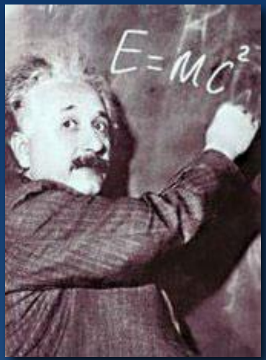
CERN and High Energy Physics

The Grand Picture

Rolf-Dieter Heuer
Director-General
LPCC
22 June 2010

Innovation
Education
CERN
uniting people
Research

The Mission of CERN



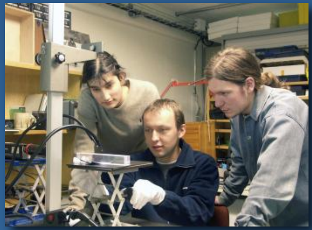
- Push back the frontiers of knowledge

  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

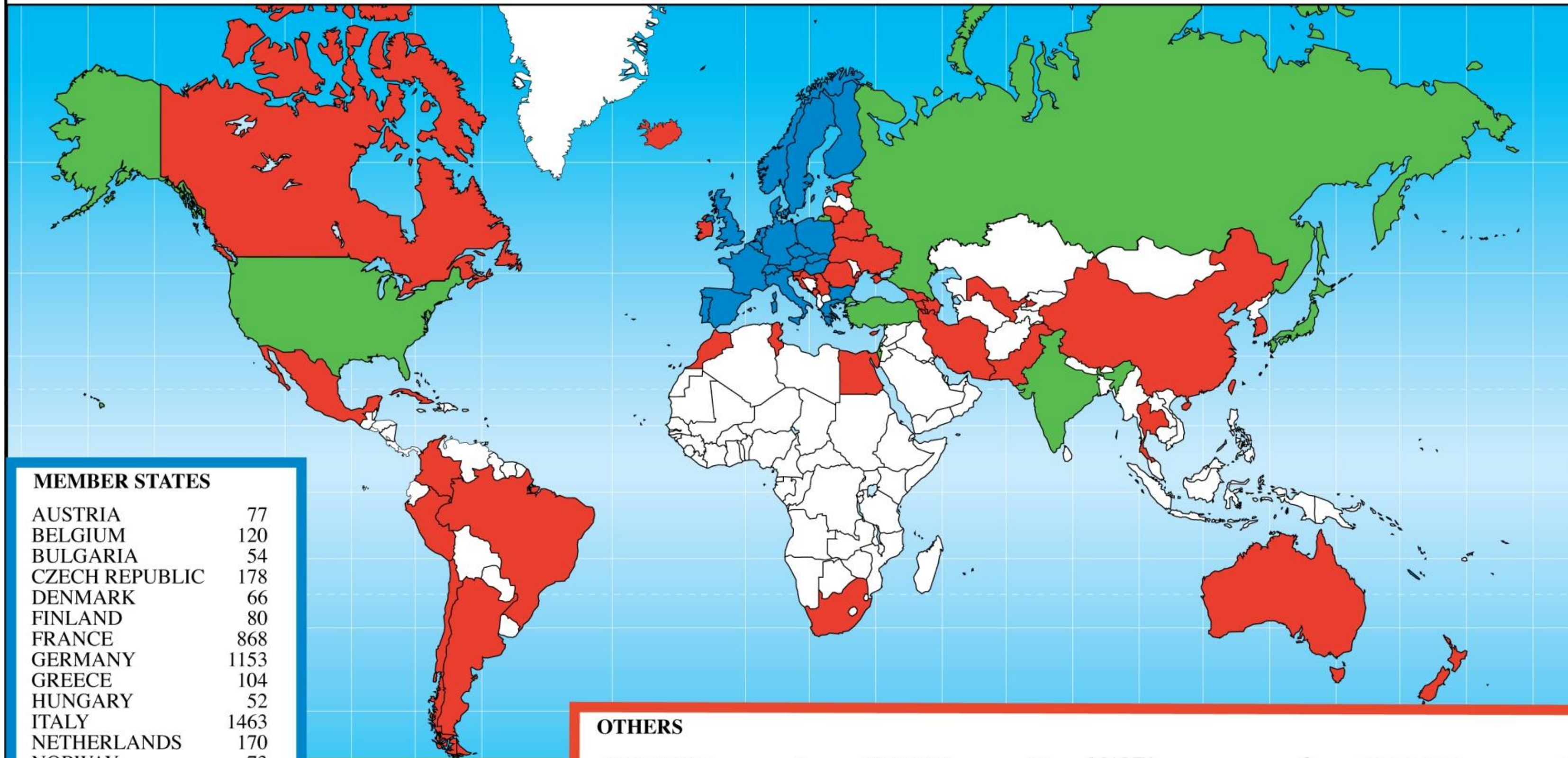
CERN was founded 1954: 12 European States
Today: 20 Member States

- ~ 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.
- 1 Candidate for Accession to Membership of CERN: Romania
- 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

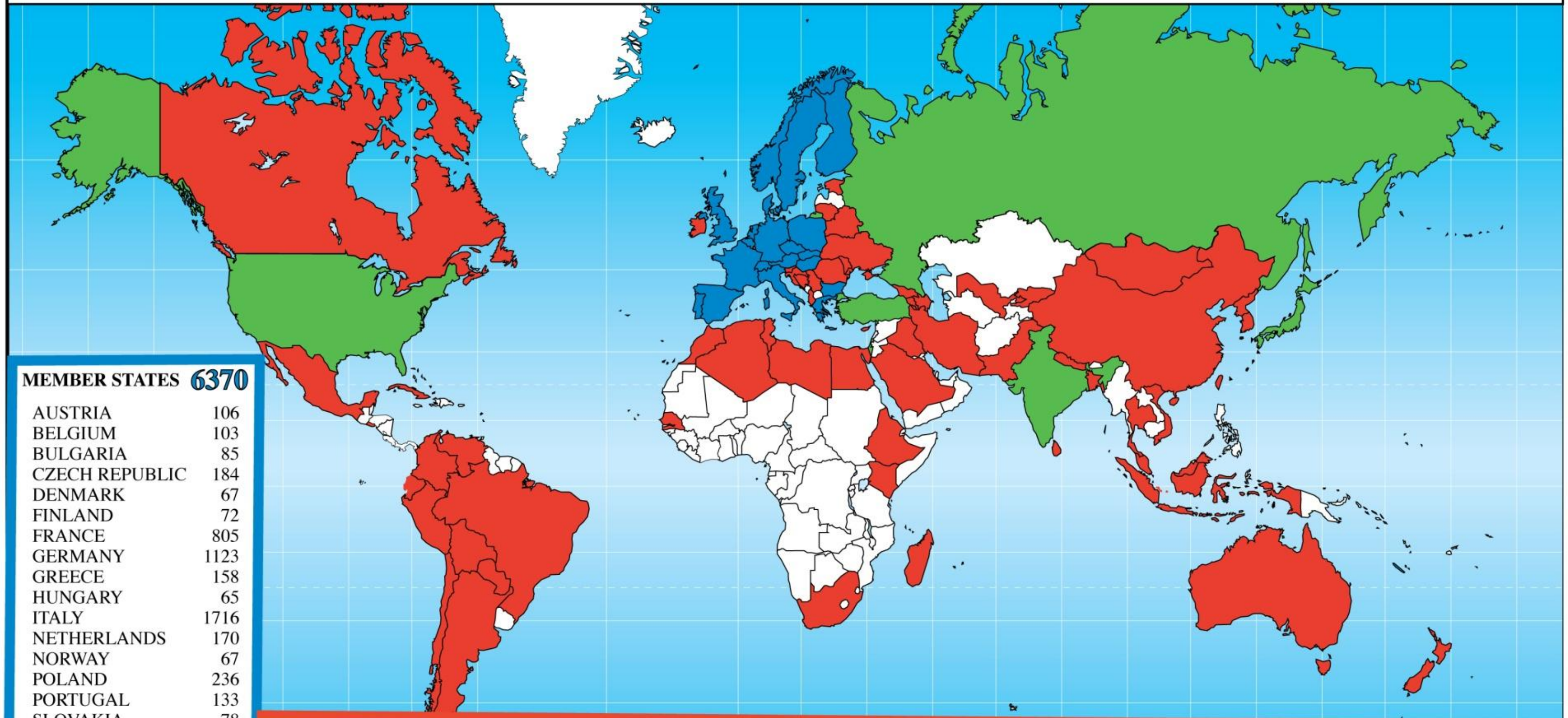
OTHERS

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

762

CERN in Numbers

Distribution of All CERN Users by Nationality on 20 January 2010



MEMBER STATES 6370

AUSTRIA	106
BELGIUM	103
BULGARIA	85
CZECH REPUBLIC	184
DENMARK	67
FINLAND	72
FRANCE	805
GERMANY	1123
GREECE	158
HUNGARY	65
ITALY	1716
NETHERLANDS	170
NORWAY	67
POLAND	236
PORTUGAL	133
SLOVAKIA	78
SPAIN	330
SWEDEN	67
SWITZERLAND	200
UNITED KINGDOM	605

OBSERVER STATES 2444

INDIA	158
ISRAEL	51
JAPAN	229
RUSSIA	1027
TURKEY	87
USA	892

OTHERS 1205

ALBANIA	2
ALGERIA	8
ARGENTINA	11
ARMENIA	24
AUSTRALIA	20
AZERBAIJAN	5
BANGLADESH	3
BELARUS	36
BOLIVIA	2
BOSNIA AND HERZEGOVINA	1
BRAZIL	79
CANADA	136
CHILE	3
CHINA	202
CHINA (TAIPEI)	41
COLOMBIA	19
CROATIA	24
CUBA	4
CYPRUS	12
ECUADOR	2
EGYPT	6
EL SALVADOR	1
ESTONIA	9
ETHIOPIA	1
GEORGIA	31
GIBRALTAR	1
HONG KONG	2
INDONESIA	1
IRAN	20
IRAQ	1
IRELAND	20
KENYA	2
KOREA, D.P.R.	3
KOREA REP.	85
KYRGYZSTAN	1
LEBANON	8
LITHUANIA	9
LUXEMBOURG	5
LIBYA	1
MADAGASCAR	3
MALAYSIA	7
MALTA	3
MAURITIUS	1
MEXICO	46
MOLDOVA	1
MONGOLIA	1
MOROCCO	16
NEPAL	3
NEW ZEALAND	10
PAKISTAN	33
PALESTINE (O.T.).	1
PARAGUAY	1
PERU	2
ROMANIA	101
SAN MARINO	1
SAUDI ARABIA	2
SENEGAL	1
SERBIA	34
SINGAPORE	1
SLOVENIA	20
SOUTH AFRICA	9
SRI LANKA	6
SYRIA	2
THAILAND	1
TUNISIA	5
UKRAINE	40
UZBEKISTAN	2
VENEZUELA	5
VIET NAM	6

CERN Governance - Council

- Council governs the CERN Geneva Laboratory by defining its strategic programmes, setting and following up its annual goals, approving its budget and appointing its Management; the Laboratory is led by the Director-General who in respect of the Laboratory under his direction is also the formal representative of the Organization.
- Government representatives of the twenty CERN Member States meet regularly in the CERN Council. These meetings are conducted in accordance with an international treaty, the CERN Convention.
- The Convention bestows upon the Organization two missions, namely the operation of laboratories and the organisation and sponsoring of international co-operation in the field.
  - The first mission relates to the governance of the CERN Laboratory in Geneva, which is also the seat of the Organization.
  - The second of the missions has been actively addressed since the adoption of the "European Strategy for Particle Physics" in July 2006. Dedicated "European Strategy Sessions" are held for this purpose.

CERN Governance - FC

- In accordance with the CERN Convention, the CERN Council set up a Finance Committee (FC), comprising delegates representing the Governments of the twenty CERN Member States, as a subordinate body to advise it on the execution and co-ordination of the different programmes of the Organization.
- The Finance Committee meets to address budgetary, procedural, personnel and commercial matters.
- For personnel issues, Finance Committee relies on the advice of TREF, the Tripartite Employment Conditions Forum, where the Staff Association, the Management and the Member States discuss proposals and measures relating to the Organization’s social and employment conditions.
- The Finance Committee adjudicates procurement and service contracts. A Working Group is about to complete a "Review of Purchasing Policy and Procedures" with aim of producing rules and regulations that are practical and enforceable and that will benefit the Organization and all the Member States.

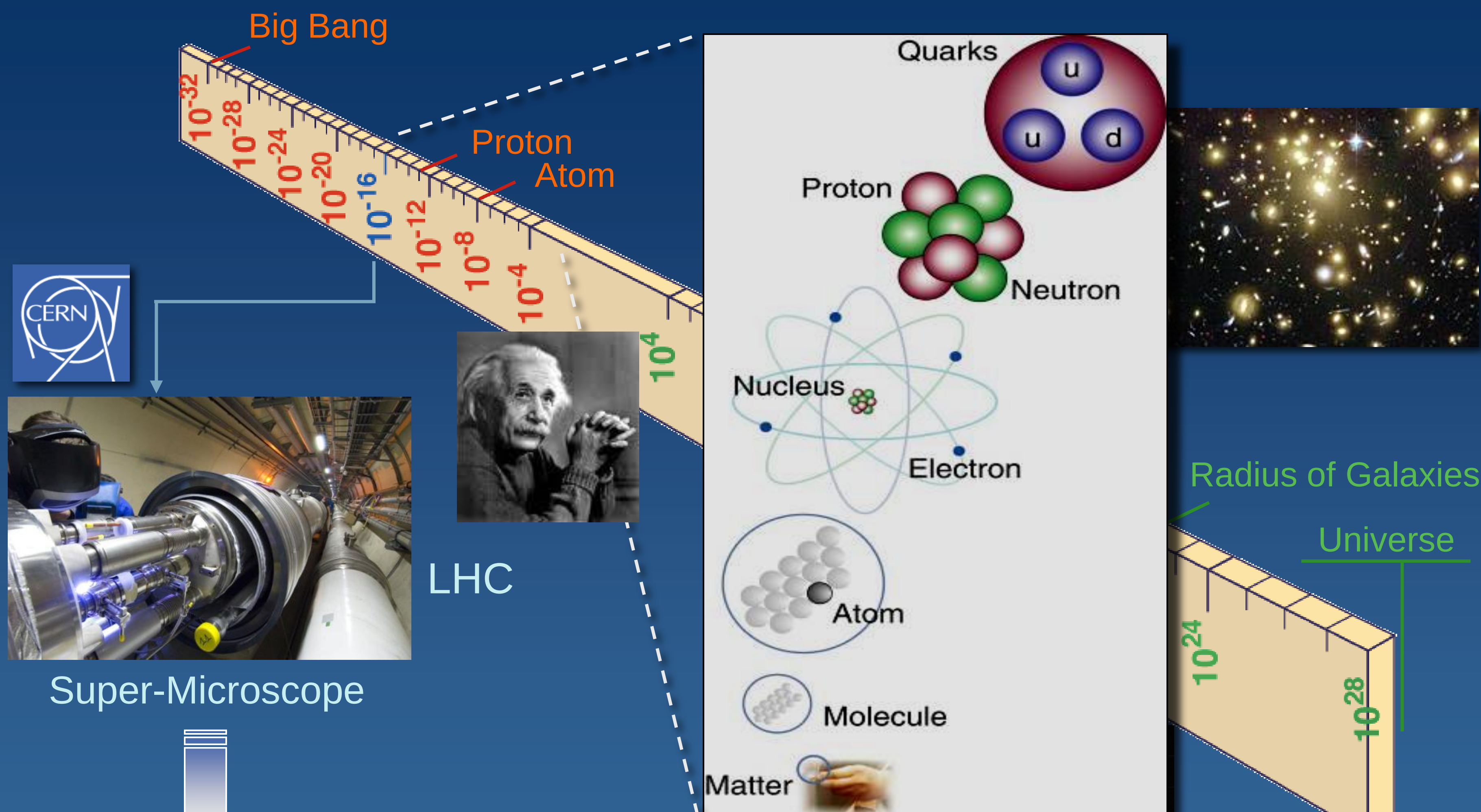
CERN Governance - SPC

- The Scientific Policy Committee (SPC) is one of two subsidiary bodies to the CERN Council established by the Convention. It was created by Council at its first meeting in 1954, and included some of the most distinguished European physicists at the time, four of its eight members being Nobel Laureates and another member awarded that distinction later in his career.

- The task of the SPC is to generally advise Council on scientific matters related to the Organization, namely
  - to make recommendations to the Council on the priorities of research programmes and the allocation of research effort both within the Laboratories of the Organization and extramurally;
  - to examine and make recommendations to the Council on the annual goals of the various scientific activities of the Organization;
  - to annually assess the achievements of the Organization with regard to the past year annual goals of the various scientific activities;
  - to advise the Council from the point of view of scientific policy on the management and staffing of the Organization, including the visitors programme and the nomination of senior staff;
  - to advise the Council on any other matters which affect the scientific activities of the Organization.

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



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

Past few decades

“Discovery” of Standard Model

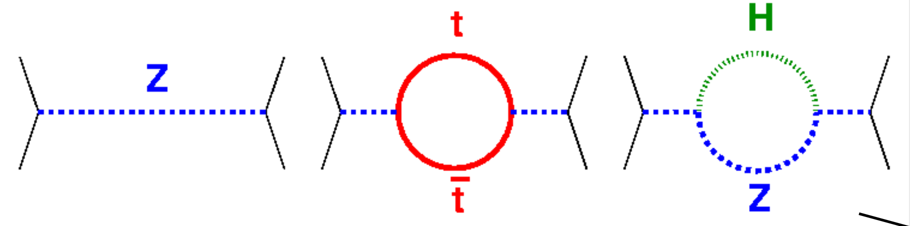
through synergy of

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

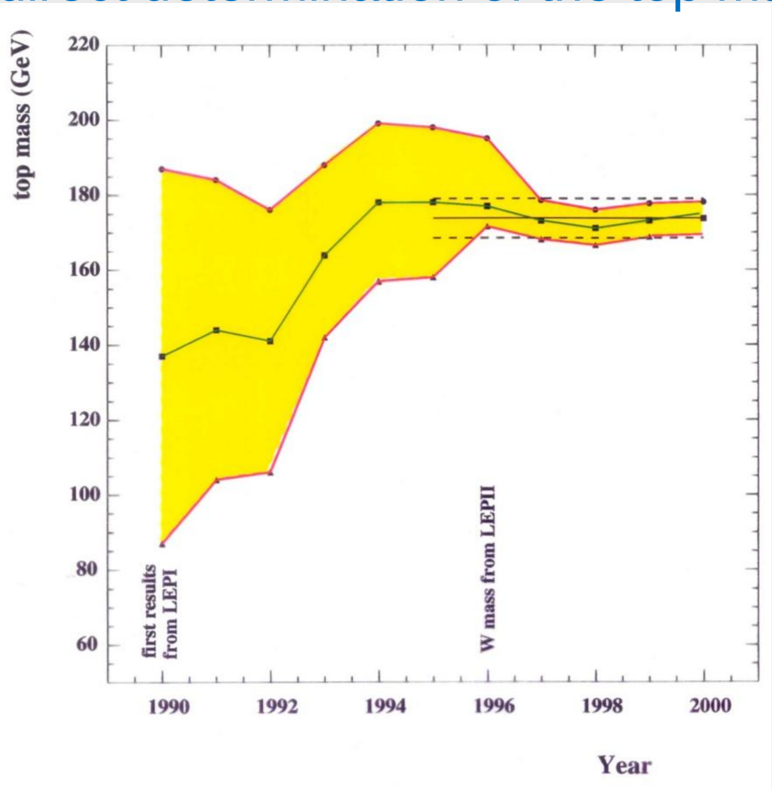
lepton - hadron colliders (HERA)

lepton - lepton colliders (e.g. LEP)

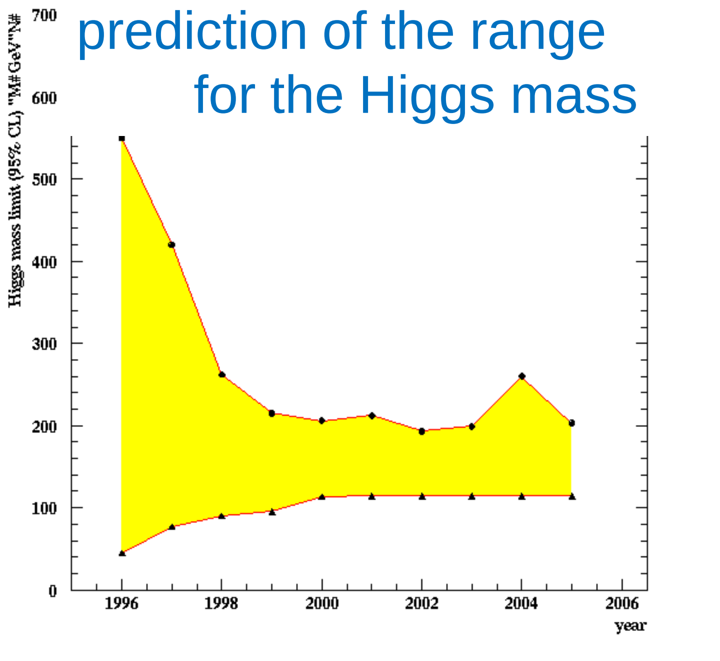
Test of the SM at the Level of Quantum Fluctuations



indirect determination of the top mass



prediction of the range for the Higgs mass



possible due to

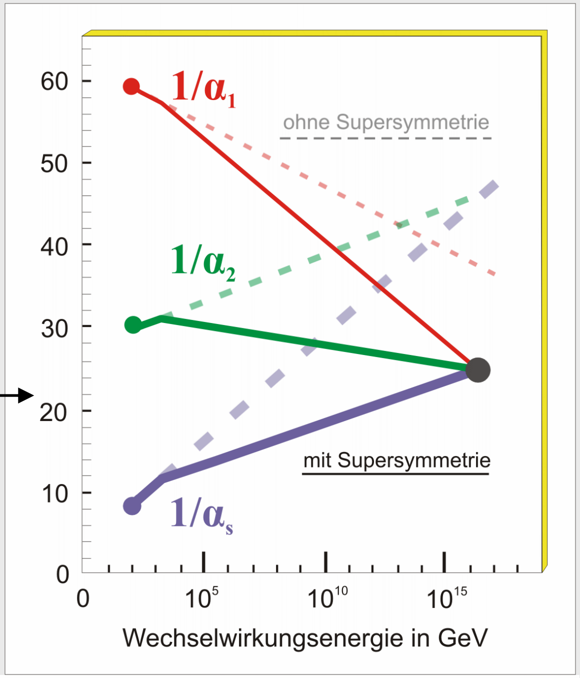
- precision measurements
- known higher order electroweak corrections

