

# HEP with Accelerators

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## Outline

- ❖ Overview
- ❖ Ongoing/future activities

# Lines of research

## ❖ Hadronic physics at high energy:

- ATLAS, CMS, LHC-f, TOTEM @ LHC (**running**)
- CDF2 @ Tevatron (**closed**)

## ❖ Flavor physics:

- BaBar @ PEP-II (**closed**)
- BES-III @ BEPC-II (**running**)
- KLOE @ DAFNE (**running**)
- LHC-B @ LHC (**running**)
- NA62 @ SPS (**building**)
- Belle II @ KEKB (**Planning**)

## ❖ Lepton Flavor Violation:

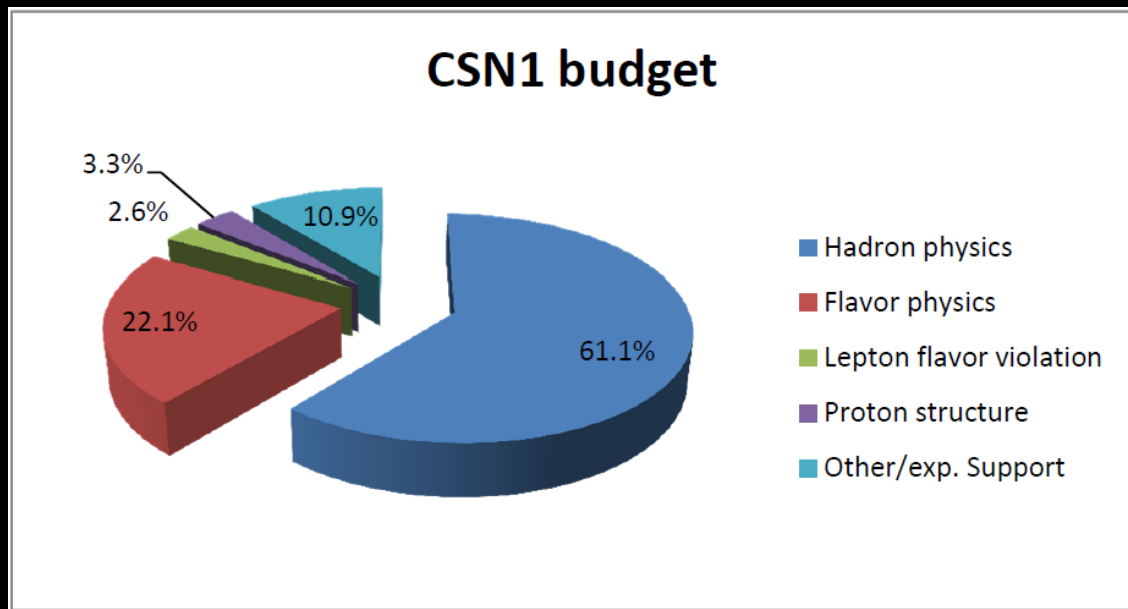
- MEG @ PSI (**running**)
- Mu2E @ Fermilab (**R&D**)
- g-2 @ Fermilab (**Planning**)

## ❖ Proton structure:

- COMPASS @ SPS (**running**)
- ZEUS @ HERA (**closed**)

