

# Recent Highlights from Particle Physics

## MAP Plenum

**Klaus Kirch, PSI-ETHZ  
CHIPP-Chairman**

**20. April 2012**

# Who is CHIPP?

## Swiss Particle Physics Landscape in 2011



an Association according to Swiss law

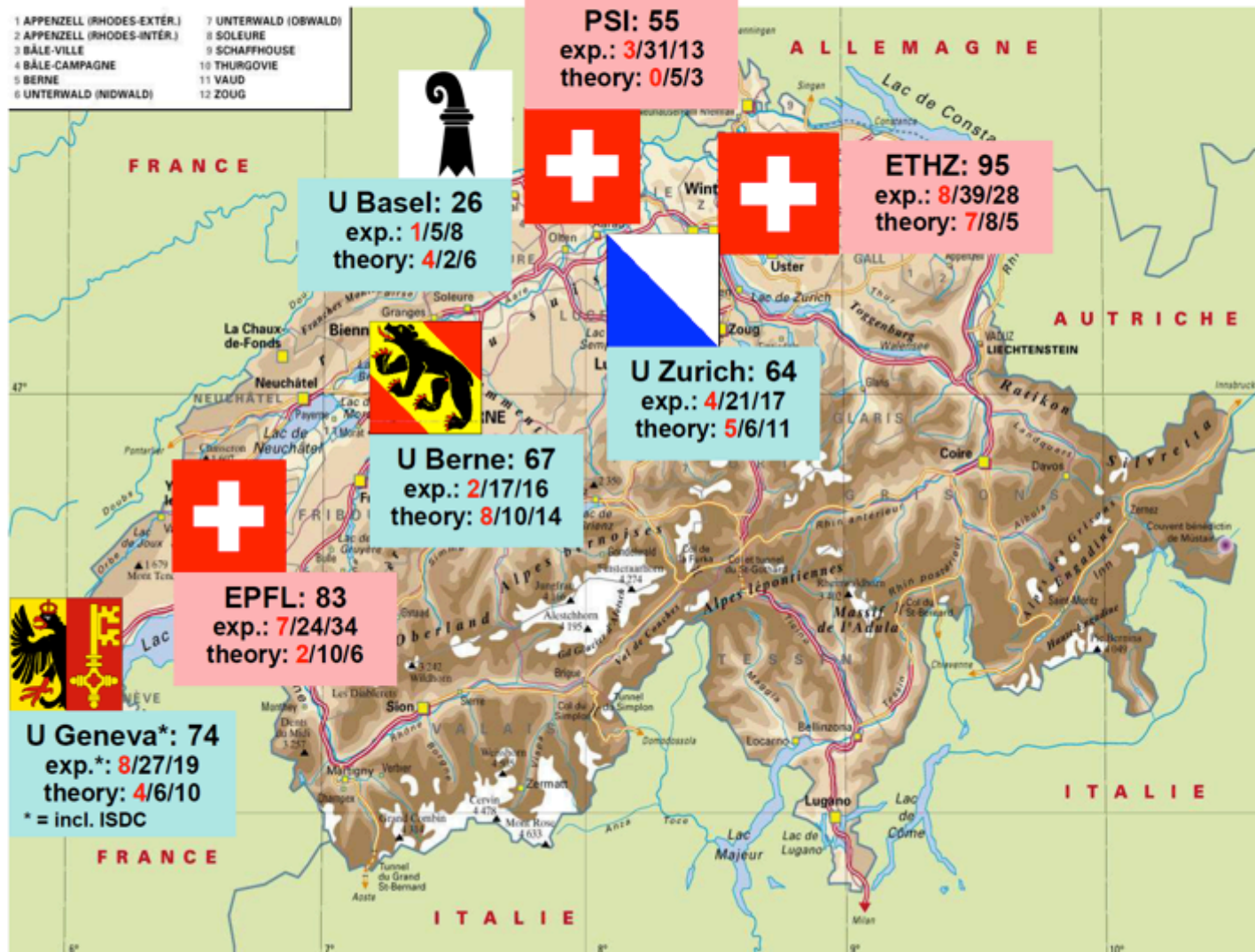
sc|nat

Member of the Swiss Academy of Sciences

Total Scientific personnel:  
Total 409

Professors /  
staff /  
PhD students  
Total 60/175/174

(admin. & technical staff  
not included: hard to  
quantify)



# What is CHIPP about?

The purpose of the Association is to strengthen  
**particle, astroparticle and nuclear physics in Switzerland**  
by being active in particular in the following fields:

- To **help** towards a successful participation of Swiss groups in projects;
- To **advise** the Universities/ETHs on vacant professorships and academic strategies, and coordinate teaching activities;
- To **ensure** a proper Swiss representation in relevant national and international bodies;
- To **promote** public awareness on particle, astroparticle and nuclear physics.

# Some CHIPP activities 2012:

**Long Range Planning for Swiss Particle Physics 2012-2020: Collecting input concerning financial needs of the projects based on estimates of the project leaders and providing feed-back information to SER and SNSF.**

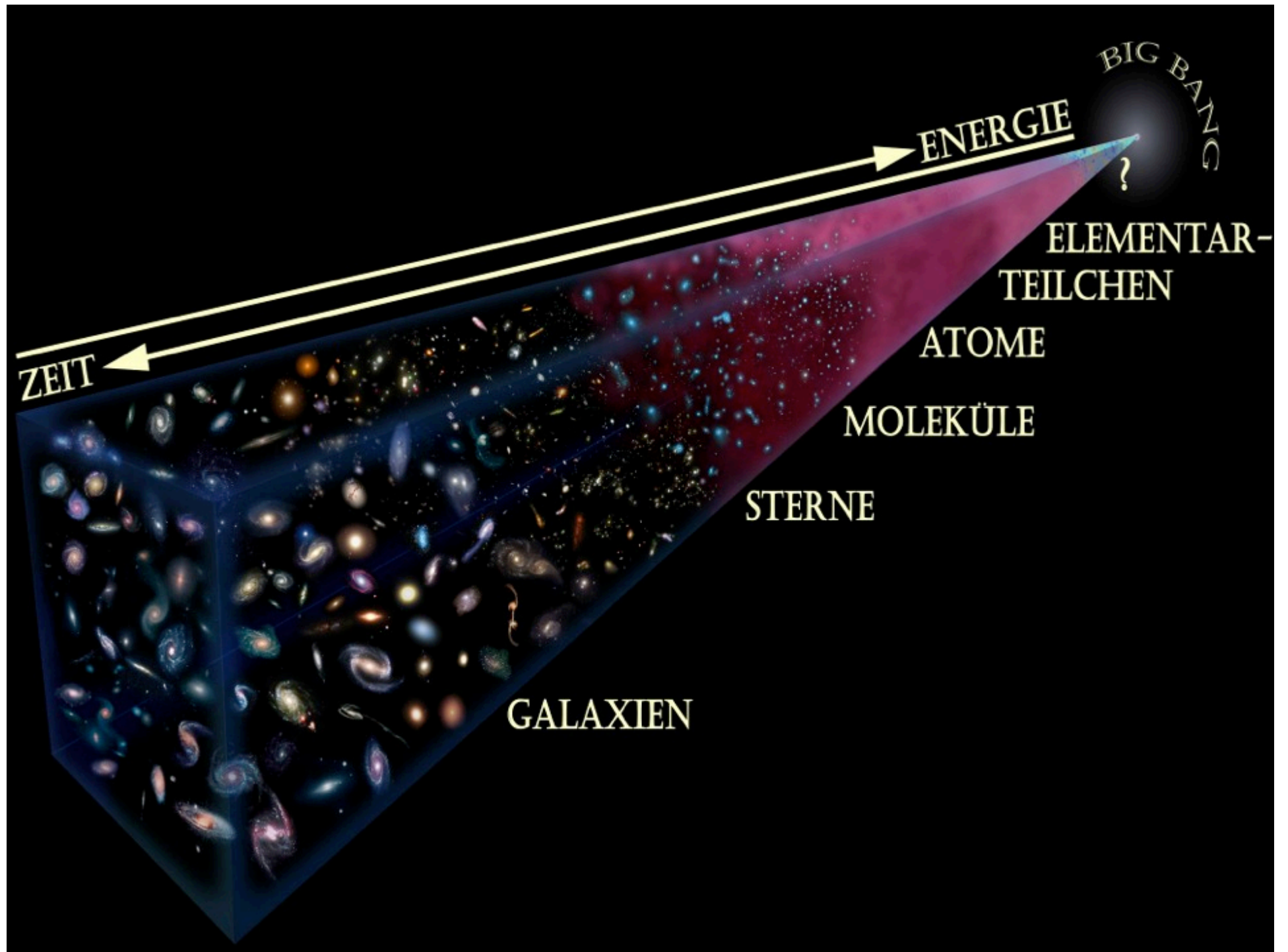
**Work in international networks and on roadmaps or position papers concerning:**

- Update of the European Strategy for Particle Physics (CERN coordinated process)
- ApPEC (Astroparticle Physics European Coordination)
- NuPECC (Nuclear Physics European Coordination Committee)

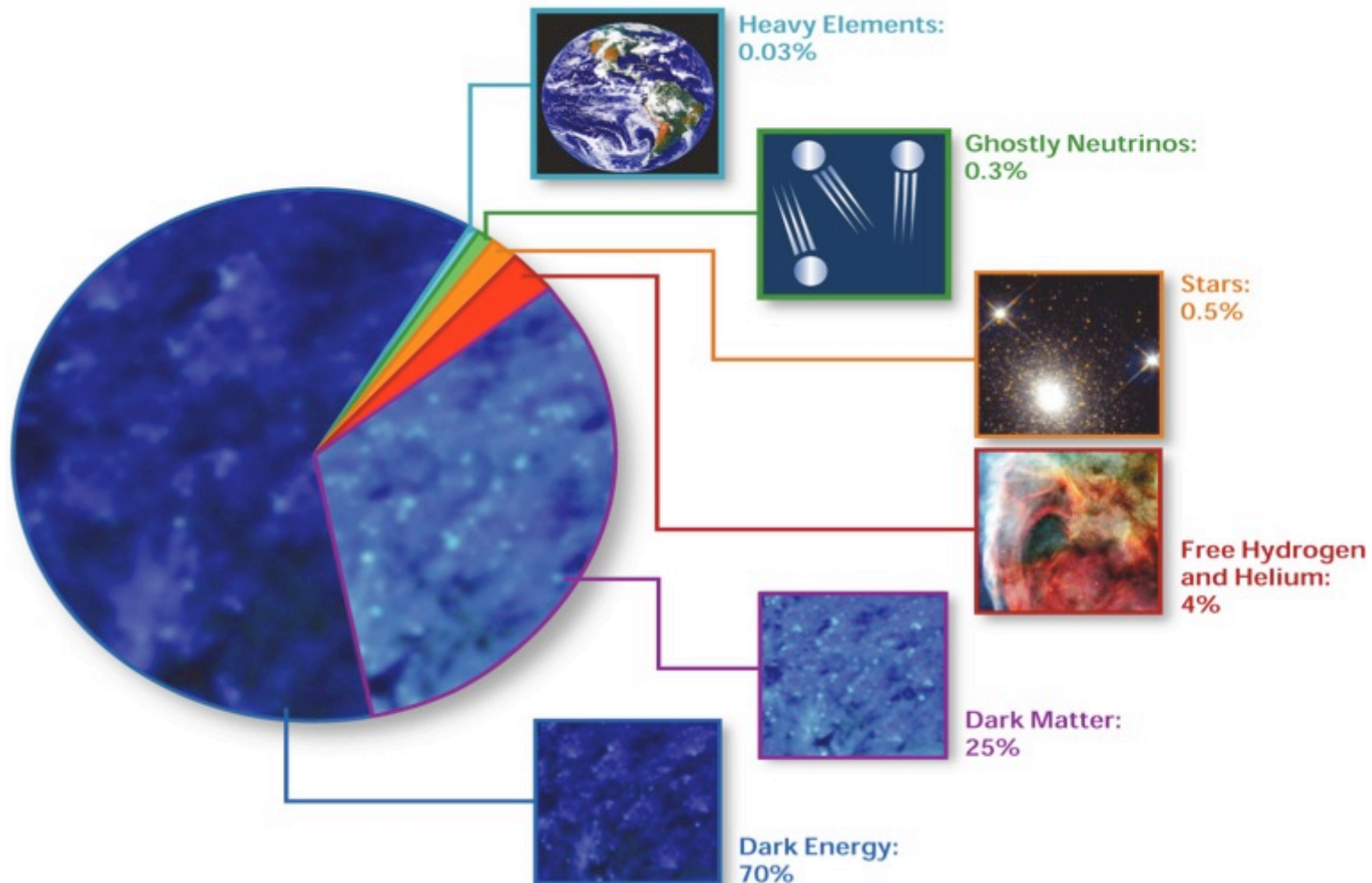
**CHIPP prize for the best PhD student:** Diploma and CHF 3000,-- given at Plenary Meeting. The Plenary Meeting is an annual 2-days scientific meeting.