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

Key Questions of Particle Physics

origin of mass/matter or
origin of electroweak symmetry breaking

unification of forces



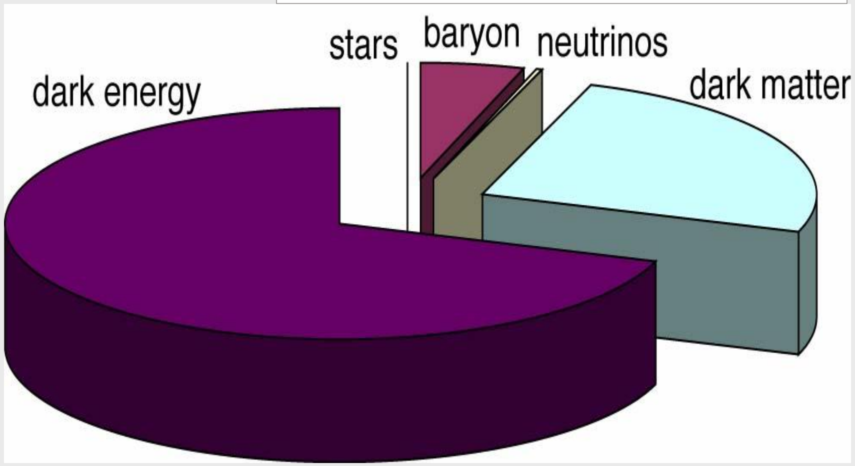
fundamental symmetry of forces and matter

unification of quantum physics and general relativity

number of space/time dimensions

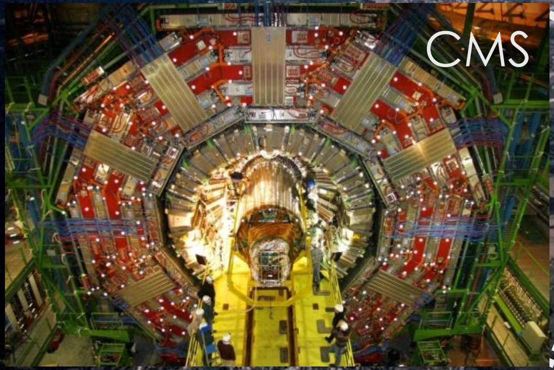
what is dark matter

what is dark energy

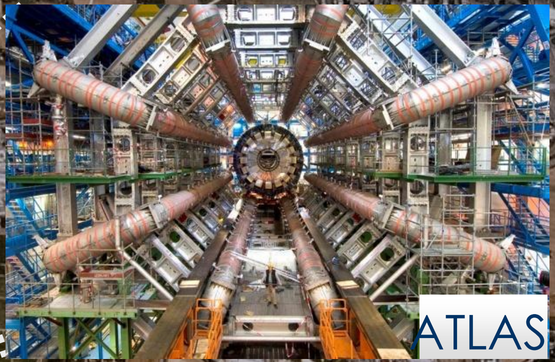


Enter a New Era in Fundamental Science

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.

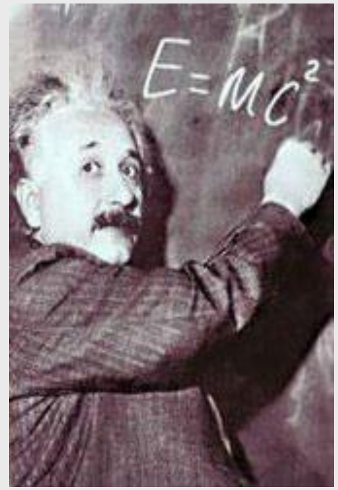


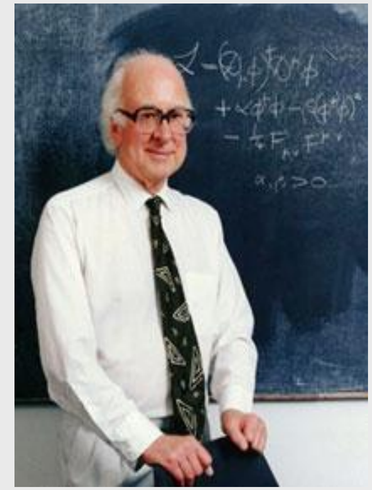
Exploration of a new energy frontier



The Science

We are poised 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?

LHC fills lecture halls because it…

- addresses fundamental science questions
- stimulates general interest
- fascinates and inspires
- stimulates fantasy
- increases knowledge
- educates
- trains scientists and engineers for tomorrow
- drives innovation and technology
- and, and, and

→ use this interest to promote our field and basic science in general

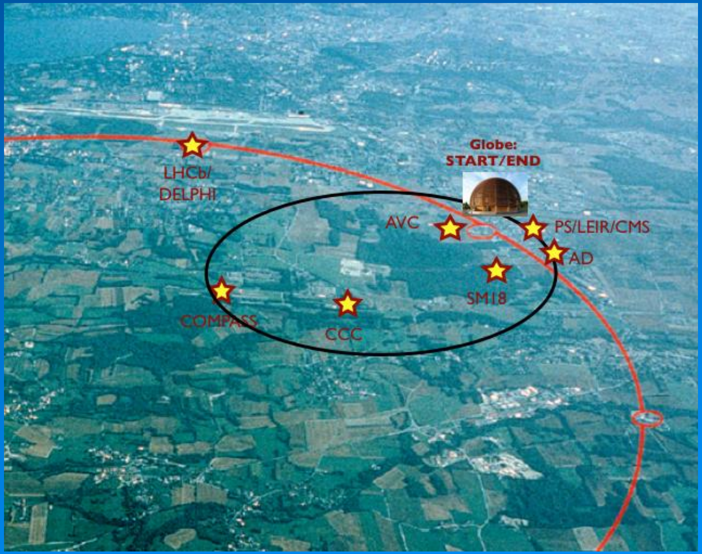
CERN

Visits Service: More guides are crucial!

Public interest is huge!

60,000+ visit requests per year
Only 35,000 visitors accepted (2009)

Main problem:
GUIDES ARE MISSING !



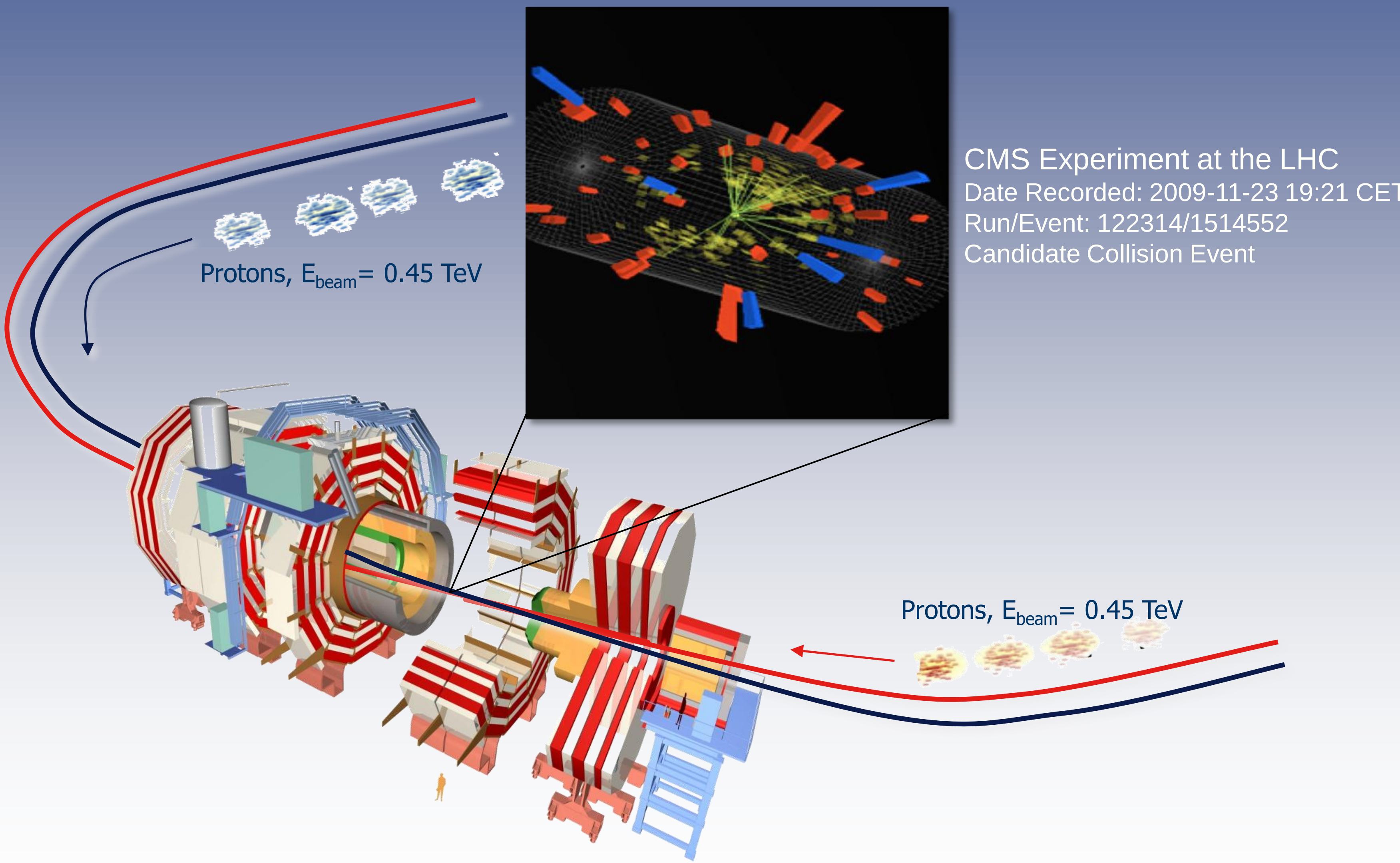
You can help by becoming a CERN guide

- About one day of training
- 1-2 guided tours per month

Universe of Particles – the new permanent CERN exhibition

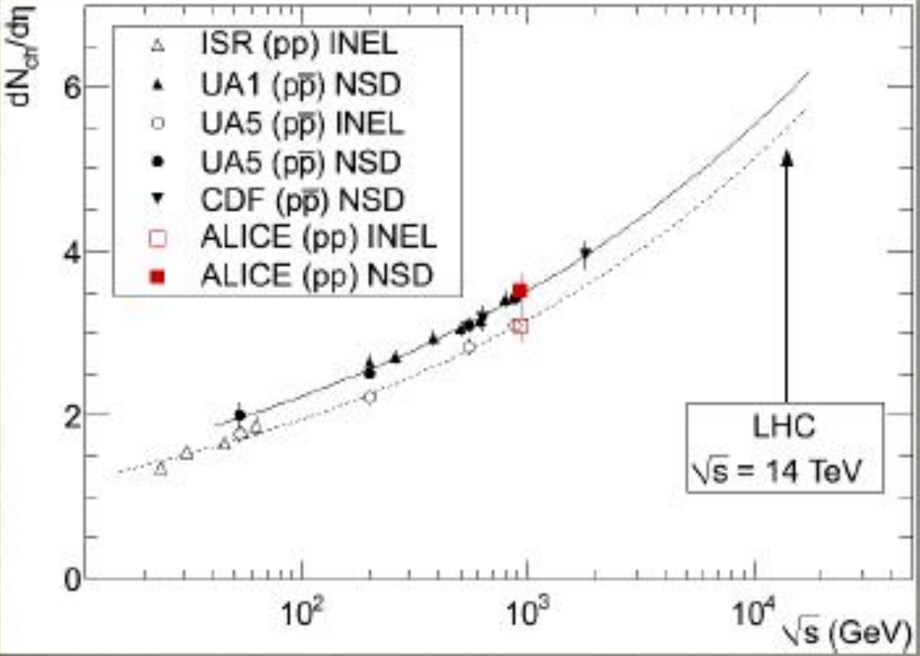
From 1 July 2010 - Immersive and interactive
Open daily (except Sunday) from 10:00-17:00
Start and end point of CERN visits
New exhibition will attract (even) more visitors
GUIDES ("EXPLAINERS") ARE NEEDED!

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

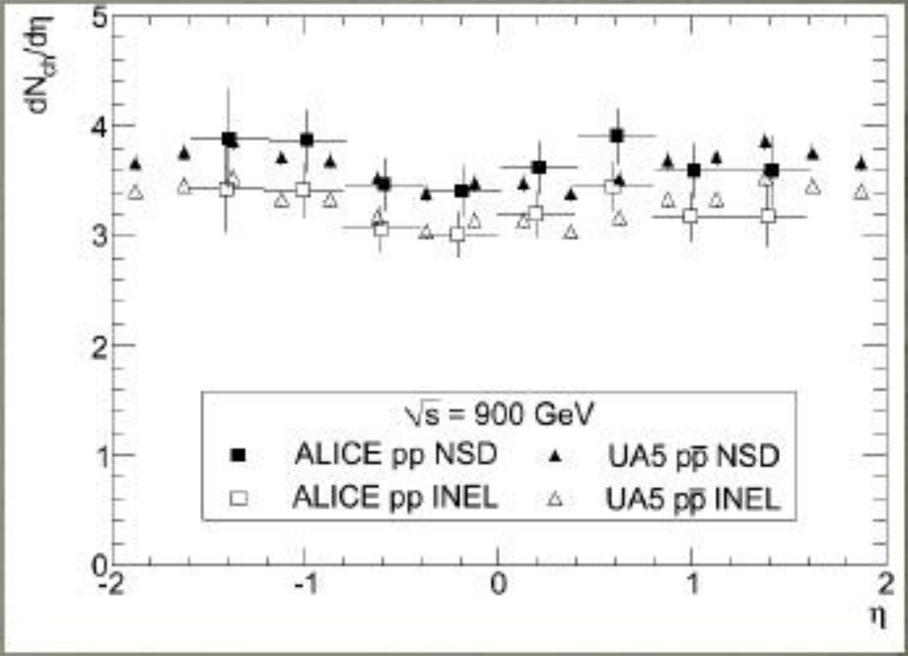


First paper (submitted 28/11)

- $dN_{ch}/d\eta$ for $|\eta| < 0.5$



- $dN_{ch}/d\eta$ vs η

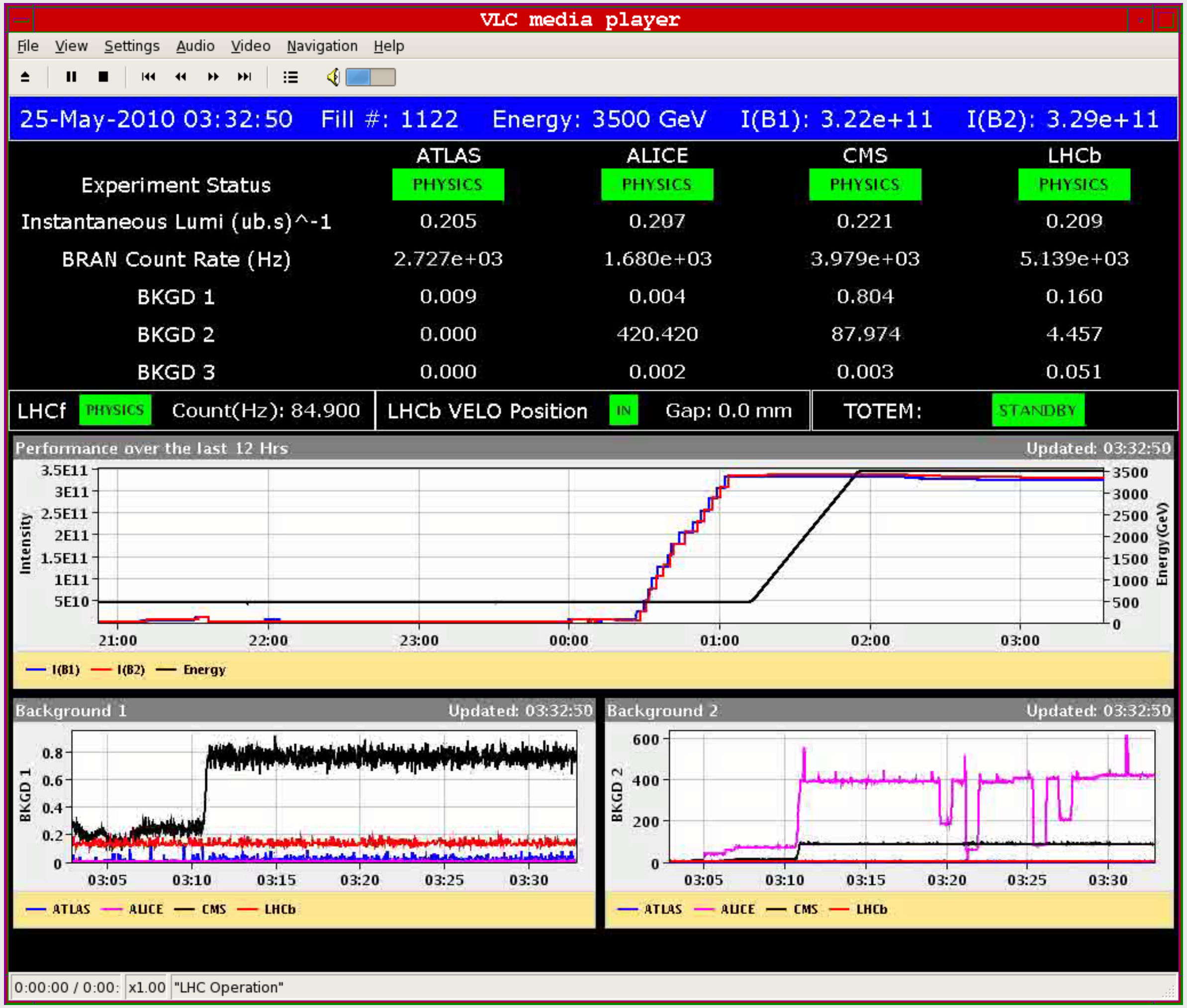


K. Aamodt et al. (ALICE), Eur. Phys. J C 65 (2010) 111

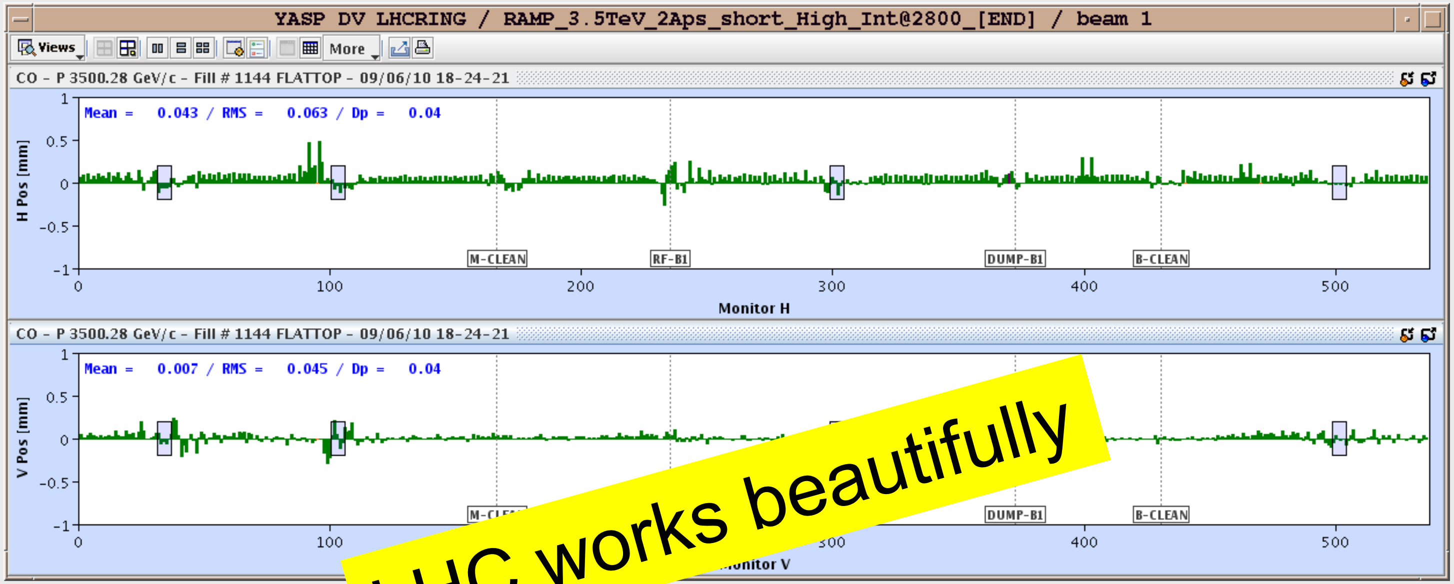
2010

- 30 March: first collisions at 3.5TeV/beam
- 19 April: order of magnitude increase in luminosity
  - doubling the number of particles/bunch
  - β * from 11 to 2m (4b/beam) L ~$2x10^{28}$.
  - Beam lifetimes of ~1000 hours
- 22 May another order of magnitude:
  - 13 bunches in each beam (L~ $3x10^{29}$)
- 26 May: Design intensity bunches were brought into collision at 3.5TeV/beam.

