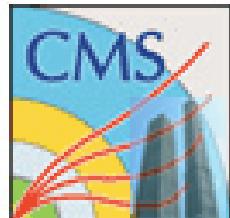
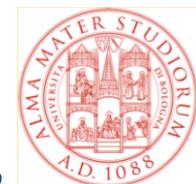


# Studi di fisica per definire l'Upgrade del rivelatore di muoni di CMS per High Luminosity LHC

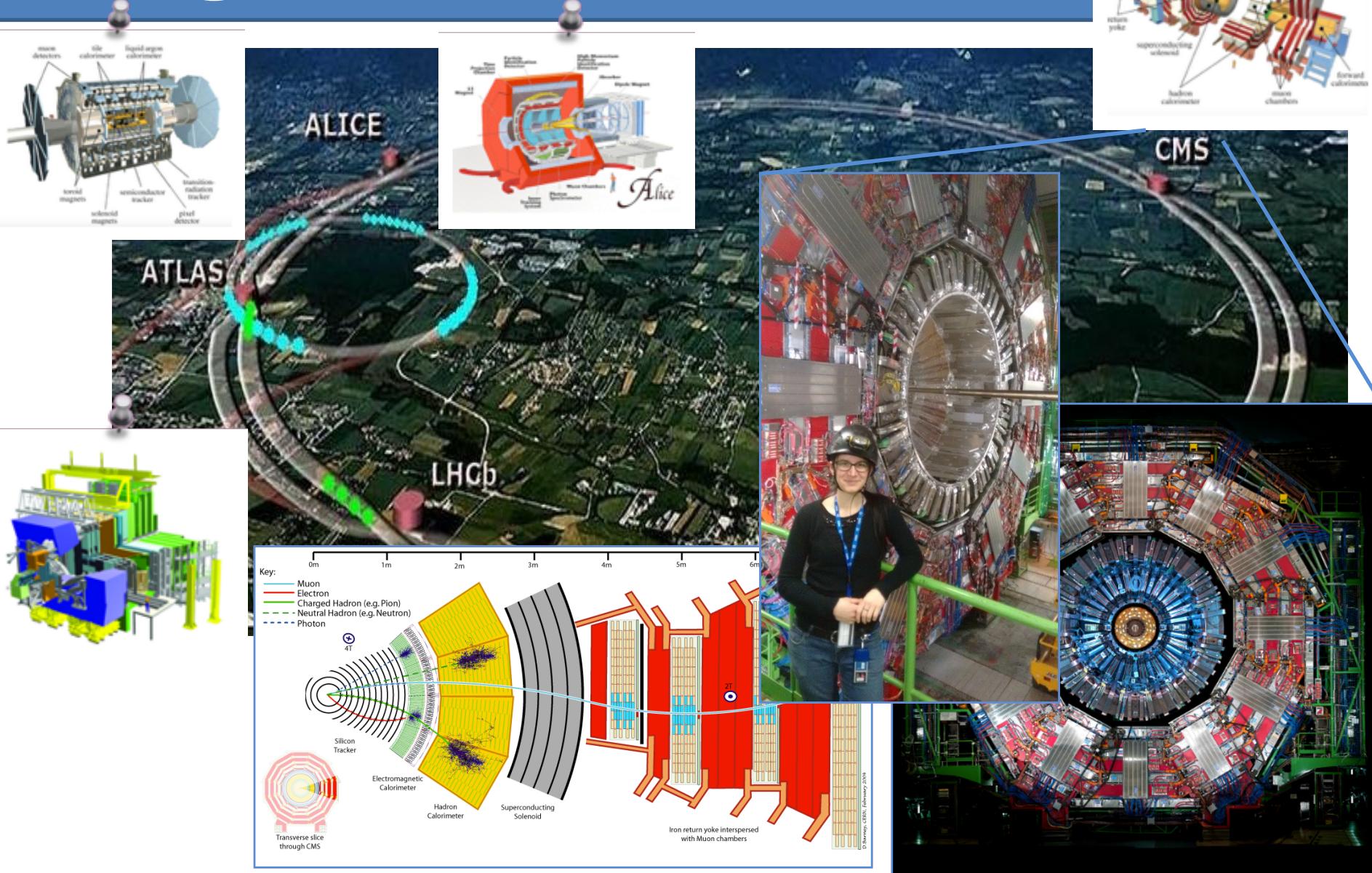


Lisa Borgonovi<sup>a</sup>  
S. Braibant<sup>a</sup>, F.R. Cavallo<sup>a</sup>, S. Chhibra<sup>a</sup>, N. de Filippis<sup>b</sup>,  
P. Giacomelli<sup>a</sup>, L. Guiducci<sup>a</sup>

