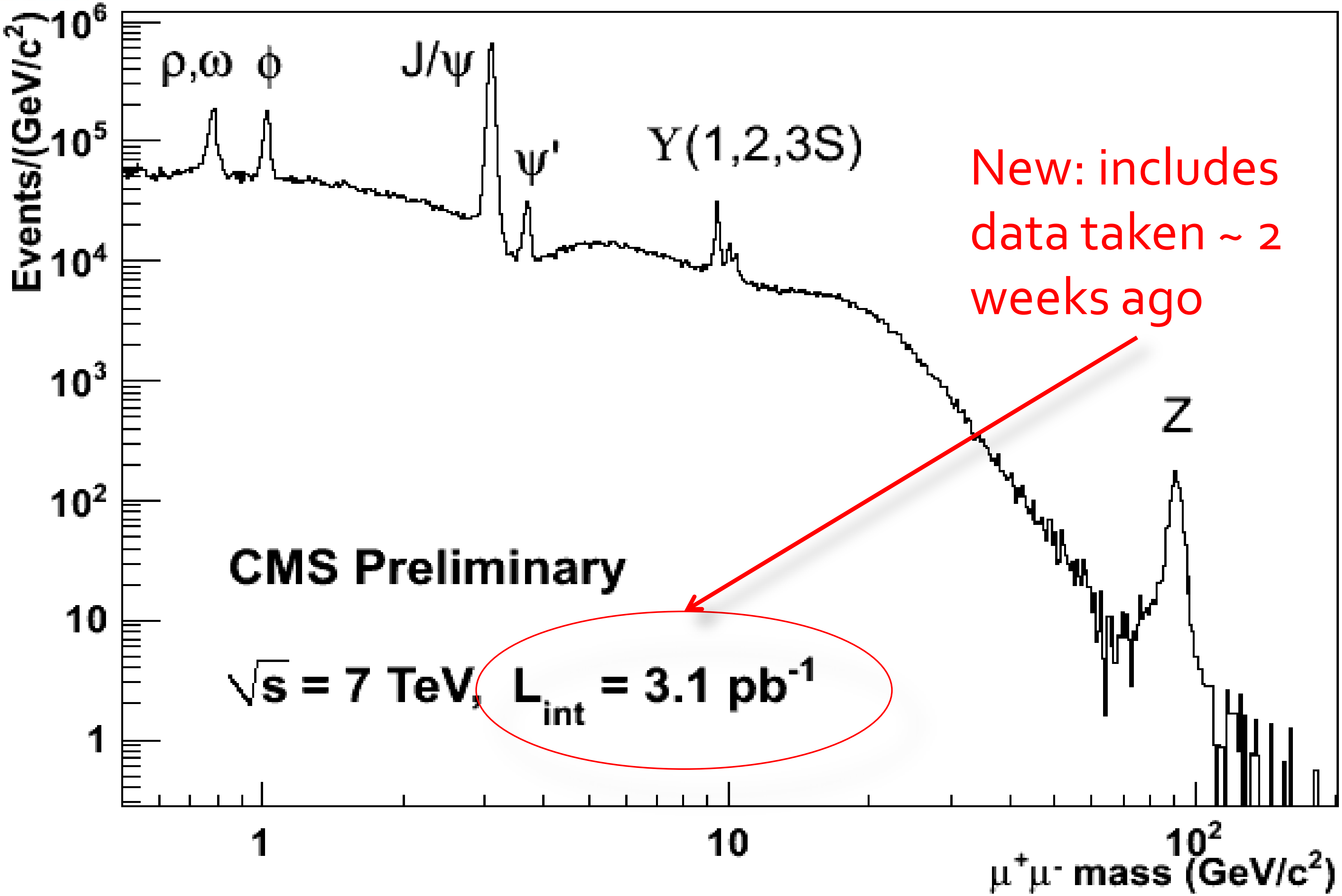


- Low initial luminosity
  - Min Bias data
    - Study dN/dh and Underlying Event
    - Define better tunes, PDFs etc..
  - Jets & MET
    - Refine noise filters, cleaning algo's
    - Optimization of jet algorithms for resolution, scale, lepton and g fakes, etc.
  - Commission higher level algo's
    - B tagging
    - Particle Flow

Also calibrate with known objects

  - Study candles for leptons and photons*
    - **p^0,h,..ϒ,ψ,...** initially to understand the detector, tracking, object id's
    - Extend to W, Z →leptons
- Compare to MC V+Jets
- Next comes the tt core region
- Then we have to deal with the tails of tt production…

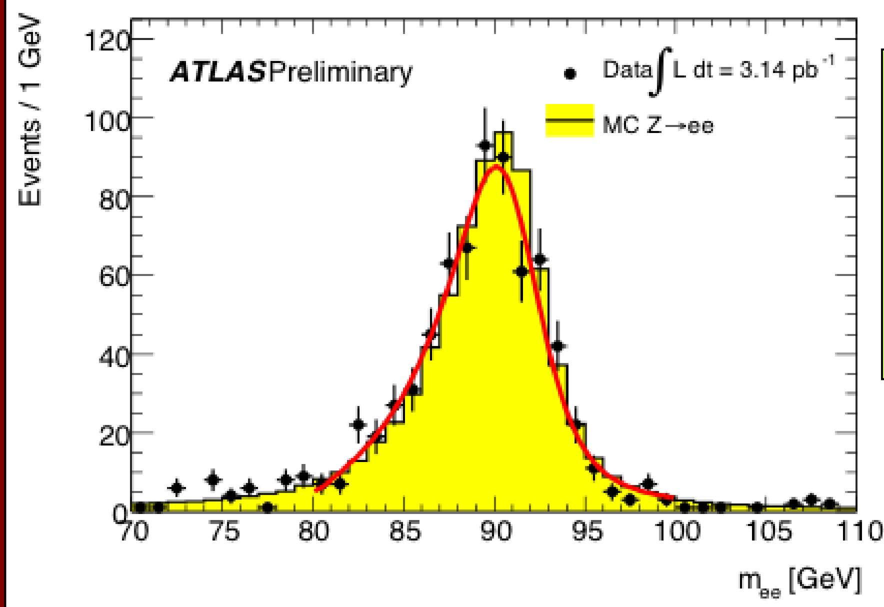
We are ~here
only 5 months into the 'life' at a new energy frontier



New: includes data taken ~ 2 weeks ago

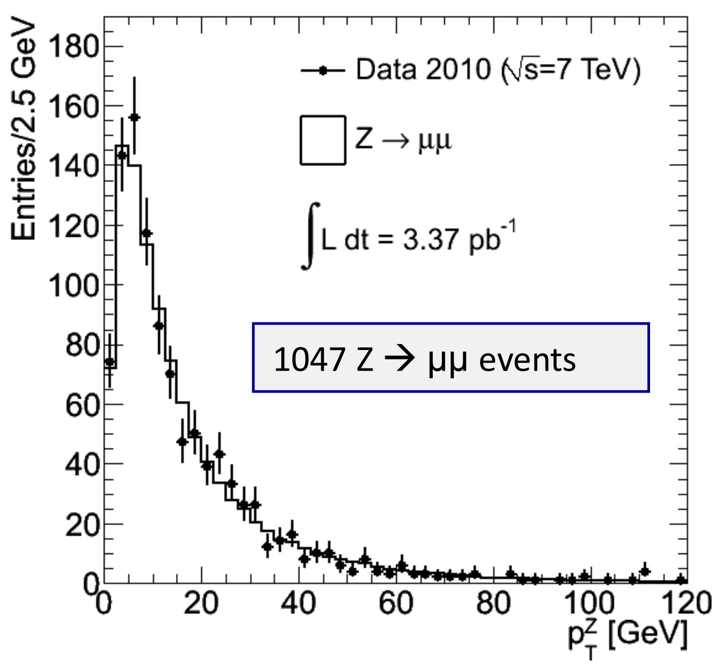
Full data sample: ~ 3.2 pb^{-1}

After all selections, observed in data
Z→ ee: 707 events
Z→ μμ: 1047 events



Z → ee sample:

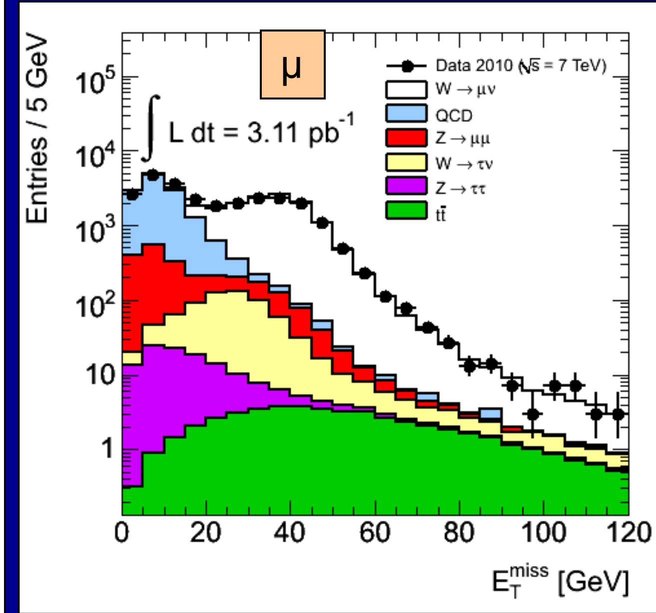
- ❑ Mass peak used to inter-calibrate absolute E-scale in 10 regions of the EM calorimeter (corrections within ~ 3%)
- ❑ Experimental mass resolution: 1.59 ± 0.04 GeV (MC: 1.40 ± 0.01 GeV)

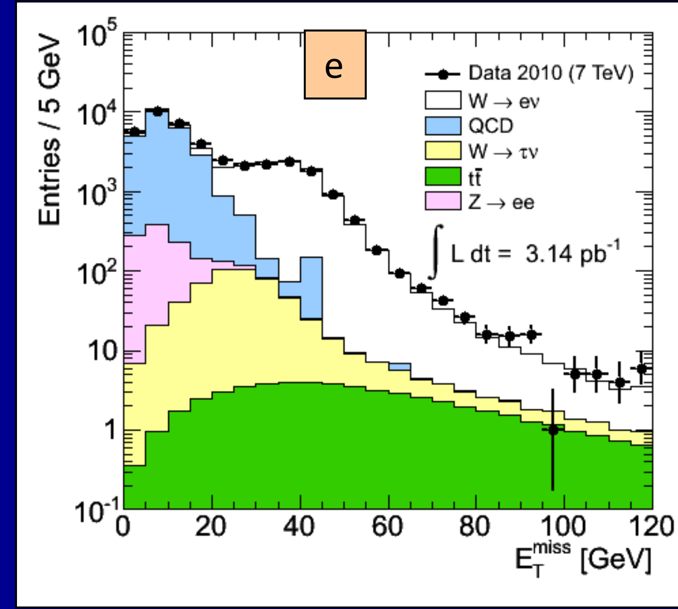


Measured Z peaks:
Z → μμ 90.9 ±0.1 GeV (MC: 91.3 GeV)
Z→ ee 90.8 ±0.1 GeV (MC: 91.6 GeV)