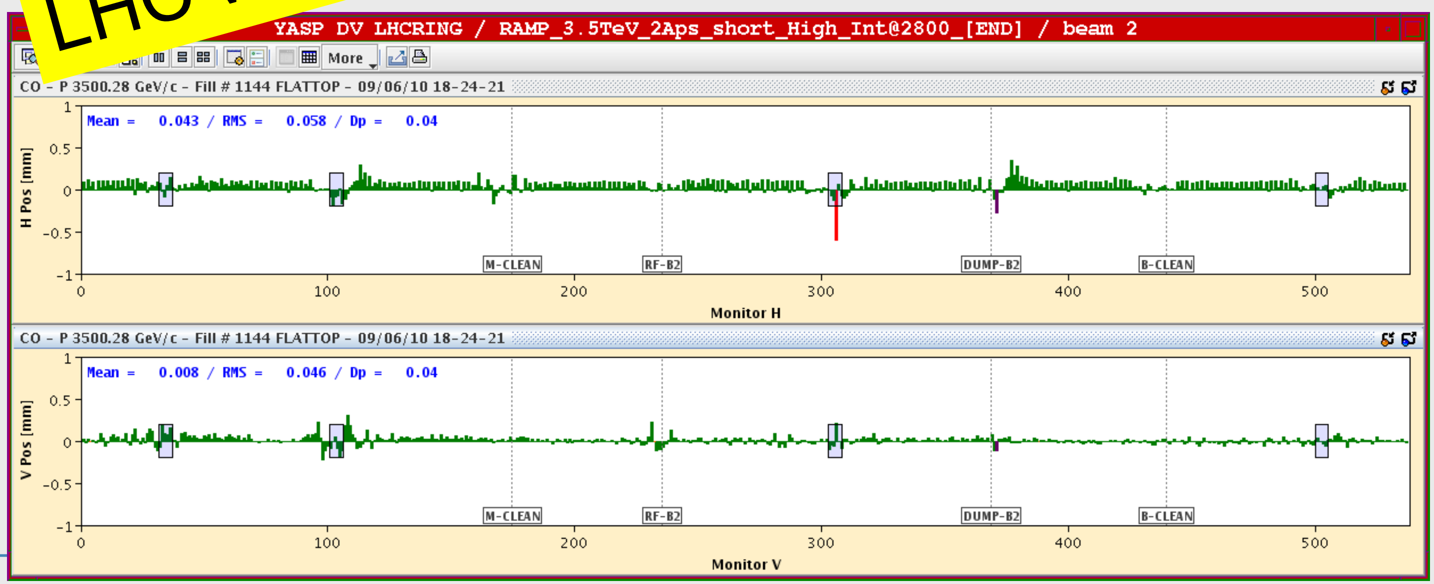
13 Bunches: $3x10^{29}$!!



Orbit on Flat Top After Correction



LHC works beautifully



Diff. wrt injection

40 to 60 micron rms

LHC @ 7 TeV: New Territory in Particle Physics

Run plan 2010-2011:

- 2010:

L = ~10^{27} –>10^{32} cm^{-2} s^{-1} –> total of 100-200 pb^{-1}

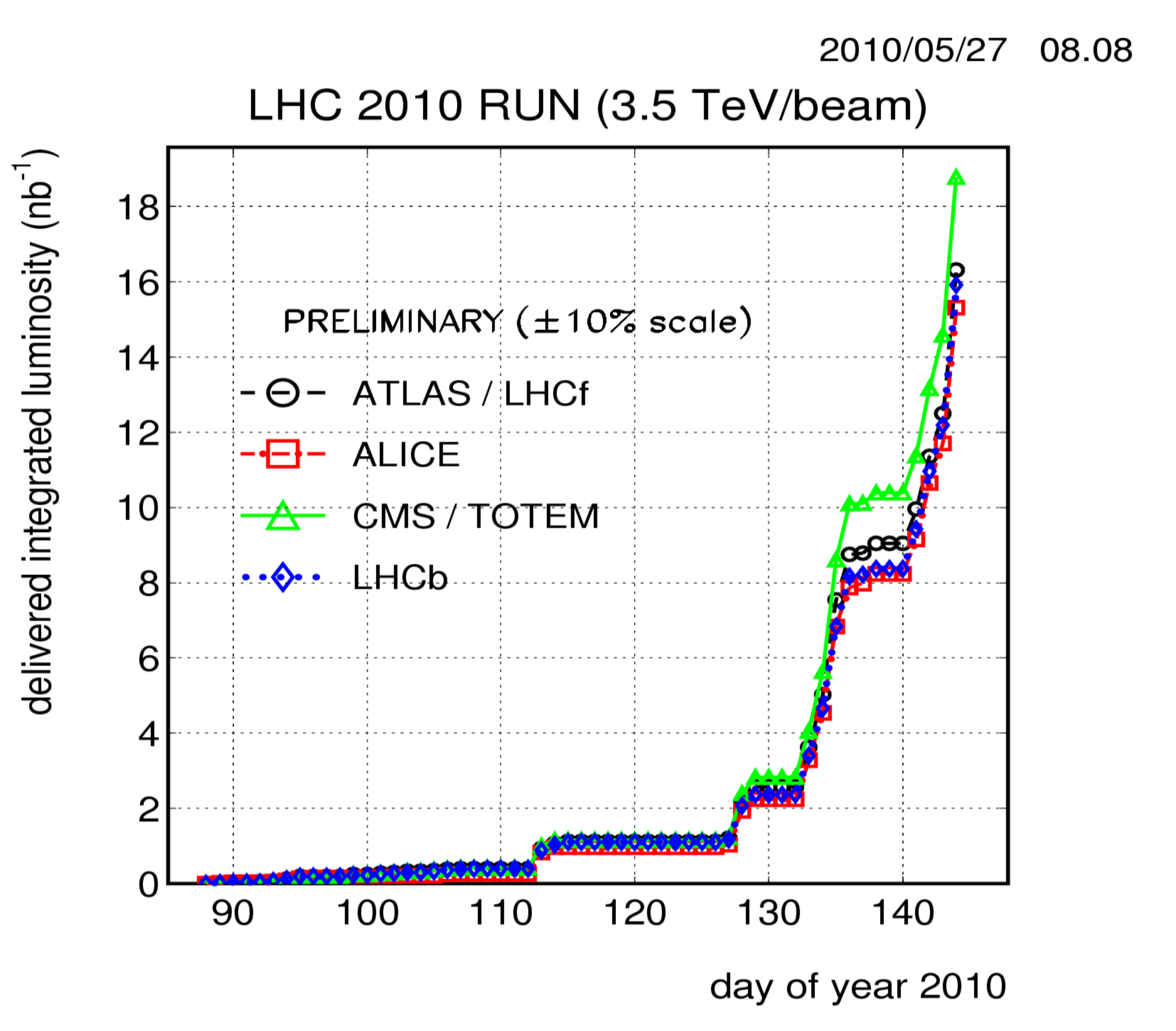
- 2011:

L = 1 –> few 10^{32} cm^{-2} s^{-1} –> collect ≥ 100 pb^{-1}/month

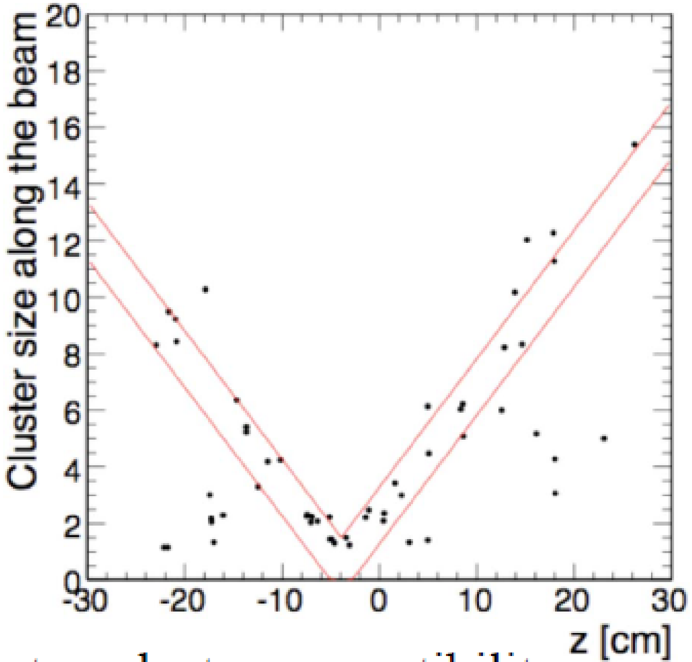
–> total of ~ 1 fb^{-1}

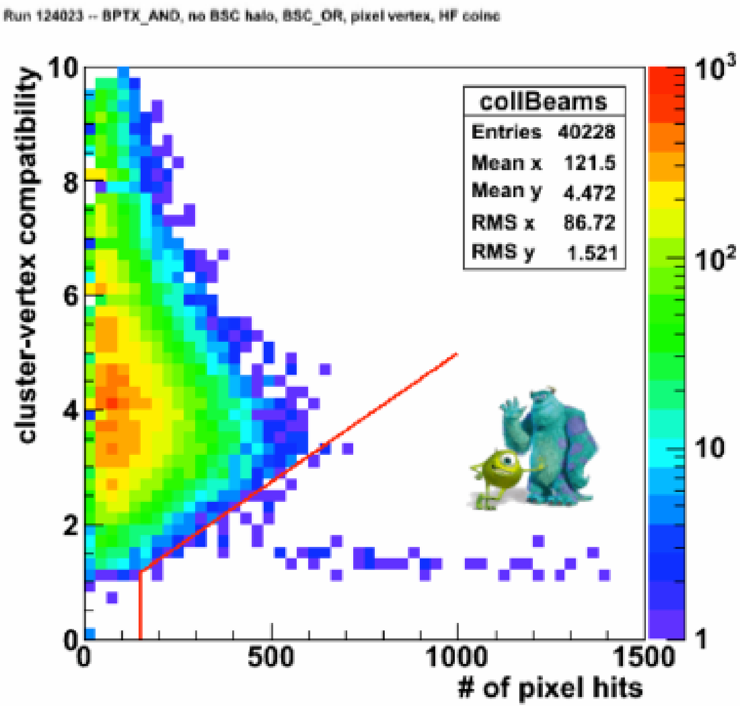
- Heavy ions runs at the end of 2010 and 2011

Integrated Luminosity (Linear Scale)



Rejecting Beam- Background Events



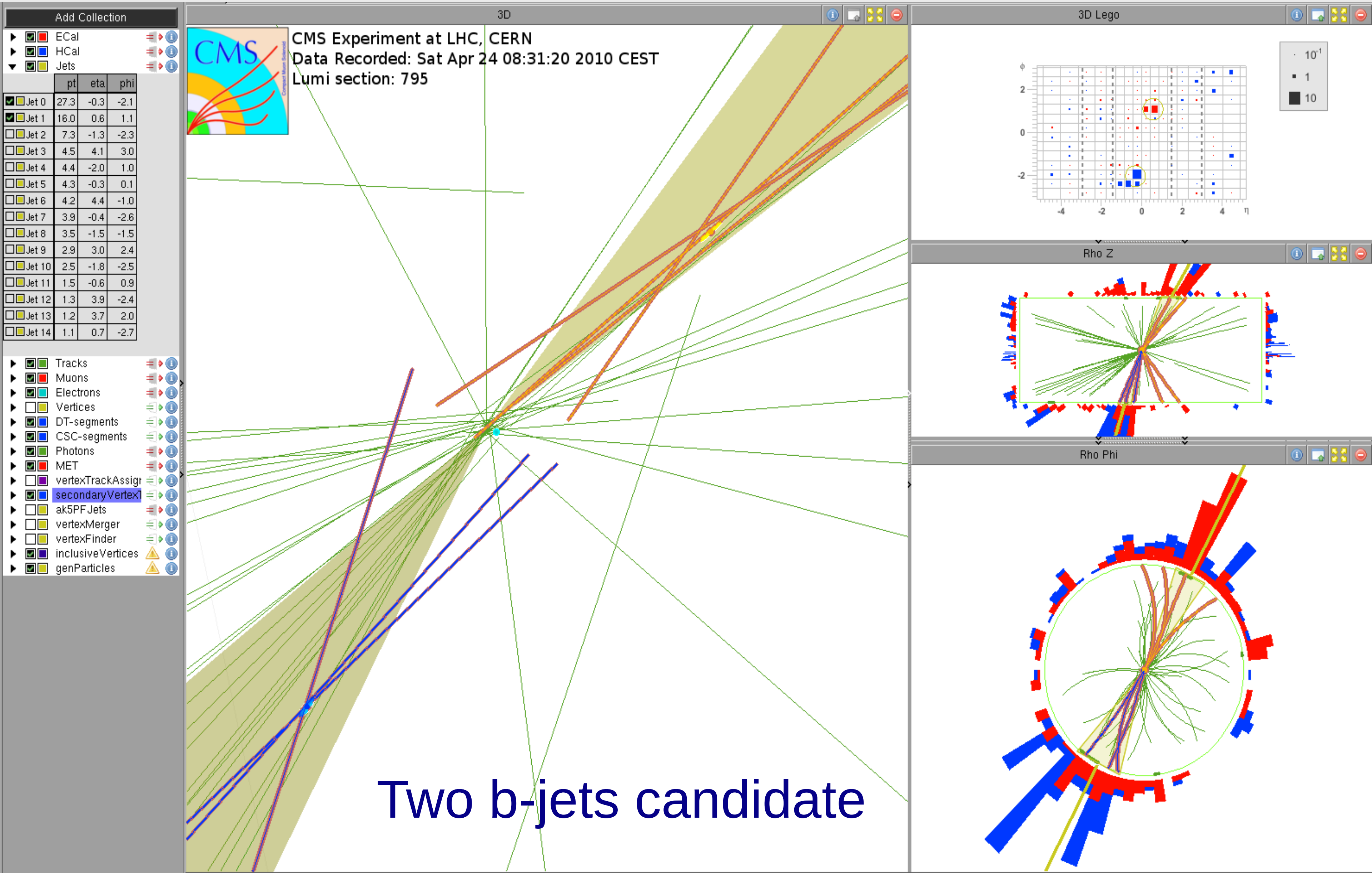


Vertex-cluster compatibility: Ratio of num clusters in the V shape and num clusters in the V-shape offset by 10 cm

Beam-scraping/gas events have a lot of pixel hits but ill-defined vertex

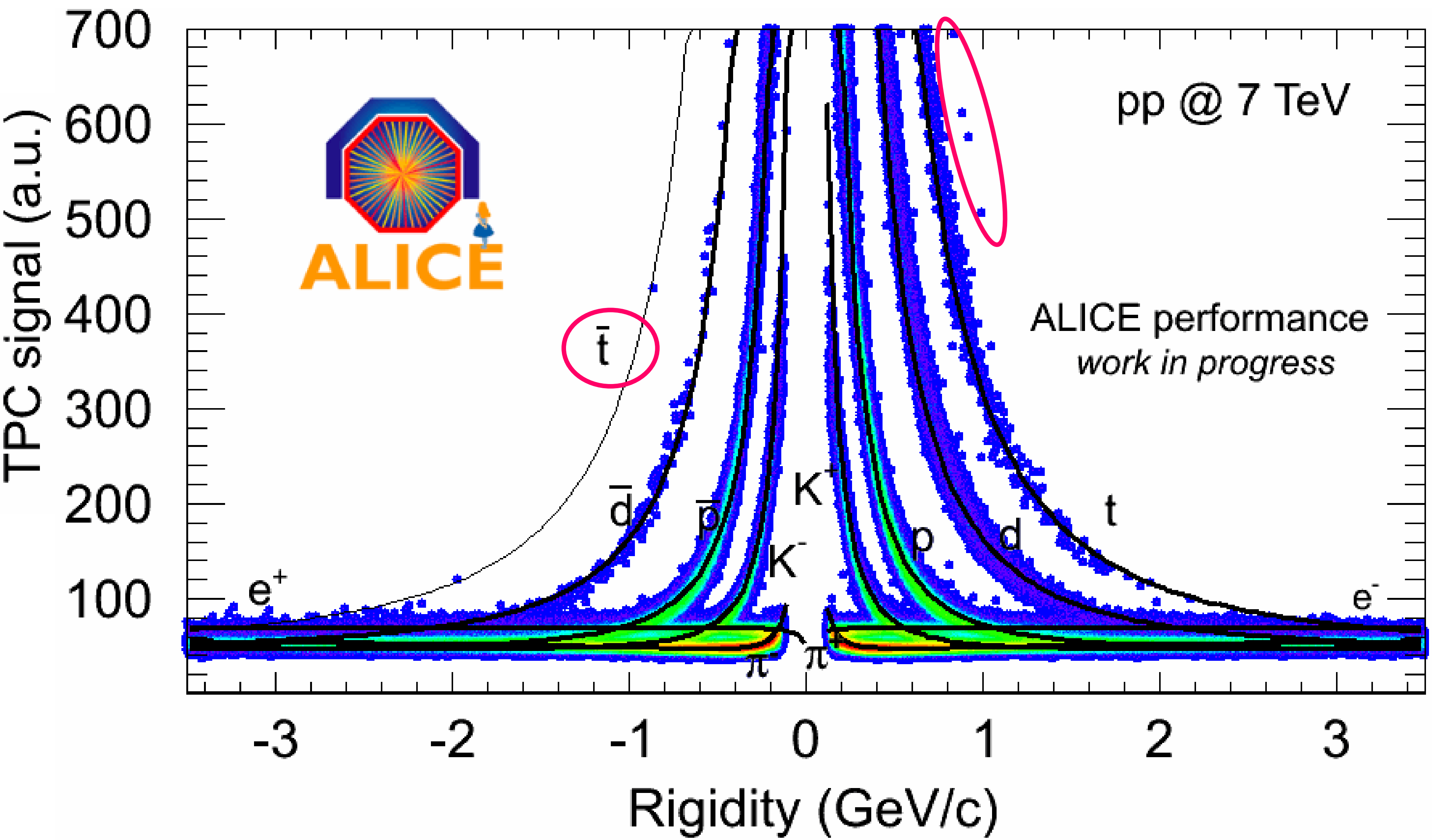
6/9/10 valerieh@princeton.edu 7

Ready for b physics (and b-tagging in general)



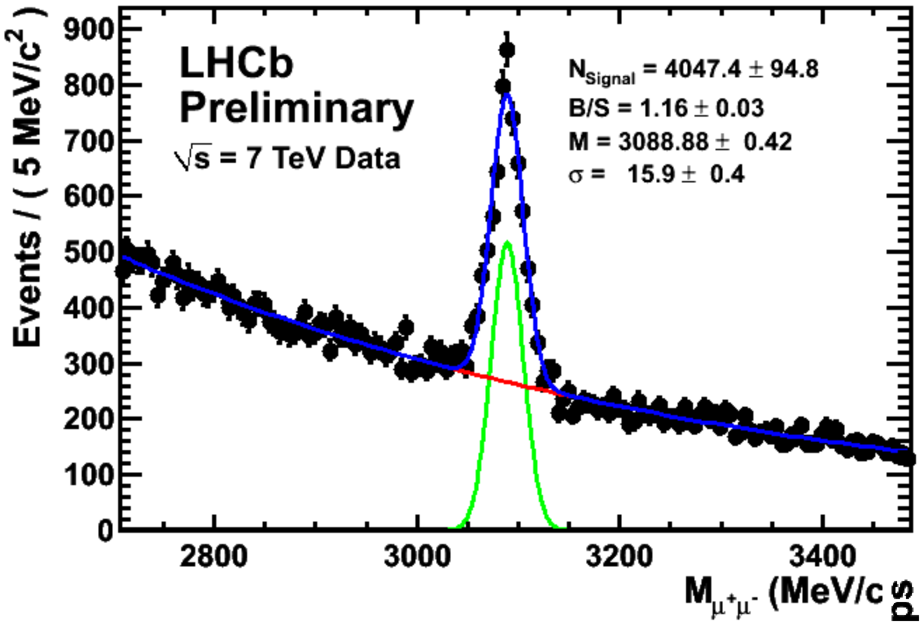
Two b-jets candidate

(Anti)Nuclei



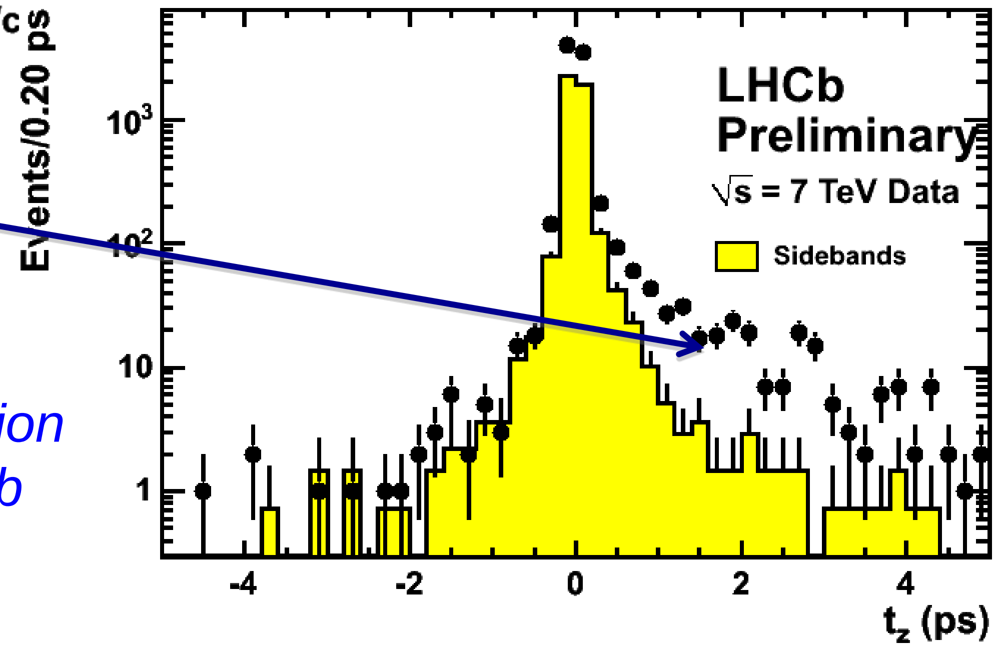
pp @ 7 TeV
ALICE performance
work in progress
ALICE
TPC signal (a.u.)
Rigidity (GeV/c)
700
600
500
400
300
200
100
-3
-2
-1
0
1
2
3
$\bar{t}$
$\bar{d}$
$\bar{p}$
K^+
K^-
p
d
t
e^+
e^-
π^-
π^+