## ❖ Other:

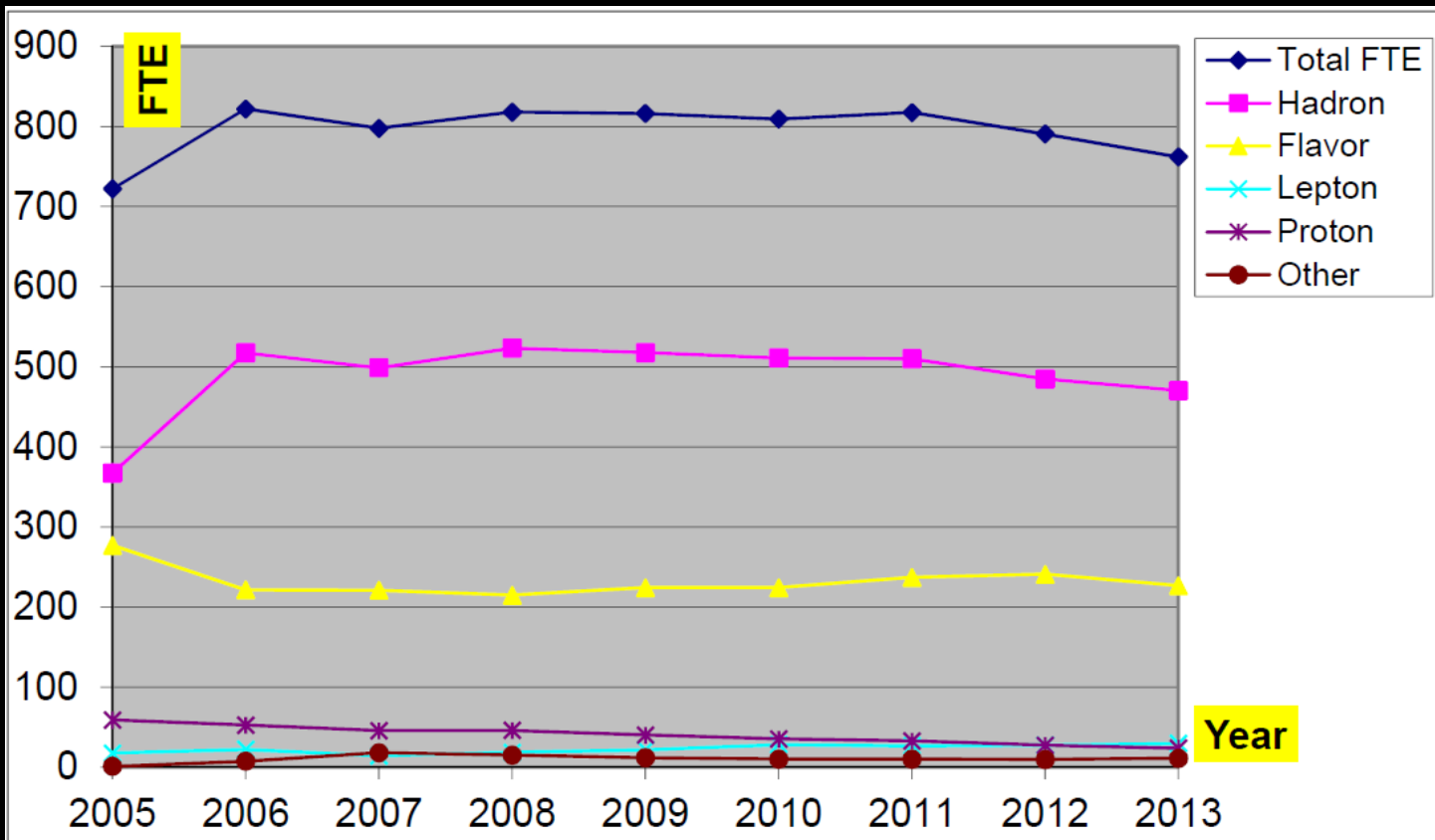
- Future lepton colliders (**Planning**)
- UA9 @ SPS&LHC (**R&D**)
- Experiment support



# Personnel INFN&University

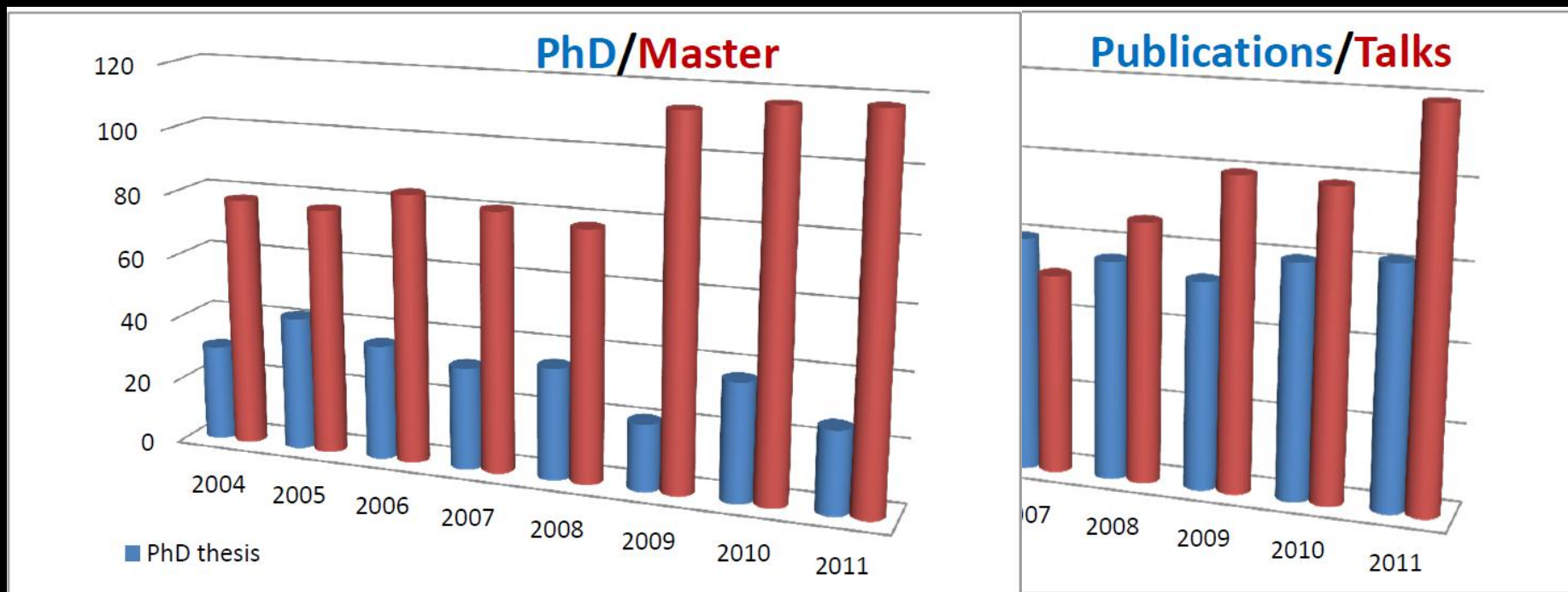
## ❖ Researchers and engineers:

➤ #people fairly stable: ~1000 scientists/800 FTE



# Scientific productivity

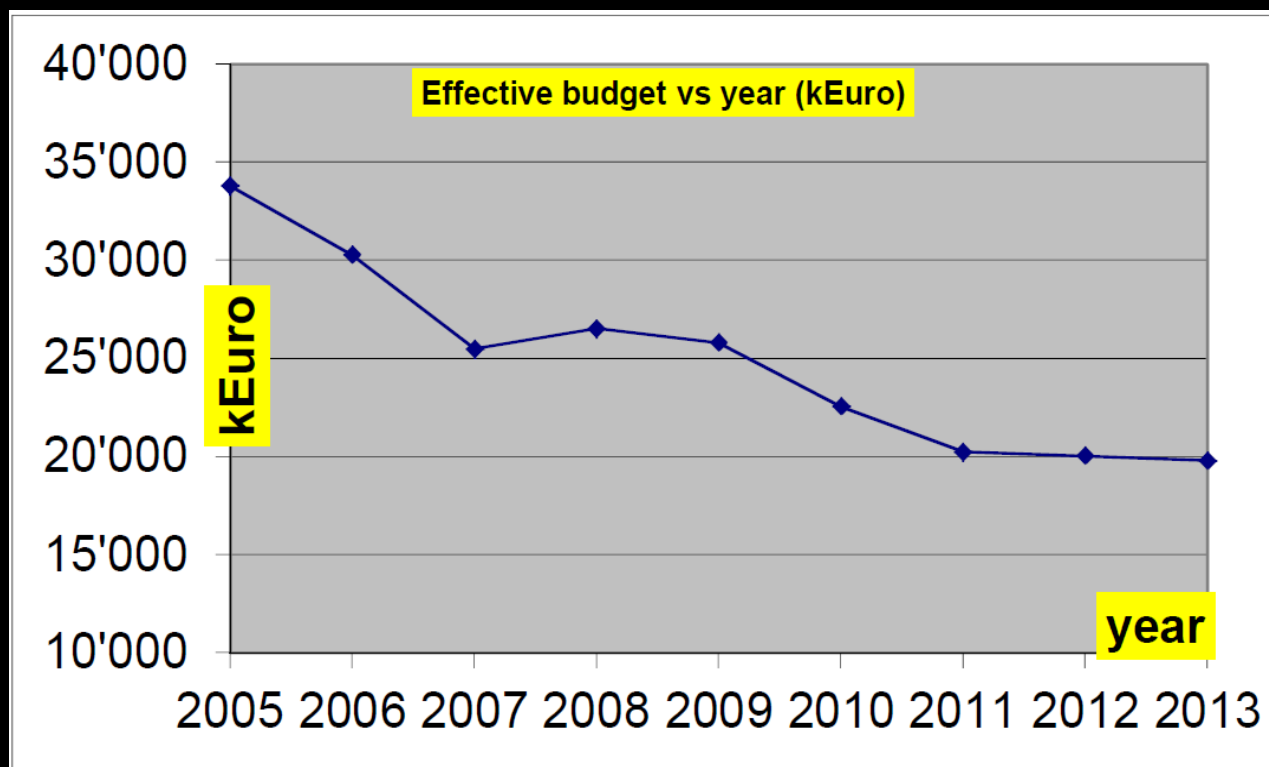
- ❖ Publication rate high and rather stable
  - Sustained mostly by large general purpose experiments
- ❖ Talk rate increase in the last years (LHC effect)



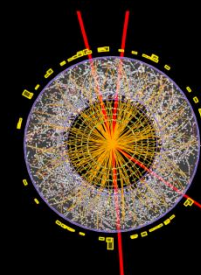
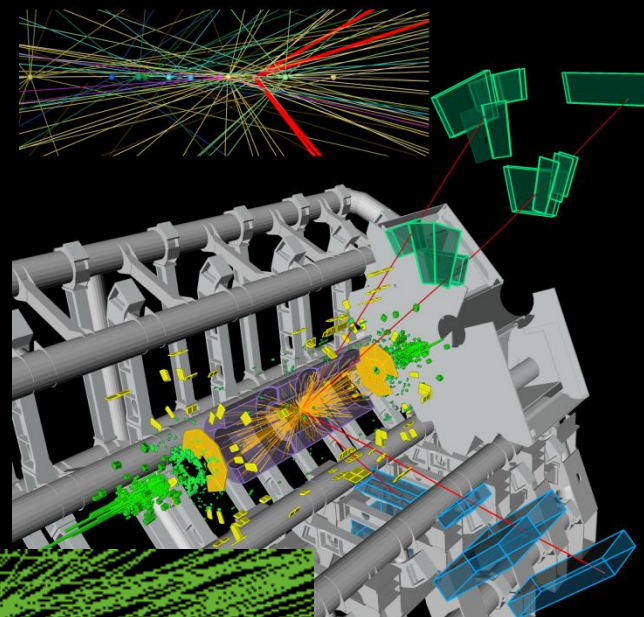
# Budget evolution