Full data sample
~ 3.1 pb^{-1}

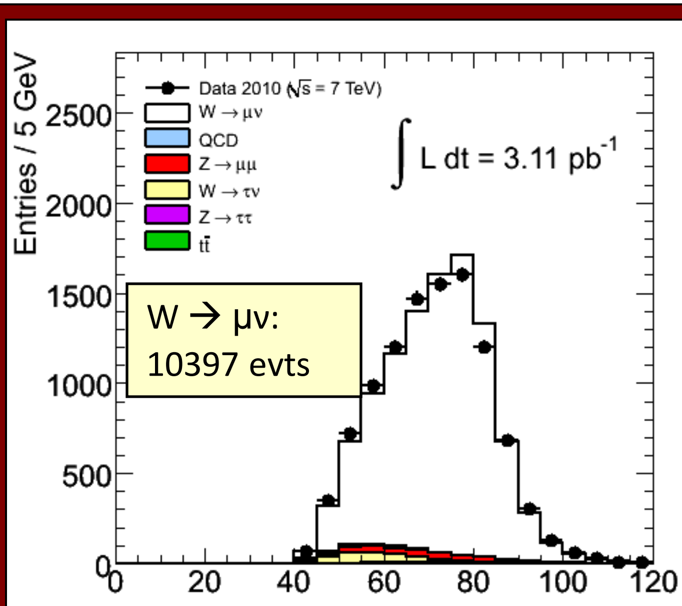
After requiring a good lepton $p_T > 20$ GeV



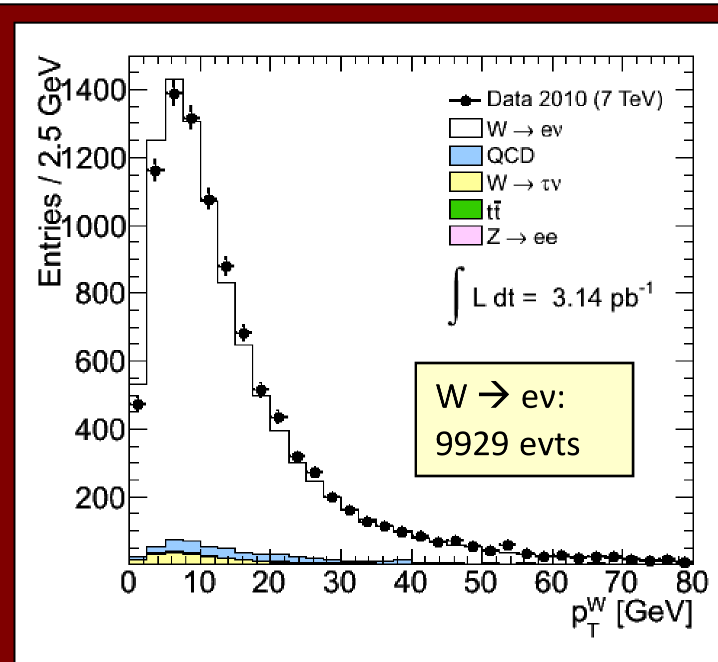


After all cuts

Observed in data:
W→ μν : 10397 events
W→ eν: 9929 events

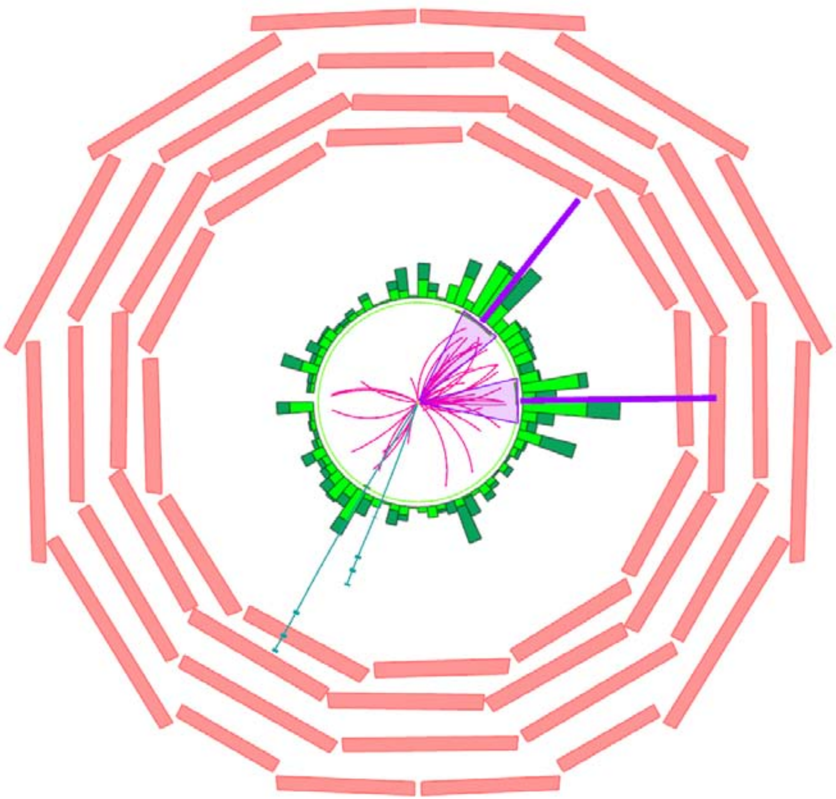


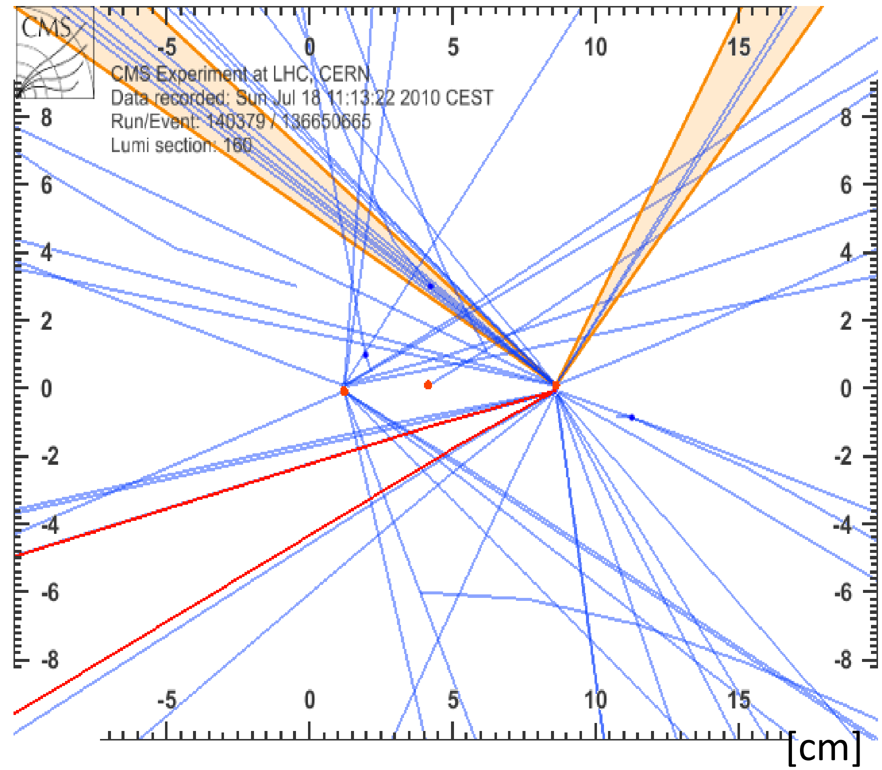
$$m_T = \sqrt{2 p_T^{\ell} p_T^{\nu} (1 - \cos(\phi^{\ell} - \phi^{\nu}))}$$



MC normalised to data

Top signals in CMS

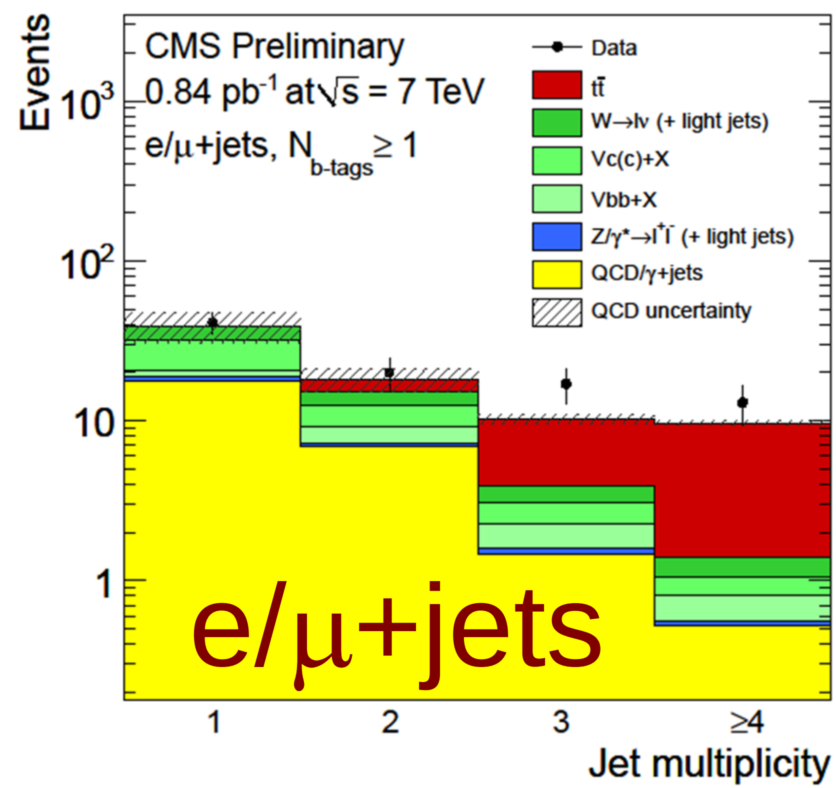




- μμ +Jets candidate event.
  - Event with 2 pp interactions (pile-up) but jets and μ's from 1 vertex.

tt : Lepton+jets

- Using 0.84pb^{-1} and requiring at least 1 secondary vertex tagger with ≥2 tracks;
  - ~50% efficiency ~1% fake rate
- N(jets)≥3
  - 30 signal candidates over a predicted background of 5.3
- tt rate consistent with NLO cross section
  - Up to experimental (JES, b-tagging) and theoretical (scale, PDF, HF modeling, …) uncertainties.