J/psi Effective Lifetime



A total of 4000 $J/\psi \rightarrow \mu\mu$ decays reconstructed

Signal window & normalized sideband

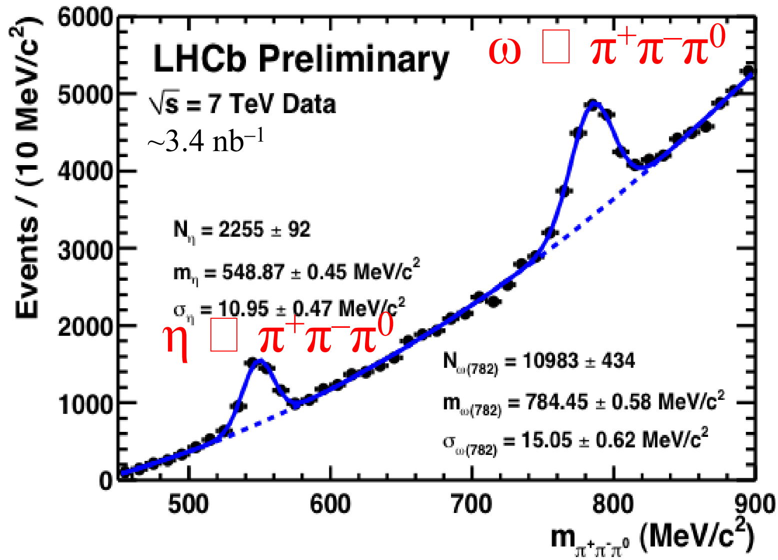


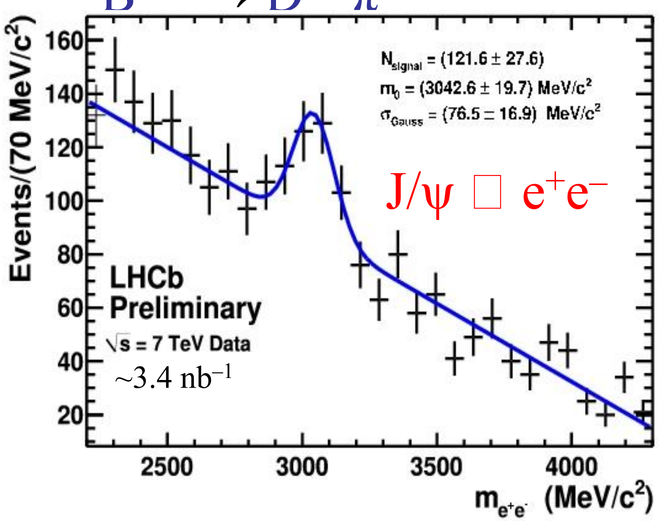
Proper life time distribution shows clear evidence for J/ψ produced in B decays

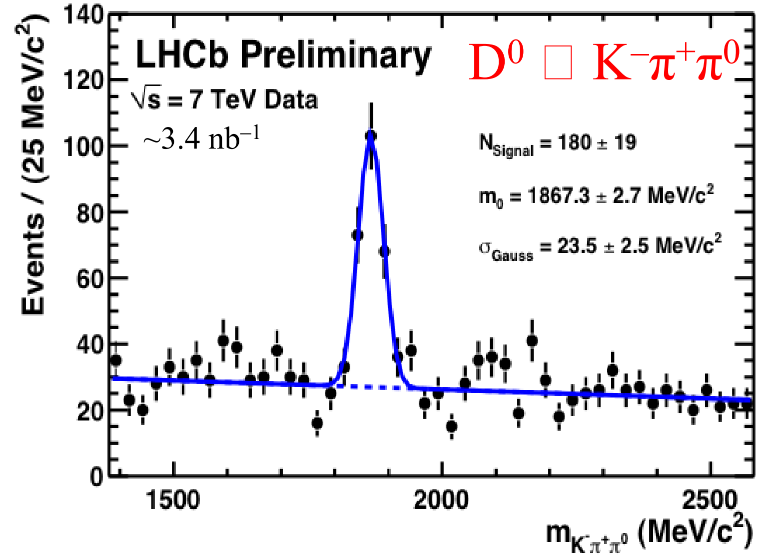
Solid prospects to measure production cross-sections for prompt J/ψ and bb at $\sqrt{s}$ = 7 TeV

2010 data: zoo expanding rapidly

- Many fully reconstructed mass peaks:
  - $\pi^0 \rightarrow \gamma\gamma$
  - $\eta \rightarrow \gamma\gamma, \pi^+\pi^-\pi^0$
  - $\Omega \rightarrow \pi^+\pi^-\pi^0$
  - $\eta' \rightarrow \pi^+\pi^-\gamma$
  - $K_S \rightarrow \pi^+\pi^-$
  - $K^{*0} \rightarrow K^-\pi^+$
  - $\Lambda \rightarrow p\pi^-$
  - $\Xi^- \rightarrow \Lambda\pi^-$
  - $\Omega^- \rightarrow \Lambda K^-$
  - $\varphi \rightarrow K^+K^-$
  - $D^0 \rightarrow K^-\pi^+, K^-K^+, \pi^-\pi^+$
  - $D^0 \rightarrow K^-\pi^+\pi^0, K^-\rho^+$
  - $D^0 \rightarrow K^-\pi^+\pi^+\pi^-$
  - $D^+ \rightarrow K^-\pi^+\pi^+, K^-K^+\pi^+, K_S\pi^+$
  - $D^{*+} \rightarrow D^0\pi^+$
  - $D_s \rightarrow K^-K^+\pi^+$
  - $\Lambda_c \rightarrow pK^-\pi^+$
  - $J/\psi \rightarrow \mu^+\mu^-, e^+e^-$
  - $\psi(2S) \rightarrow \mu^+\mu^-$
  - $B^{0/+} \rightarrow D^{+/0}\pi^{-/+}$
- Important for calibration:
  - detector
  - trigger
  - physics





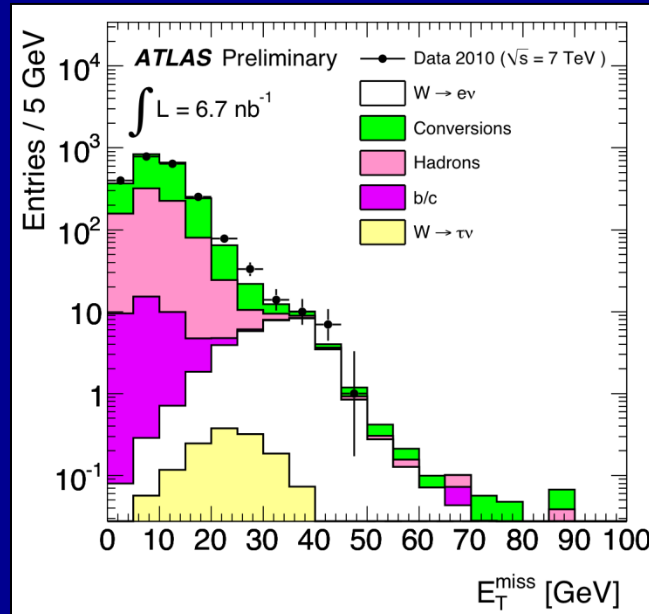


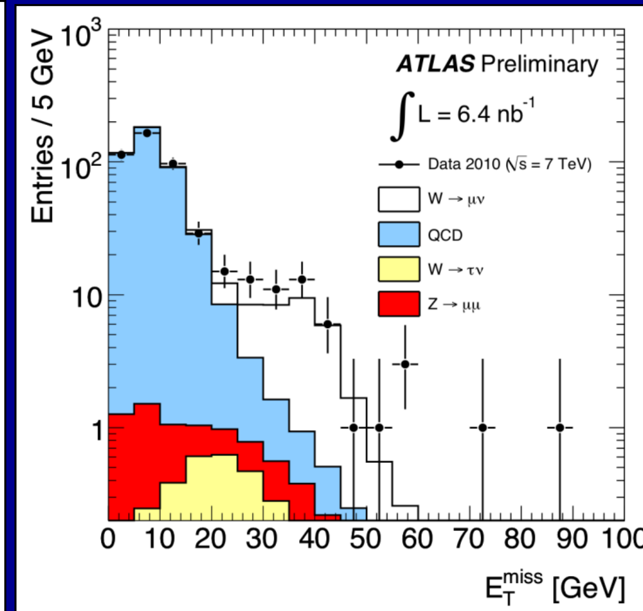
After pre-selection:

-- $W \rightarrow e\nu$:
 loose $e^{\pm}$, $E_T > 20$ GeV

-- $W \rightarrow \mu\nu$:
 p_T (μ)> 15 GeV
 $|\Delta p_T(\text{ID-MS})| < 15$ GeV
 $|Z_{\mu}-Z_{vtx}|<1$ cm

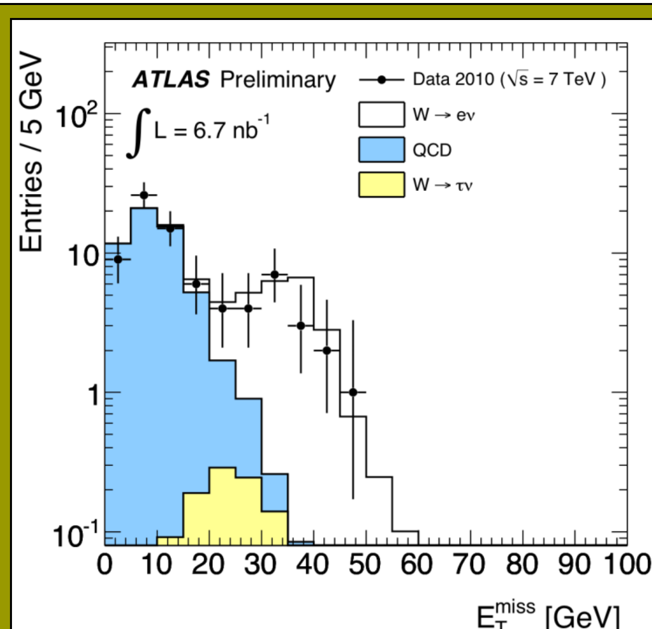
MC: normalised to data (total number of events)

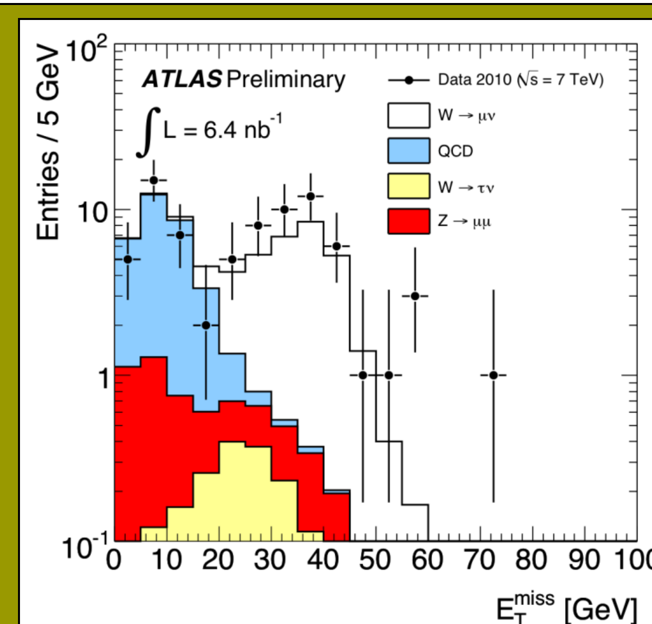




Observed events: 57

After all cuts but E_T^{miss} and m_T



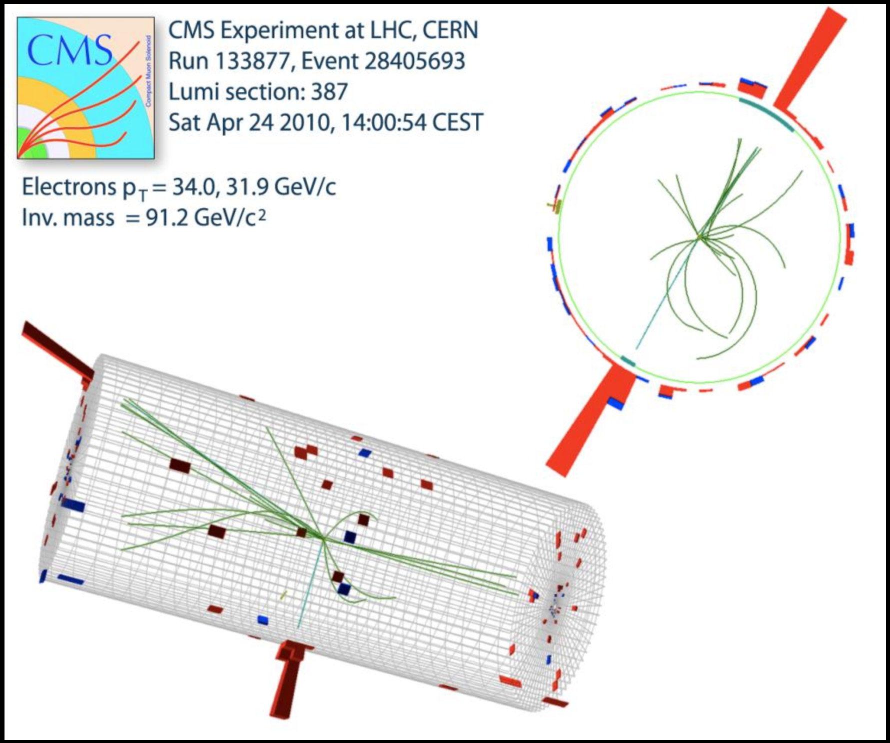


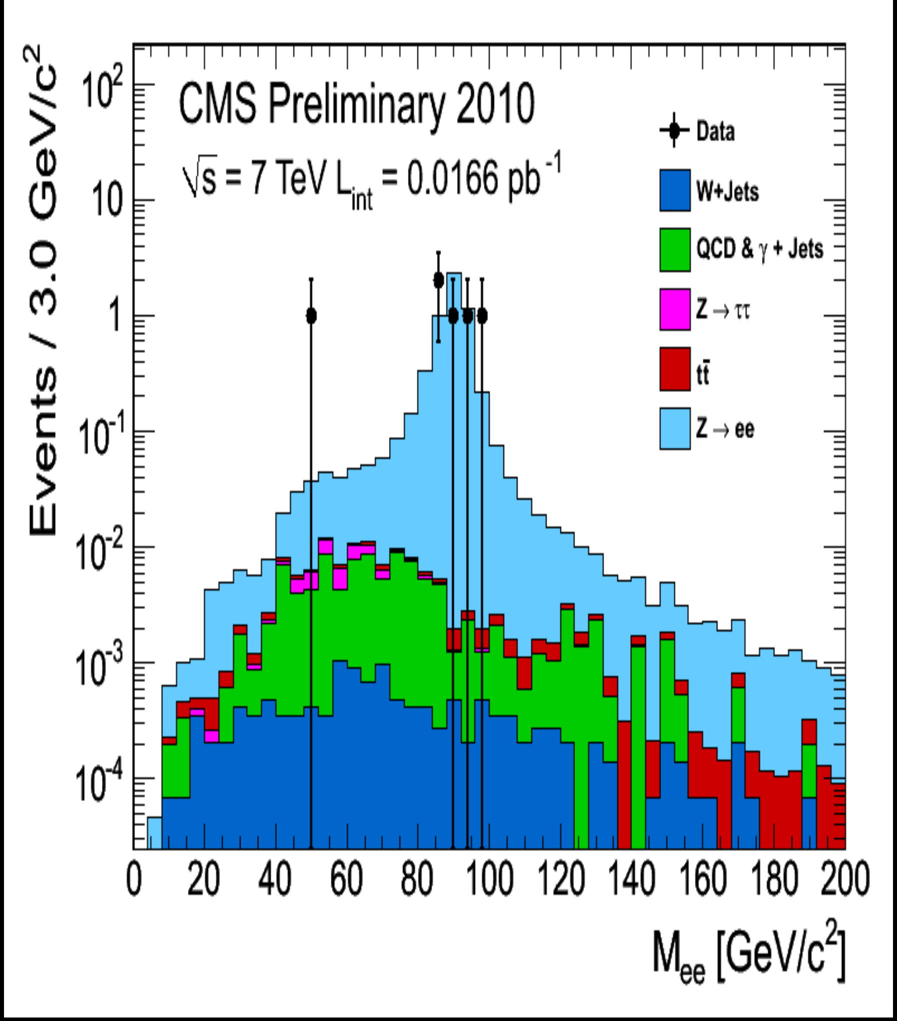
Final candidates inspected in detail → timing, lepton reconstruction quality, event topology …

$Z \rightarrow e^+e^-$ Observation

Event selection: *both electrons with a SuperCluster with Et > 20 GeV*

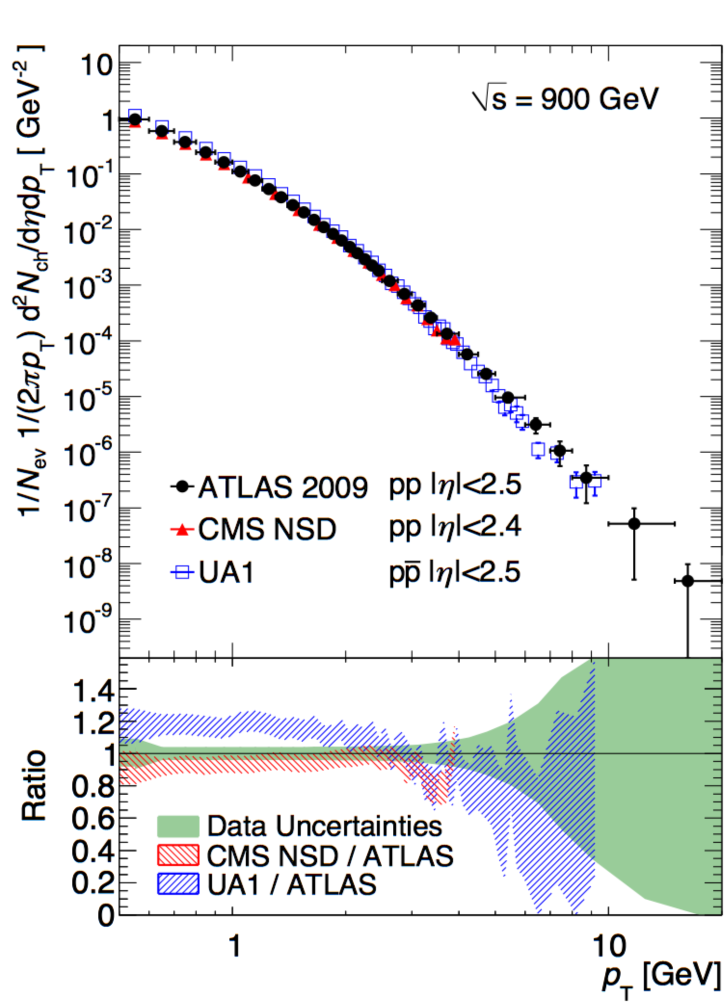
Monte Carlo : *cross section normalized to 17 nb^{-1} integrated luminosity*