**Schools and Workshops:**

- CHIPP PhD Winterschool (January, Engelberg)
- Phenomenology Workshop (January, Zürich)
- DarkAttack2012 (Dark Matter, Juli, Ascona)
- ZuoZ Summer School (August)



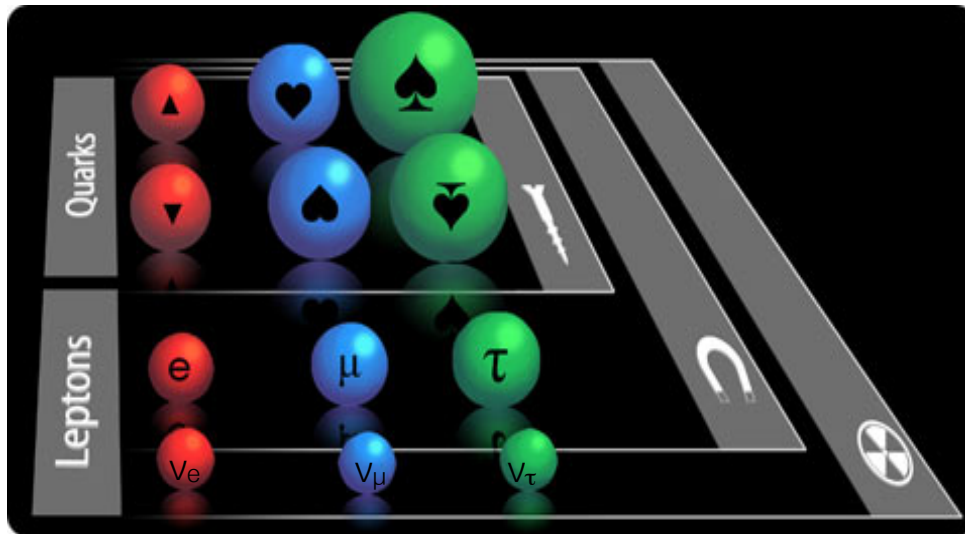
# Matter and Energy Content of our Universe



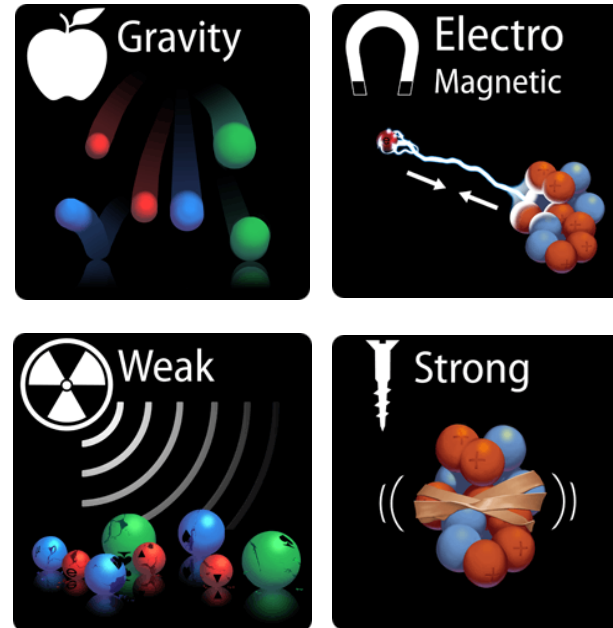
MAP, April 20, 2012

# Standard model of particle physics

Matter: quarks and leptons



Fundamental interactions:  
mediated by bosons



Very successful theory, describing all observations up to  $\approx 1$  TeV

However, we *expect new particles and phenomena* as we probe higher and higher energies

For example: None of the standard model particles is a good dark matter candidate!

# An incomplete list of open fundamental issues:

- Will a Higgs boson complete our Standard Model?
- What is beyond the Standard Model?
- Is supersymmetry realized in nature?
- Why is matter dominating over anti-matter?
- What is the special role of neutrinos?
- Why three families/flavors?
- What is dark matter made of?
- Are particle physics and dark energy connected?
- ...

# Swiss Particle Physics

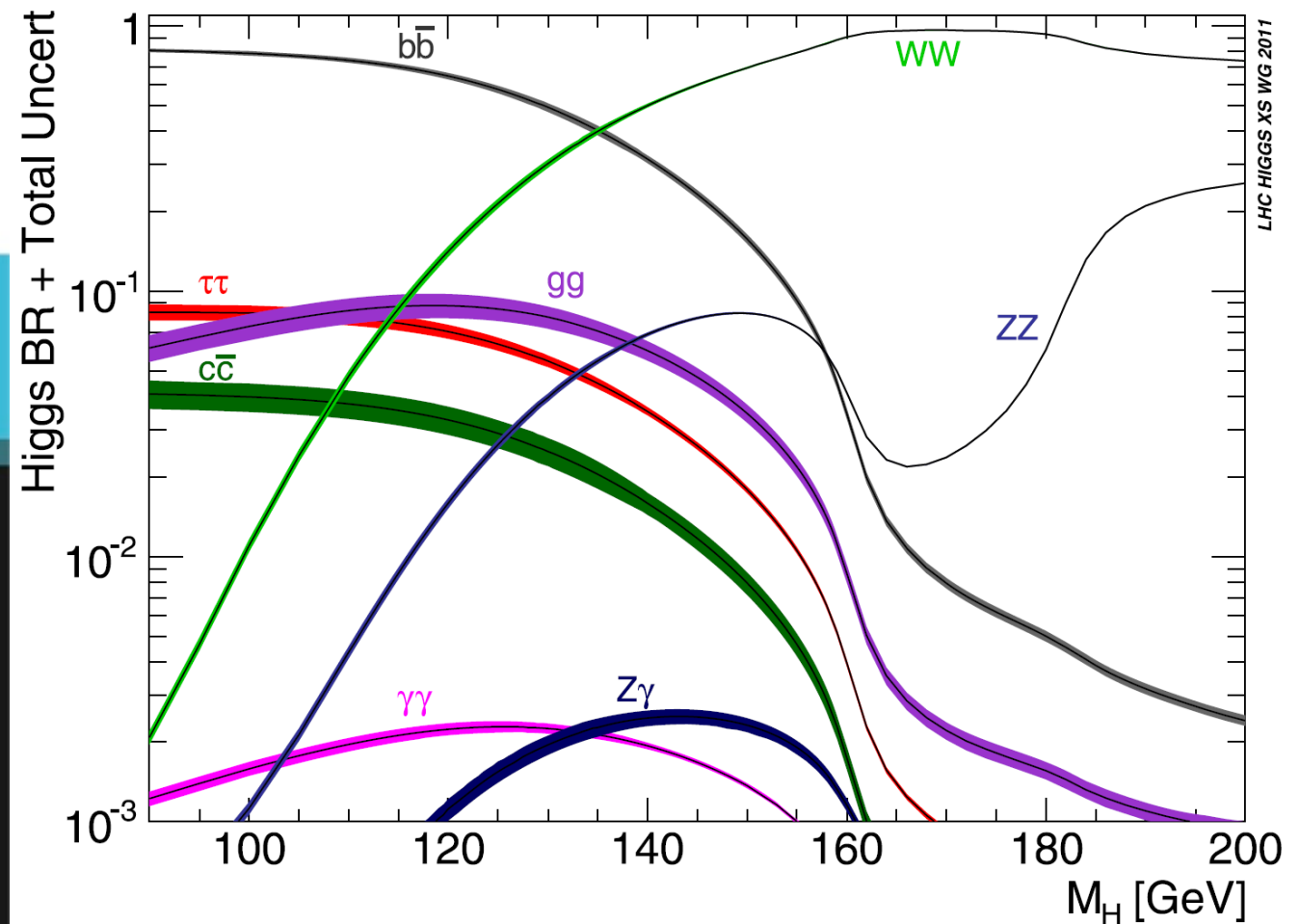
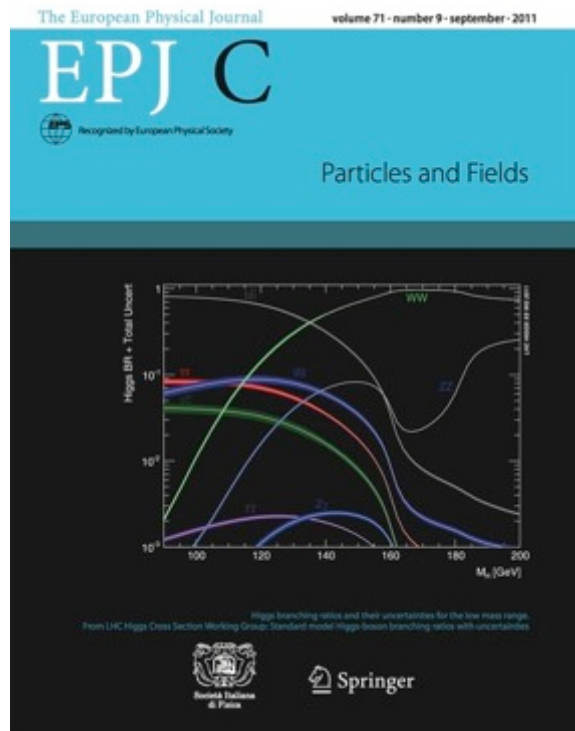
is involved in leading efforts striving  
for answers to these questions via ...

- theory and model calculations
- experiments at the highest energies
- experiments at the highest intensities
- experiments underground and on surface
- experiments in space
- activities in small labs and at large facilities

# Some

selected highlights 2011 on the way  
answering these open questions ...

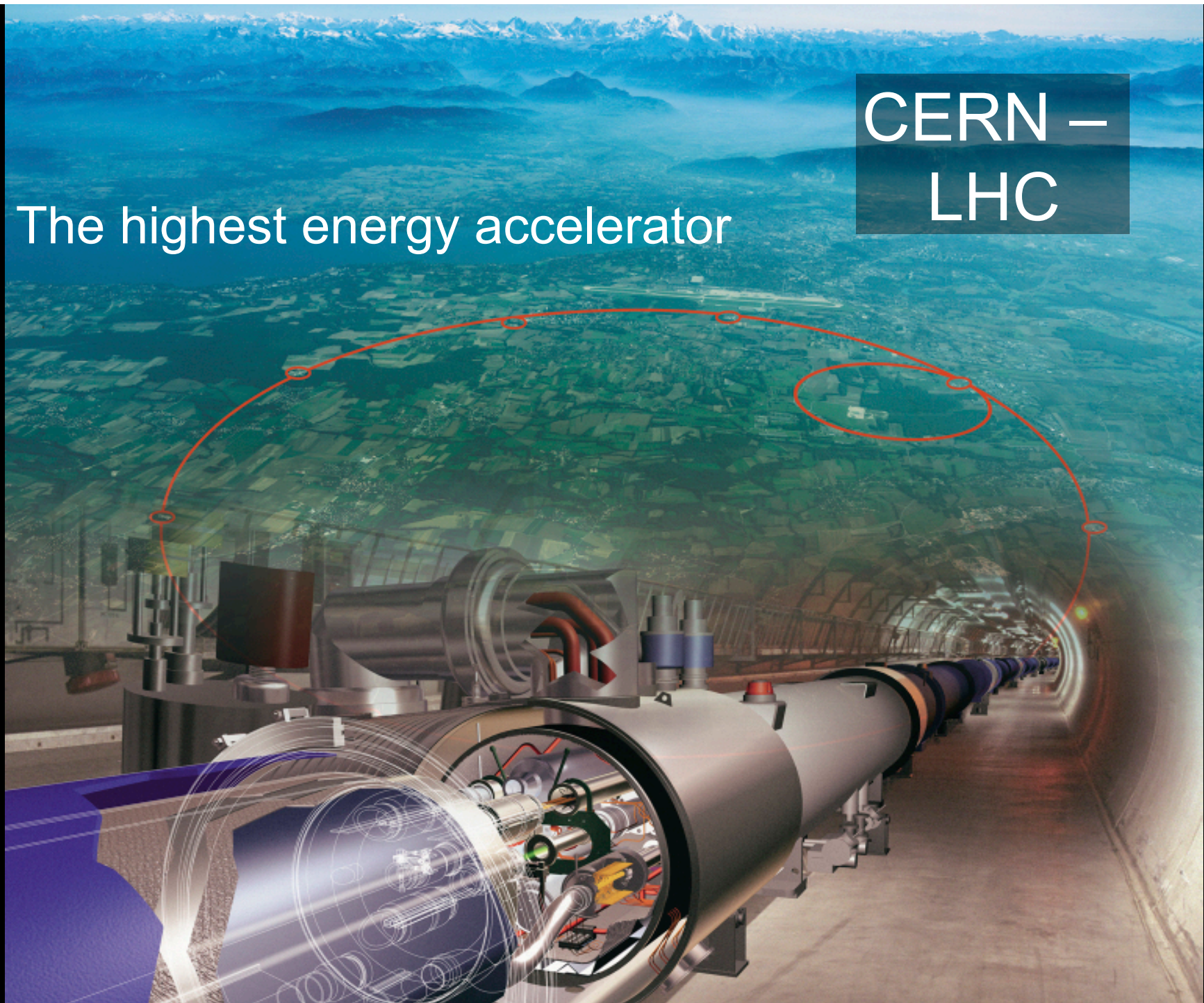
# Precision Standard Model Calculations: One example for crucial theoretical input