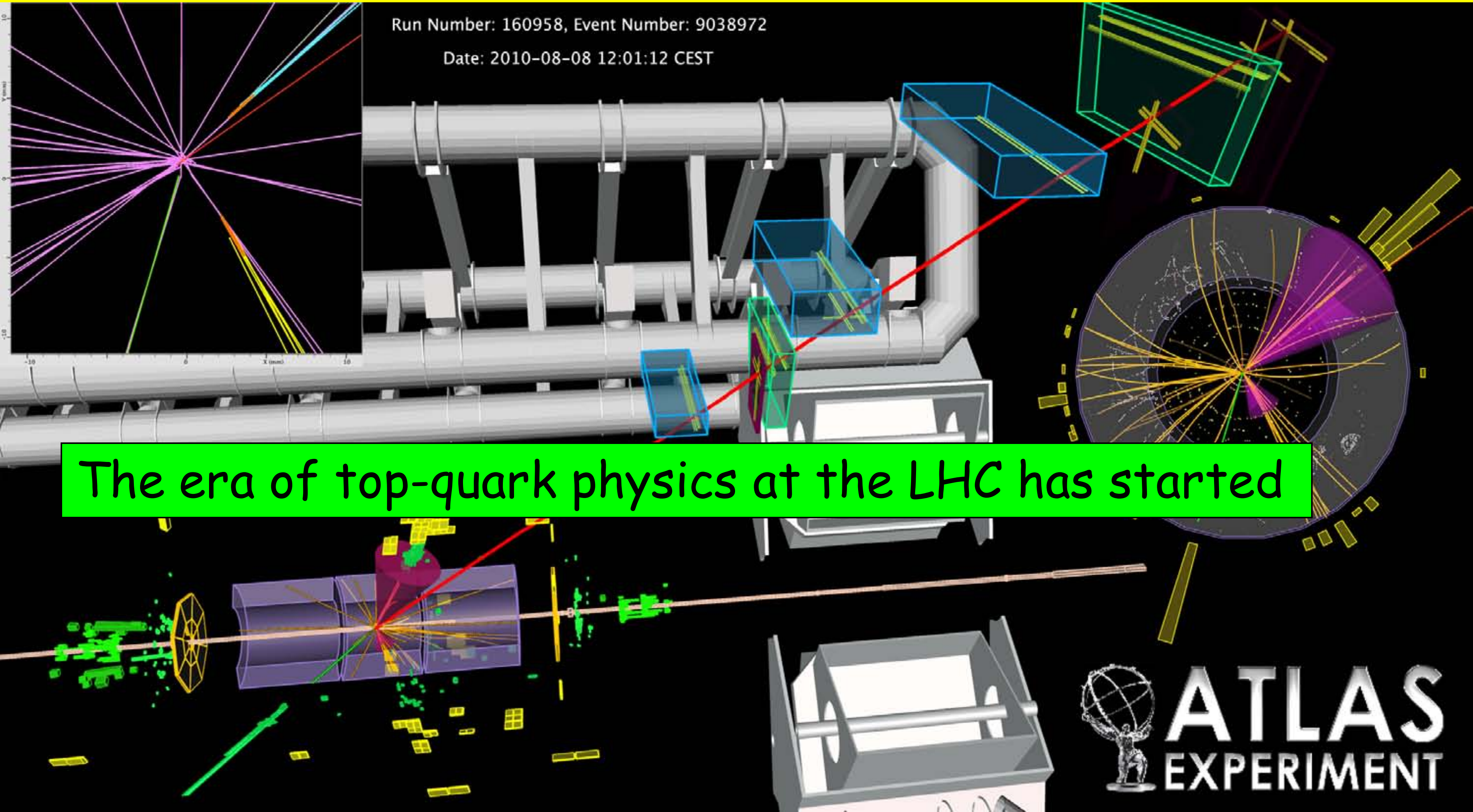
More-gold-plated-than-gold candidate: eμ event with 2 b-jets

Purity > 96%

$p_T(\mu)$= 51 GeV $p_T(e)$=66 GeV p_T (b-tagged jets) = 174, 45 GeV E_T^{miss} = 113 GeV,
Secondary vertices:

-- distance from primary vertex: 4mm, 3.9 mm

-- vertex mass = ~2 GeV, ~ 4 GeV



The era of top-quark physics at the LHC has started

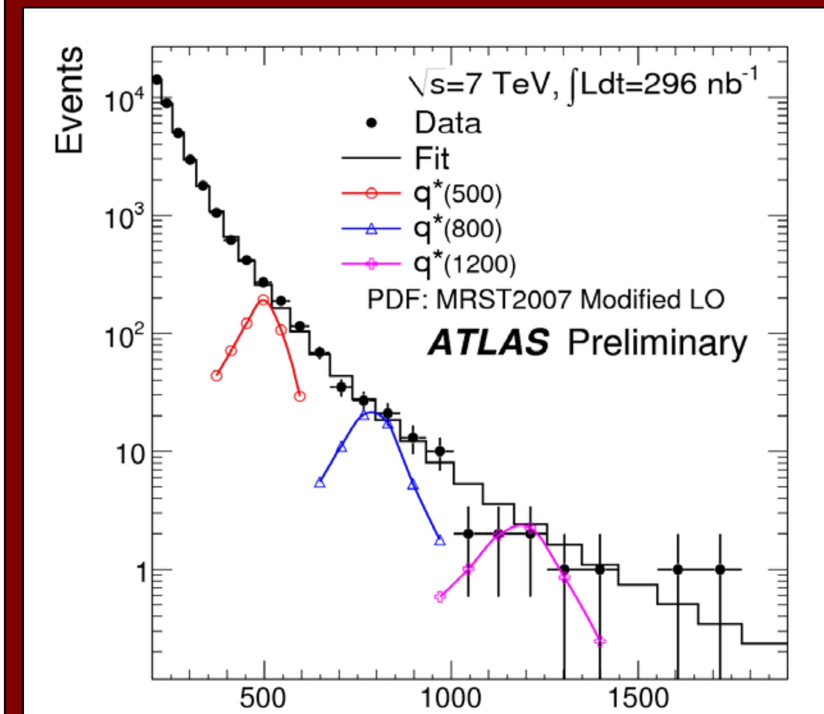
Searches for excited quarks: q*→ jj

ICHEP

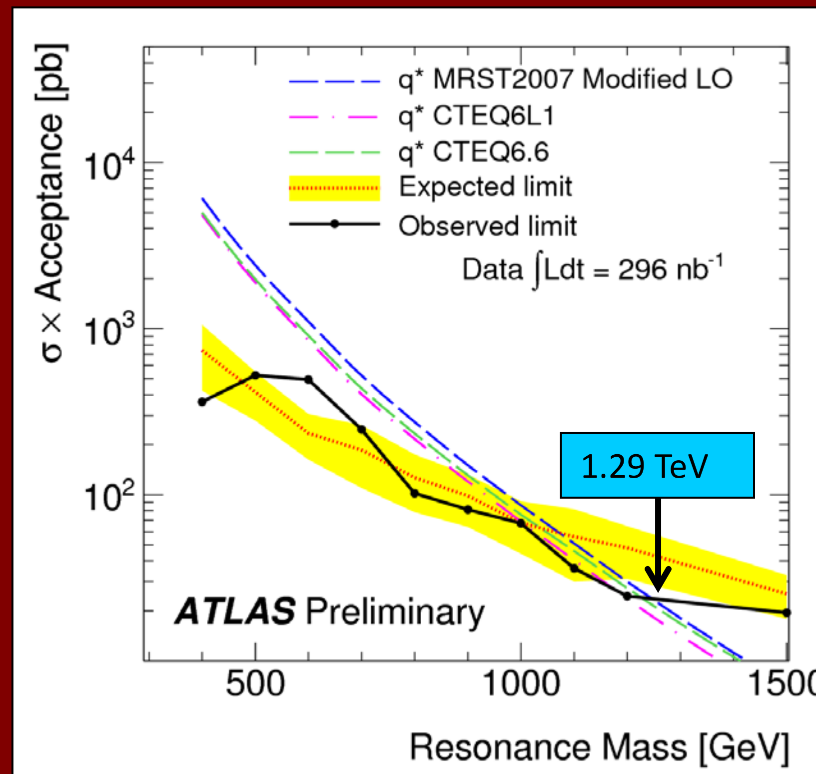
Looked for di-jet resonance in the measured M(jj) distribution
→ spectrum compatible with a smooth monotonic function → no bumps

➡ 0.4 < M (q*) < 1.29 TeV excluded at 95% C.L.

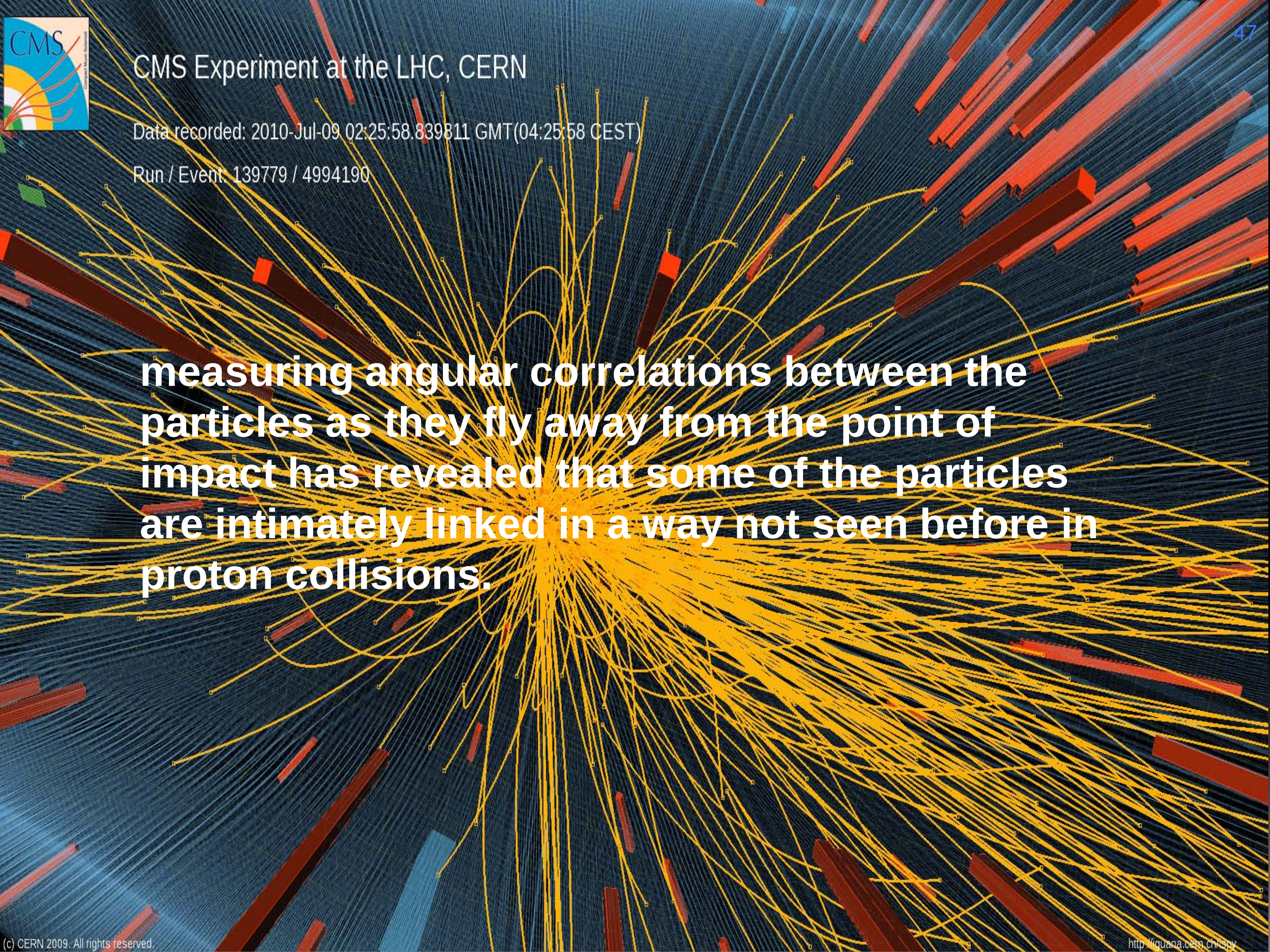
Latest published limit:
CDF: 260 < M (q*) < 870 GeV



q* model simulated with Geant4



- ❑ Experimental systematic uncertainties included: luminosity, JES (dominant), background fit, ..
- ❑ Impact of different PDF sets studied → with CTEQ6L1: 0.4 < M (q*) < 1.18 TeV



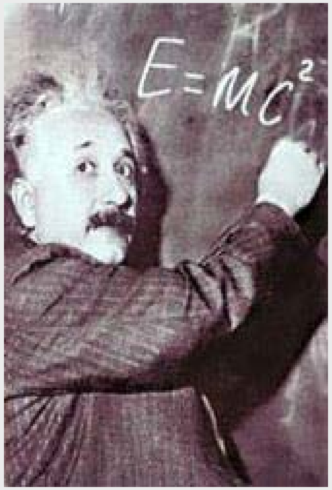
measuring angular correlations between the particles as they fly away from the point of impact has revealed that some of the particles are intimately linked in a way not seen before in proton collisions.