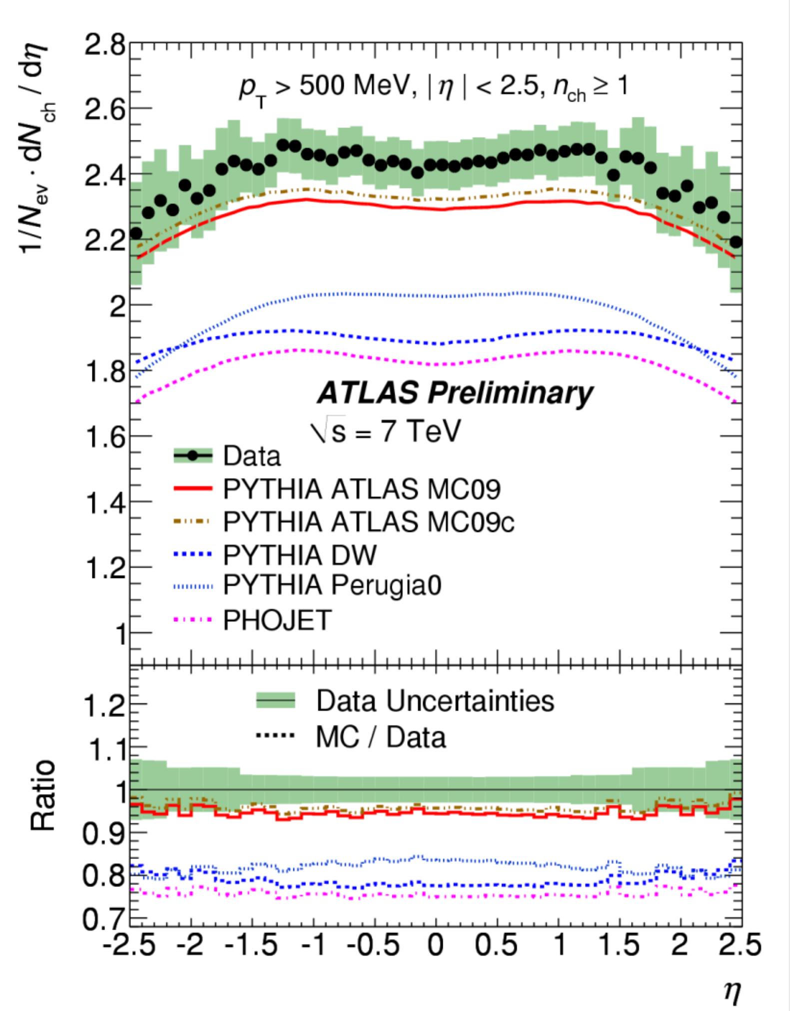




5 $Z \rightarrow e^+e^-$ candidates

Charged Particle Multiplicities at √s=0.9, 7 TeV





Monte Carlo underestimates the track multiplicity seen in ATLAS

ALICE, CMS

Performance of Missing Transverse Energy (0.3nb^{-1})

Understanding of high ETmiss tails is crucial for NP

Hopefully very low rate of new physics events sitting in these ta

Test ETmiss up to 250 GeV of transverse energy
time stability within 3%

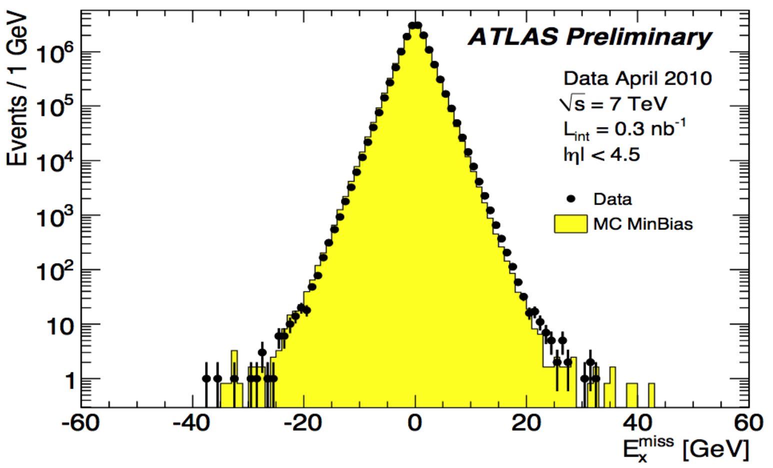
Event cleaning: find jets from noise burst or photons from cosmic muon bremsstrahlung.

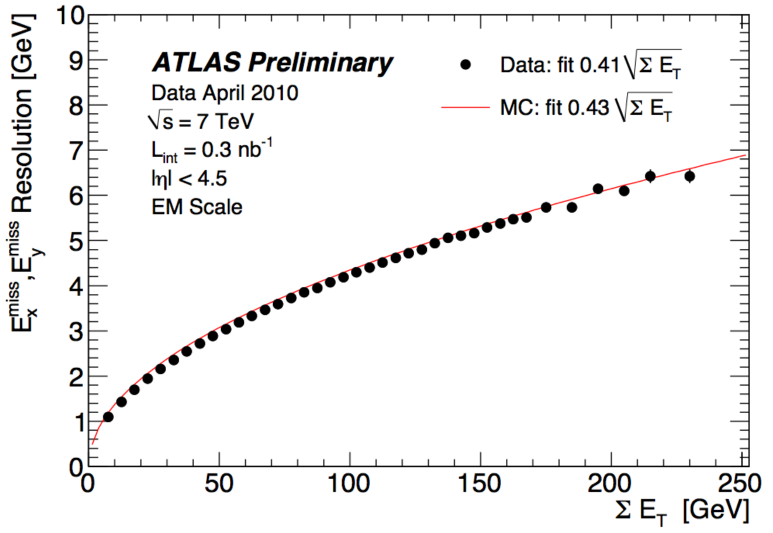
$$E_T^{miss} = -\Sigma E_{cell} \text{ (vector sum)}$$

Due to large granularity of calorimeter, use only cells belonging to 3D calorimeter "topo" cluster 4σ/2σ algorithm

Excellent agreement between data and MC at this early stage

More advanced computation of ETmiss including electrons, muons, taus, jets and their proper calibration under way





LHC Experiments Summary

- So far, so good….
- Experiments tracking nicely the machine evolution, eagerly awaiting more data
- Computing infrastructure supports magnificently the swift data analysis
- Experiments are re-discovering the Standard Model (only top quark missing…..)
- …exciting times !

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

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

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
- …….

Particle Physics Strategy (short term)

European Strategy for Particle Physics
first established 2006
update planned for 2012

Input from LHC mandatory

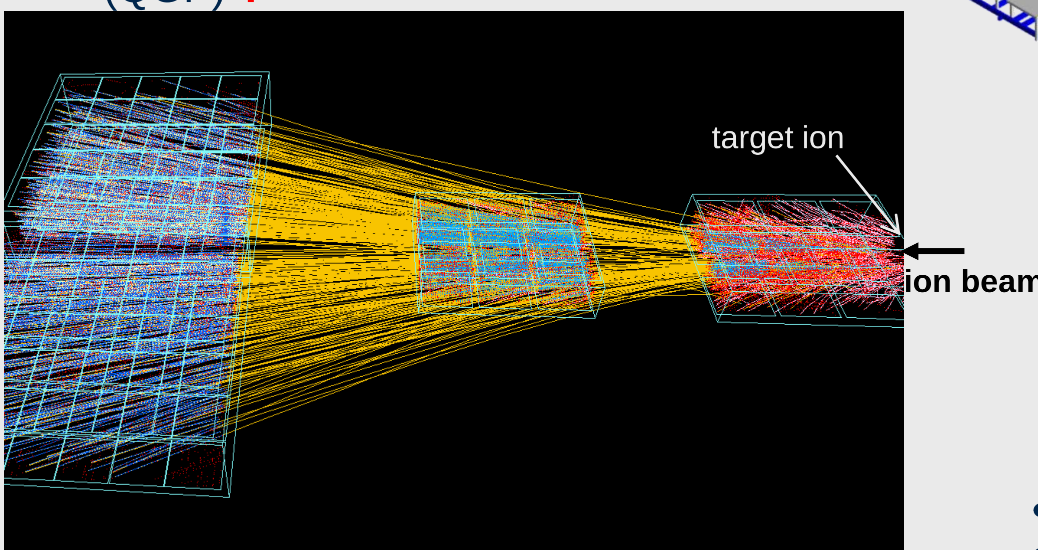
→ Need to have interpretation of LHC results ready

→ Need close collaboration exp/theory
LHC and LC

Fixed Target Physics

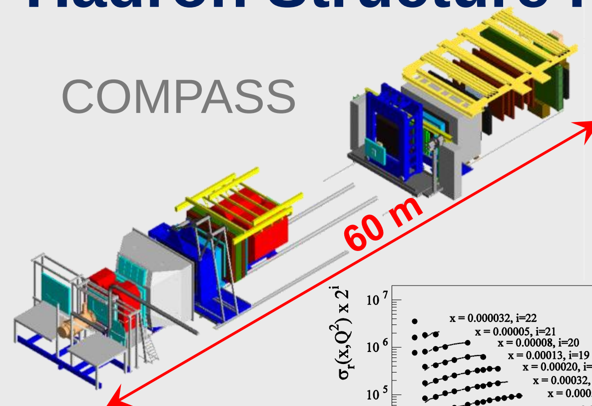
Heavy-ion Physics

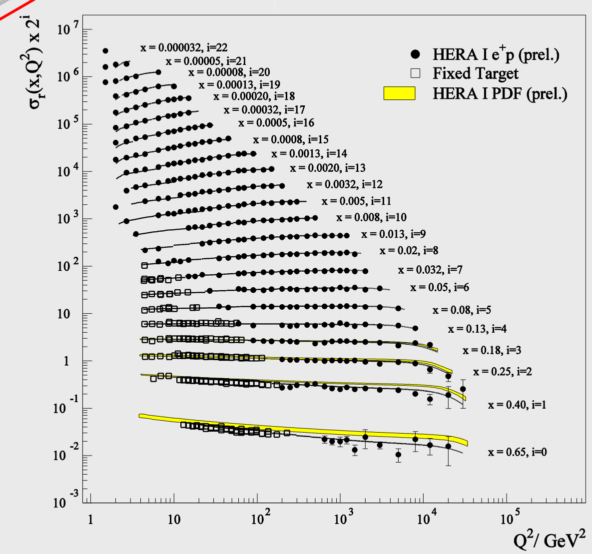
- Heavy ion fixed-target physics
  - study of matter at extreme energy density
  - search for state of quasi-free partons
    quarks and gluons → quark-gluon plasma
    (QGP) ?



Hadron Structure Physics

COMPASS





- spin structure of nucleon (w/ μ beam)
- uds + g QCD spectroscopy (w/ hadron beam)

Fixed Target Physics

Antiproton Physics

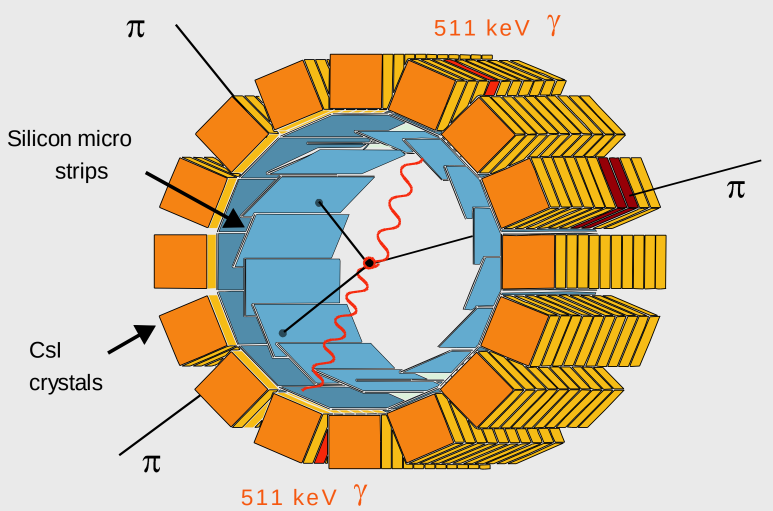
Cold antiprotons
("manufacturing anti-matter")

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

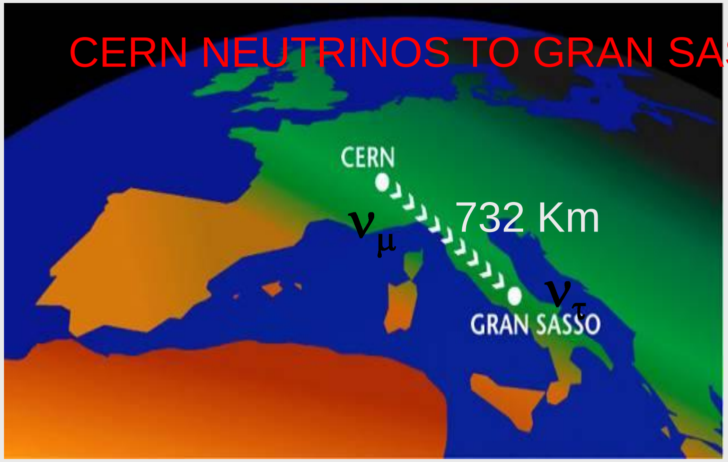
Anti-H annihilations detected

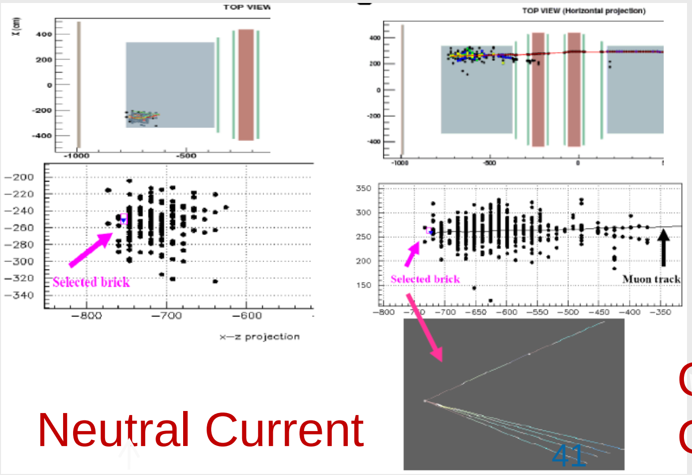
ATHENA (→ ALPHA)

anti-H (pe^+) + matter → $\pi^+\pi^-$ + $\gamma\gamma$



Neutrino Physics



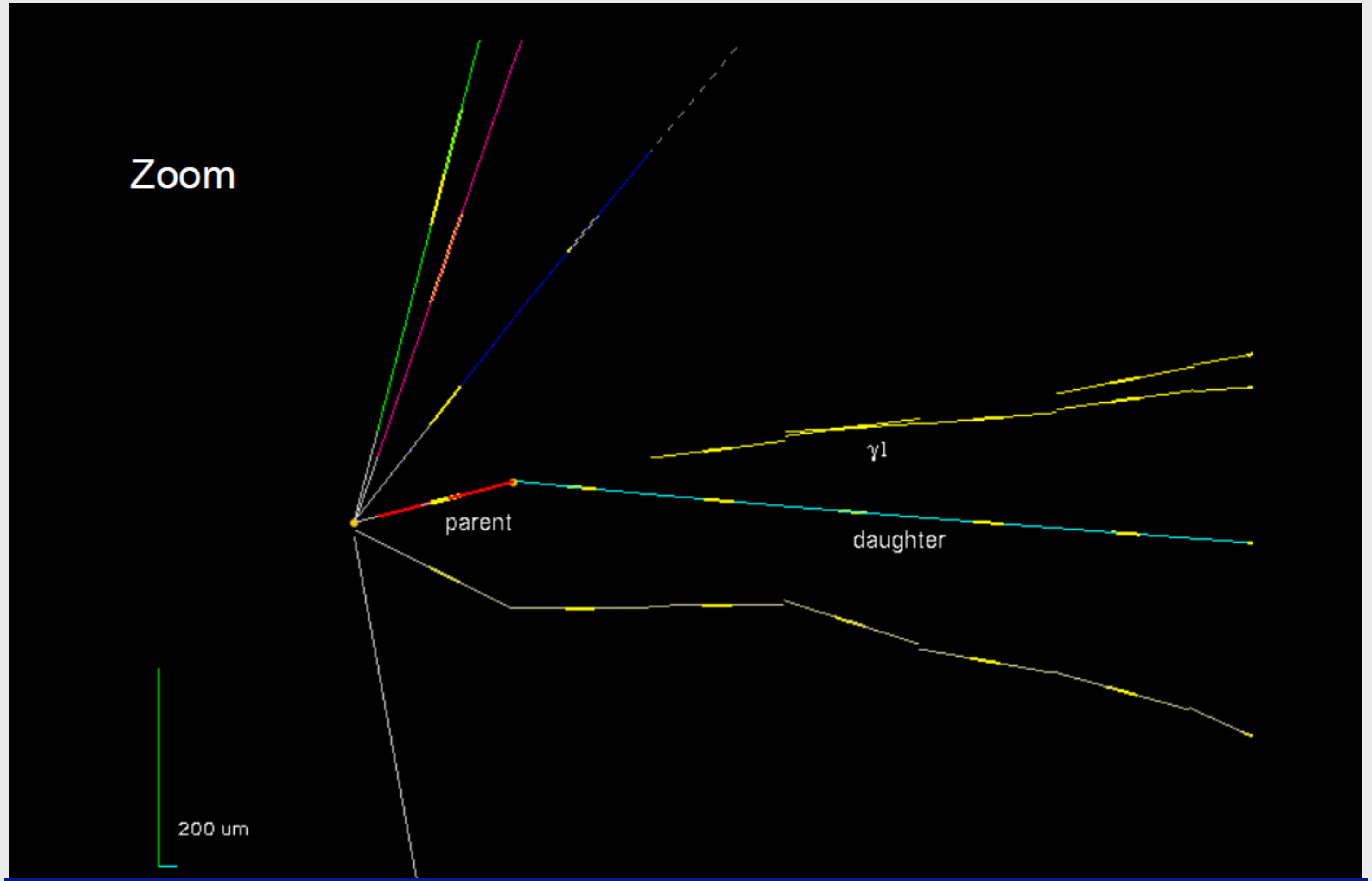


OPERA

Charge Current

CNGS - OPERA

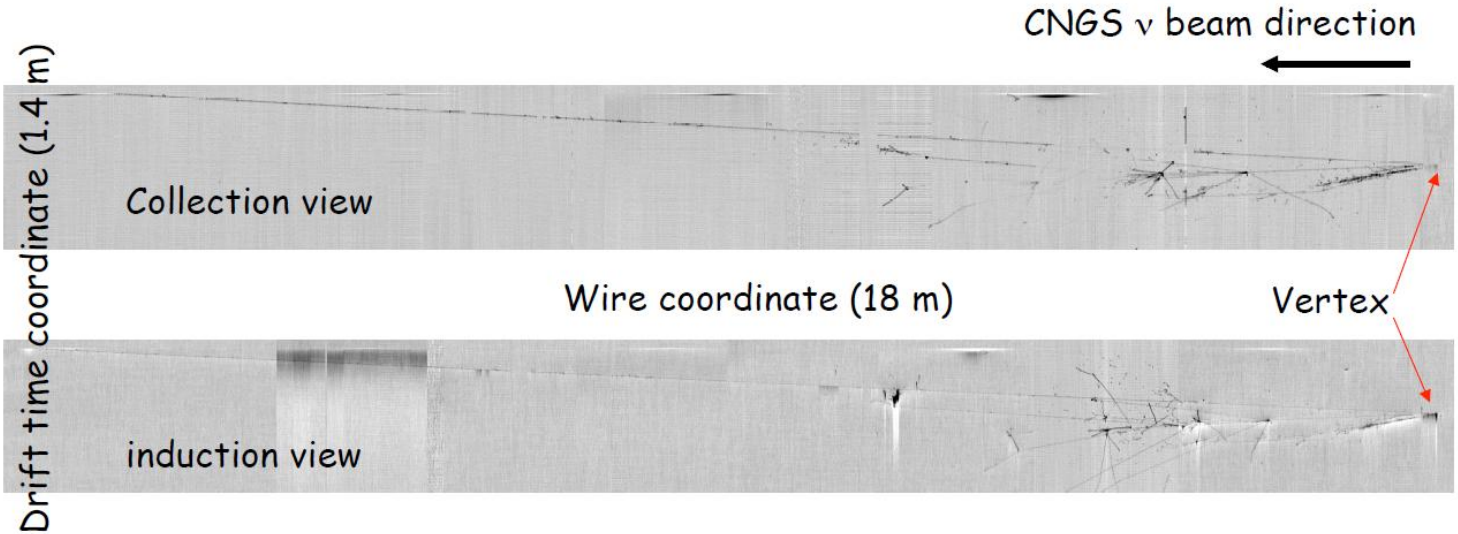
First υ_τ Candidate



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

CNGS - ICARUS

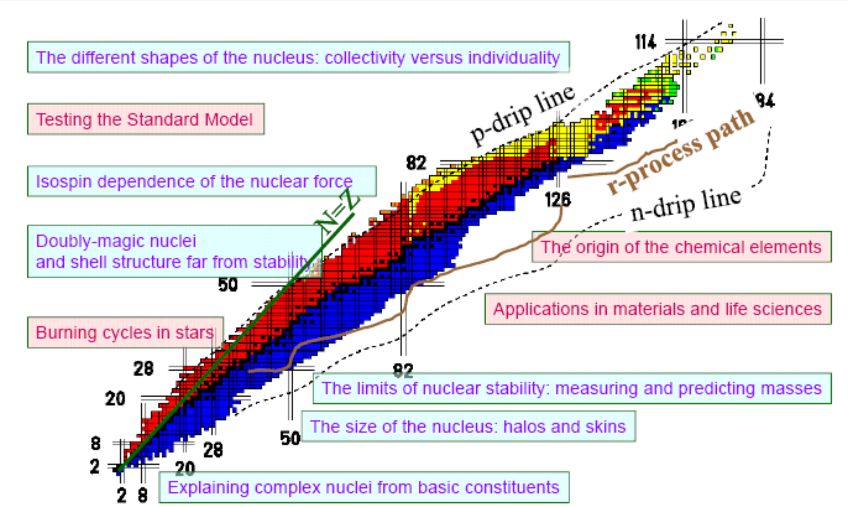
The first CNGS neutrino interaction in ICARUS T600

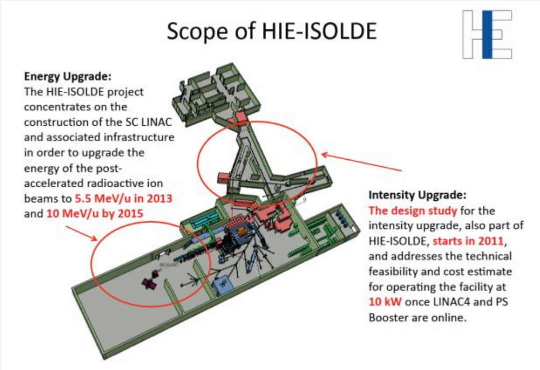


- Leading muon (crossing horizontally the whole cryostat)
- Two charged particle tracks undergoing hadronic interactions
- Two γ converting at 14 and 16 cm from vertex (π^0?)
- Vertex not fully visible in collection view, due to locally wrong wire biasing

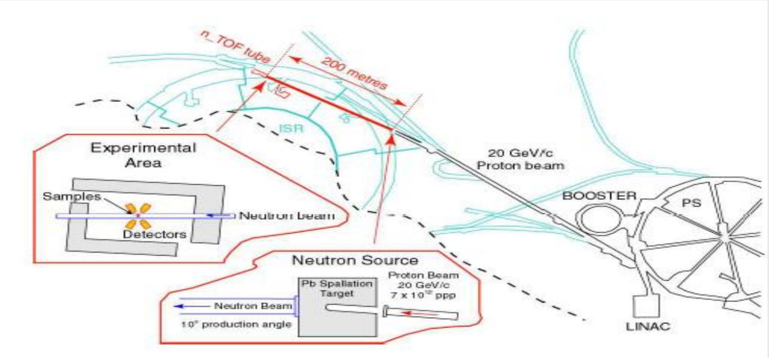
Fixed Target Physics

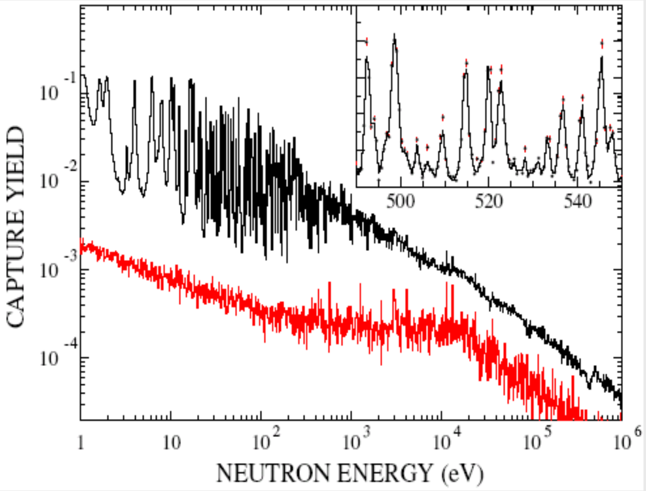
ISOLDE





nTOF





At thermal energy of kT=30 keV the Maxwellian averaged cross section of this 151Sm ($t_{1/2}$=93 yr)
was determined to be 3100±160 mb, significantly larger than theoretical predictions.
Nucleosynthesis in giant branch stars.