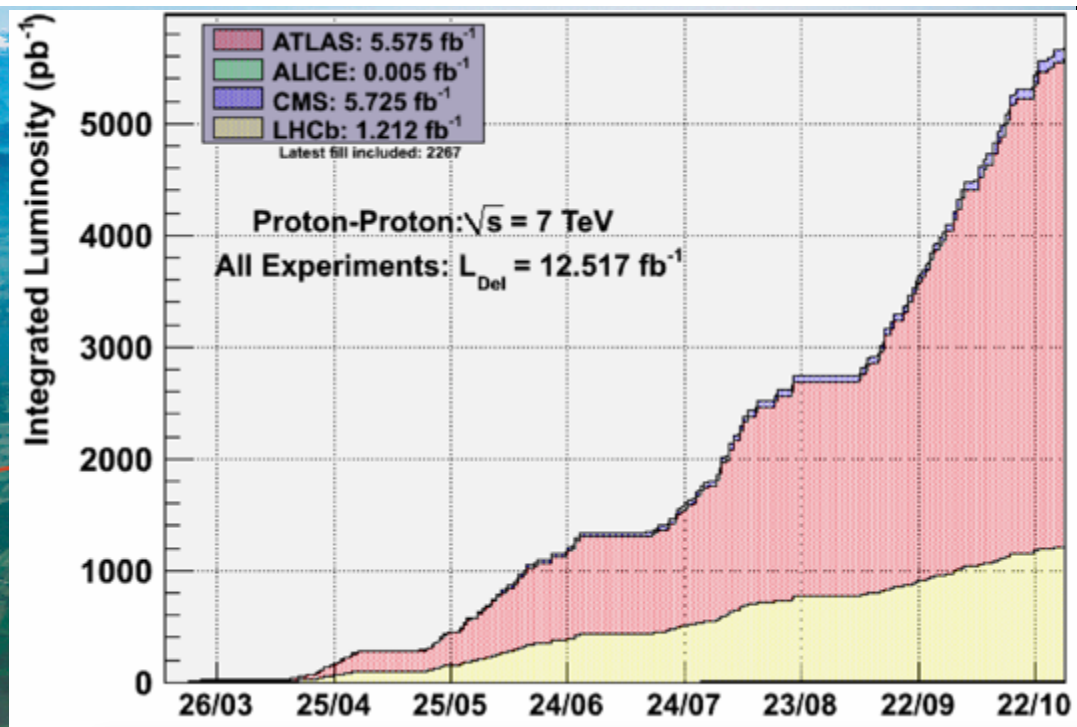
A. Denner<sup>1,a</sup>, S. Heinemeyer<sup>2</sup>, I. Puljak<sup>3</sup>, D. Rebuszi<sup>4</sup>, M. Spira<sup>5</sup>

The highest energy accelerator

CERN –  
LHC



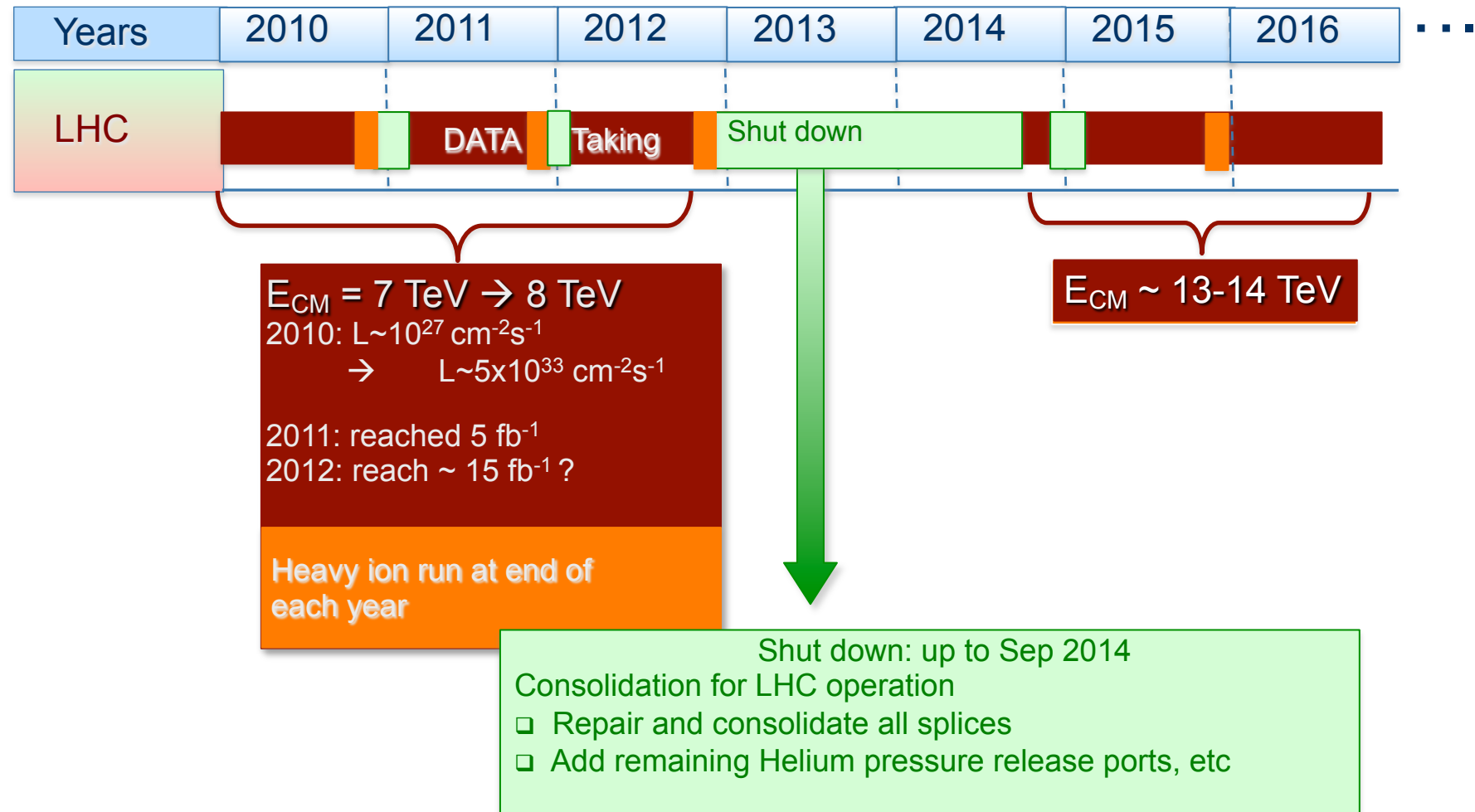
2011 was extremely  
successful  
for LHC operations  
and experiments



2011: Factor  $\sim 20$  gain in peak luminosity w.r.t. 2010

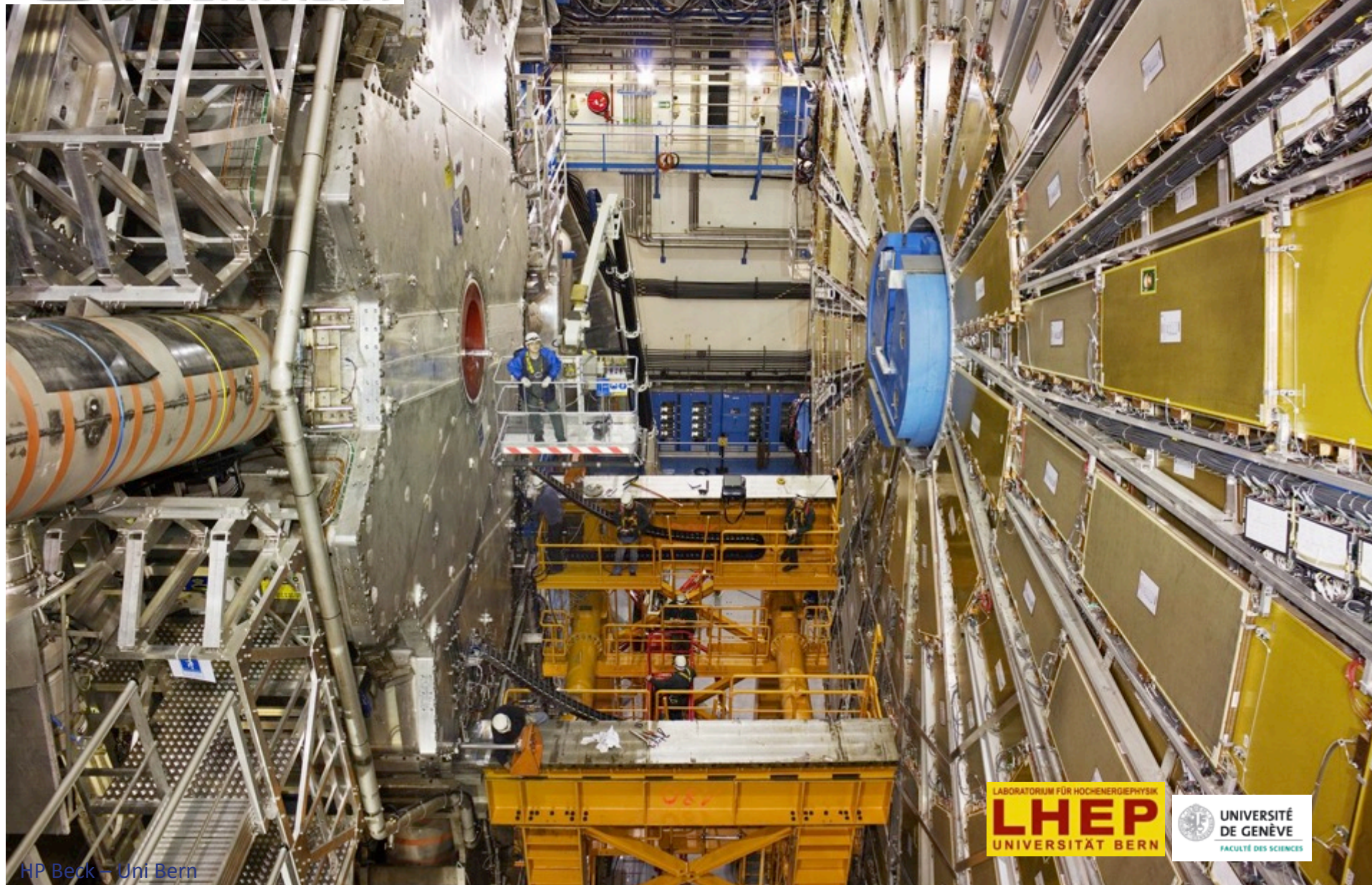
Latest NEWS:  
First 8 TeV  
collisions started  
end of March 2012