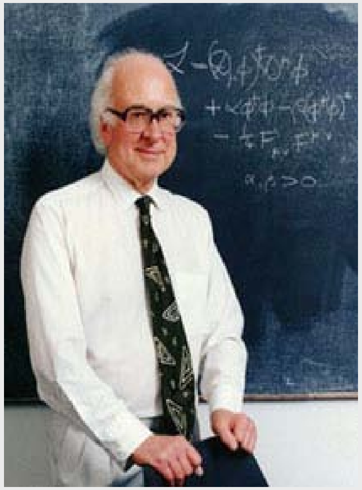
Summary as of today

- Experiments enthusiastically following the exceptional machine progression
- Standard Model particle zoo completed with the observation of the "european" top quark
- WLCG keeping the pace smoothly
- A steady flow of physics results streaming out
- Ready for more and the first unexpected results are around the corner. . . !

The Science

We are now ready to tackle some of the most profound questions in physics:





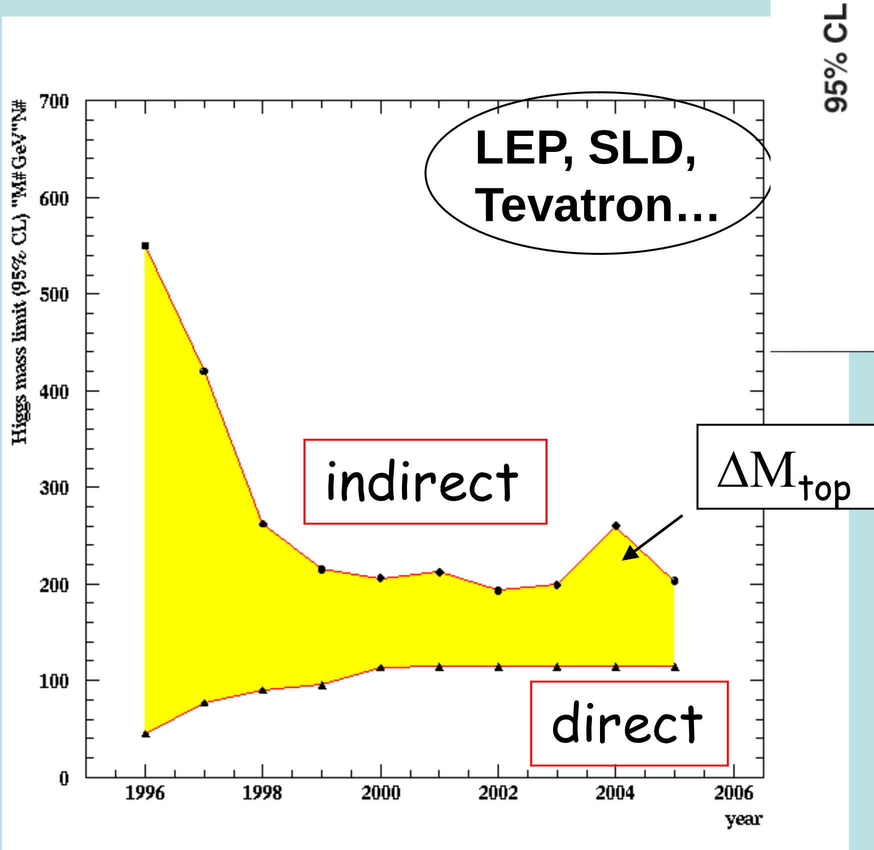
Newton's unfinished business… what is mass?

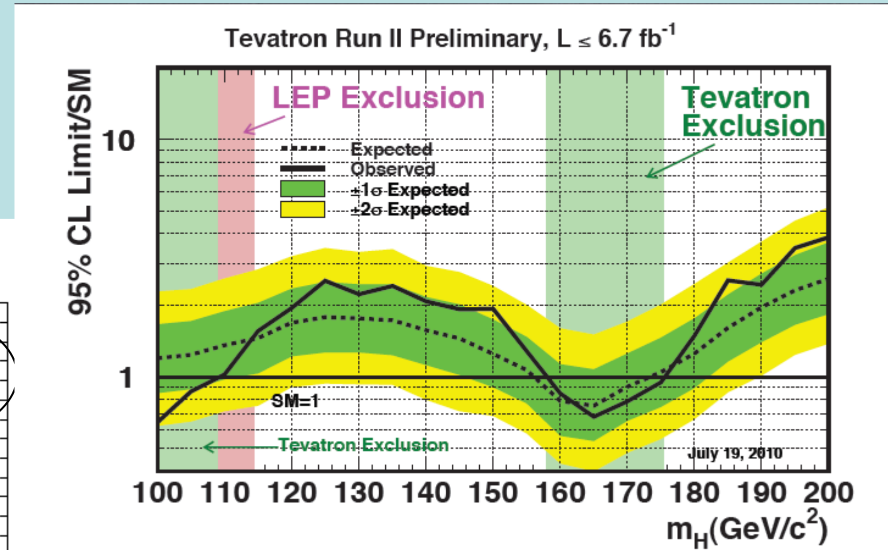
Nature's favouritism… why is there no more antimatter?

The secrets of the Big Bang… what was matter like within the first second of the Universe's life?

Science's little embarrassment… what is 96% of the Universe made of?

Time evolution of experimental limits on the Higgs boson mass





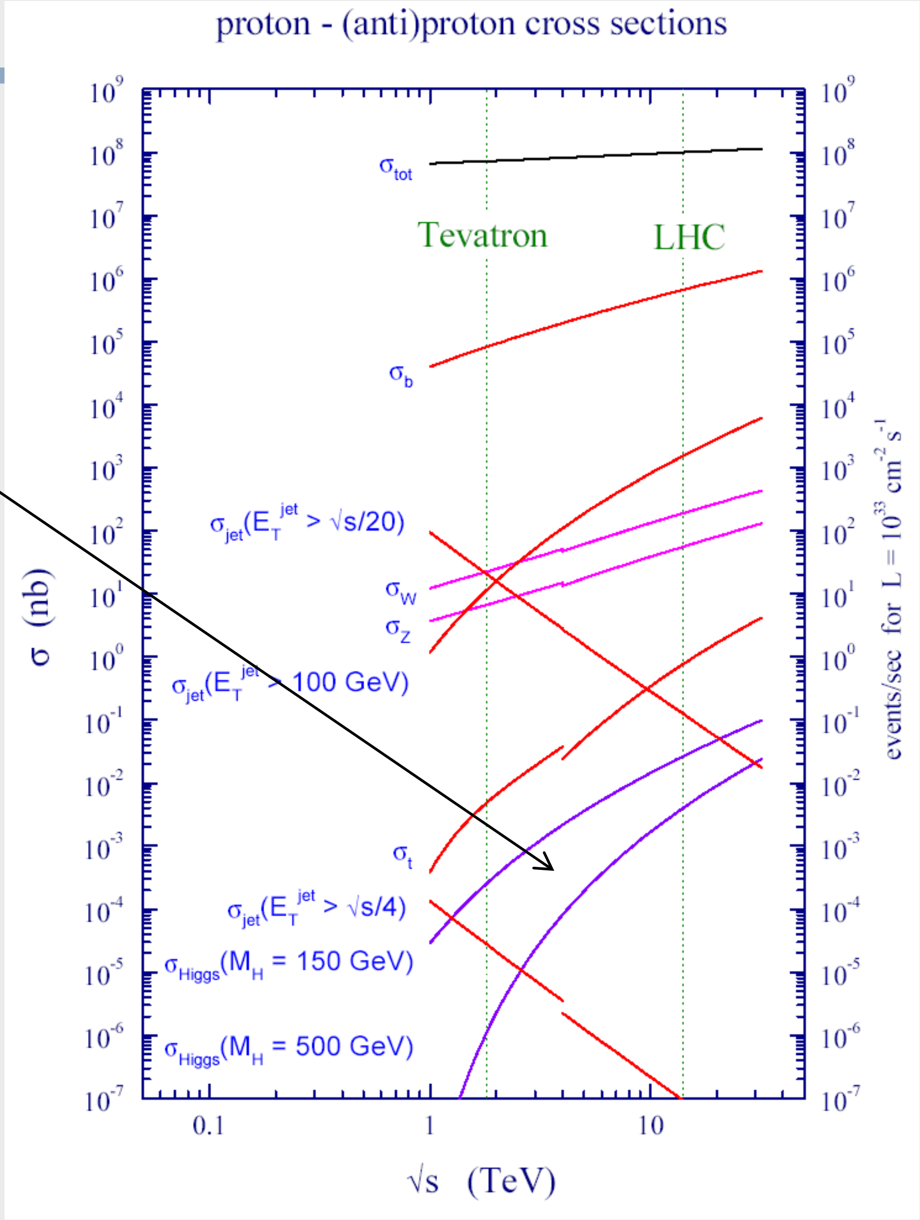
M_H between 114 and ~200 GeV,

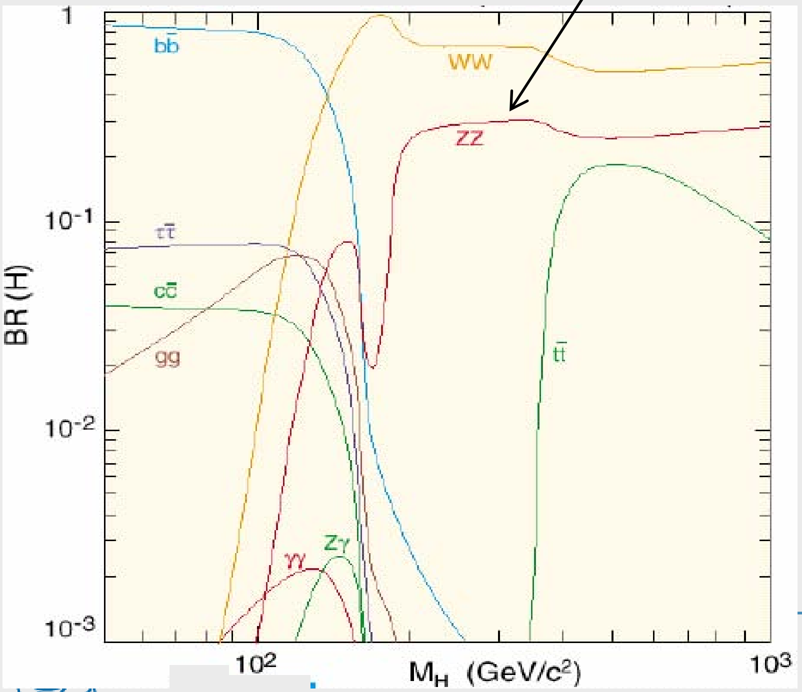
If the Higgs-Boson exists it will be found at the LHC