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

Knowledge Transfer Modes

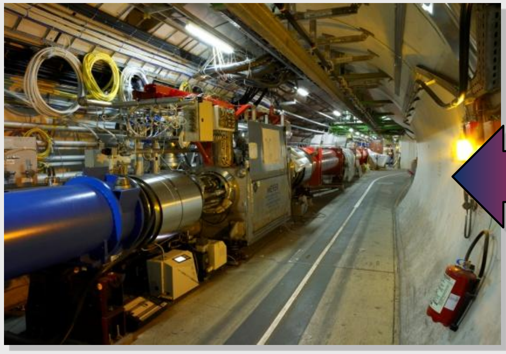
- Licensing of intellectual property and consulting
- Joint R&D with external partners
- CERN training programs and personnel mobility
- Procurement activities
- Various initiatives aimed at facilitating knowledge transfer and exchange

CERN Technologies - Innovation

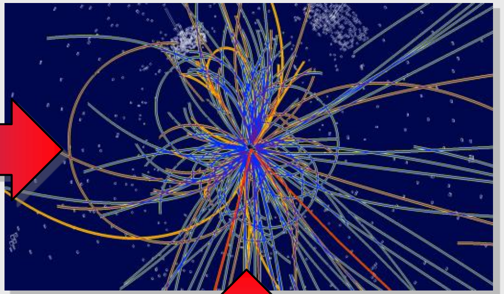
Medical imaging

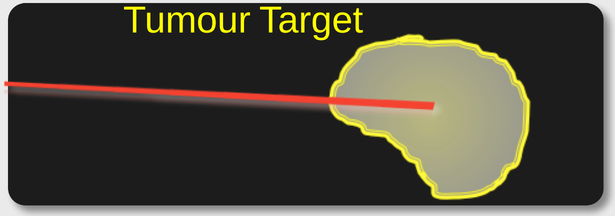
Example: medical application

Accelerating particle beams



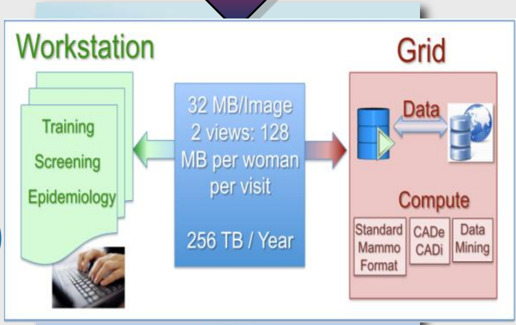
Detecting particles





Charged hadron beam that loses energy in matter

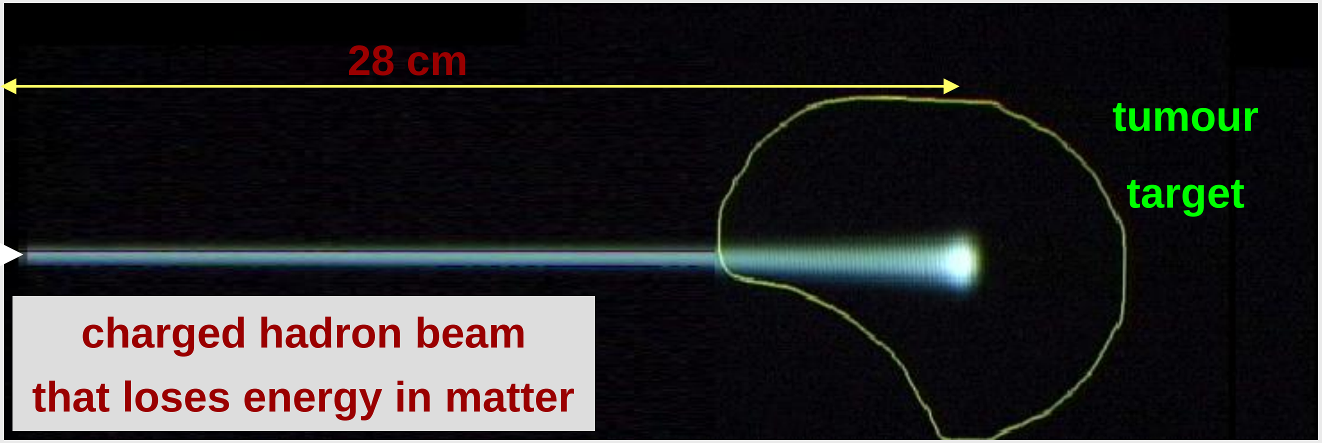
Large-scale **computing** (Grid)



Grid computing for medical data management and analysis

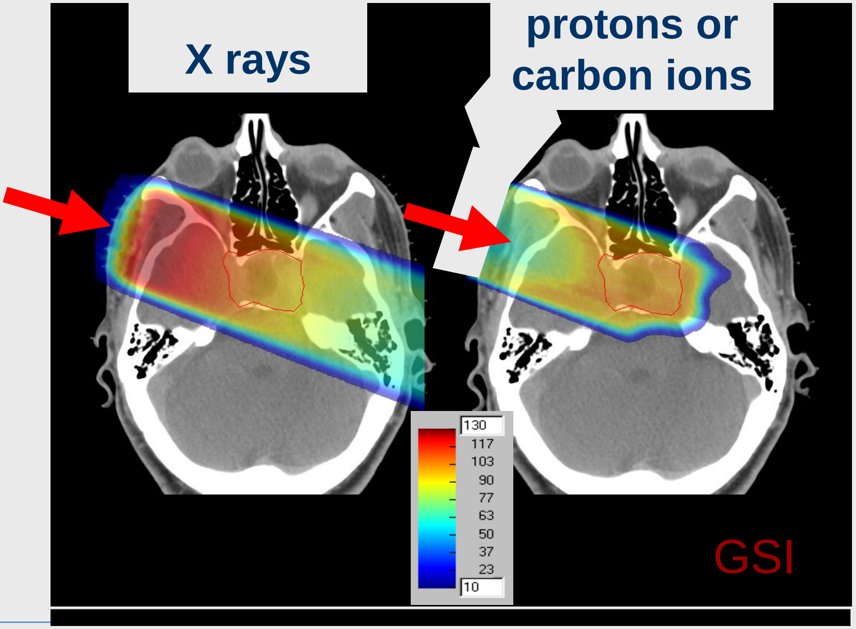
Hadron Therapy – The Principle

200 MeV protons



Hadron beams provide new treatment opportunities for deep-seated tumours.

Hadron beams are more effective than X-rays in destroying tumours while sparing healthy tissues nearby.



Hadron Therapy - Partnerships

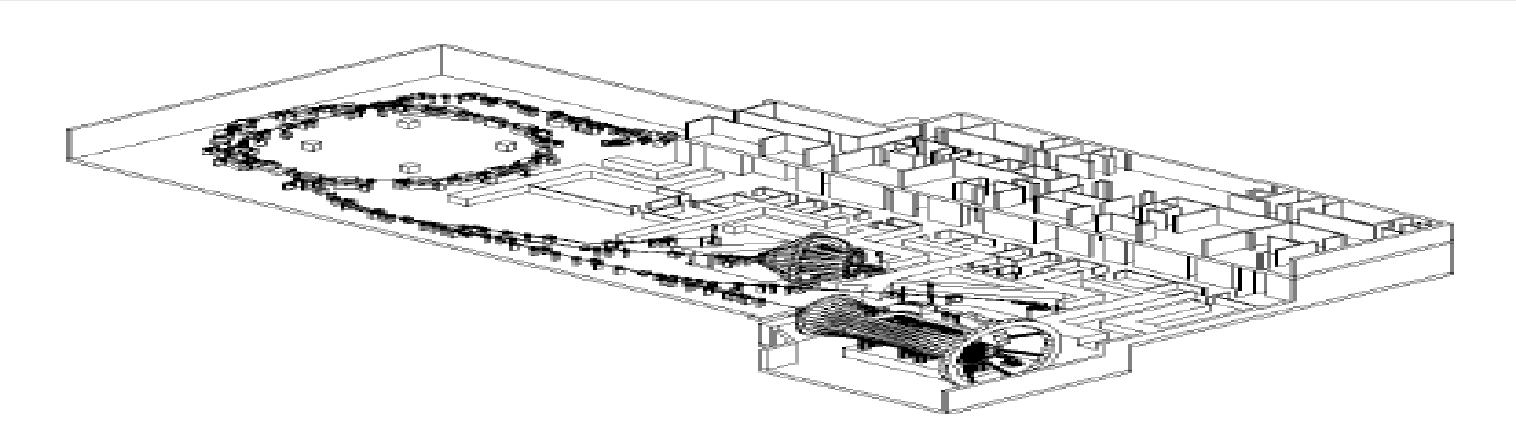
PIMMS study
Long-term partnerships with CERN towards new treatment centres

TERA Fondazione per Adroterapia Oncologica → fondazione CNAO

Treatment center in Italy.
Ready for irradiation in 2010

ebg *Med*Austron

Treatment centre in Austria, scheduled to be ready in 2014



CERN

Hadron Therapy – Training & Networking

Several EC-funded networks and projects where CERN plays a coordinating role

ENVISION
European NoVel Imaging Systems for ION therapy
(Project started 1st February 2010)

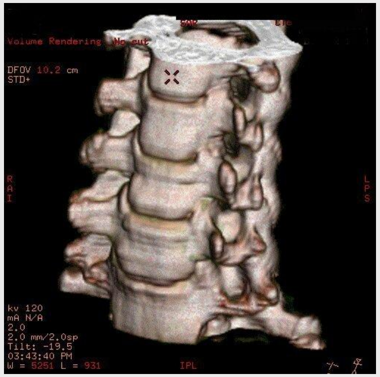
PARTNER
Particle Training Network for European Radiotherapy

ULICE - Union of Light Ion Centres in Europe

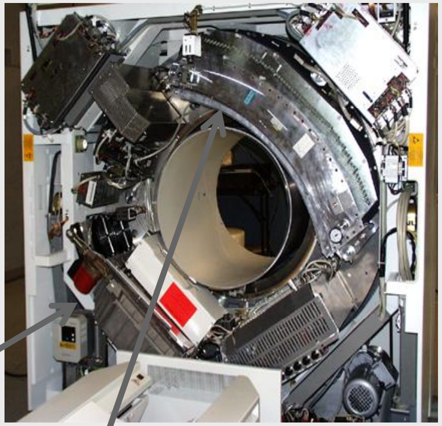
CAPACITIES

Medical Imaging – Computer Tomography (CT)

Morphological imaging



- The X-ray source and the detector array rotate around the body
- The bed supporting the patient moves through the device
- Whole-body 3-D images constructed from 2-D slices in a given bed position



Courtesy GE

X-ray source

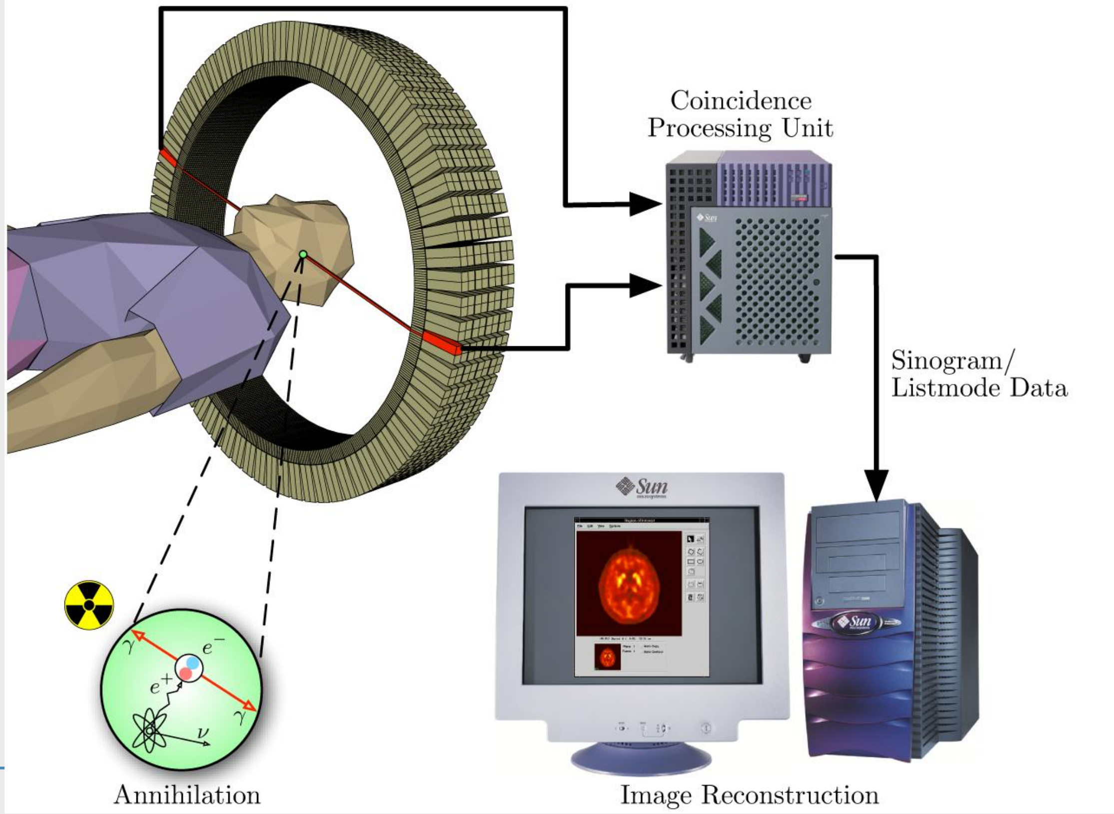
Banana detector

Medical Imaging – PET (Positron Emission Tomography)

Functional imaging

The system detects pairs of gamma rays emitted indirectly by a positron-emitting radionuclide (tracer), which is introduced into the body on a biologically active molecule.

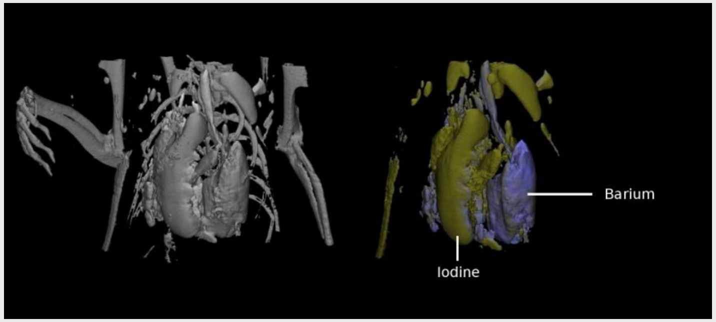
Images of tracer concentration in 3-dimensional space within the body are then reconstructed by computer analysis.



New applications powered by CERN techs

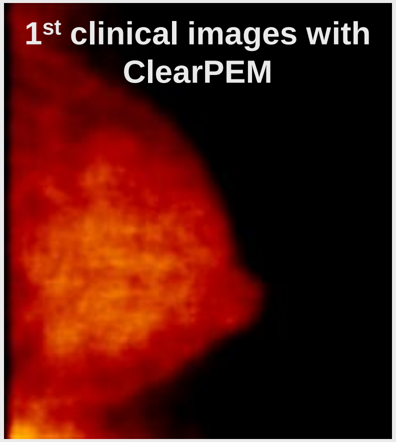
- Colour CT X-ray images from MARS project, based on MEDIPIX technology

  (courtesy of MARS scanner project)



- ClearPEM-Sonic project: a dedicated PET scanner for mammography including innovative ultrasonic features for morphological imaging

  (courtesy of Crystal Clear Collaboration)

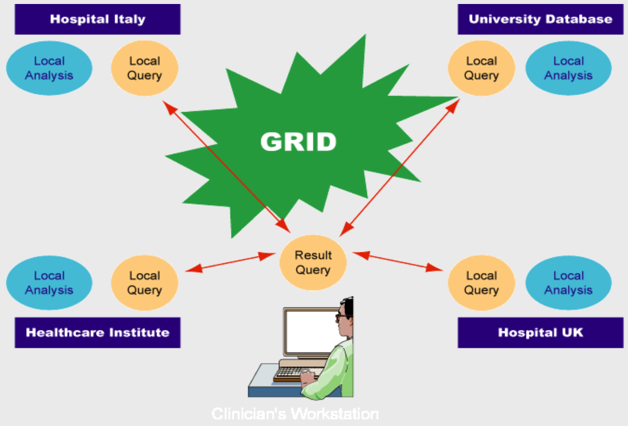


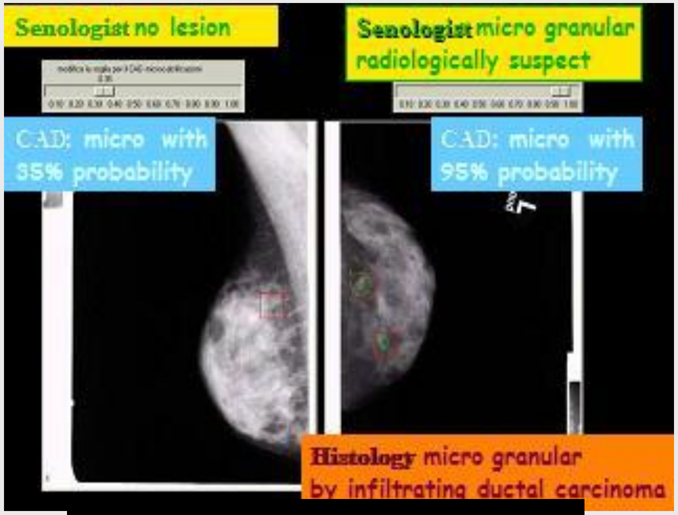
Grid Applications: MammoGrid

Mammogrid project

Grid-based implementation of distributed mammogram database across Europe

- Give each medical doctor access to thousands of diagnosed images
- Enable remote diagnosis
- Software to extract tissue information for clinical studies (pattern recognition algorithms, etc)





Developed by Italian University

Knowledge Transfer through Procurement

Results from a survey of companies involved in technology-intensive procurement contracts with CERN (1997-2001).
178 questionnaires analyzed, related to 503 MCHF procurement budget.