## ❖ Flat budget in last 3 years ~ 20 M€

- No correction for inflation
- Effort to maintain support at this level over the next years



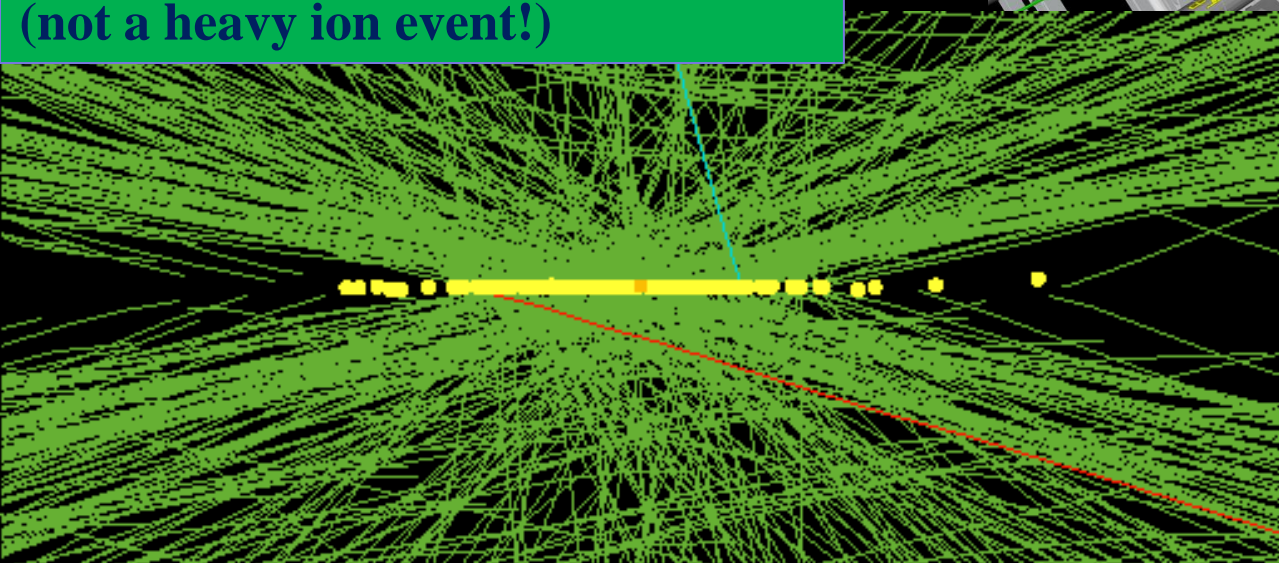
# Ongoing activities



$H \rightarrow 4\mu$

Run: 204769  
Event: 71902630  
Date: 2012-06-10  
Time: 13:24:31 CEST

**CMS: 78 simultaneous interactions  
(not a heavy ion event!)**



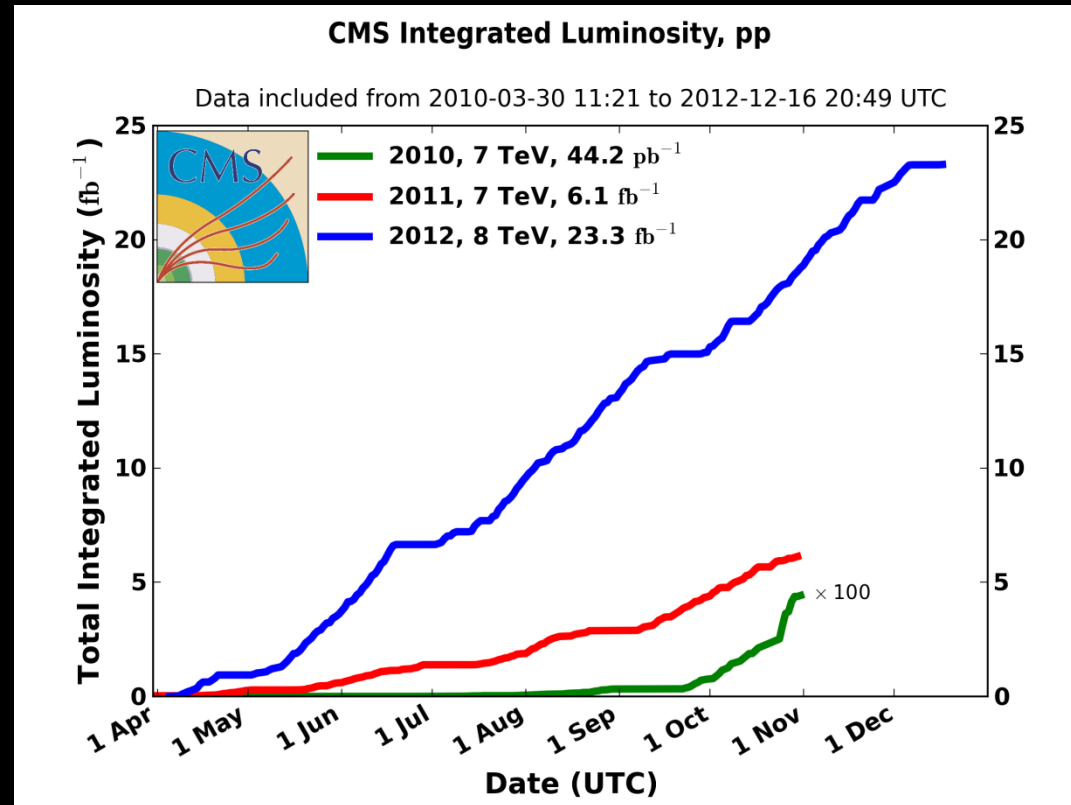