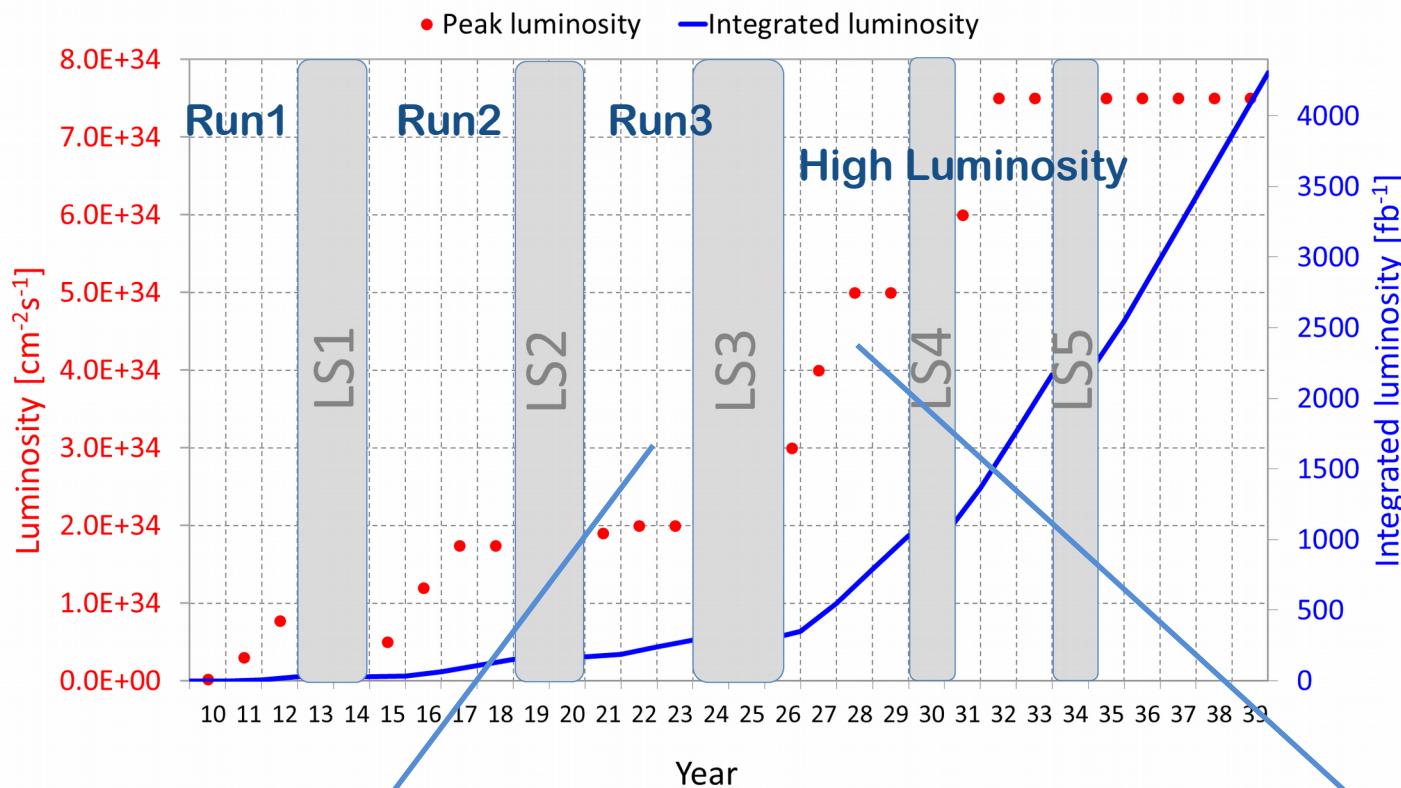
<sup>a</sup> Università e INFN Bologna  
<sup>b</sup> Politecnico e INFN Bari



# CMS @ LHC



# Towards High Luminosity LHC



$$\mathcal{L} = 2 \cdot 10^{34} \text{ cm}^{-2}\text{s}^{-1}$$

$$\sqrt{s} = 14 \text{ TeV}$$

PU 50

$$\mathcal{L} = 5 \cdot 10^{34} \text{ cm}^{-2}\text{s}^{-1}$$

$$\sqrt{s} = 14 \text{ TeV}$$

PU 140-200

# CMS Upgrades



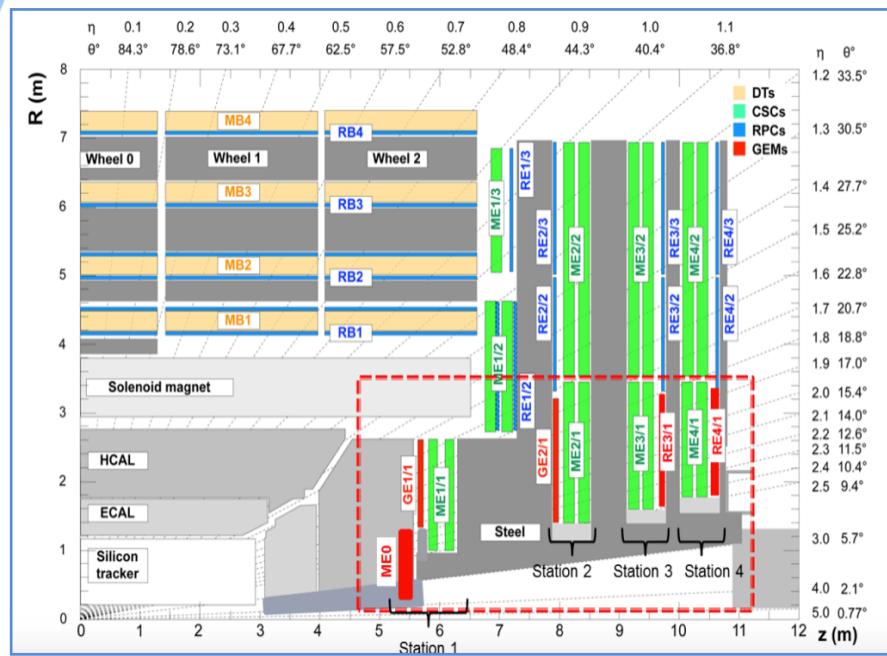
## Phase II (2024)