# LHC - Next steps : 2012 - 2016





# LHC: ATLAS





# LHC: ATLAS



Run Number: 189280,  
Event Number: 143576946  
Date: 2011-09-14, 11:37:11 CET

EtCut: 0.3 GeV  
PtCut: 3.0 GeV  
Vertex Cuts:  
Z direction < 1cm  
Rphi < 1cm

Muon: blue  
Cells: Tiles, EMC

**4-muon event  
with invariant  
mass of  
124.6 GeV**

Persint

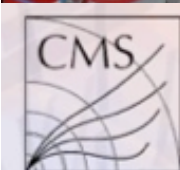


# LHC: CMS





# LHC: CMS



CMS Experiment at LHC, CERN  
Data recorded: Mon Sep 27 02:29:14 2010 CEST  
Run/Event: 146713 / 179622537  
Lumi section: 178  
Orbit/Crossing: 46487568 / 1807

di-photon event

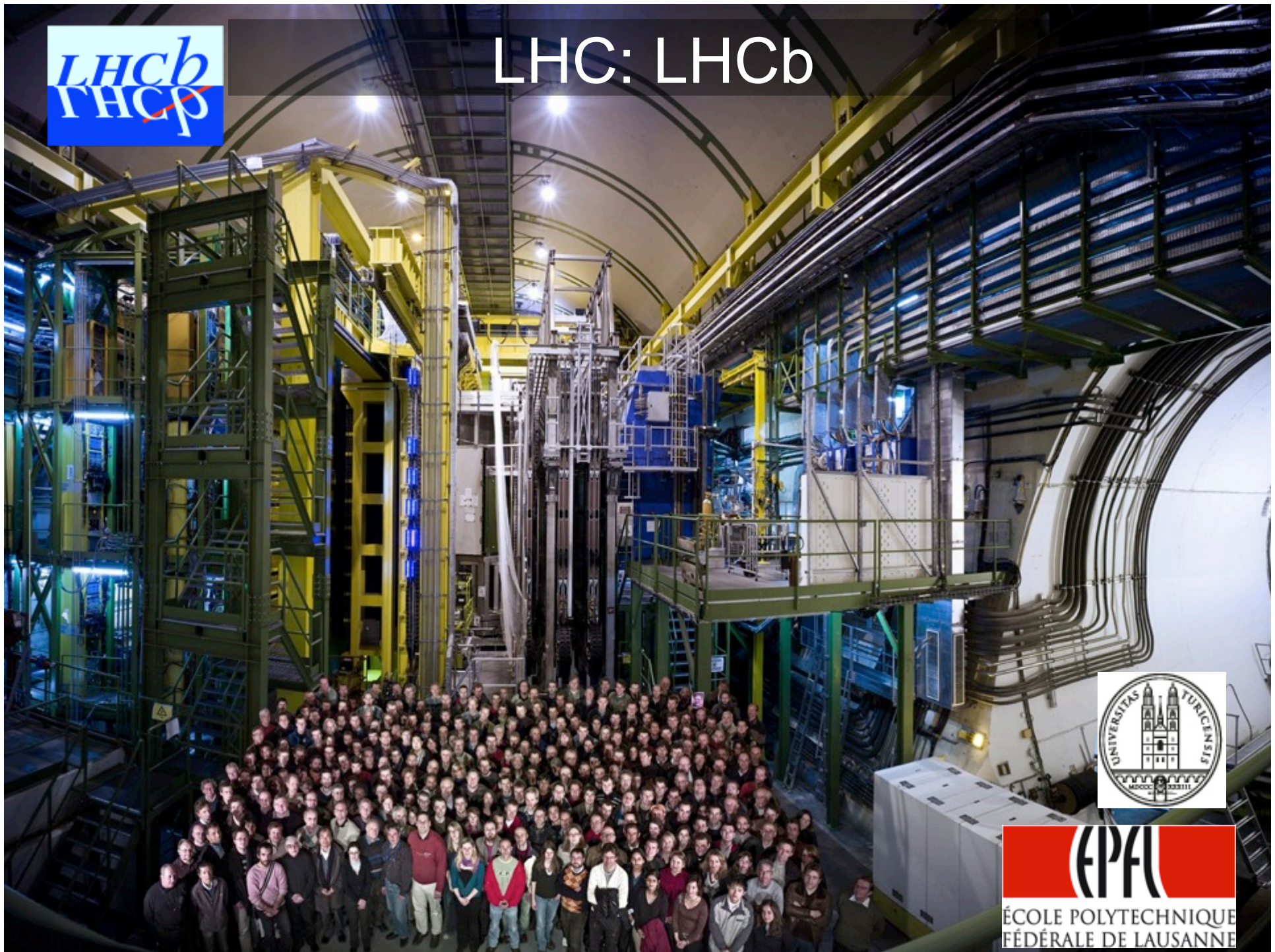


CMS Experiment at LHC, CERN  
Data recorded: Wed Oct 26 08:10:31 2011 CEST  
Run/Event: 179889 / 533479508  
Lumi section: 320

$B_s \rightarrow \mu\mu$  candidate

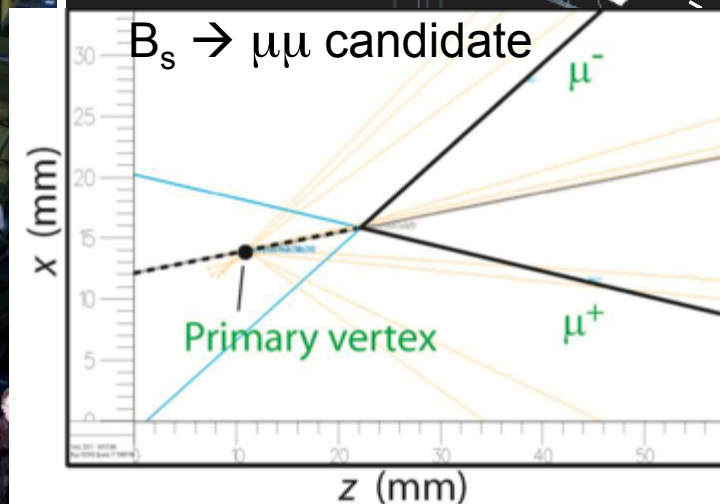
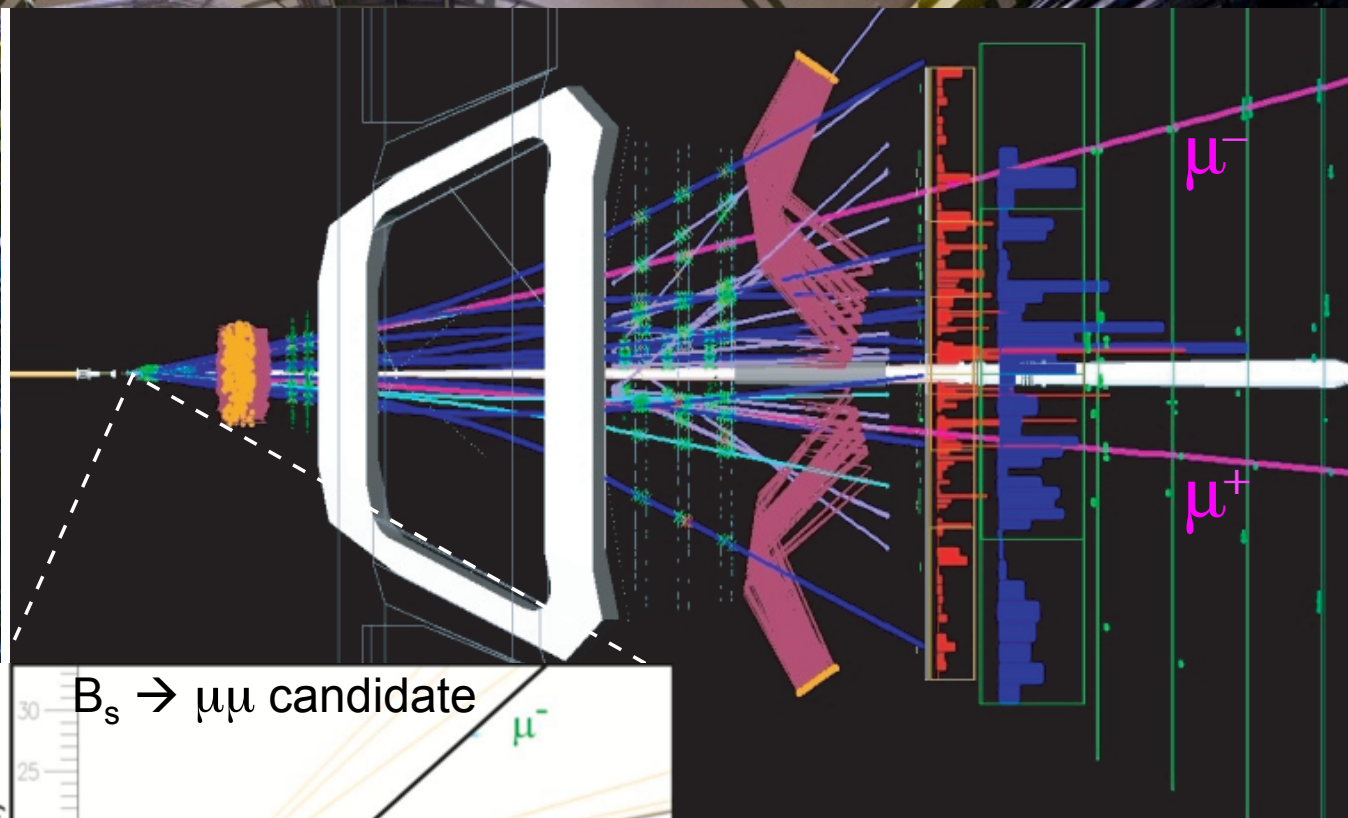


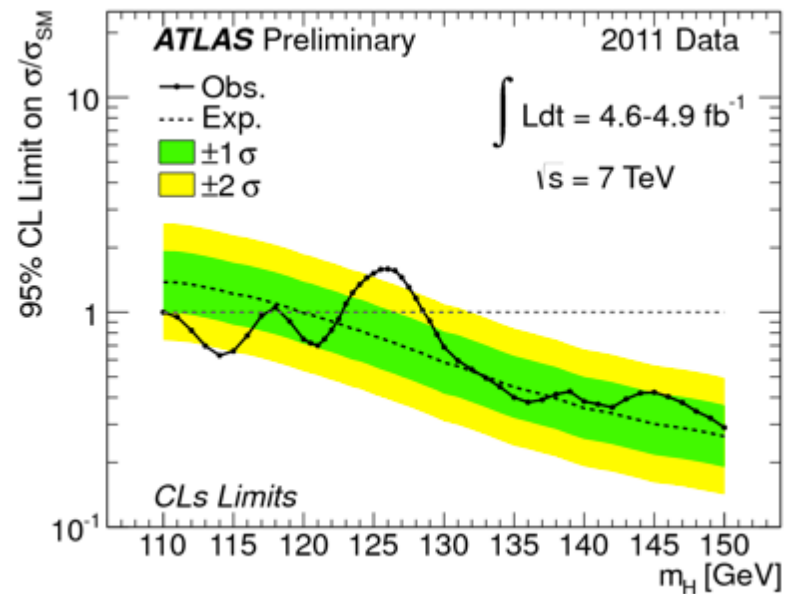
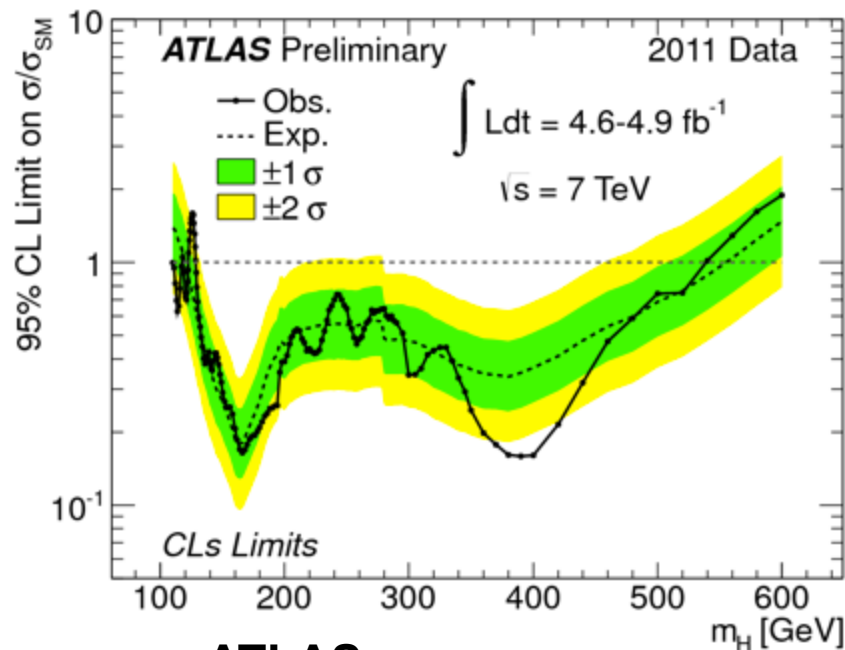
# LHC: LHCb





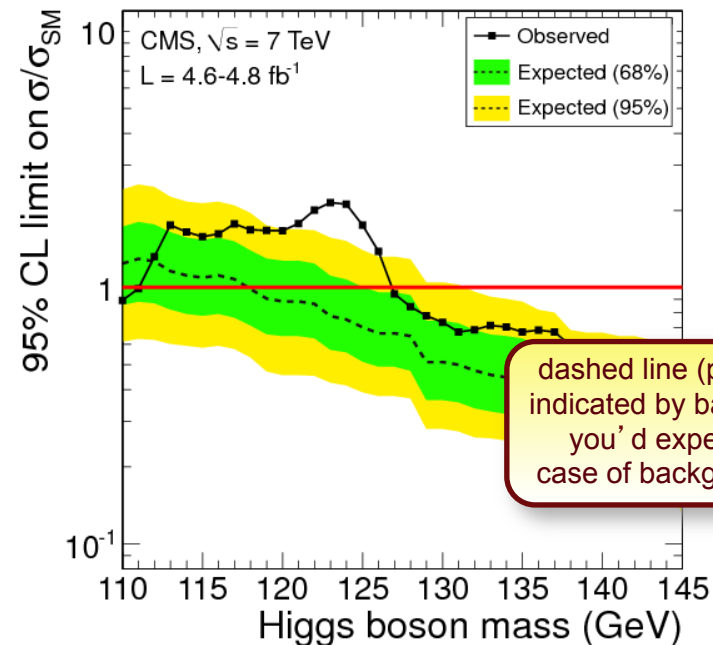
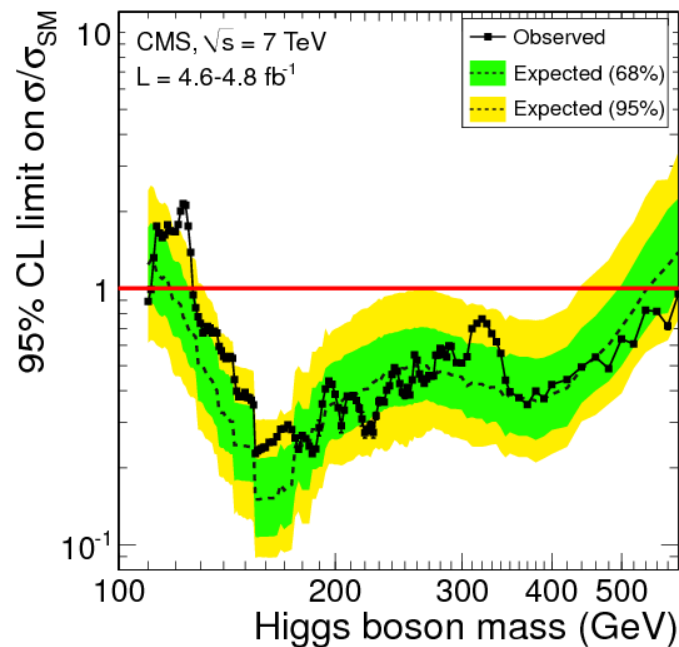
# LHC: LHCb