Results:

- 44% indicated technological learning
- 42% increased their international exposure
- 38% developed new products
- 36% indicated market learning
- 13% started new R&D teams
- 52% would have had poorer sales performance without CERN
- 41% would have had poorer technological performance

CERN Global Network

A facilitator
for knowledge
exchange

- ❑ Dedicated web site

    Visibility for partnership opportunities across the Network

- ❑ Member database

    Professional networking for CERN "Alumni"
    Useful data on researcher's mobility and career evolution in Europe
    Discussion fora for special interest groups

- ❑ Interactions between individual and institutional members

    Exchange of best practices between institutions in specific thematic areas

CERN Education Activities

Scientists at CERN
Academic Training Programme

Young Researchers
CERN School of High Energy Physics
CERN School of Computing
CERN Accelerator School

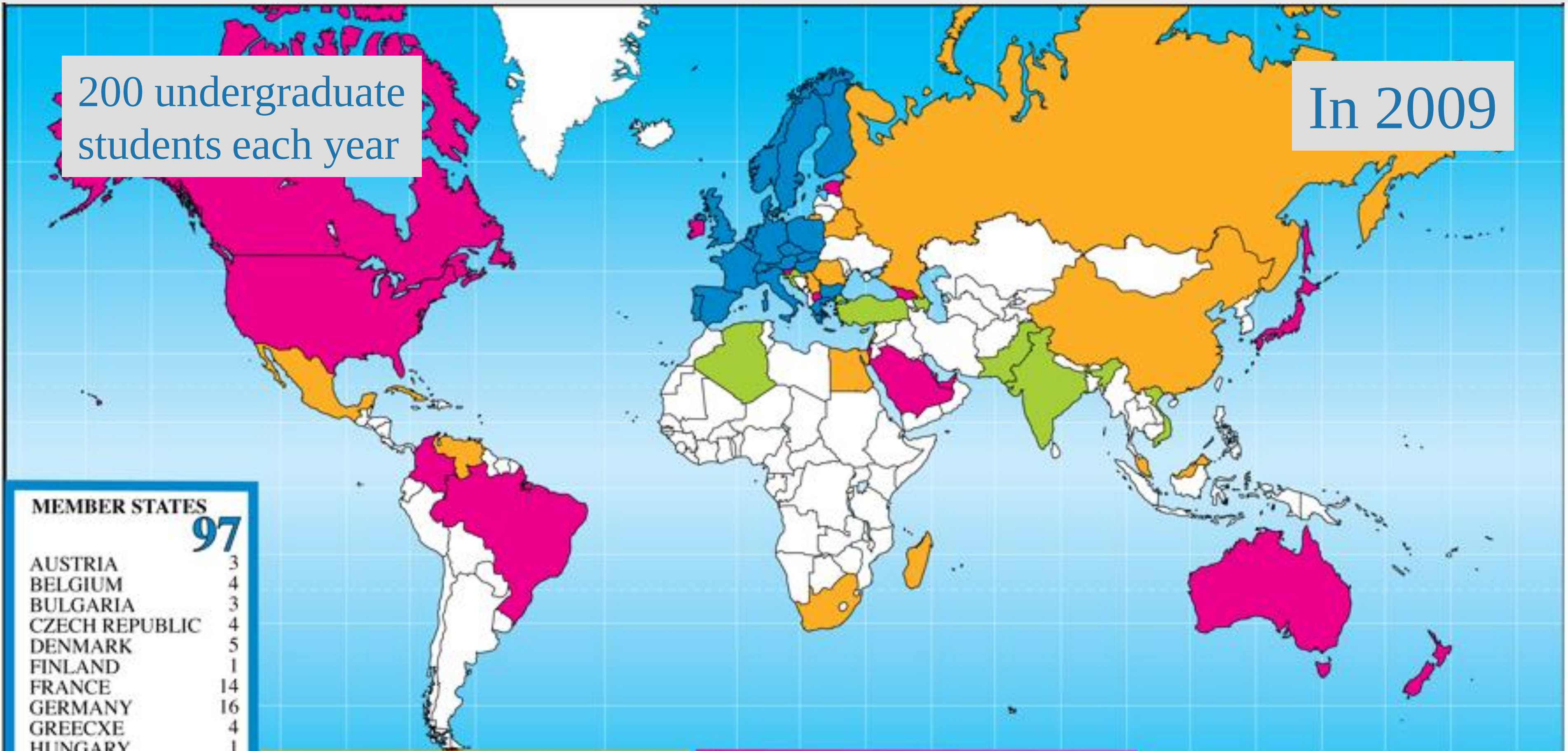
Physics Students
Summer Students
Programme

CERN Teacher Schools
International and National
Programmes

Summer Students @ CERN

200 undergraduate students each year

In 2009



MEMBER STATES 97

AUSTRIA	3
BELGIUM	4
BULGARIA	3
CZECH REPUBLIC	4
DENMARK	5
FINLAND	1
FRANCE	14
GERMANY	16
GREECXE	4
HUNGARY	1
ITALY	7
NETHERLANDS	5
NORWAY	3
POLAND	2
PORTUGAL	1
SLOVAKIA	3
SPAIN	4
SWEDEN	7
SWITZERLAND	1
UNITED KINGDOM	9

SUPPORTED BY CERN 22

BELARUS	1	MAURITIUS	1
CHINA	1	MEXICO	1
CUBA	1	ROMANIA	1
EGYPT	1	RUSSIA	9
LEBANON	1	SERBIA	1
MADAGASCAR	1	SOUTH AFRICA	1
MALAYSIA	1	VENEZUELA	1

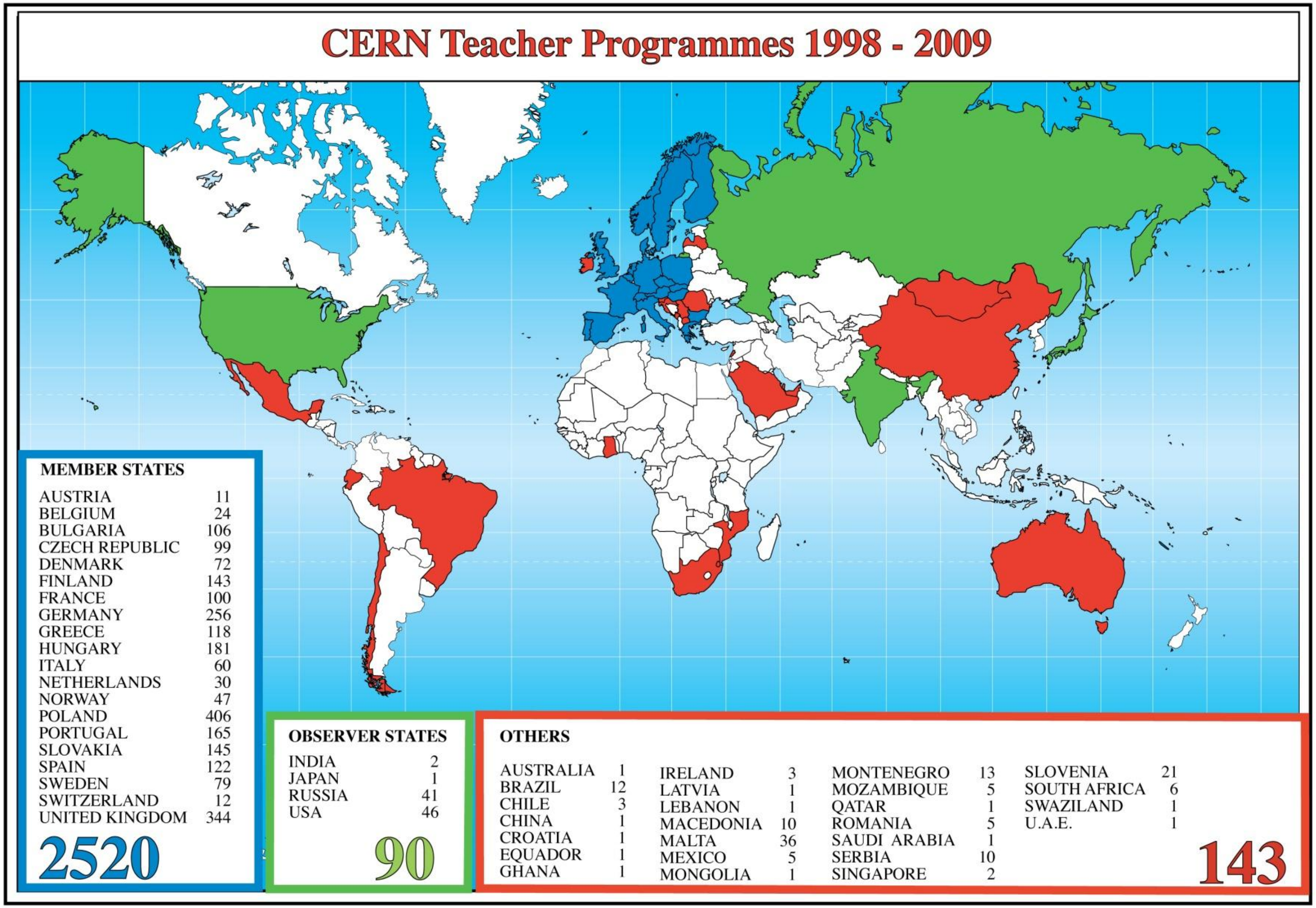
EXTERNAL SUPPORT 52

AUSTRALIA	2	JAPAN	5
BRAZIL	1	MACEDONIA	5
CANADA	6	N. ZEALAND	2
COLOMBIA	1	QATAR	2
ESTONIA	2	SAUDI A	2
GEORGIA	1	SLOVENIA	1
IRELAND	1	UAE	1
ISRAEL	4	USA	16

BOTH SOURCES 38

ALGERIA	2	TURKEY	3
AZERBAIJAN	2	VIETNAM	4
CROATIA	3		
CYPRUS	3		
INDIA	11		
MALTA	3		
PAKISTAN	4		
PALESTINE	3		

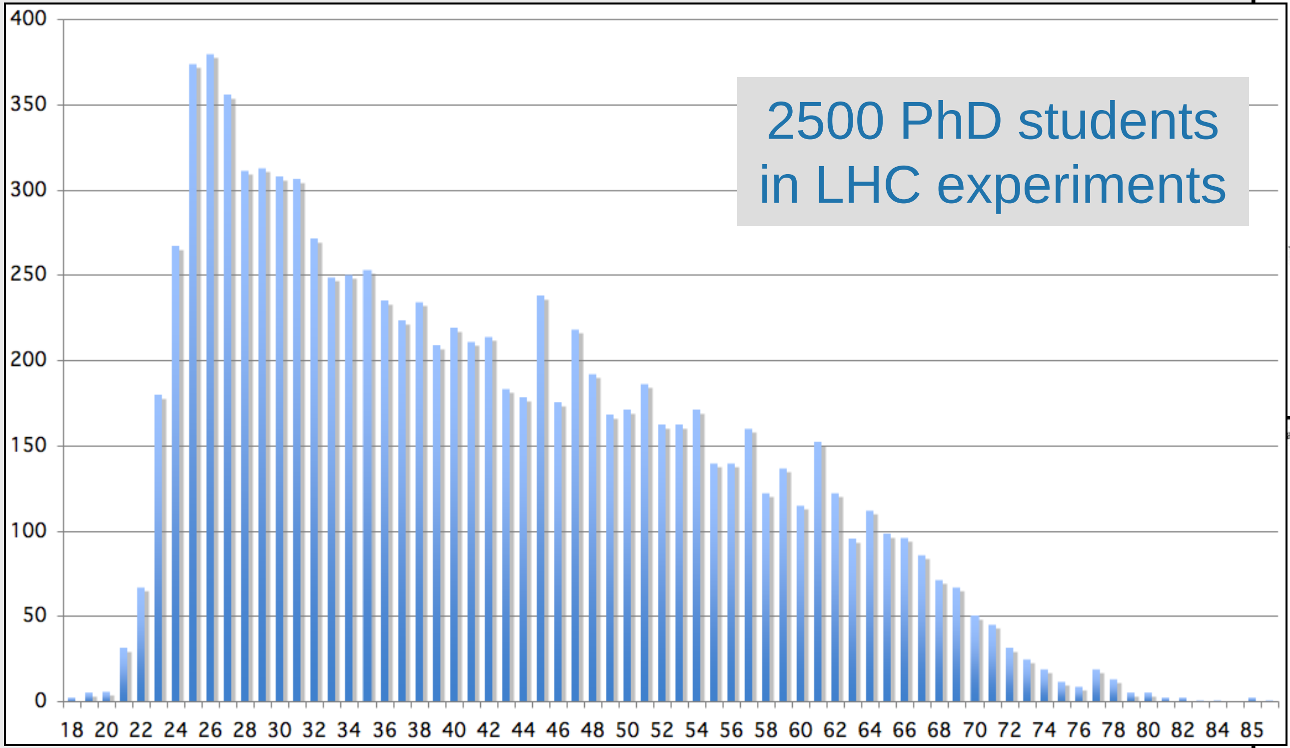
CERN Teacher Programmes



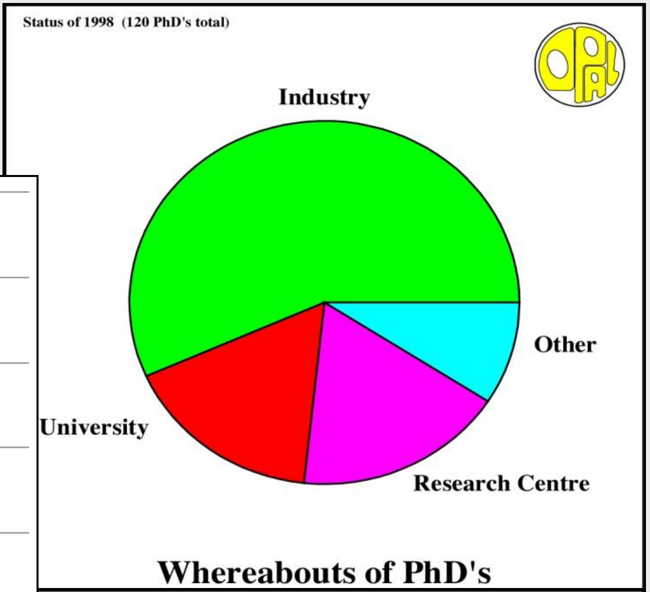
Age Distribution of Scientists

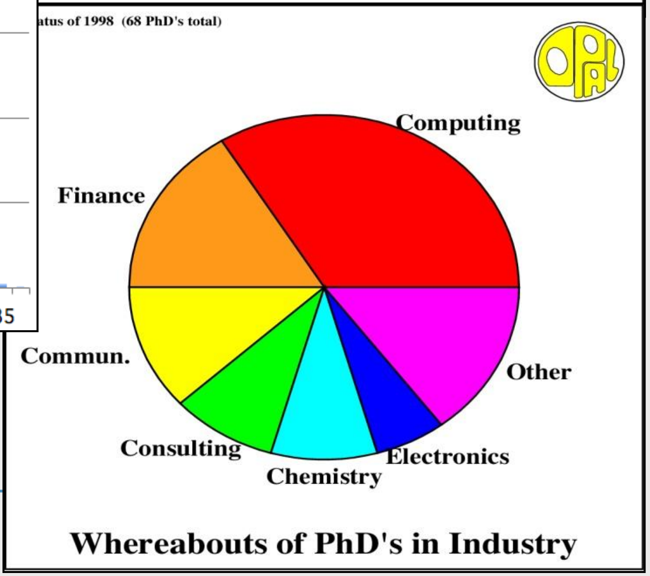
- and where they go afterwards

Survey in March 2009



2500 PhD students in LHC experiments





They do not all stay: where do they go?

LHC Strategy (II)

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

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

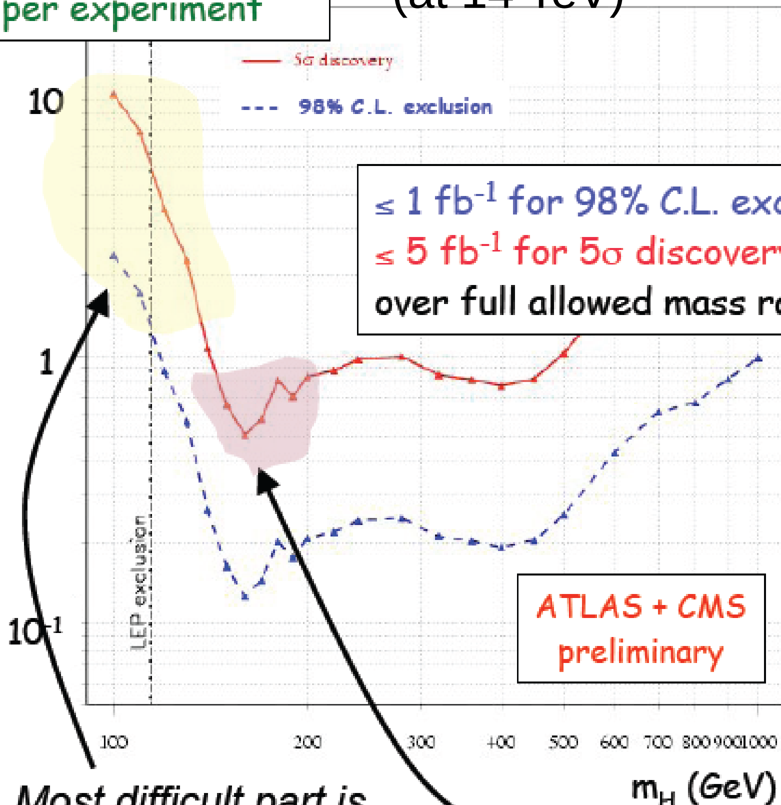
- Between 2010 and ~2020: ~design luminosity (~10^{34}/cm^2/s)
  connection of LINAC4 earliest 2015
  detector modifications to optimize data collection

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

SM Higgs Reach

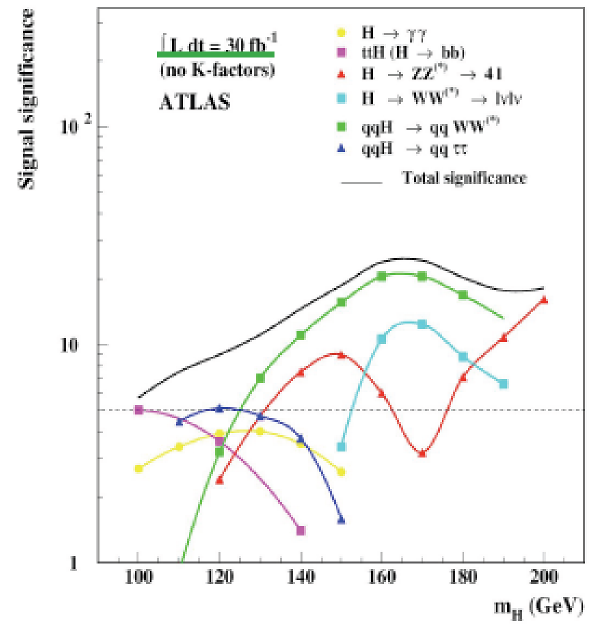
Needed ∫Ldt (fb^{-1}) per experiment

(at 14 TeV)



≤ 1 fb^{-1} for 98% C.L. exclusion
≤ 5 fb^{-1} for 5σ discovery
over full allowed mass range

ATLAS + CMS preliminary



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!

Most difficult part is M_h~115 GeV

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

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?

Key Messages

- Need to clear the cloud of TeV-scale physics to obtain clear views
- Synergy of colliders
- LHC and HL-LHC with prospects towards 2030
- ILC could be constructed now
- CLIC more R&D needed
- Converge towards one LC project
- Detector R&D mandatory for all projects
- LHC results decisive

Great opportunities ahead at the TeV scale

Window of opportunity for enabling decision on the way forward around 2011/2012 (?)

Past few decades

"Discovery" of Standard Model

through synergy of

hadron - hadron colliders (e.g. Tevatron)

lepton - hadron colliders (HERA)

lepton - lepton colliders (e.g. LEP)

Linear e^+e^- Colliders

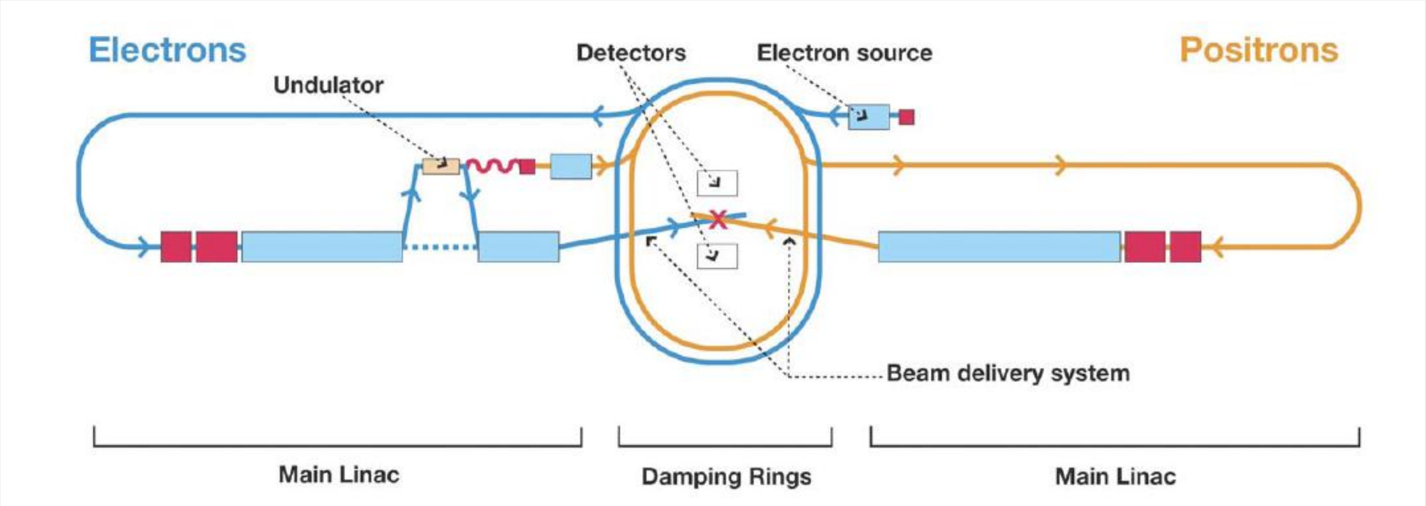
- The machine which will complement and extend the LHC best, and is closest to be realized, is a Linear e^+e^- Collider with a collision energy of at least 500 GeV.