Improvement or substitution of ALL sub-detectors

- New tracker and end-cap calorimeter:  
Pixel + SiStrips + HGCAL
- Geometrical acceptance extension:  
 $\eta = 2.4 \rightarrow 2.8$  for tracker and muon system

## Phase I (2019)

- **Pixel:** 4<sup>th</sup> layer for better RECO
- **L1 Trigger:** high efficiency and low rate despite worse PU and Luminosity conditions
- **HCAL:** electronics



# Detector Simulation

**Geant 4**

## Full Simulation

- Complete simulation of the detector:  
interaction particle-detector material
- Time and computing resources  
consuming



## CMS detector “aged”

- NO upgrades
- Radiation damage of  $1000 \text{ f b}^{-1}$

## Delphes

- Fast and parametrized detector simulation
- C++ modular framework
- Limitations → Validation!



## CMS upgrade detector

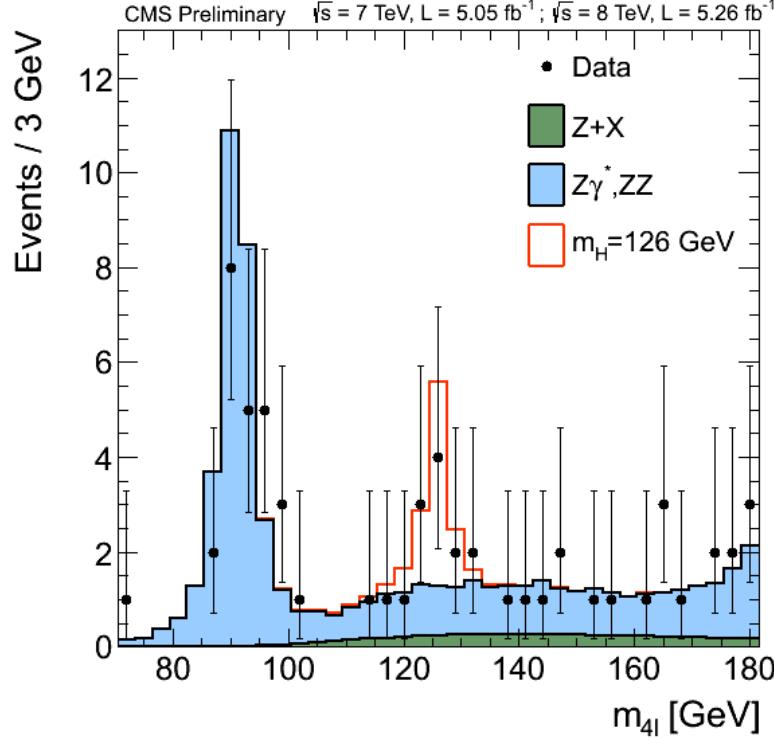
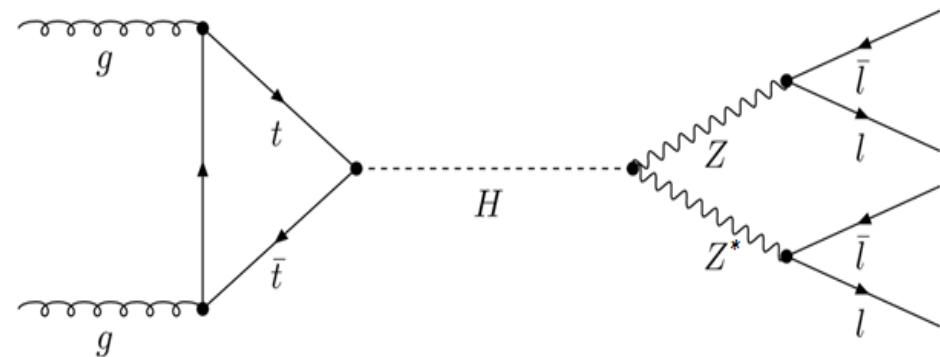
- Phase II geometry
- Planned upgraded detector
- $\eta$  Coverage extension



# $H \rightarrow ZZ^* \rightarrow 4l$ ( $4\mu$ ) analysis

## Golden channel

- Clean final state
- Small background contamination



## Higgs Boson discovery

2012 @ LHC ( ATLAS & CMS)

Nobel prize to Higgs and Englert:  
Spontaneous Symmetry Breaking of the  
Electroweak Theory (the BEH mechanism)