Search for the Higgs-Boson at the LHC

Production rate
of the Higgs-Bosons
depends on its mass

as well as its decay possibilities
("Signiture (or picture)"
as seen in the detector)

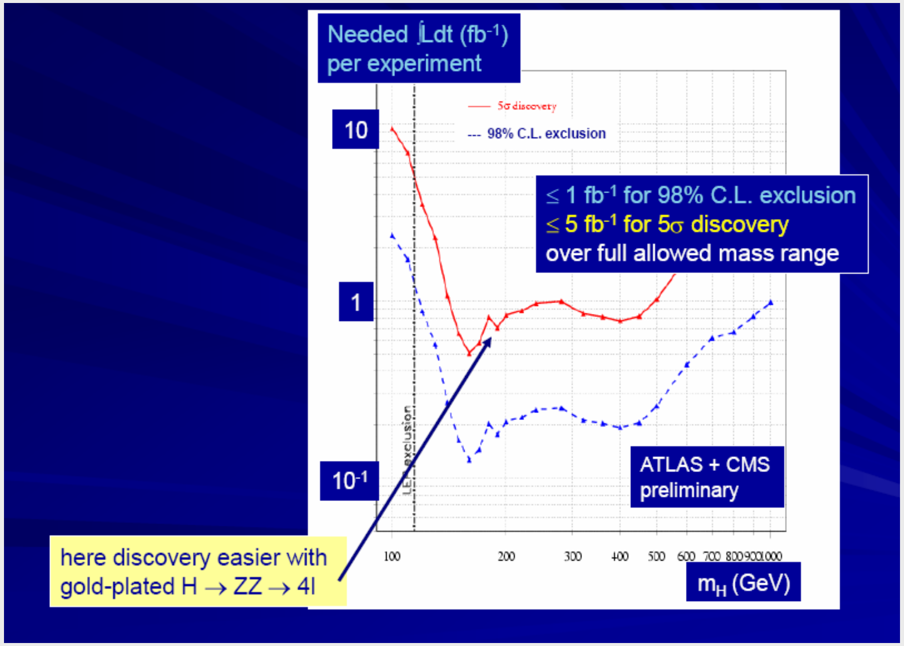




Search for Higgs at LHC Start-up

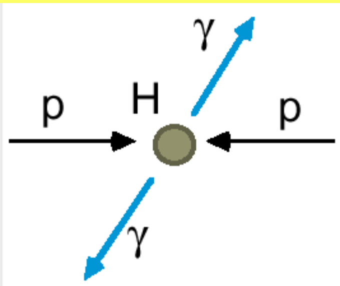
- Sizeable integrated luminosity is needed before significant inroads can be made in SM Higgs search.
- However, even with moderate luminosity per experiment, Higgs boson discovery is possible in particular mass regions.

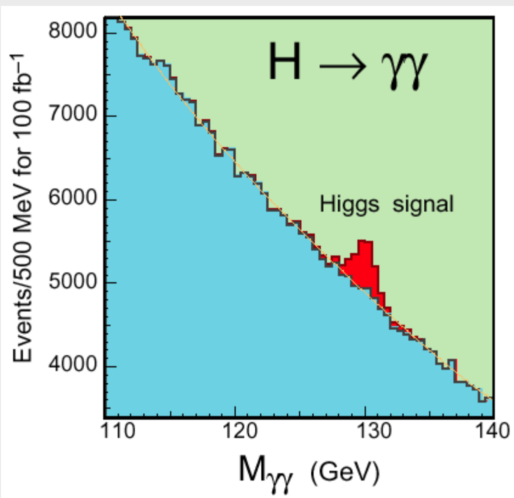
Example Reach ATLAS + CMS

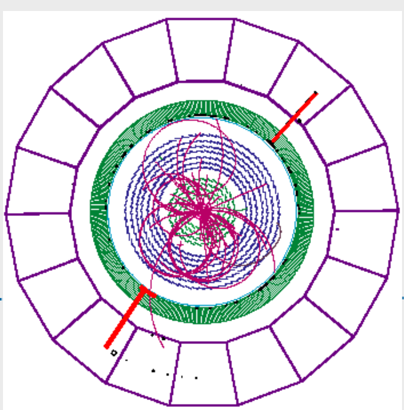


Higgs Searches

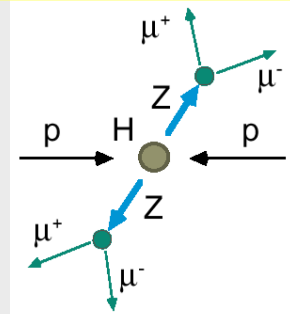
Low $M_H < 140$ GeV/c^2

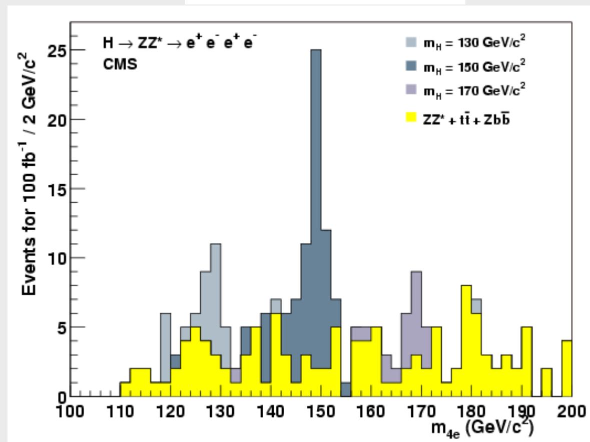


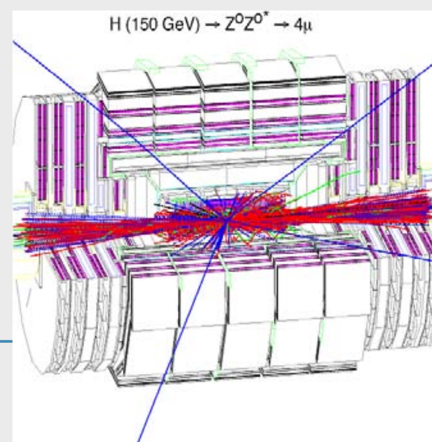




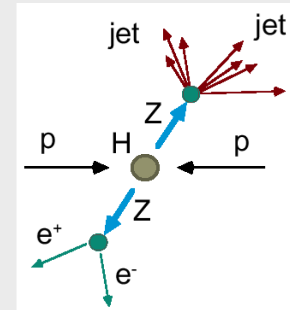
Medium $130 < M_H < 500$ GeV/c^2

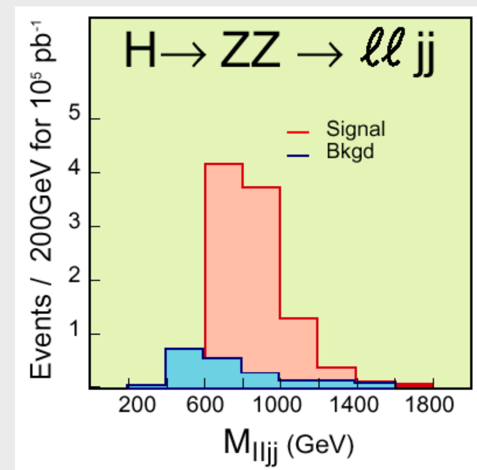


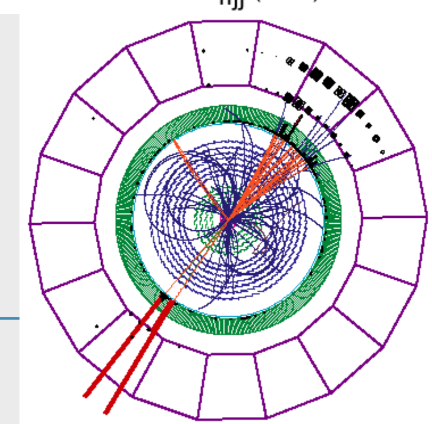




High $M_H > \sim 500$ GeV/c^2



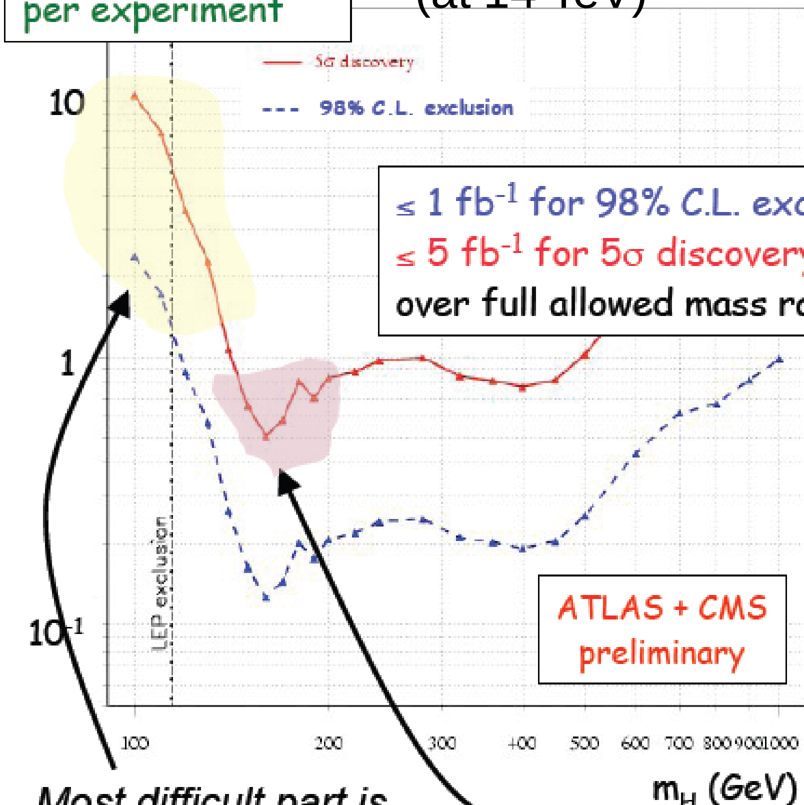




SM Higgs Reach

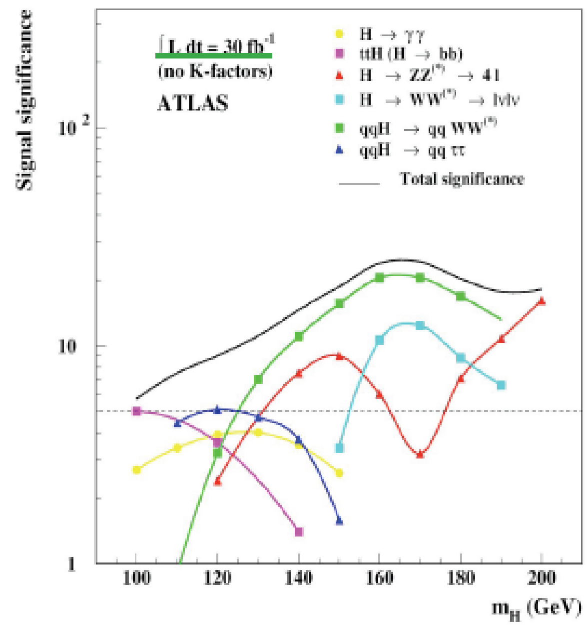
Needed ∫Ldt (fb^{-1})
per experiment

(at 14 TeV)



Most difficult part is M_h~115 GeV

Early discovery already Possible with $1fb^{-1}$ $H \to WW^{(*)} \to 2l$



With $1fb^{-1}$ of understood data:

- *potential to exclude almost all m_h values*
- *potential to discover higgs with m_h~165 GeV*

LHC will give us an answer!