**ATLAS**  
**CMS**

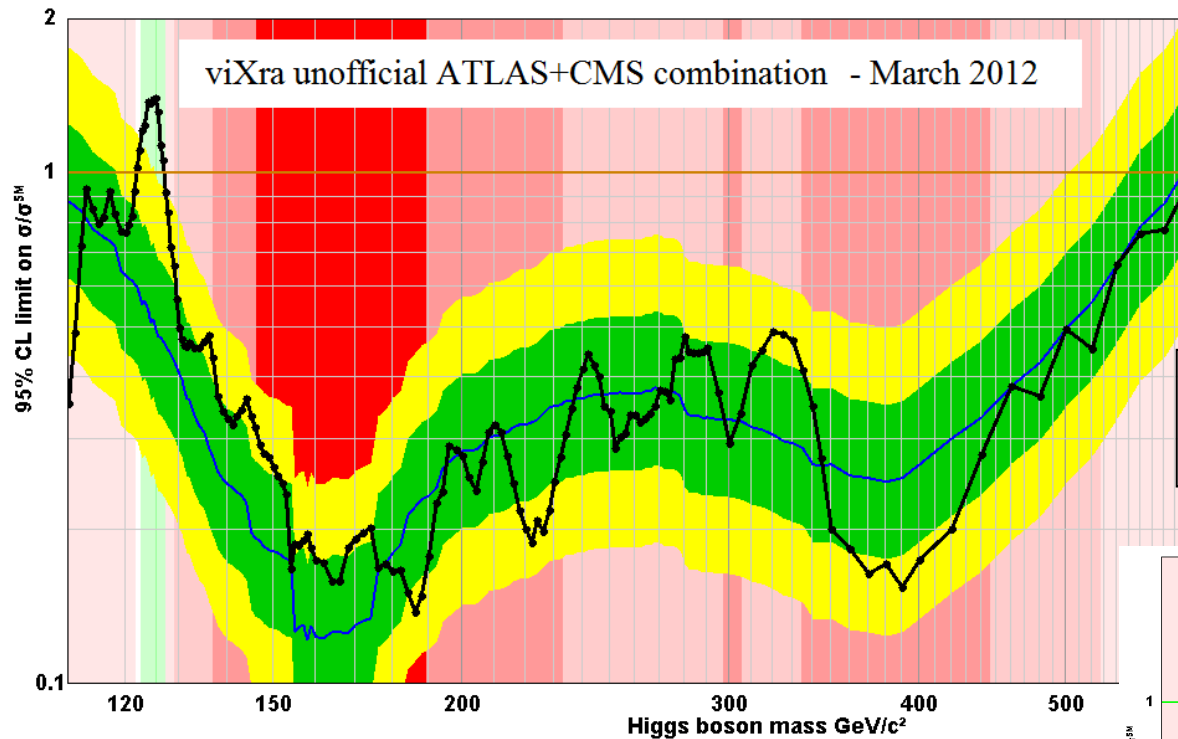
# Hunting the Higgs Boson



MAP, April 20,

# Being neither ATLAS nor CMS

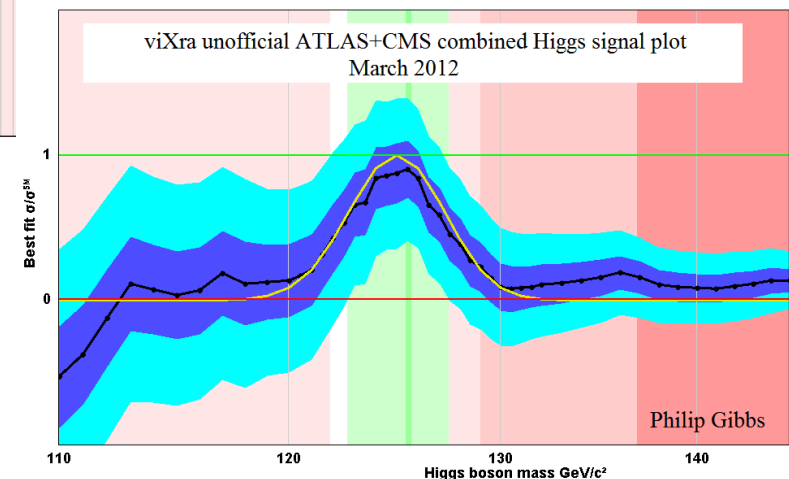
## I can show you an **unofficial** combination



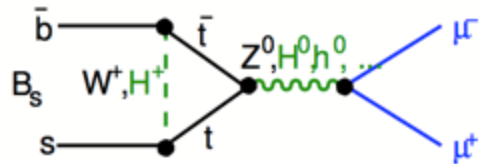
The full Higgs mass range is excluded except for the region of approximately  $[122, 128] \text{ GeV}$

This is a major achievement of 2011 data taking and analysis

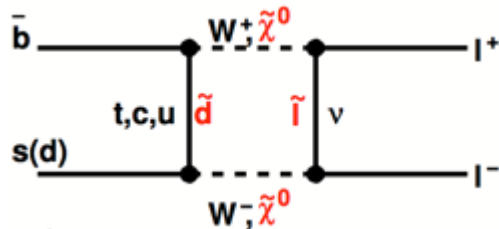
<http://blog.vixra.org/> by Philip Gibbs



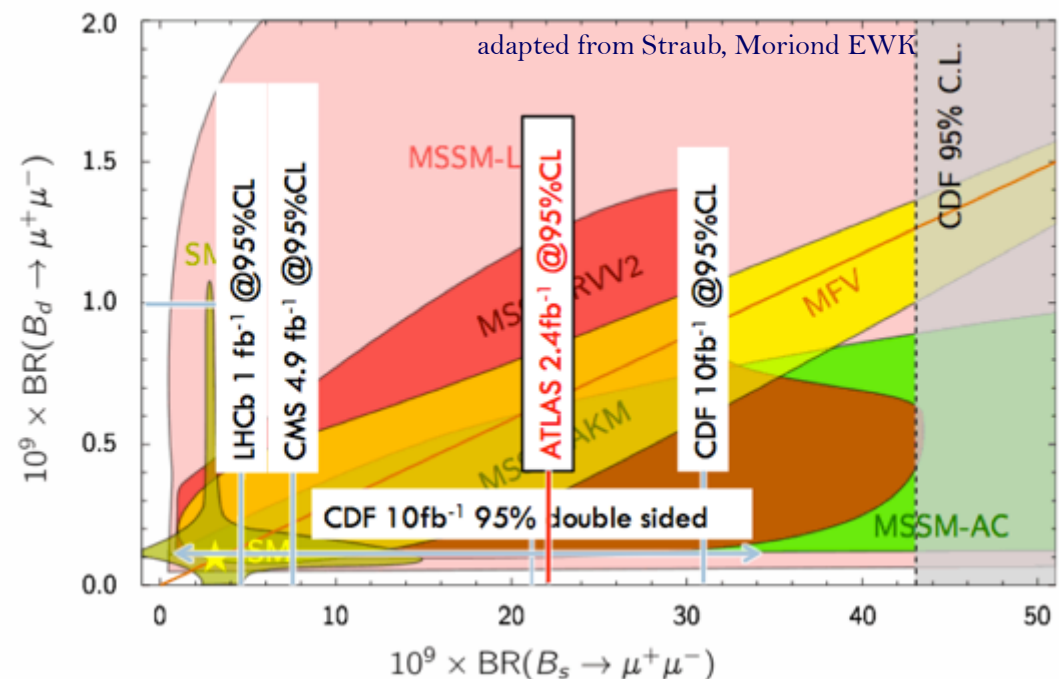
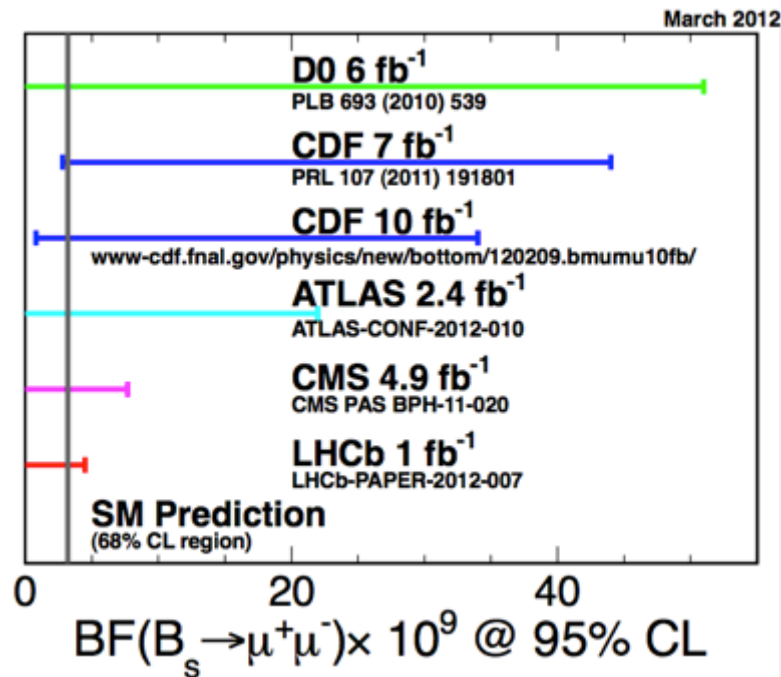
# Rare decay $B_s \rightarrow \mu^+ \mu^-$



The Standard Model of particle physics predicts  
 $BR = (3.2 \pm 0.2) \times 10^{-9}$