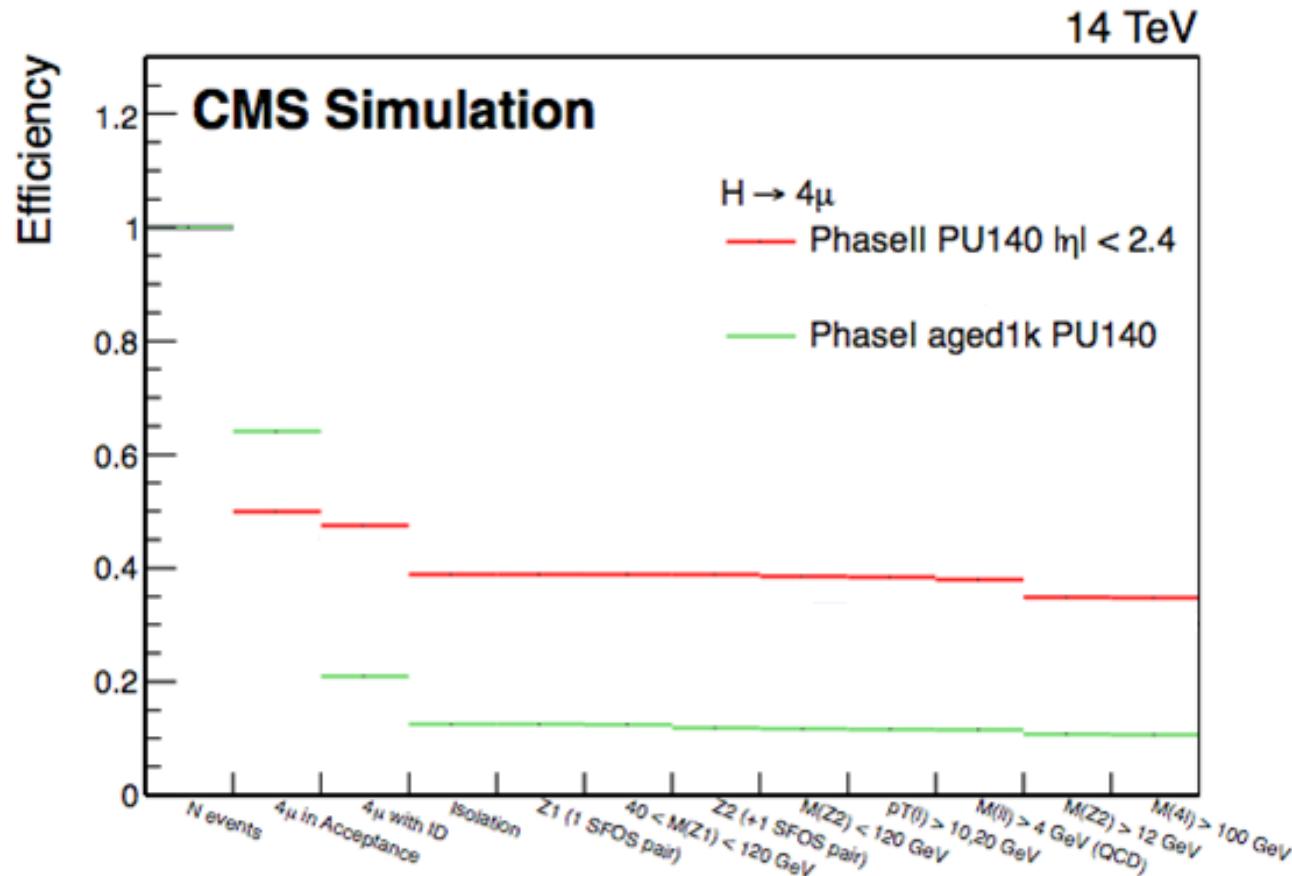
## Backgrounds

- $ZZ \rightarrow 4l$
- $Z+jets$  (mis-identified as isolated leptons)