# Hadronic physics at High Energy

## ❖ LHC very successful:

- $L_{\max} \sim 7.7 \times 10^{33}$
- About  $30 \text{ fb}^{-1}$  delivered to each experiment
- Outstanding performance!

## ❖ Tevatron closed in september 2011

- Analysis work still in progress

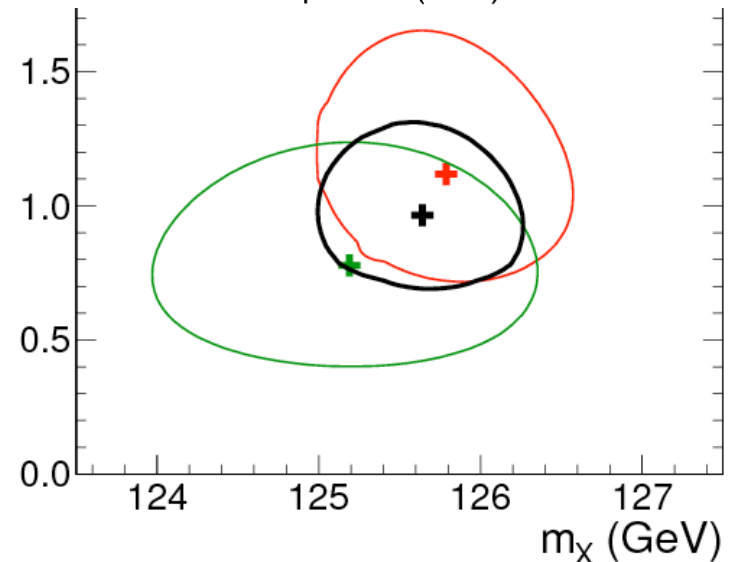
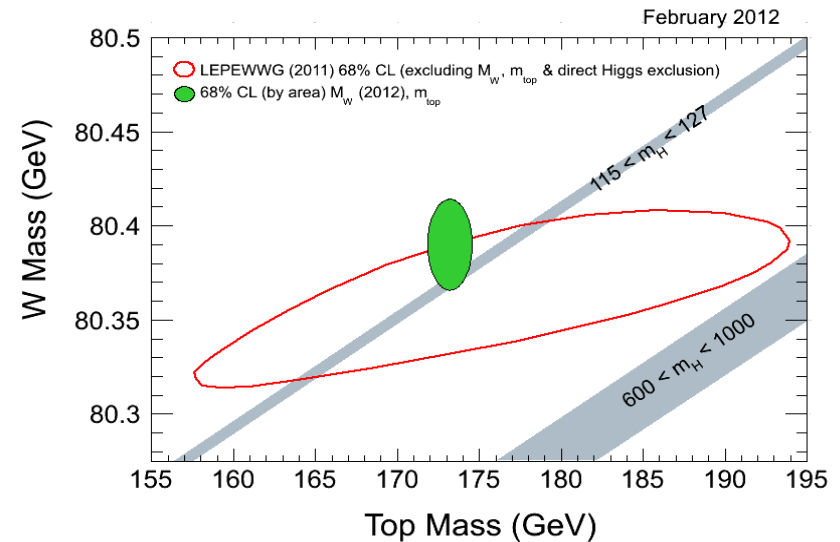
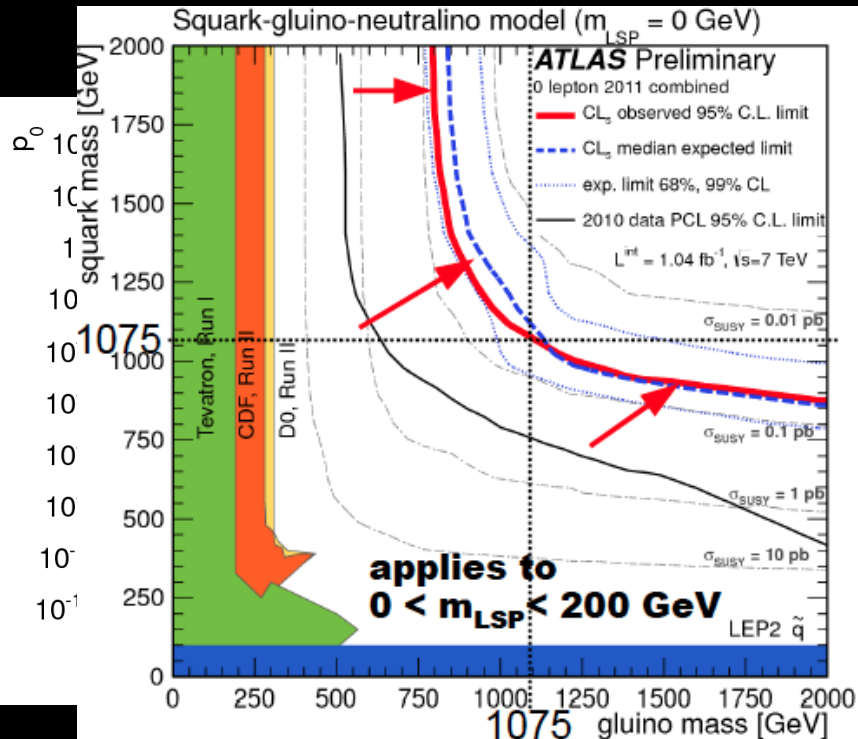