25/07/2007 HEP 2007 C

55

but it will take time. . .

In conclusion (G.Altarelli, LP09)

Is it possible that the LHC does not find the Higgs particle?

Yes, it is possible, but then must find something else

Is it possible that the LHC finds the Higgs particle but no other new physics (pure and simple SM)?

Yes, it is technically possible but it is not natural

Is it possible that the LHC finds neither the Higgs nor new physics?

⊕

Dark Matter

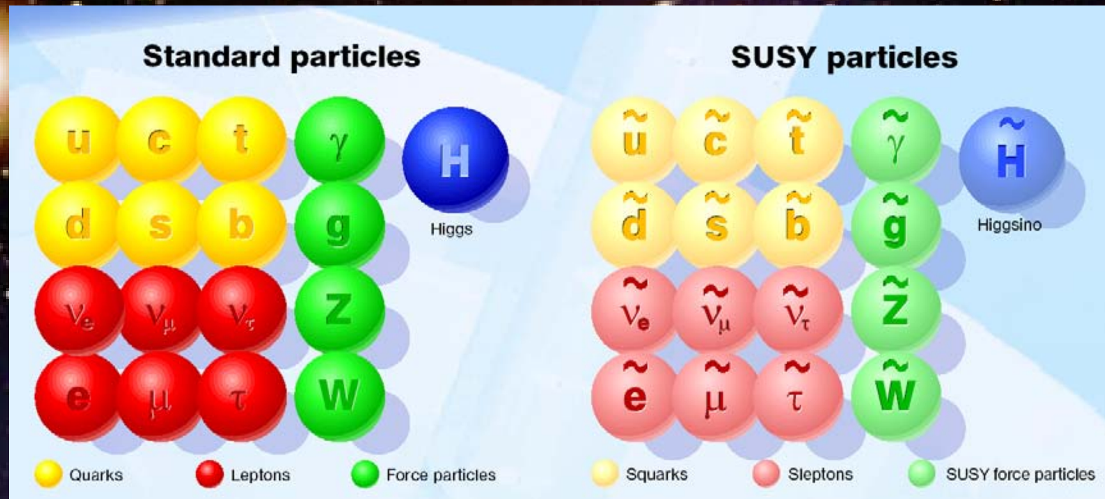
Astronomers & astrophysicists over the next two decades using powerful new telescopes will tell us how dark matter has shaped the stars and galaxies we see in the night sky.

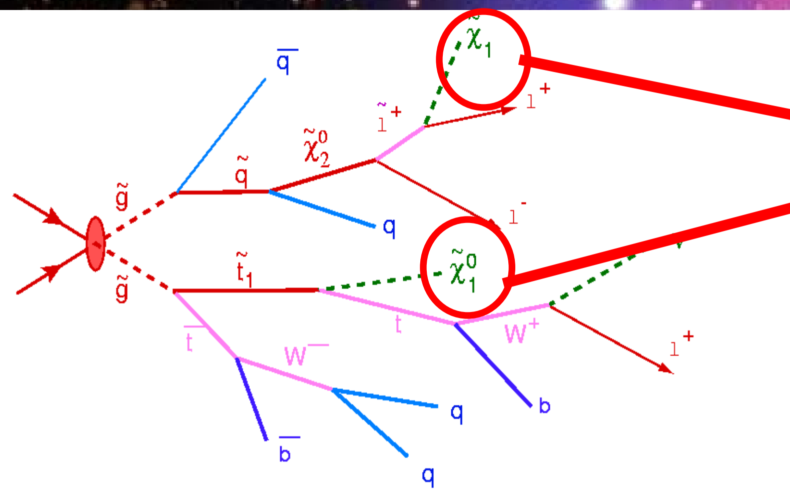
Only particle accelerators can produce dark matter in the laboratory and understand exactly what it is.

Composed of a single kind of particle
or
more rich and varied (as the visible world)?

LHC may be the perfect machine to study dark matter.

Supersymmetry: A New Symmetry in Nature

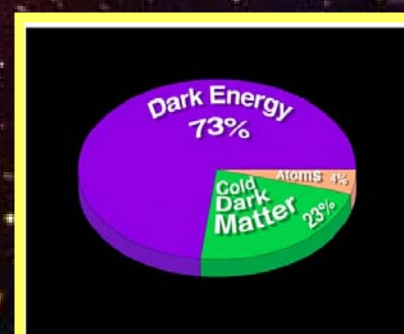




3 isolated leptons
+ 2 b-jets
+ 4 jets
+ E_t^{miss}

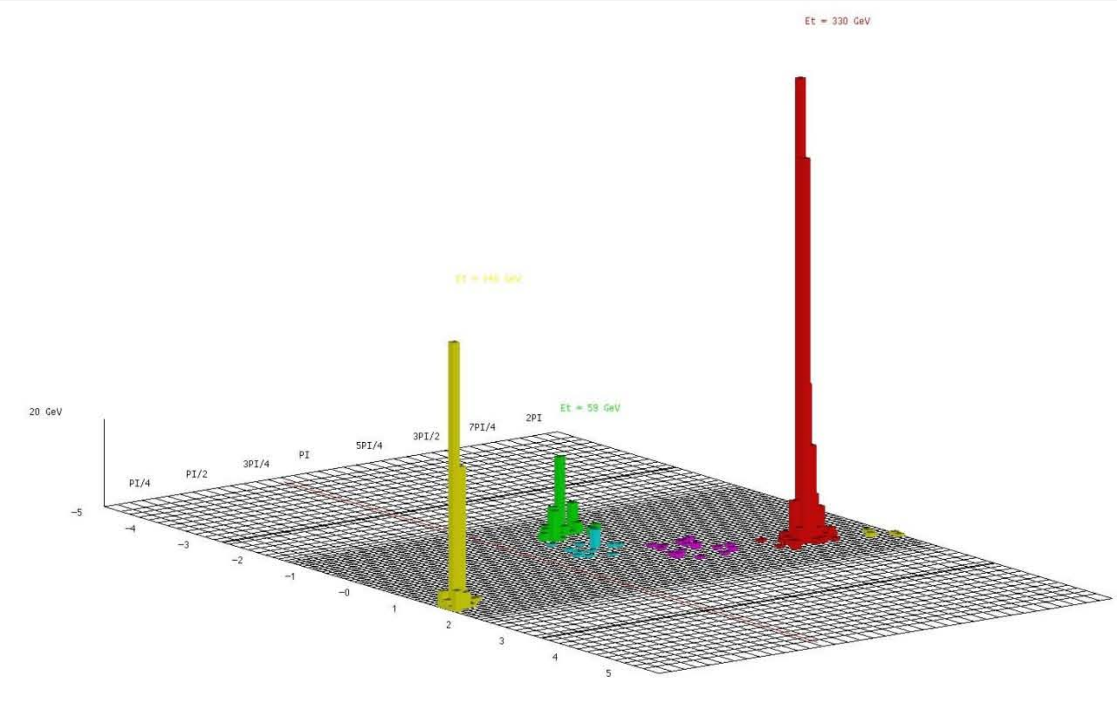
Candidate Particles for Dark Matter
⇒ Produce Dark Matter in the lab