# Results (1)

## 4 $\mu$ cut flow table

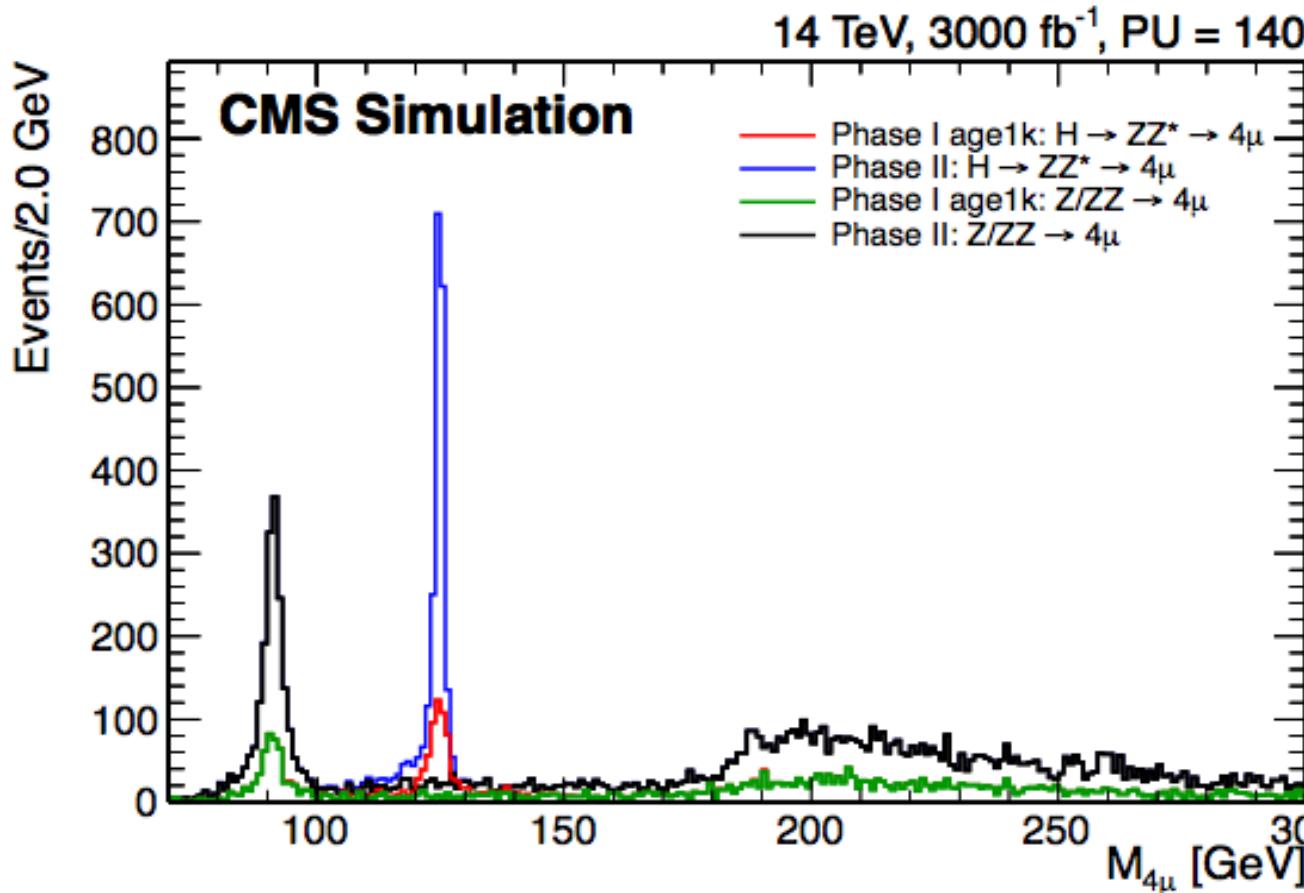
Signal only,  $\eta < 2.4$



# Results (2)

## 4 $\mu$ invariant mass distribution

Signal + background,  $\eta < 2.4$

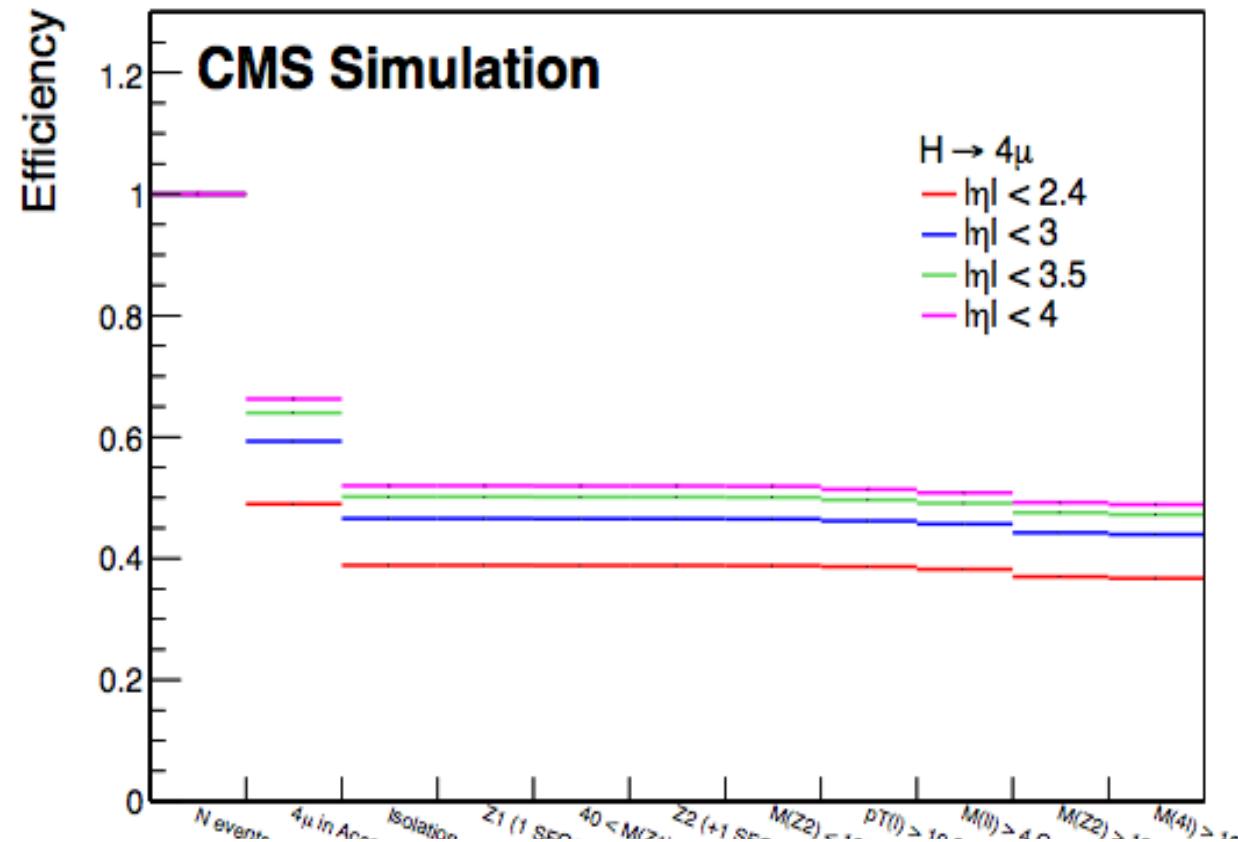


# Results (3)

## 4 $\mu$ cut flow table for different acceptances

Signal only

14 TeV

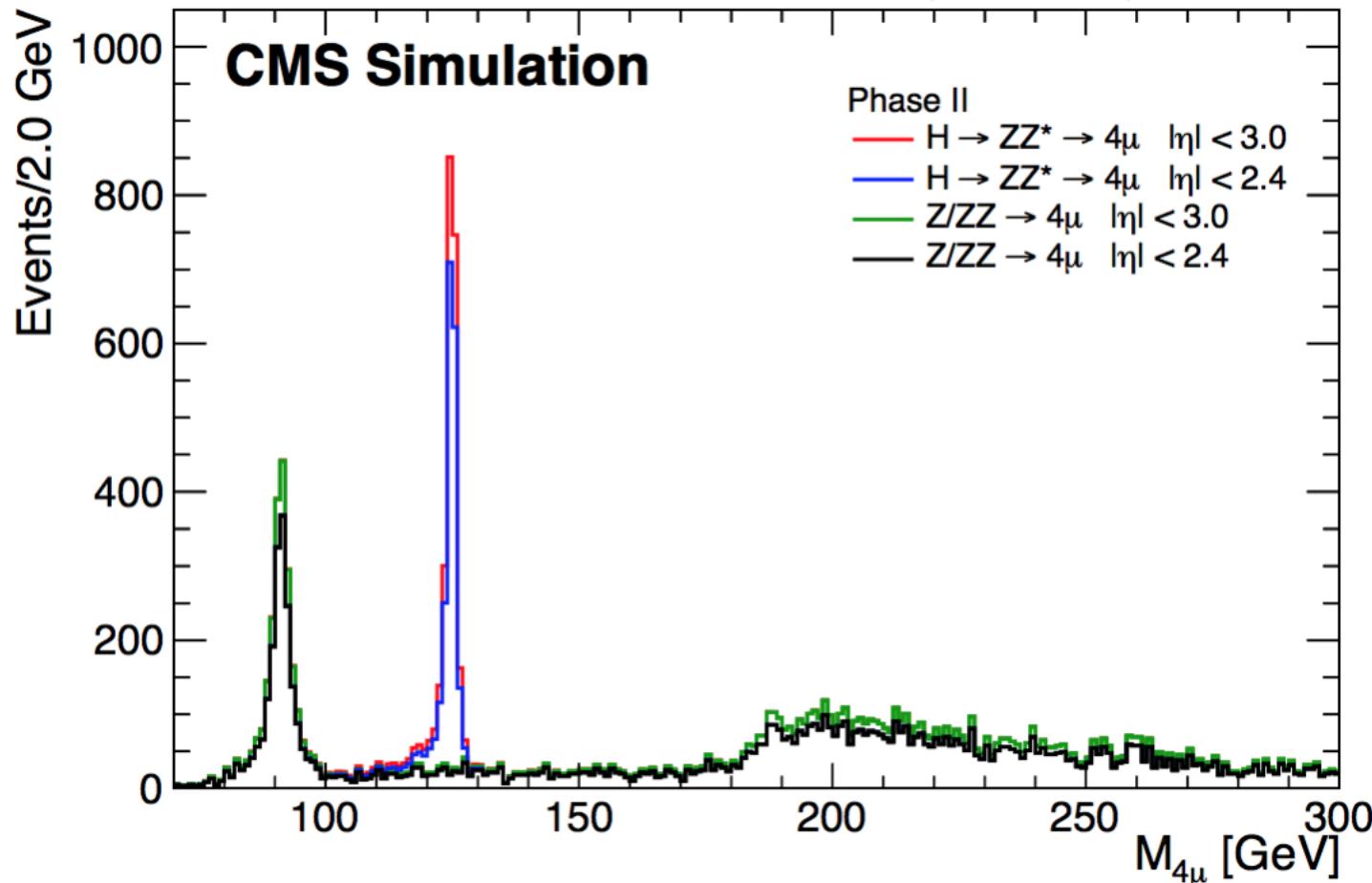