# Physics highlights (HP)

## ❖ Hadronic physics

- Higgs-like particle discovery
- No SUSY
- CDF measurement of W mass





# Present/future activities (HP)

## ❖ LHC phase 1 upgrades with INFN involvement

### ➤ ATLAS:

- Inner pixel layer (IBL) – almost complete
- Hardware track trigger (FBK) – in progress
- New Small Wheels (micromega based muon chambers) – under discussion
- LAr calorimeter upgrade – under discussion
- Beamline tracking (AFP) – maybe

### ➤ CMS:

- Pixel detector – starting
- Chambers/RPC/Electronics for muon system – in progress
- Forward GEM based muon system – under discussion
- L1 trigger upgrade – under discussion

# Present/future activities (HP)

## ❖ LHC phase 2 upgrades for HL-LHC

- Large costs involved
  - INFN share ~ 70 M€ at current estimates
  - Funding still unclear, but it has high priority from ESG, CERN and INFN
  
- Expect significant R&D before start of big constructions possibly around 2018 in the following areas:
  - Pixel and strip silicon sensors and related FE/trigger electronics
  - Muon tracking chambers and trigger counters
  - Other trigger and FE/DAQ electronics
  - Software architectures
  
- Important to find commonalities between experiments and involve also other sources of funding in the R&D process (CSN5, EU, ...)

# Flavor physics

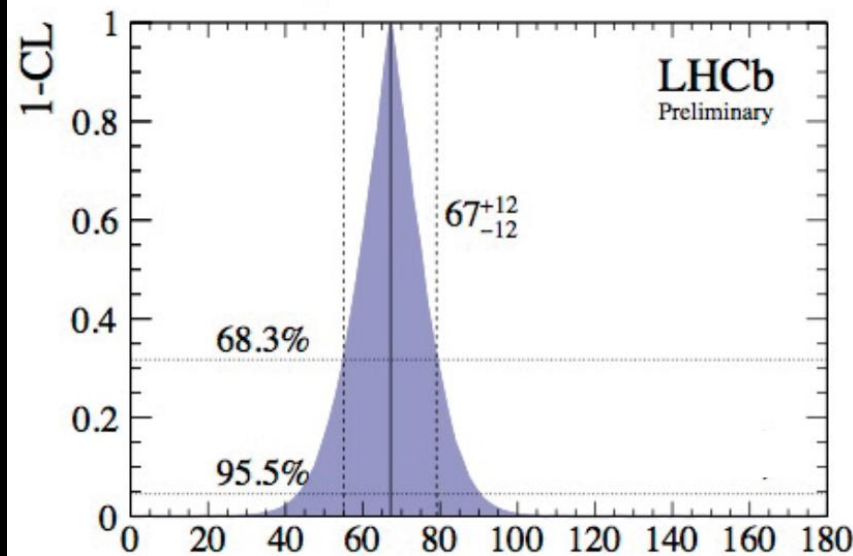
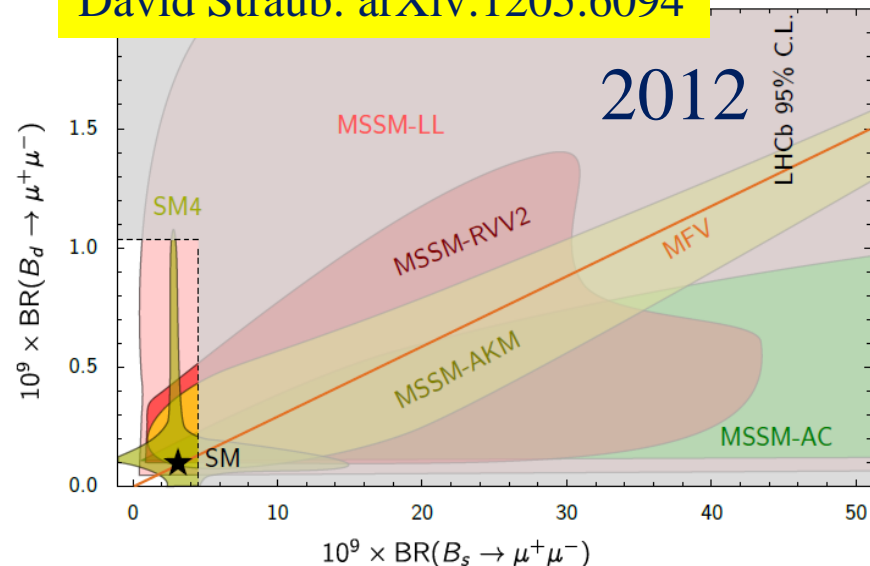
## ❖ Mostly from LHCb