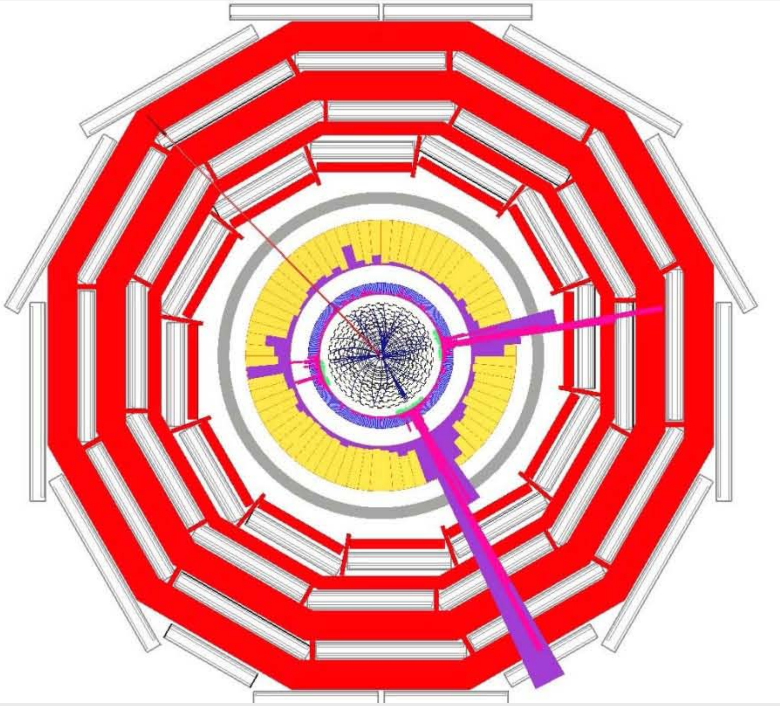
SUSY particle production at the LHC



n Marusa Bradac

Looking for Dark Matter



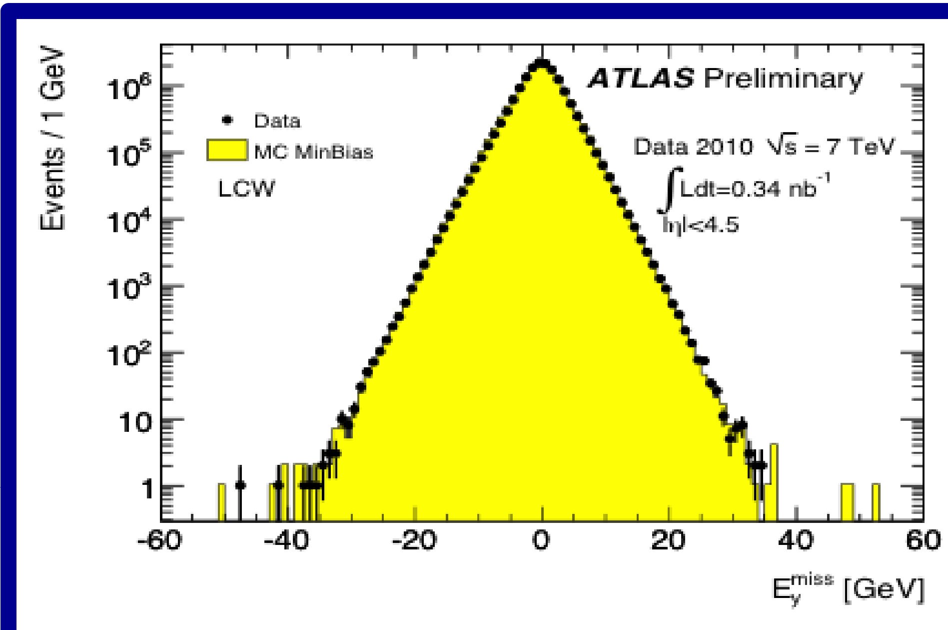


Missing energy
taken away by dark matter particles

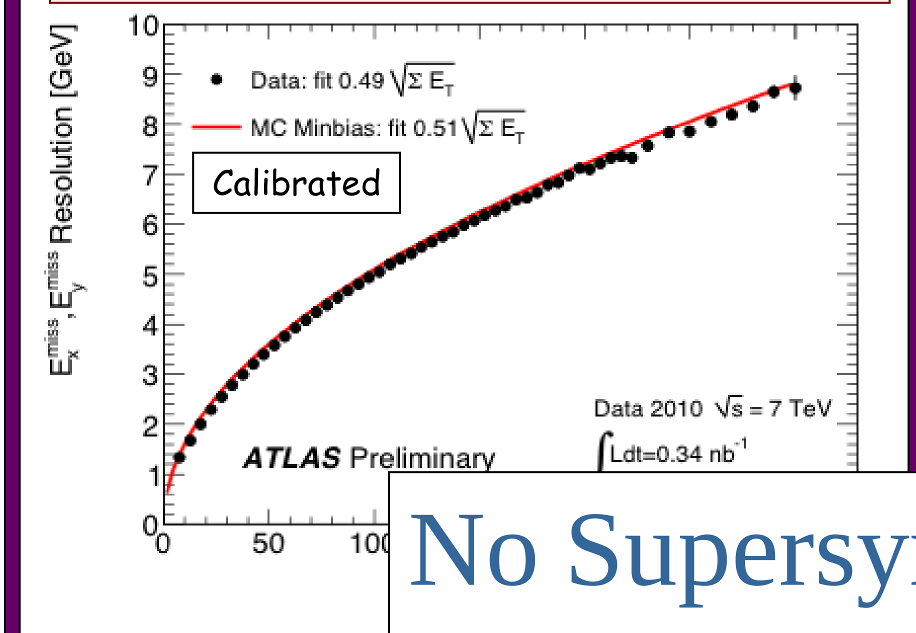
Missing transverse energy in the calorimeters

Sensitive to calorimeter performance (noise, coherent noise, dead cells, mis-calibrations, cracks, etc.), and cosmics and beam-related backgrounds

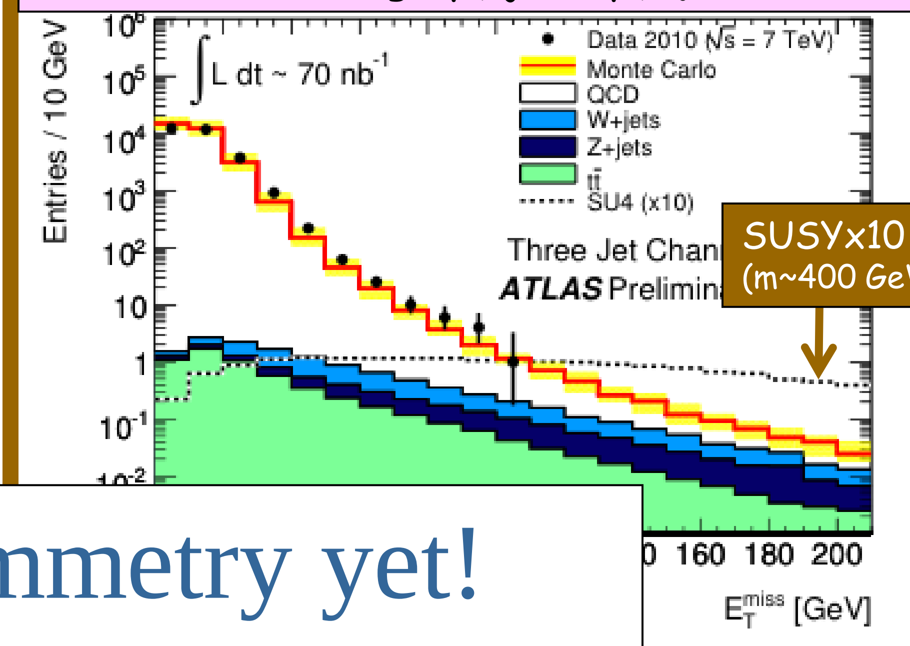
Calibrated E_T^{miss} from minimum-bias events



Measured over ~ full calorimeter coverage (360⁰ in φ, |η| < 4.5, ~ 200k cells)



E_T^{miss} spectrum from SUSY searches: events with ≥ 3 high-p_T jets, p_T (j1) > 70 GeV



No Supersymmetry yet!

LHC@7TeV: New Physics Reach

New Physics : approximate LHC reach (one experiment) for some benchmark scenarios ($\sqrt{s}$ = 7 TeV, unless otherwise stated)

Z′ (SSM): Tevatron limit ~ 1 TeV (95% C.L)

$50\ pb^{-1}$: exclusion up to ~ 1 TeV (95% C.L.)
$500\ pb^{-1}$: discovery up to ~ 1.3 TeV
exclusion up to ~ 1.5 TeV
$1\ fb^{-1}$: discovery up to ~ 1.5 TeV

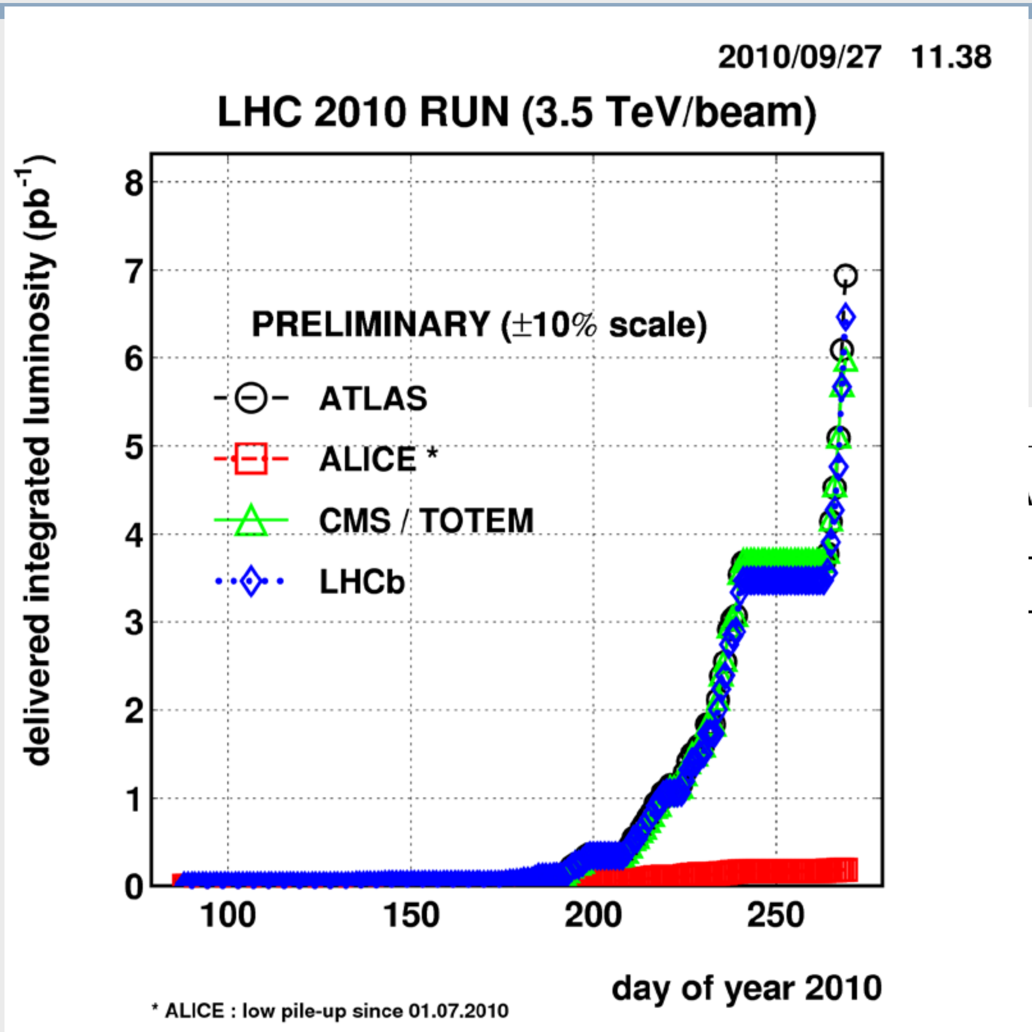
W′ : Tevatron limit ~ 1 TeV (95% C.L)

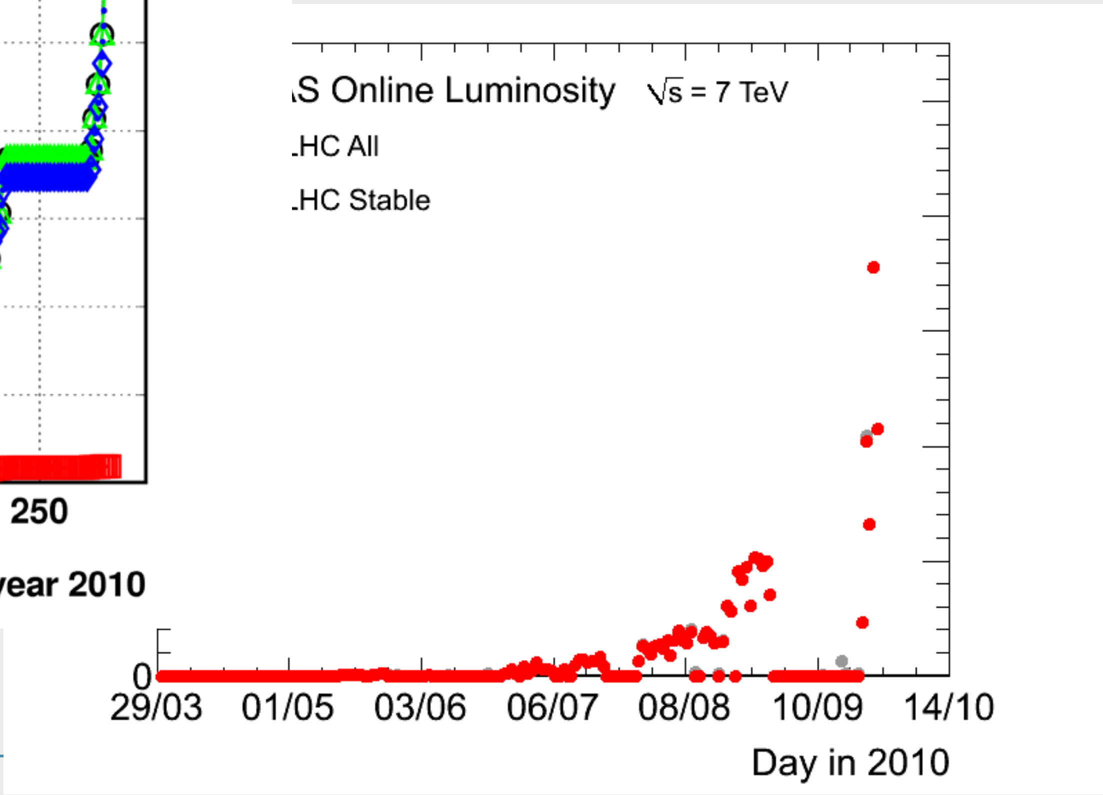
$10\ pb^{-1}$: exclusion up to 1 TeV
$100\ pb^{-1}$: discovery up to ~ 1.3 TeV
$1\ fb^{-1}$: discovery up to ~ 1.9 TeV
exclusion up to ~ 2.2 TeV

SUSY $(\tilde{q},\tilde{g})$: Tevatron limit ~ 400 GeV (95% C.L)

$100\ pb^{-1}$: discovery up to ~ 400 GeV
$1\ fb^{-1}$: discovery up to ~ 800 GeV

Development of luminosity March 30 until today





LHC Strategy (I)

Full exploitation of the LHC physics potential
→ maximize integrated luminosity useful for physics

- Longer running periods (~ two years)
- Longer shutdowns in between, coordinated activities between experiments and experiments/machine

- Physics Run 2010/11 @ 7 TeV
- decide about slightly higher energy later in the run

- Shutdown 2012 to prepare LHC towards 14 TeV (copper stabilizer consolidation, He-release valves, . . .)