Selection efficiency	Signal	zz background
$ \eta  < 2.4$	$(36.7 \pm 0.2)\%$	$(14.8 \pm 0.1)\%$
$ \eta  < 3.0$	$(43.9 \pm 0.2)\%$	$(19.8 \pm 0.2)\%$
$ \eta  < 3.5$	$(47.2 \pm 0.2)\%$	$(22.6 \pm 0.2)\%$
$ \eta  < 4.0$	$\approx 12\%$ $(48.9 \pm 0.2)\%$	$(24.4 \pm 0.2)\%$

# Results (4)

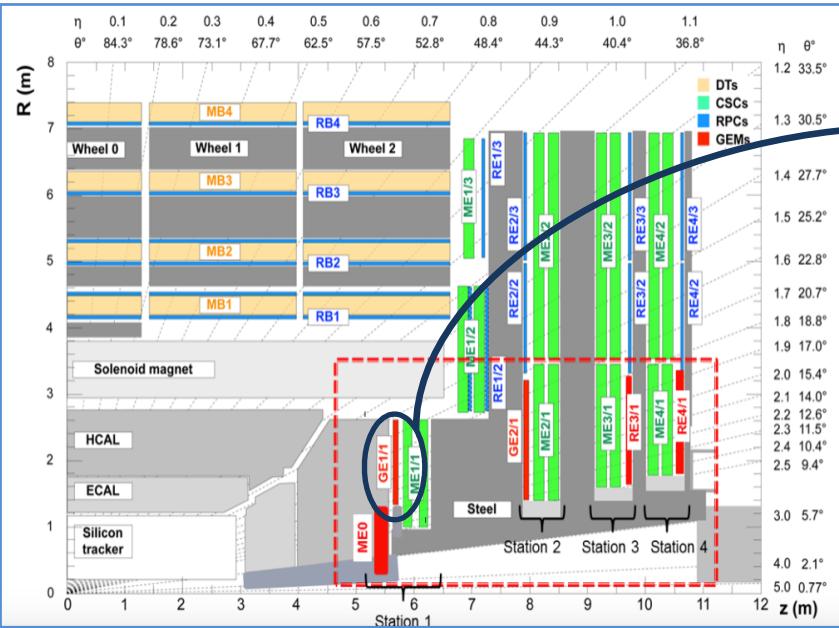
## 4 $\mu$ invariant mass for $\eta=2.4$ , $\eta =3.0$