- Luminosity leveled  $\sim 4e32$
- $1 \text{ fb}^{-1}$  in 2011/  $2 \text{ fb}^{-1}$  in 2012

## ❖ Some highlights

- Mixing phase error  $< 0.1 \text{ rad}$
- Detailed studies of rare decays
  - $\text{BR}(B \rightarrow \mu\mu), B^0 \rightarrow K^* \mu\mu \dots$
- First results on  $\gamma$  comparable to B factories

David Straub: arXiv:1205.6094



# Present/future activities (FP)

- ❖ **LHCb: Restart running in 2015**
  - Preparing for major upgrade to be completed by 2018-19 – under discussion
    - INFN: Muon chamber electronics, RICH (sensors/electronics), fast networking, trigger
- ❖ **Belle II: starting collaboration**
  - INFN: Vertex detector, EM calorimeter – under discussion
- ❖ **BES-III: running successfully and growing**
  - INFN: ZDC, cylindrical GEM chamber – in progress (partly funded)
- ❖ **BaBar:**
  - INFN: Data analysis still in progress
- ❖ **NA62: completing detector construction during next year**
  - INFN: all aspects of detector – in progress
- ❖ **KLOE: restart data taking in fall 2013**
  - Upgrade installation and machine refurbishing

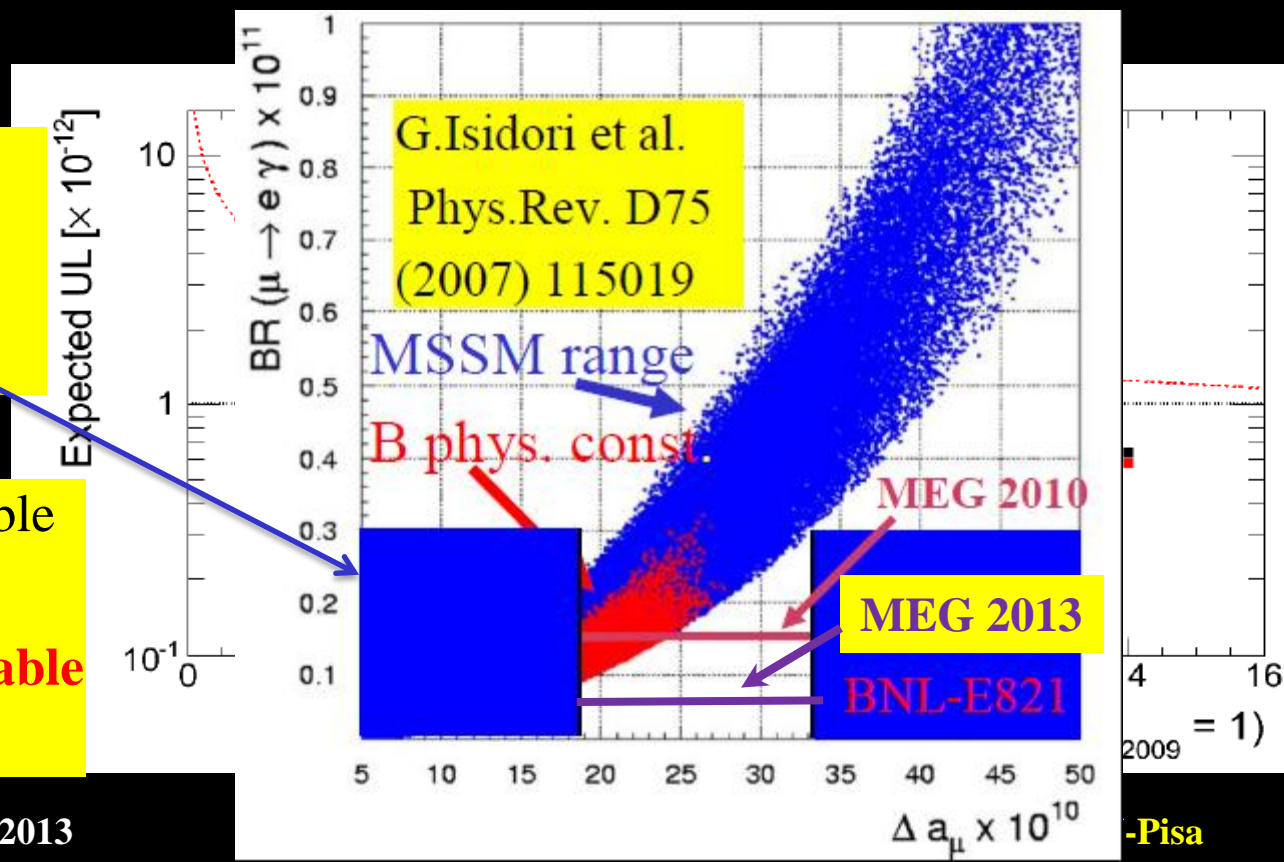
# Charged lepton physics

## ❖ Searches for $\mu \rightarrow e \gamma$ ( $\gamma$ real MEG, $\gamma$ virtual Mu2E)

- MEG improves limit (2010) → with 2011 data:  $5.7 \times 10^{-13}$
- Mu2E receives CD 1 in June 2012

New  $g-2$  exp. at FNAL received CD0 in Sept. 2012

→  $5 \times 10^{-13}$  range reachable with 2012-2013 data  
 →  $5 \times 10^{-14}$  range reachable with upgrade



# Present/future activities (CLP)

## ❖ MEG

- Major upgrade construction 2013-2015
  - INFN: Tracking chamber, timing counters, active target – in progress

## ❖ Mu2E

- Preparing for construction to start ~ 2015
  - INFN: EM calorimeter, SiPM, veto system – under discussion

## ❖ New g-2 experiment at FNAL

- Preparing for construction to start soon
  - INFN: Calorimeter calibration, (possibly) tracking – maybe

# Proton structure (PS)

## ❖ ZEUS:

- Hera has been closed, some analyses continue
- Pdf updates, merging with H1 results
  - INFN: Last efforts of data analysis

## ❖ COMPASS:

- Measurement of spin structure functions
- Upgrade construction in progress
  - INFN: absorber for DY, RICH chambers (TGEM) – In progress