- Physics Run 2013/14 @ ~ 14 TeV

2010-2013: Decisive Years

- Experimental data will take the floor to drive the field to the next steps:

- LHC results
- Θ_{13} (T2K, DChooz, etc..)
- υ masses (Cuore, Gerda, Nemo…)
- Dark Matter searches
- …….

LHC Strategy (II)

Full exploitation of the LHC physics potential
→ maximize integrated luminosity useful for physics

- LHC operation until around 2030, aim at $\int L dt \approx 3000$/fb

- Between 2010 and ~2020: ~design luminosity (~$10^{34}/cm^2/s$)
  connection of LINAC4 earliest 2015
  detector modifications to optimize data collection

- High Luminosity LHC (HL-LHC) from ~2020 to ~2030
  luminosity around $5 \times 10^{34}/cm^2/s$, luminosity leveling
  new Inner Triplet around 2020 (combine both phases)
  detector upgrades around 2020 → R&D NOW

Next decades

Road beyond Standard Model

through synergy of

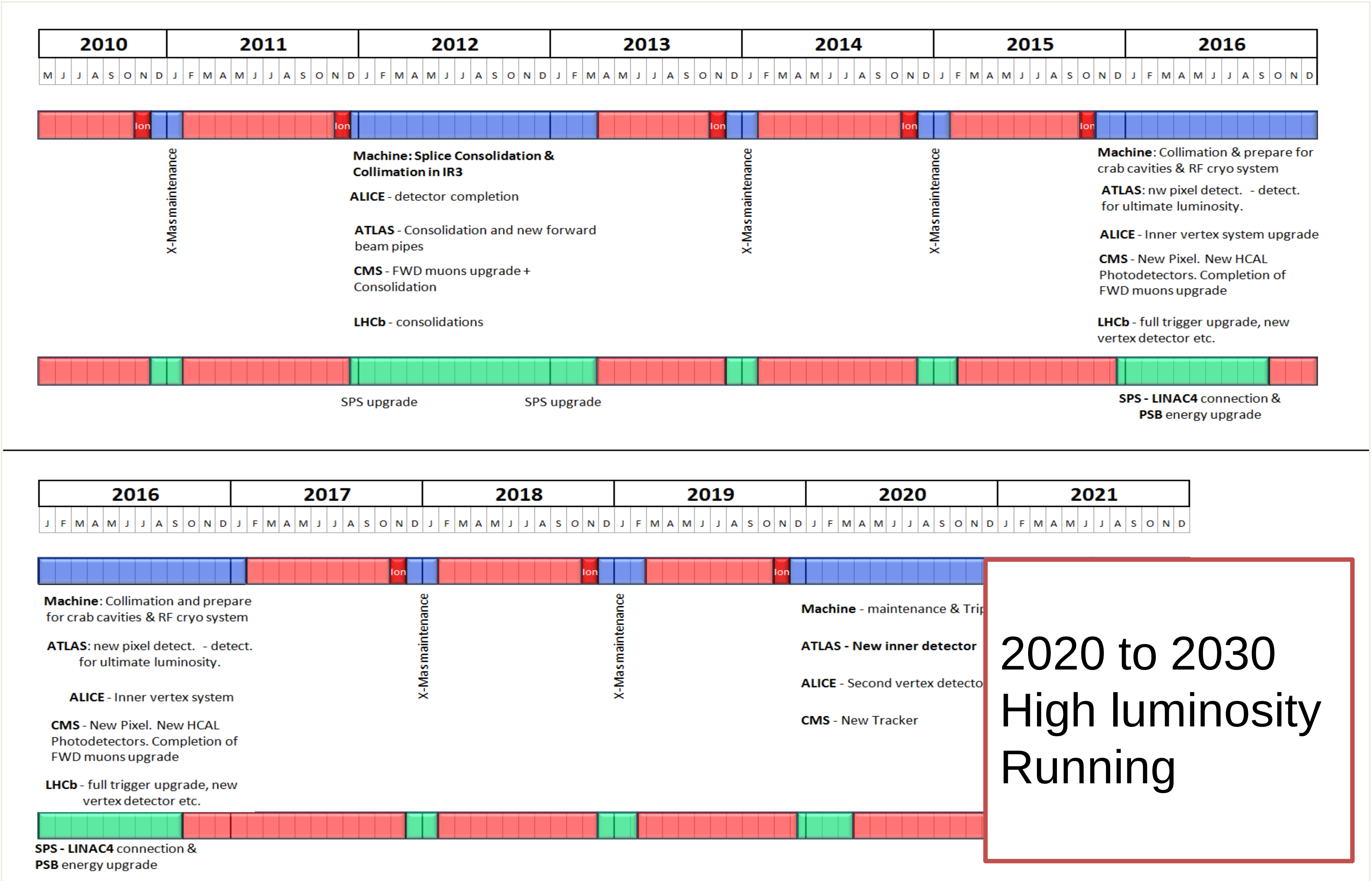
hadron - hadro… (LHC, HL/HE-LHC?)

l… …adron colliders (LHeC ??)

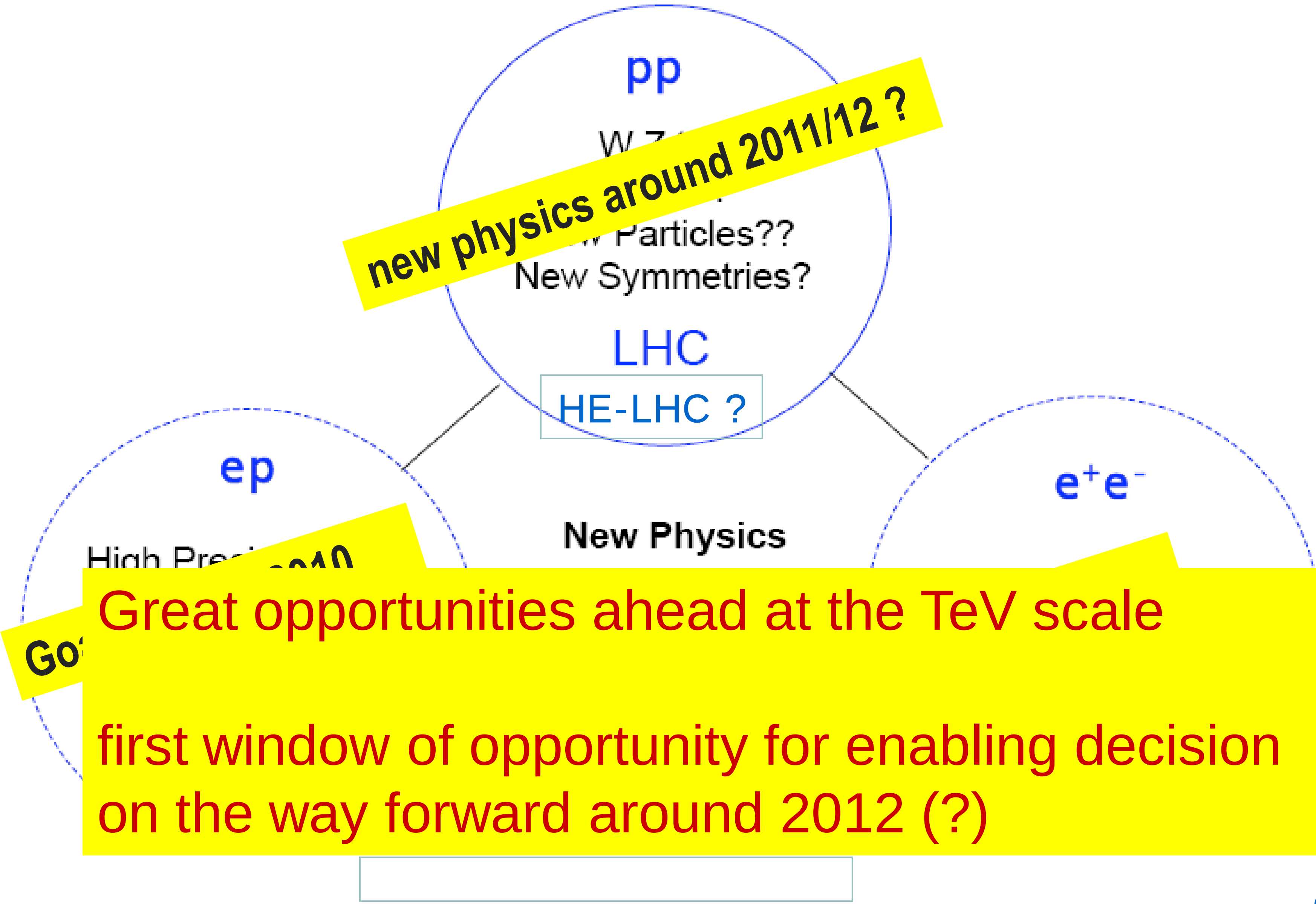
lepton - lepton colliders (LC ?)

LHC results will guide the way at the energy frontier

LHC 10 year technical Plan



The TeV Scale (far) beyond 2010



Great opportunities ahead at the TeV scale

first window of opportunity for enabling decision on the way forward around 2012 (?)

Results from LHC will Guide the Way

Expect

- period for decision enabling on next steps earliest 2012 (at least) concerning energy frontier
- (similar situation concerning neutrino sector Θ_{13})

We are NOW in a new exciting era of accelerator planning-design-construction-running

and need

- intensified efforts on R&D and technical design work to enable these decisions
- global collaboration and stability on long time scales (don‘t forget: first workshop on LHC was 1984)

Opening the door…

- Council opened the door to greater integration in particle physics when it recently unanimously adopted the recommendations to examine the role of CERN in the light of increasing globalization in particle physics.
  - *Particle physics is becoming increasingly integrated at the global level.*
  - *Council's decision contributes to creating the conditions that will enable CERN to play a full role in any future facility wherever in the world it might be.*

- The key points agreed by Council include:
  - *All states shall be eligible for Membership, irrespective of their geographical location;*
  - *A new Associate Membership status is to be introduced to allow non-Member States to establish or intensify their institutional links with CERN;*
  - *Associate Membership shall also serve as the obligatory pre-stage to Membership.*

- Applications for Membership from Cyprus, Israel, Serbia, Slovenia and Turkey have already been received by the CERN Council, and are undergoing technical verification.

We need to define the most appropriate organizational form NOW and need to be open and inventive
(scientists, funding agencies, politicians. . .)

Mandatory to have accelerator laboratories in all regions as partners in accelerator development / construction / commissiong / exploitation

Planning and execution of HEP projects today need global partnership for *global, regional and national* projects
in other words: for the whole program

Use the exciting times ahead to establish such a partnership

Particle Physics can and should play its role as

spearhead in innovations as in the past

now and in future