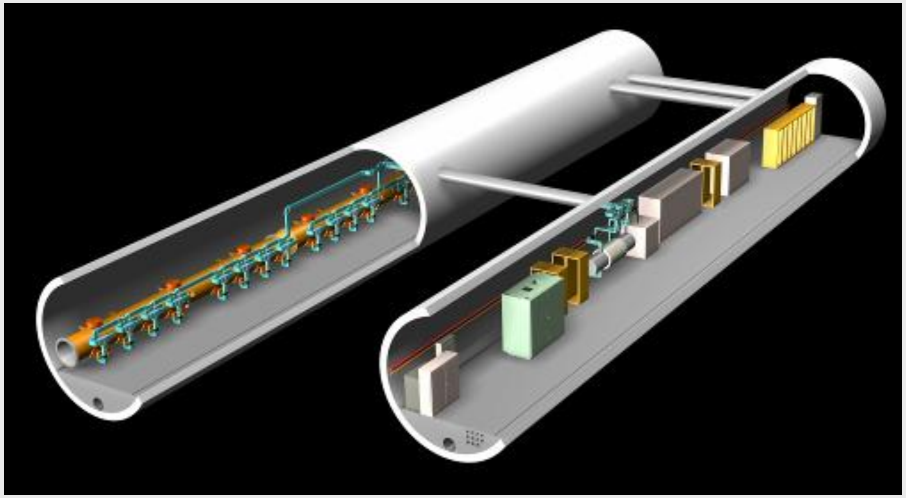
PROJECTS:

$\Rightarrow$ TeV Colliders (CMS energy up to 1 TeV) $\rightarrow$ Technology ~ready
ILC with superconducting cavities

$\Rightarrow$ Multi-TeV Collider (CMS energies in multi-TeV range) $\rightarrow$ R&D
CLIC $\rightarrow$ Two Beam Acceleration

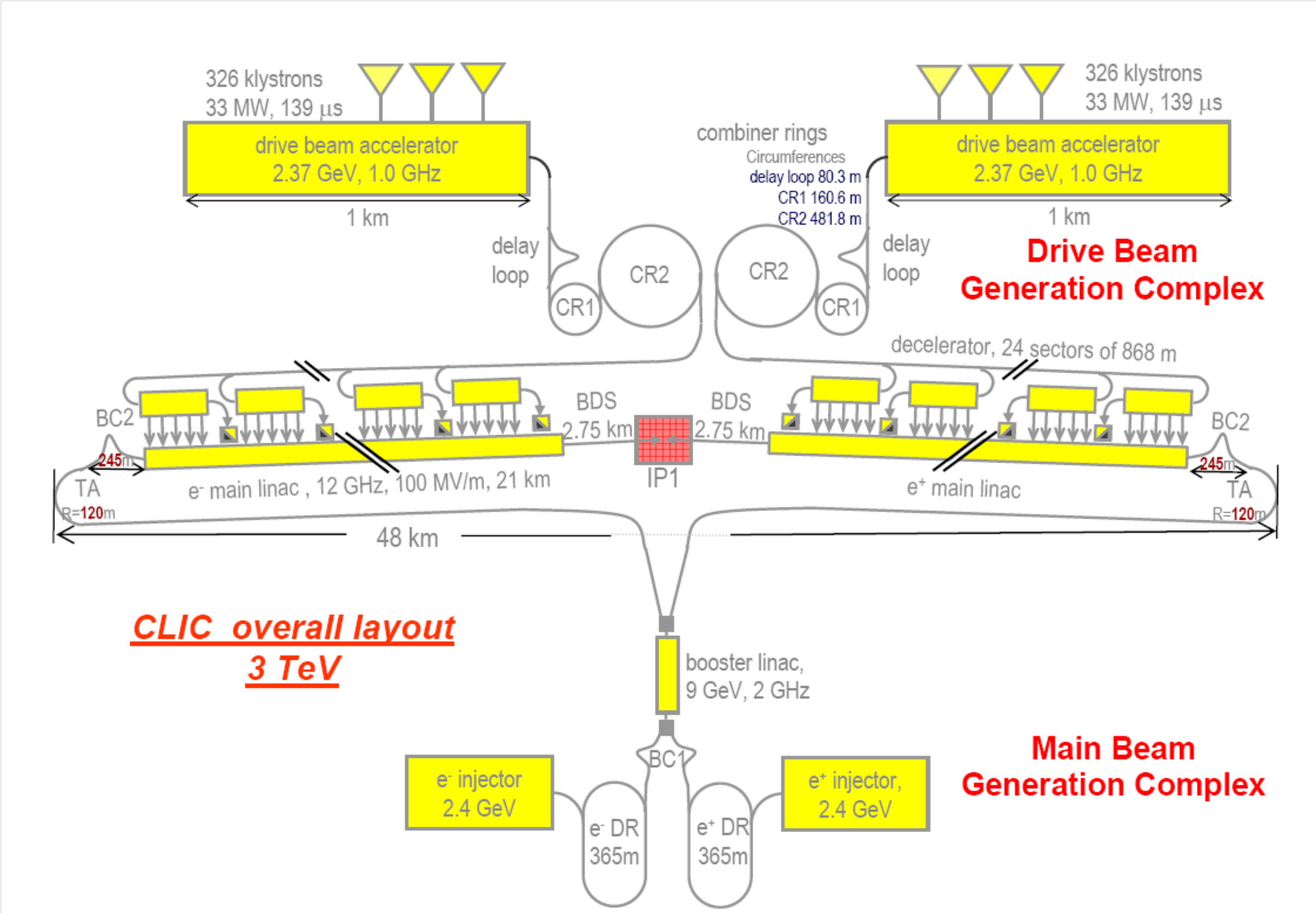
The International Linear Collider





Energy	250 Gev x 250 GeV
# of RF Units	560
# of Cryomodules	1680
# of 9-cell Cavities	14560
Accelerating Gradient	31.5 MeV/m
Peak luminosity	2 10^{34} $cm^{-2}s^{-1}$
Rep. Rate	5 Hz
IP	σ_x 350 – 620 nm; σ_y 3.5 – 9.0 nm
Total Power	~230 MW
2 Detectors Push-pull	

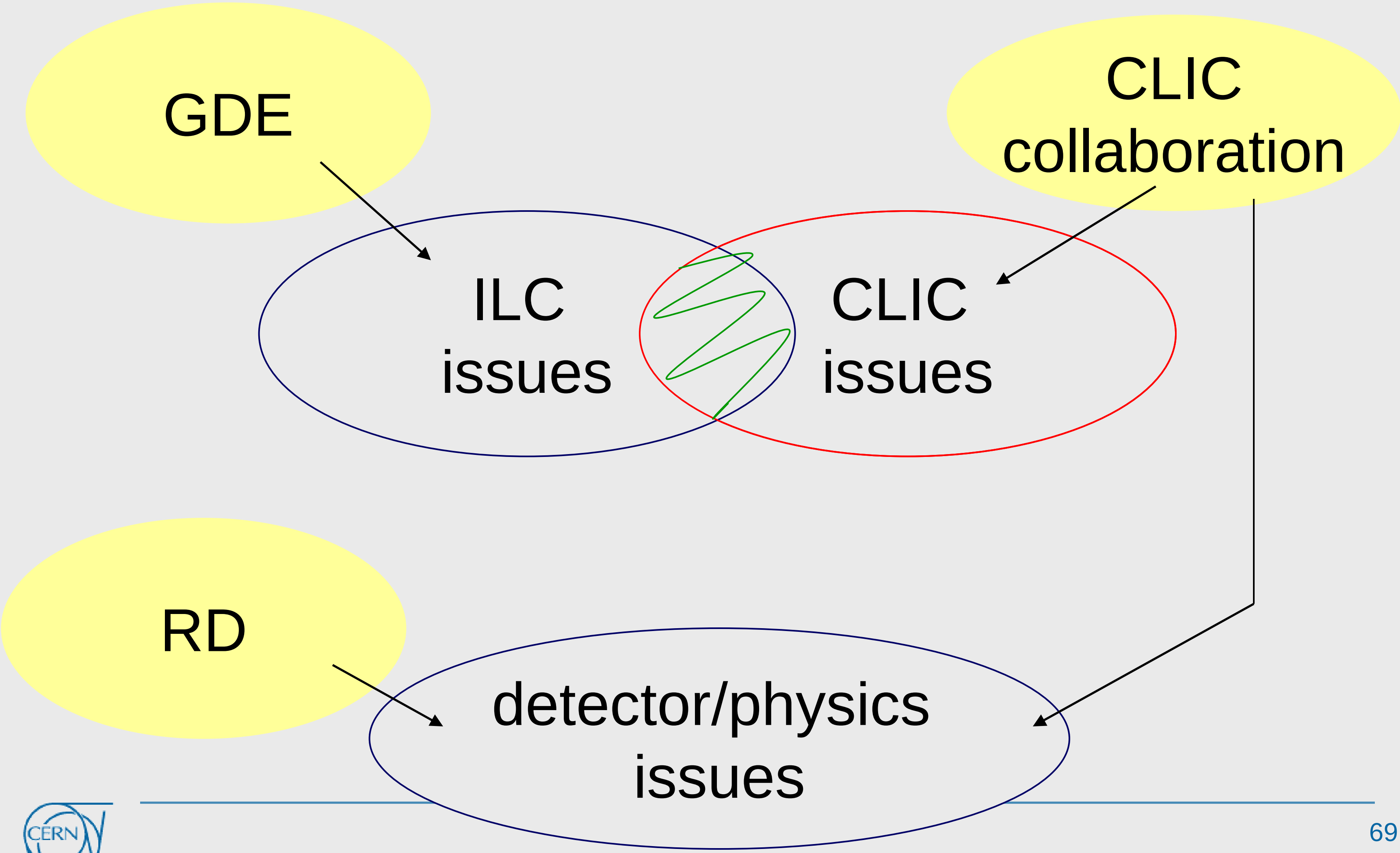
CLIC Overall Lay-out



Strategy to Address LC Key Issues

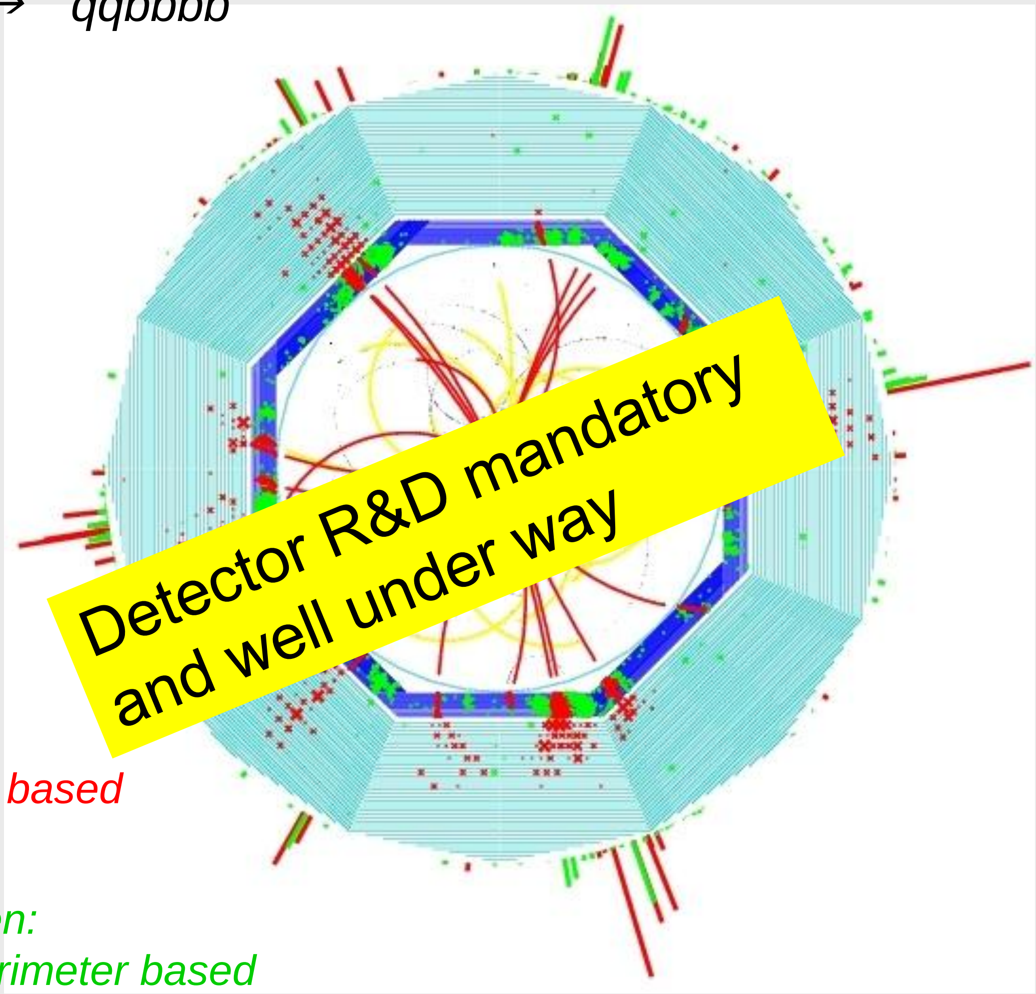
Recent progress: much closer collaboration

first meeting: February 08



LC Detector Challenges: Calorimeter

ZHH → qqbbbb



red:
track based

green:
calorimeter based

High precision measurements demand new approach to the reconstruction:

- particle flow (i.e. reconstruction of ALL individual particles)

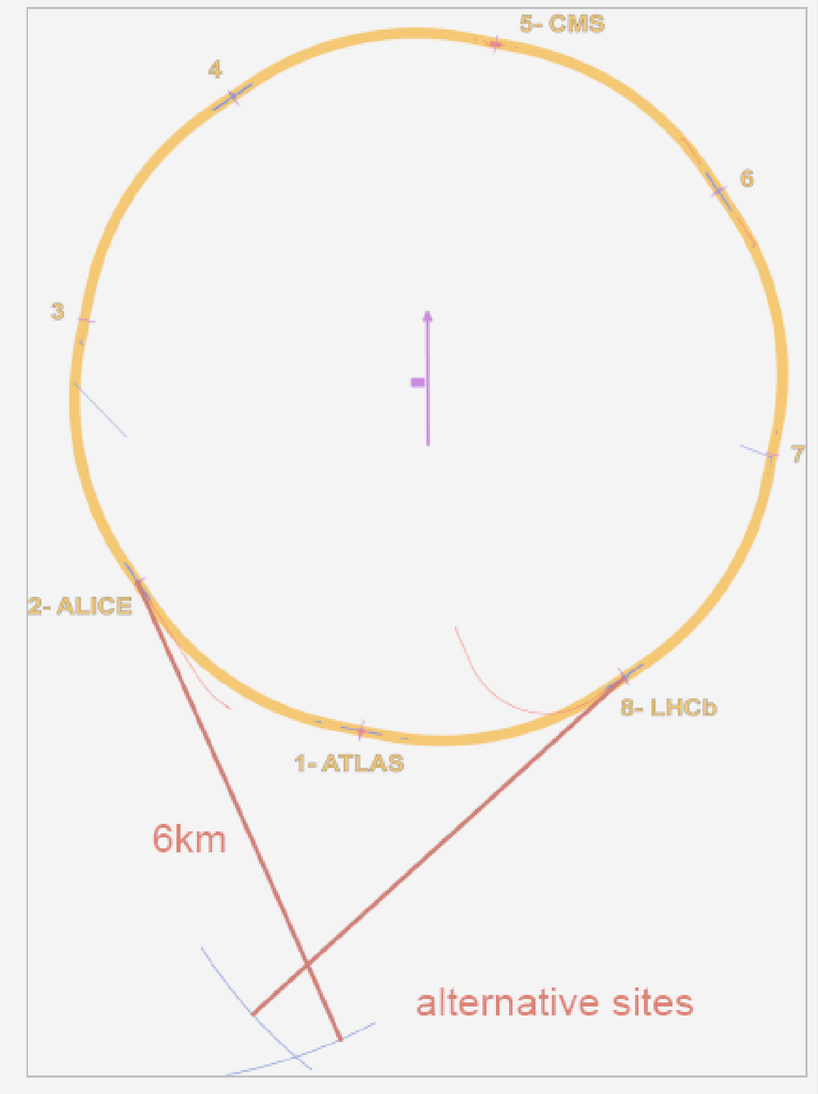
this requires

- unprecedented granularity

in three dimensions

R&D needed now for key components

Large Hadron electron Collider: possible layouts



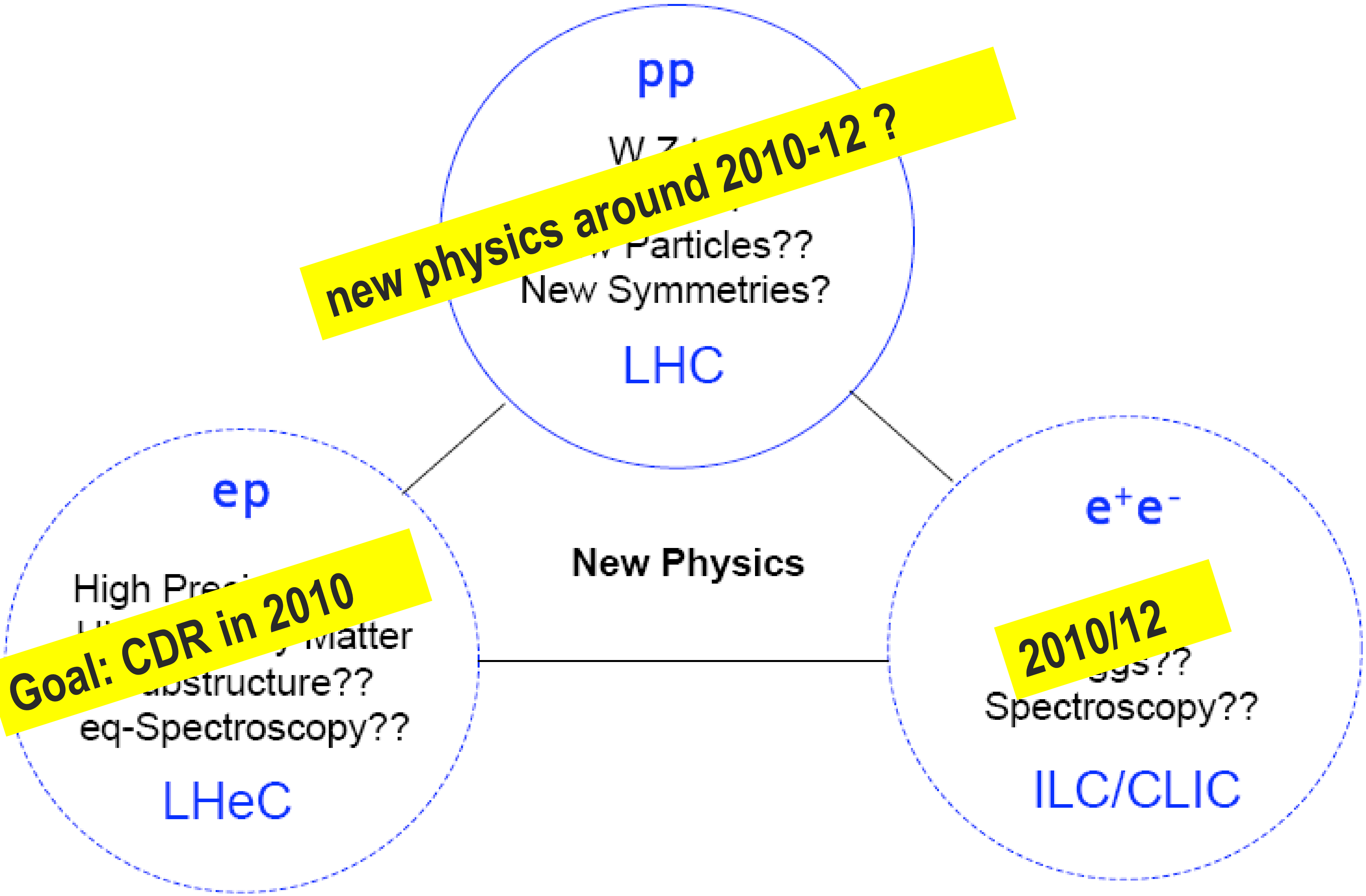
40 - 140 GeV
on
1 - 7 TeV

ring-ring solution:
L ≤ 10^{33}

linac-ring solution:
L few 10^{31}

Would be the successor of HERA at higher cms

The TeV Scale beyond 2010



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)

….facts today

facilities for HEP (and other sciences) becoming larger and expensive

funding not increasing

fewer facilities realisable

time scales becoming longer

laboratories are changing missions

→ more coordination and more collaboration required

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.

- *"This is a milestone in CERN's history and a giant leap for particle physics"*, said Michel Spiro, President of the CERN Council. *"It recognizes the increasing globalization of the field, and the important role played by CERN on the world stage."*

We need

- to maintain expertise in all regions

  national – regional – global projects
- long term stability and support in all three regions

- to engage all countries with HEP communities

- to integrate HEP emerging countries (regions)

- a global forum for funding agencies

- a closer link among particle and astroparticle physics

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

Looking forward to more moments like this