# Other technological activities

## ❖ UA9:

- Development of a new LHC collimation system by channeling with crystals
- Demonstrated at SPS – Now proving application at LHC
  - INFN: crystals and mechanical controls – in progress

# Future

## ❖ What is the future beyond LHC?

- Driven by detailed study of Higgs: HL-LHC, ILC, TLEP
- Driven by physics at a higher scale (if any!): HL-LHC, ILC, CLIC, TLEP (pp option), Muon Collider

|  | LHC(300)  | LHC (3000) | ILC<br>(250+350+500) | TLEP<br>(240+350) | Comment          |
|--|-----------|------------|----------------------|-------------------|------------------|
| $\Delta m_H$ (MeV)                                 | ~100      | ~50        | ~30                  | ~7                | Overkill for now |
| $\Delta\Gamma_H/\Gamma_H$ ( $\Delta\Gamma_{inv}$ ) |           |            | 5.5(1.2)%            | 1.1(0.3)%         |                  |
| H spin   | ✓         | ✓          | ✓                    | ✓                 |                  |
| $\Delta m_W$ (MeV)                                 | ~10       | ~10        | ~6                   | <1                | Theo. limits     |
| $\Delta m_t$ (MeV)                                 | 800-1000  | 500-800    | 20                   | 15                | ~100 from theo.  |
| $\Delta g_{HVV}/g_{HVV}$                           | 2.7-5.7%* | 1-2.7%*    | 1-5%                 | 0.2-1.7%          |                  |
| $\Delta g_{Hff}/g_{Hff}$                           | 5.1-6.9%* | 2- 2.7%*   | 2-2.5%               | 0.2-0.7%          |                  |
| $\Delta g_{Htt}/g_{Htt}$                           | 8.7%*     | 3.9%*      | ~15%                 | ~30%              |                  |
| $\Delta g_{HHH}/g_{HHH}$                           | --        | ~30%       | 15-20%**             | --                | Insufficient ?   |

# Summary

- ❖ INFN very active on HEP accelerator experiments in spite of declining budgets
- ❖ Getting very good returns from major efforts of the past
- ❖ Starting upgrades and some new activities
  
- ❖ Future big new initiatives are still being debated, but funding the experiments appropriately may be difficult with the current budgets