14 TeV, 3000 fb<sup>-1</sup>, PU = 140

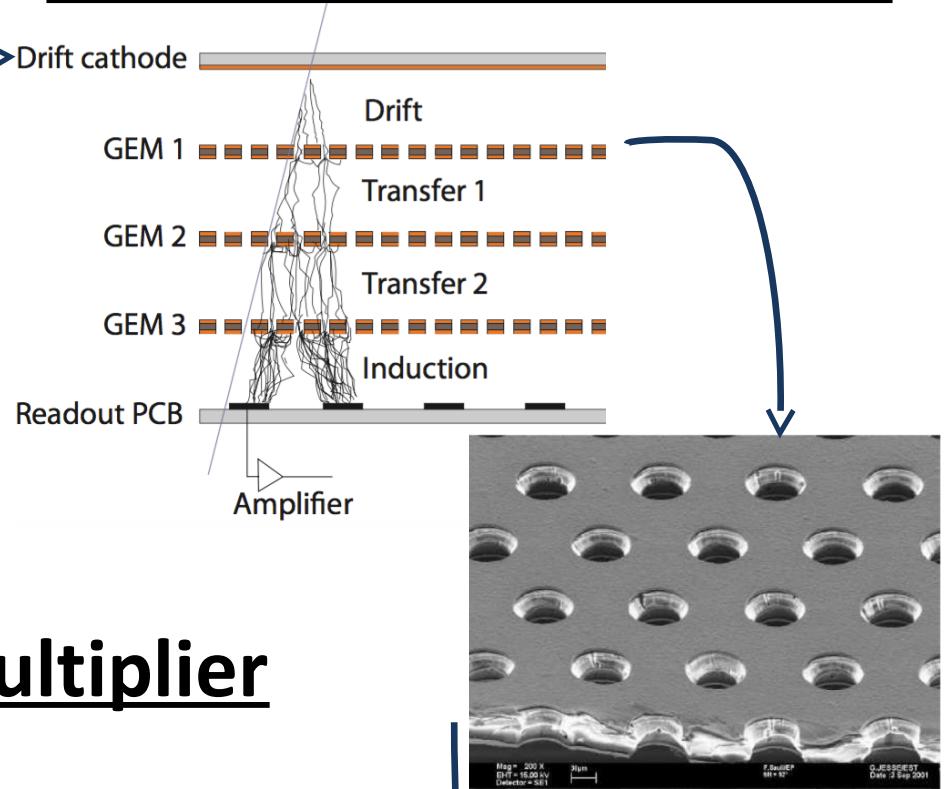


Improved signal selection efficiency with the  $\eta$  extension

# Which technology? MPGD → GEM



## Micro-Pattern Gaseous Detectors



## GEM: Gas Electron Multiplier

Capacità di rate

$\approx 100 \text{ MHz/cm}^2$

Risoluzione spaziale

$\approx 100\text{-}300 \mu\text{m}$

Guadagno

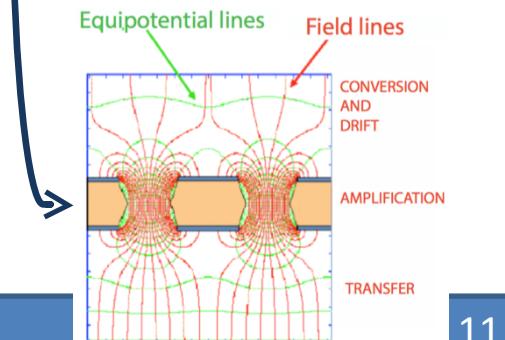
$> 10^4$

Risoluzione temporale

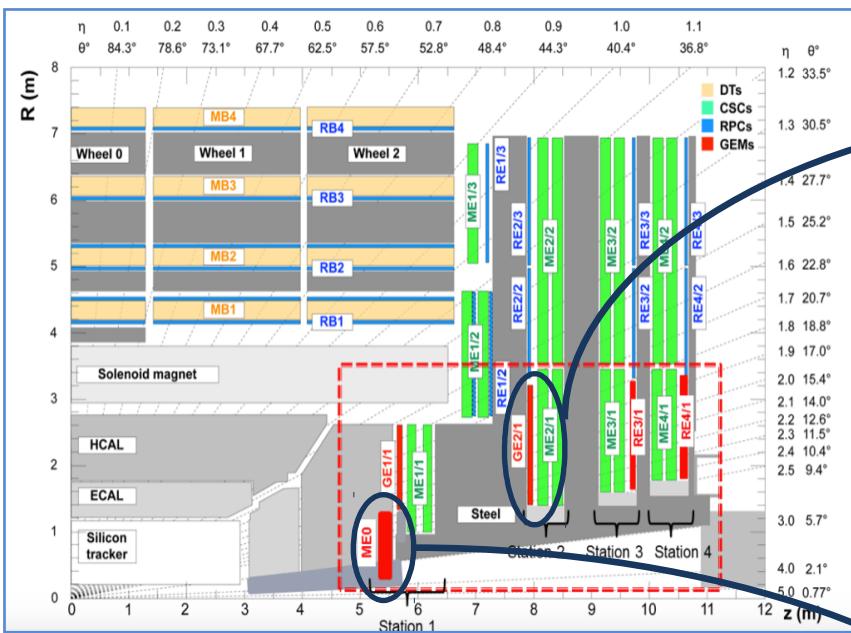
$\approx 5\text{-}8 \text{ ns}$

Efficienza

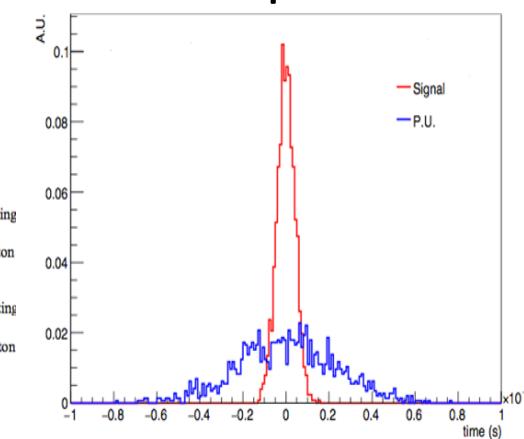
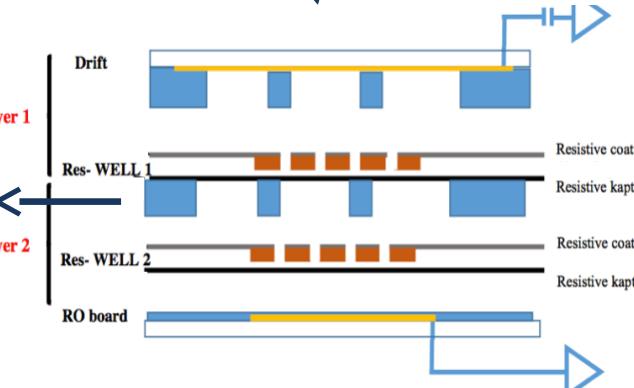
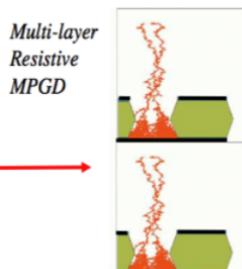
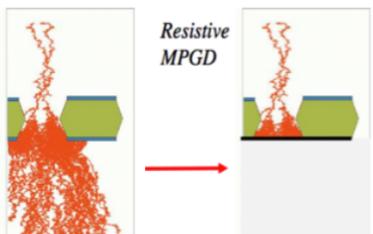
$> 97\%$



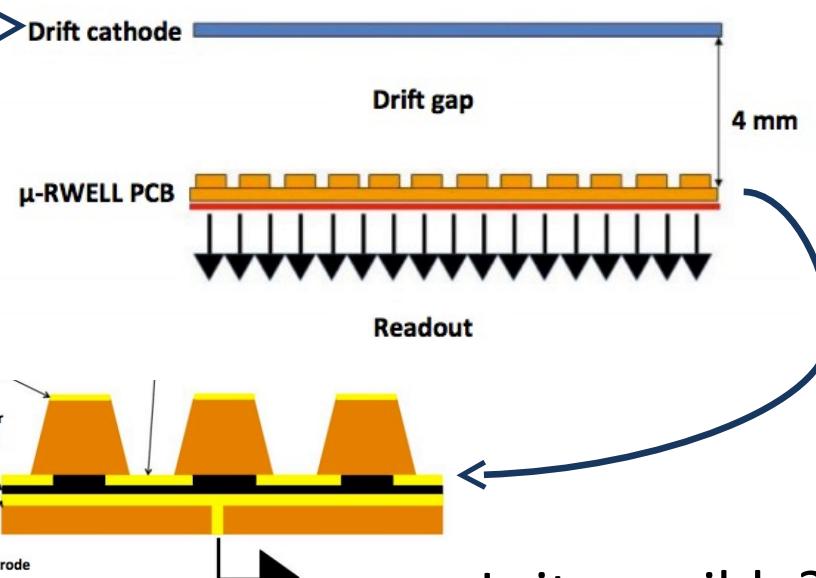
# Which technology? MPGD → new!



## FTM: Fast Timing Micro-Pattern detector



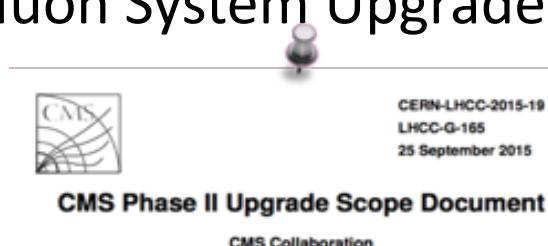
## μ-Resistive Well



Is it possible?

# Conclusions

- Performances of the Phase I “aged” detector configuration are significantly degraded and cannot allow fundamental physics studies
- Phase II upgrade detector configuration :
  - better  $4\mu$  reconstruction and event selection
  - it copes with the challenging conditions of HL-LHC
- Geometry extension increases the event selection efficiency: better  $4\mu$  invariant mass distribution
- New technologies under study for the Muon System Upgrade:
  - GEM, FTM,  $\mu$ -RWell



**The CMS Phase II Upgrade Technical Desing Reports are expected in 2018**