Rare decays:  
 indirect limits on new physics



courtesy: G. Dissertori, O. Schneider

# AMS-02 Launch

## STS-134 Endeavour:

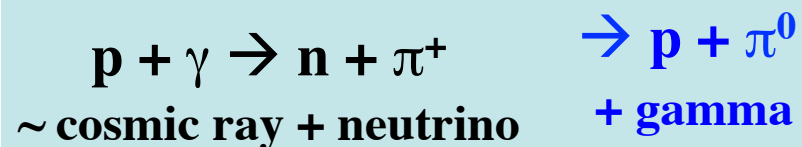
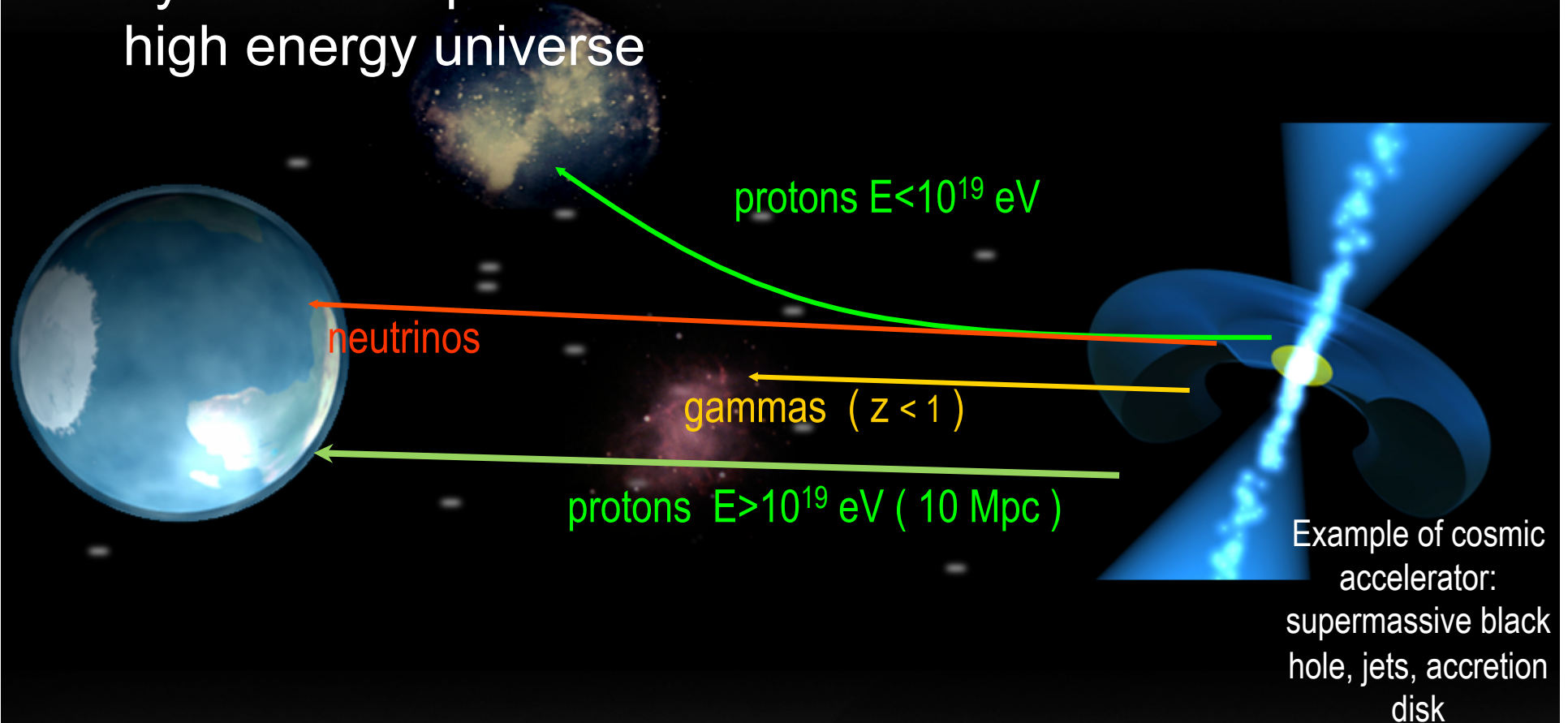
- Successful launch:  
May 16, 14:56
- Docking with ISS:  
May 17, 17:59
- AMS installation  
complete: May 19,  
11:46
- AMS up and running:  
May 19, 16:38
- First He nucleus:  
May 19, 16:42
- First public science  
result expected  
for summer 2012

courtesy: M. Pohl



# Multi-messenger astronomy

- Cosmic Rays - Neutrinos - gamma are produced by the same powerful sources that illuminate the high energy universe



# Cherenkov- and Neutrinoastronomy

courtesy:  
A. Biland, T. Montaruli

Very High Energy  $\gamma$ -ray astronomy with  
**MAGIC**



11 Oct 2011

**FACT**

First operation (full moon!)

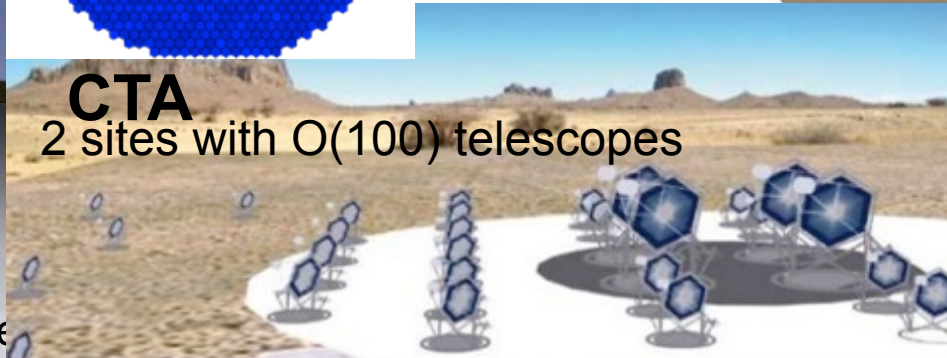


Event taken on  
11 Oct 2011

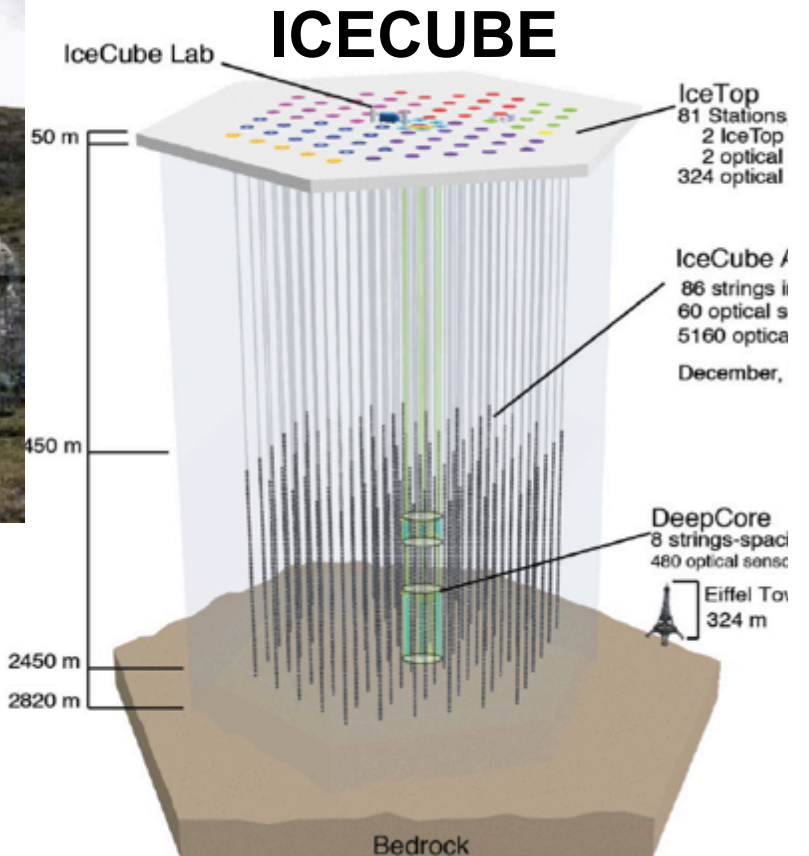
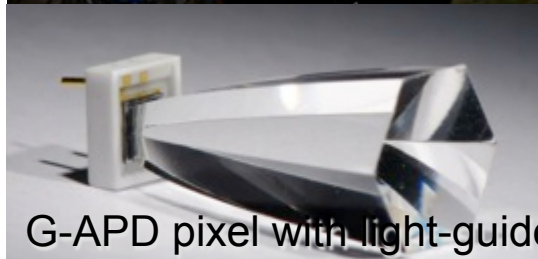


**CTA**

2 sites with  $O(100)$  telescopes

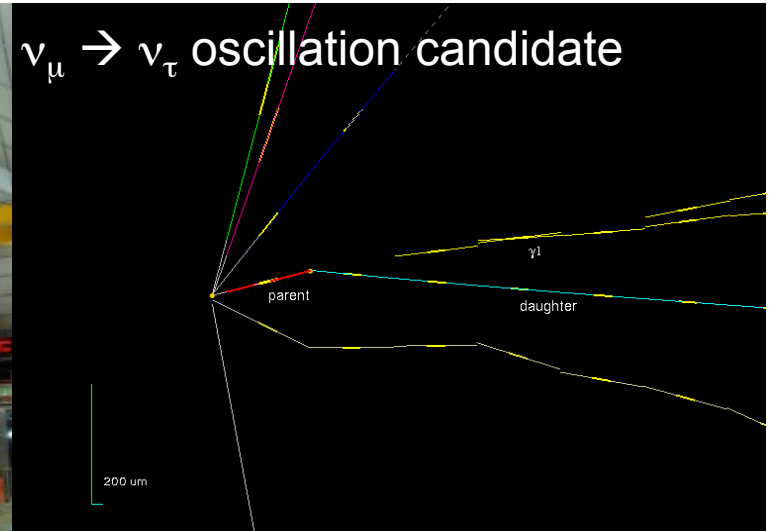


G-APD pixel with light-guide





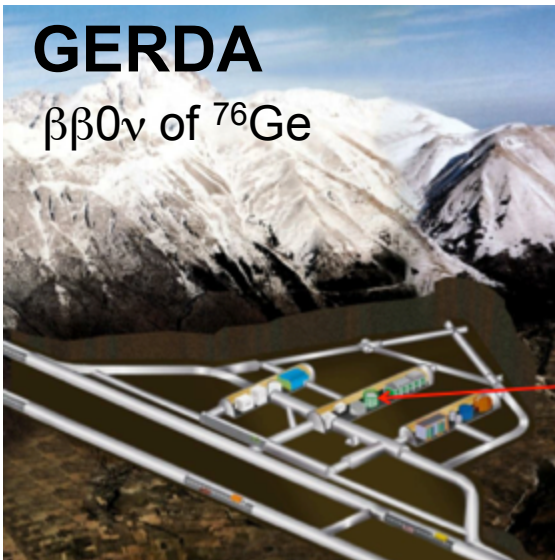
# OPERA



- $\nu_\mu \rightarrow \nu_e$  oscillation
- last mixing angle  $\Theta_{13}$  different from zero
- Earth quake stopped T2K at  $2.5\sigma$ , running again
- meanwhile: Daya Bay with  $5\sigma$  observation

# GERDA

$\beta\beta 0\nu$  of  $^{76}\text{Ge}$



# Neutrinos

- all mixing angles different from 0
- Absolute mass scale?
- Dirac or Majorana particles?
- CP violation in neutrino mixing?
- LAGUNA study ongoing

courtesy: L. Baudis, A. Ereditato

# XENON: status and sensitivity

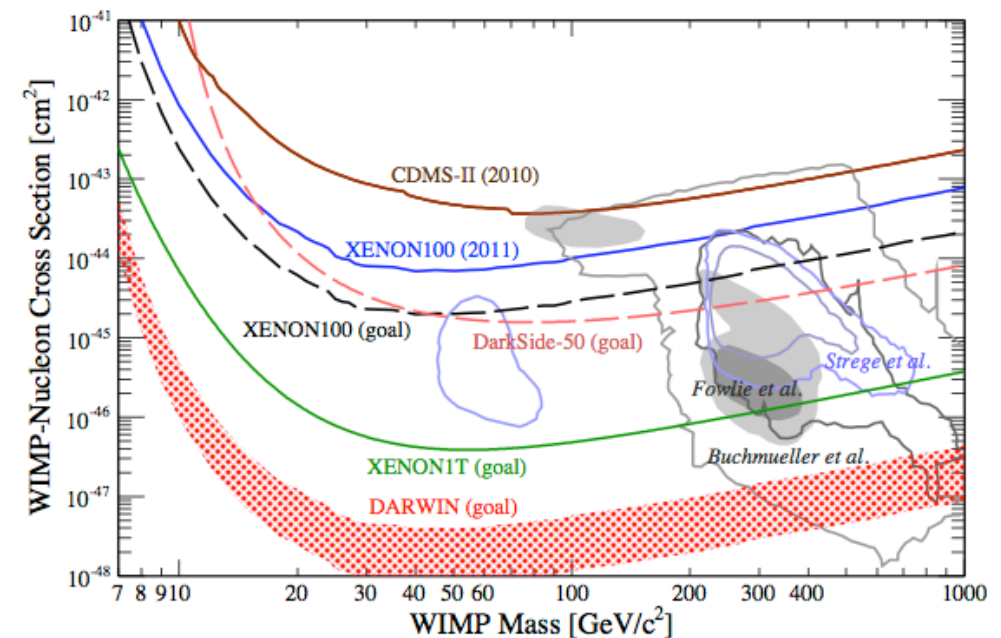
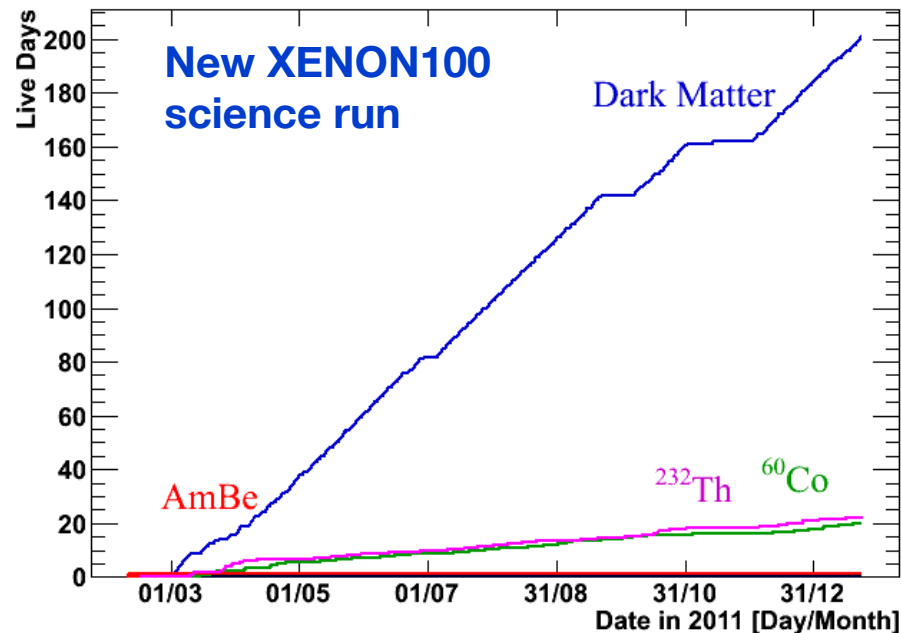
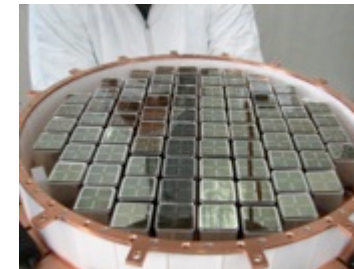
New dark matter run started in March 2011

Concentration of  $^{85}\text{Kr}$ : lower by a factor of 5

Improved LXe purity and lower trigger threshold

Analysis in progress; release of results beginning of April

In parallel: construction of XENON1T @ LNGS



courtesy: L. Baudis

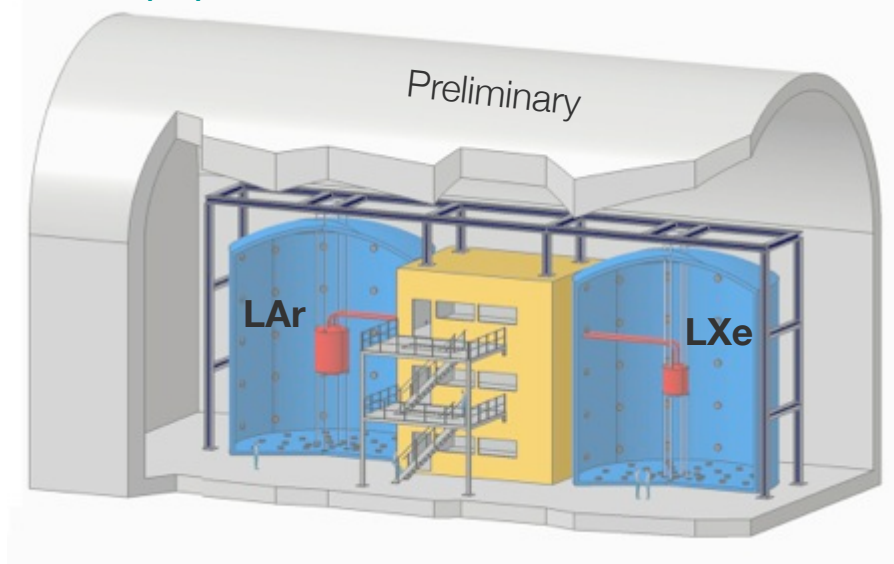
# DARWIN: DARk matter WImp search with Noble liquids

R&D and design study for next-generation noble liquid detector

- Physics goal: build the “ultimate WIMP detector”, before the possibly irreducible neutrino background takes over

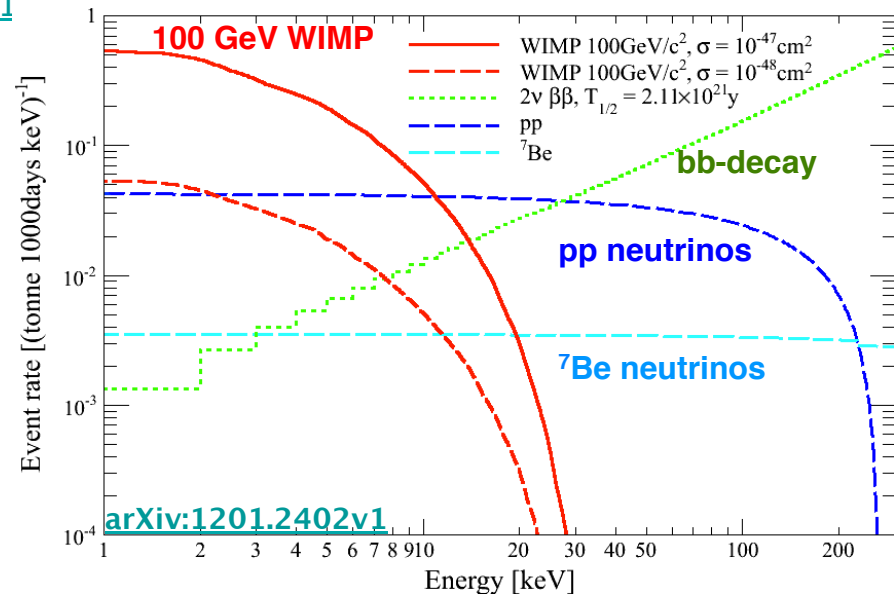
[darwin.physik.uzh.ch](http://darwin.physik.uzh.ch)

[arXiv:1012.4764v1](https://arxiv.org/abs/1012.4764v1)



Sketch of possible layout for LAr and LXe cryostats in large water Cherenkov shields

courtesy: L. Baudis

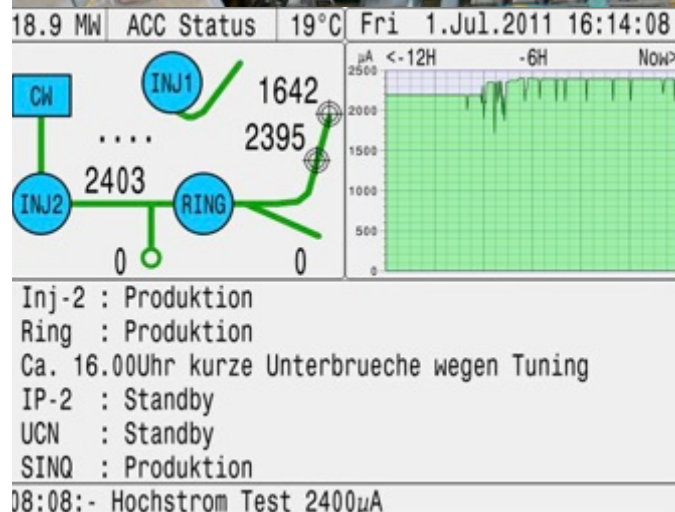


2vbb: EXO measurement of  $^{136}\text{Xe}$   $T_{1/2}$

Assumptions: 50% NR acceptance, 99.5% ER discrimination  
Contribution of 2vbb background can be reduced by depletion

# The 590 MeV Ringcyclotron at PSI

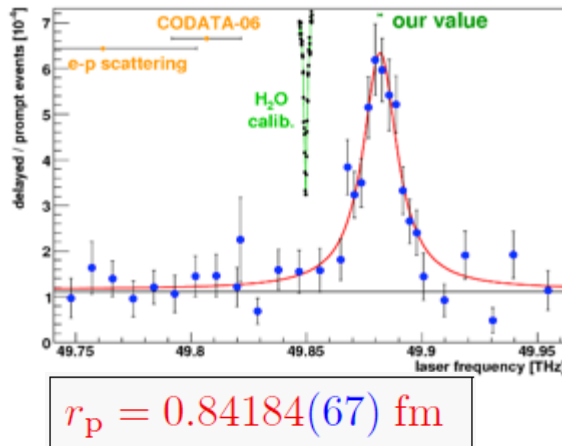
The highest power accelerator: 1.4 MW



# Recent results from particle physics at PSI

## Bound state QED

The most precise value of the **proton charge radius** via a measurement of the Lambshift in muonic hydrogen

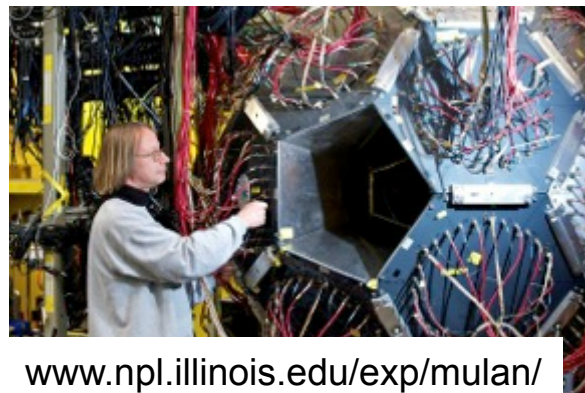
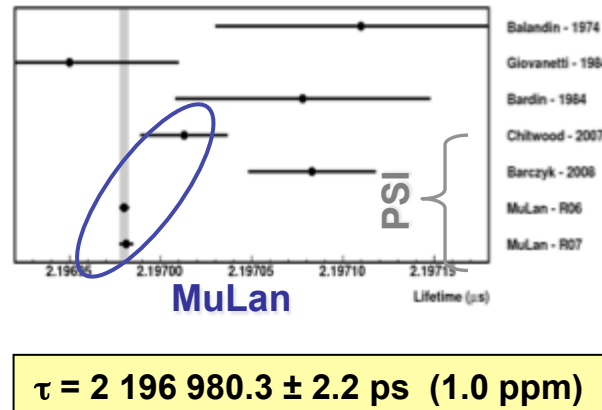


[muhy.web.psi.ch](http://muhy.web.psi.ch)

R. Pohl et al., Nature 466 (2010) 213

## Weak interaction

The most precise measurement of any lifetime: the muon's and a 0.6 ppm determination of the **Fermi coupling constant**

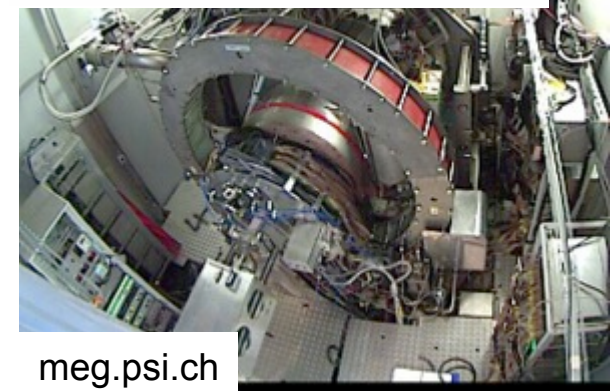
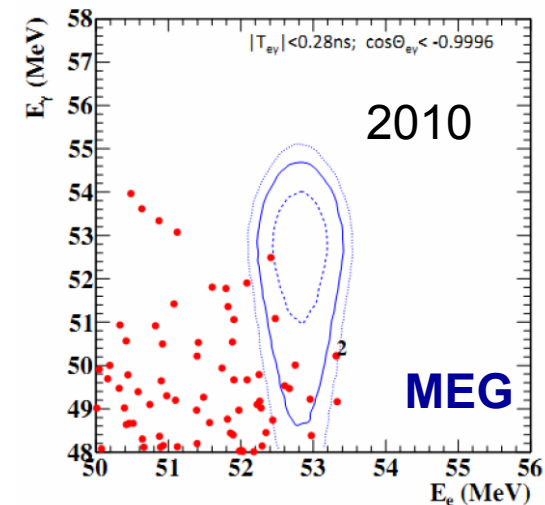


[www.npl.illinois.edu/exp/mulan/](http://www.npl.illinois.edu/exp/mulan/)

D.M. Webber et al., PRL 106(2011)041803

## New physics search

The best rare decay limit:  
A new **search for  $\mu \rightarrow e \gamma$**  yields a branching less than  $2.4 \times 10^{-12}$



[meg.psi.ch](http://meg.psi.ch)

J. Adam et al., PRL 107(2011)171801

# I will conclude with

# some applications

## 6 MV Tandem Accelerator

Pelletron Charging system since 2011

### Beams

- HI (5 - 75 MeV),  $\alpha$  (3 - 18 MeV),  
p (2 - 12 MeV)

### Program

- AMS with  $^{10}\text{Be}$  &  $^{36}\text{Cl}$
- AcceleratorSIMS\*: stable trace elements
- Materials Sciences



**ETH**

Eidgenössische Technische Hochschule Zürich  
Swiss Federal Institute of Technology Zurich

**Laboratory of Ion Beam Physics**

**National and International Center  
of Accelerator Mass Spectrometry  
and Materials Sciences**

Ion Beam Physics:  
Methods  
Applications  
Novel Instrumentation  
Service Laboratory  
e.g. Carbon dating

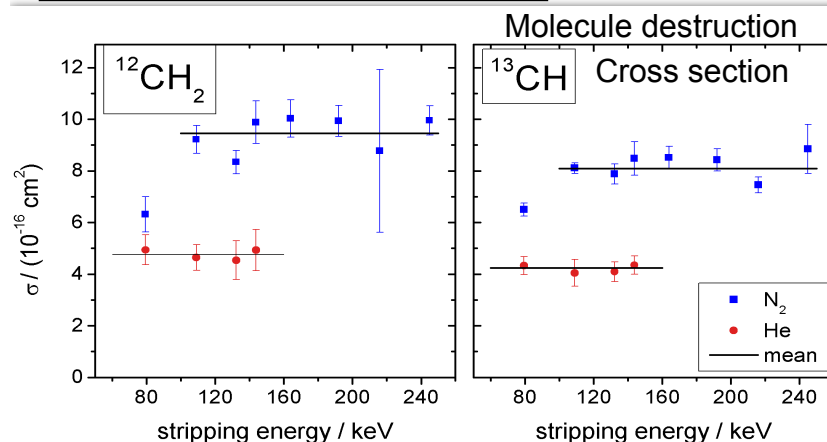
## 500 kV Pelletron Tandem

Beams (500 – 1700 keV)

- $^{10}\text{Be}$ ,  $^{41}\text{Ca}$ ,  $^{129}\text{I}$ ,  $^{236}\text{U}$ ,  $^{239}$ ,  $^{240}$ ,  $^{241}$ ,  $^{242}$ ,  $^{244}\text{Pu}$

### Program

- Accelerator Mass Spectrometry  
(Developments and Applications)

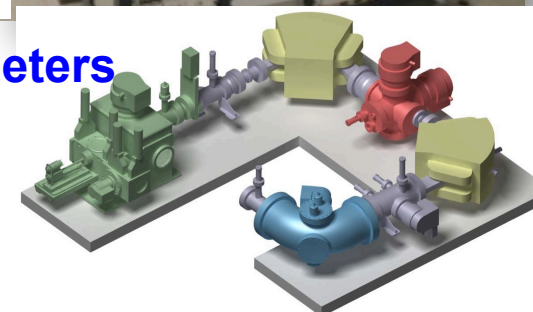


## MICADAS Systems (built by LIP)

- Dedicated  $^{14}\text{C}$  AMS systems
- 7 system operating worldwide

## Novel Mass Spectrometers for $^{14}\text{C}$ detection

- Tabletop Instruments
- Full dating capabilities
- No Accelerator required



courtesy: H.-A. Synal



**AX-PET :**

**ETH**

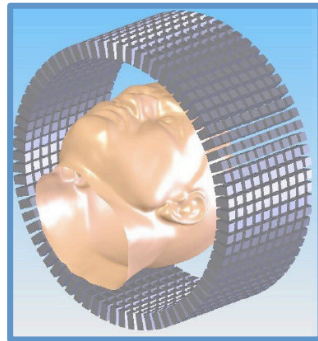
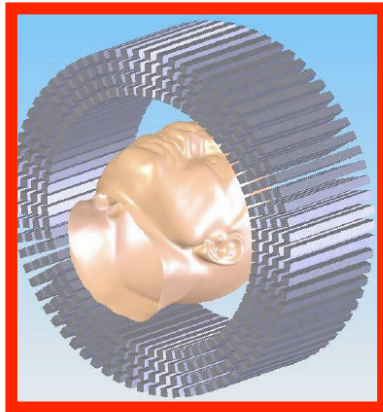
Eidgenössische Technische Hochschule Zürich  
Swiss Federal Institute of Technology Zurich

## AXial Positron Emission Tomography

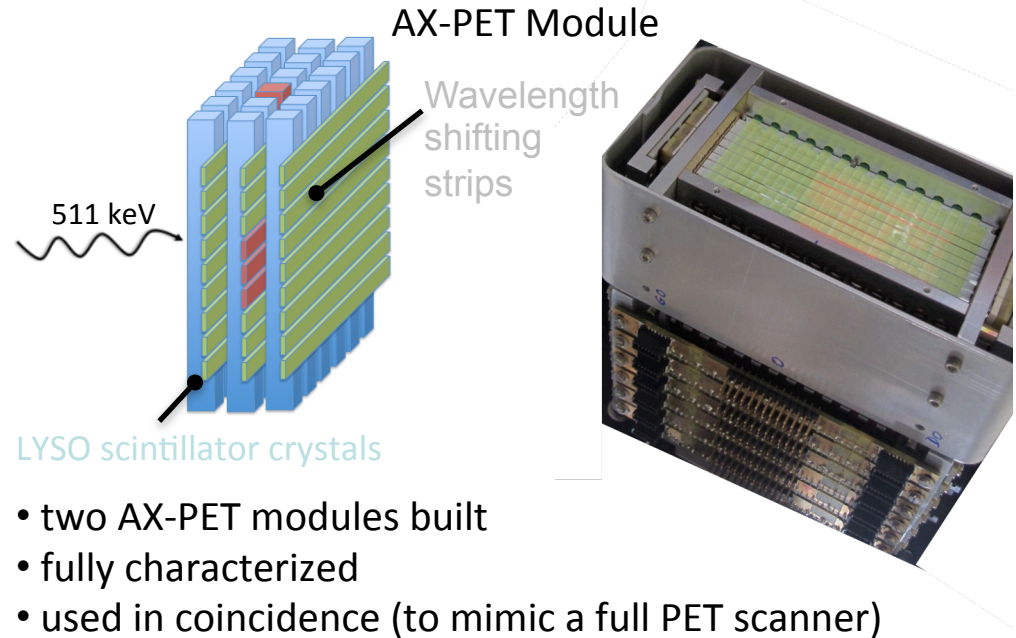
- new geometrical concept for a PET
- high sensitivity and high resolution PET concept
- demonstrator for a PET scanner built and characterized ("**Demonstrator**": 2 modules)

From radial (conventional PET geometry)...

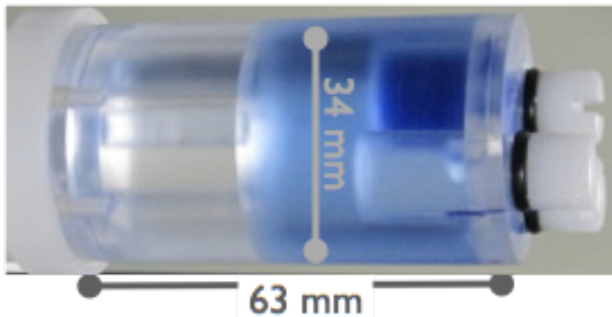
**... to axial !**



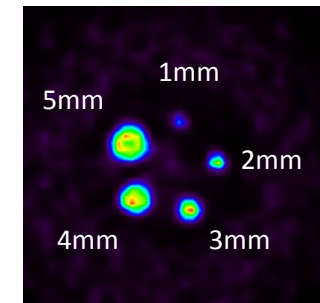
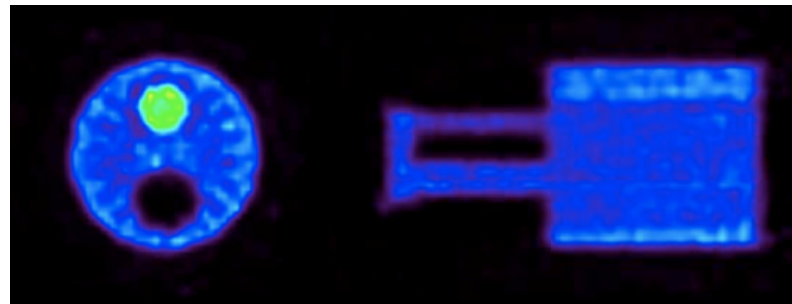
Long axially oriented scintillator crystals



Example of reconstructed image of NEMA phantom filled with 18-F in water solution (with 2 AX-PET modules)



courtesy: C. Casella, G. Dissertori



<https://twiki.cern.ch/twiki/bin/view/AXIALPET/>

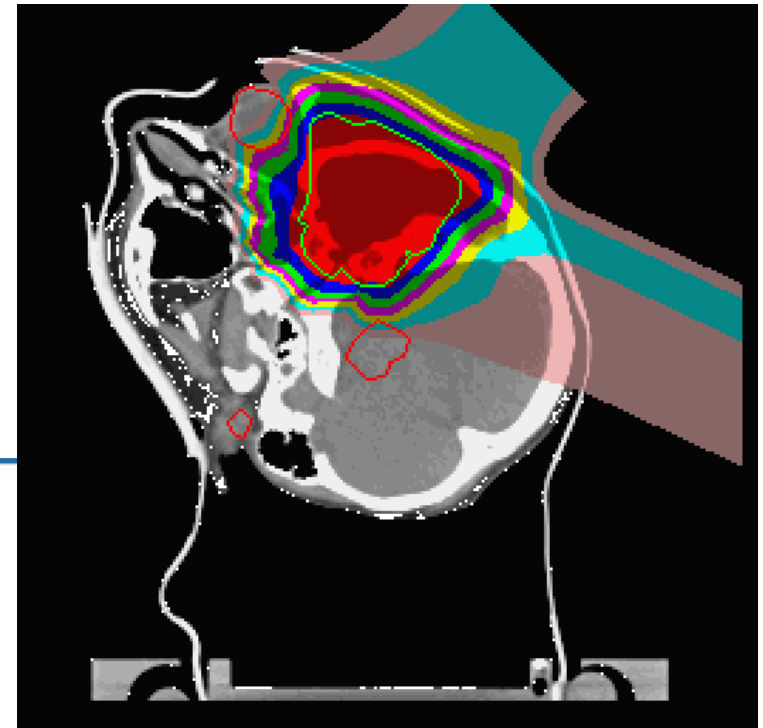
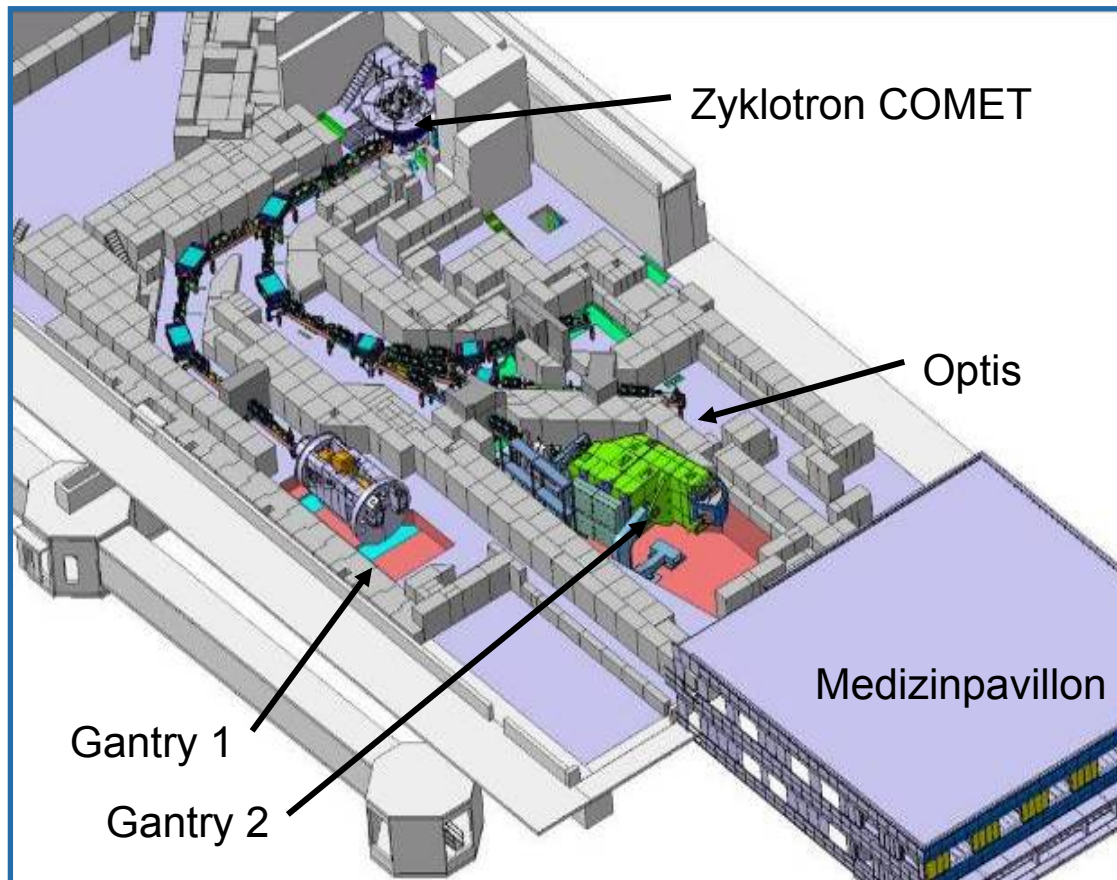


# Proton Therapy: PROSCAN at PSI

OPTIS: since 1984, >6000 patients, 98% success

GANTRY 1: especially >200 children treated

GANTRY 2: commissioning



courtesy: M. Grossmann

**Particle, astroparticle  
and nuclear physics  
in Switzerland in a global context**



**Thank you for your attention!**

**Thanks to my colleagues:**

- Aldo Antognini
- Laura Baudis
- Hans-Peter Beck
- Adrian Biland
- Chiara Casella
- Paolo Crivelli
- Günther Dissertori
- Antonio Ereditato
- Martin Grossmann
- Teresa Montaruli
- Martin Pohl
- Stefan Ritt
- Olivier Schneider
- Michael Spira
- Hans-Arno Synal