

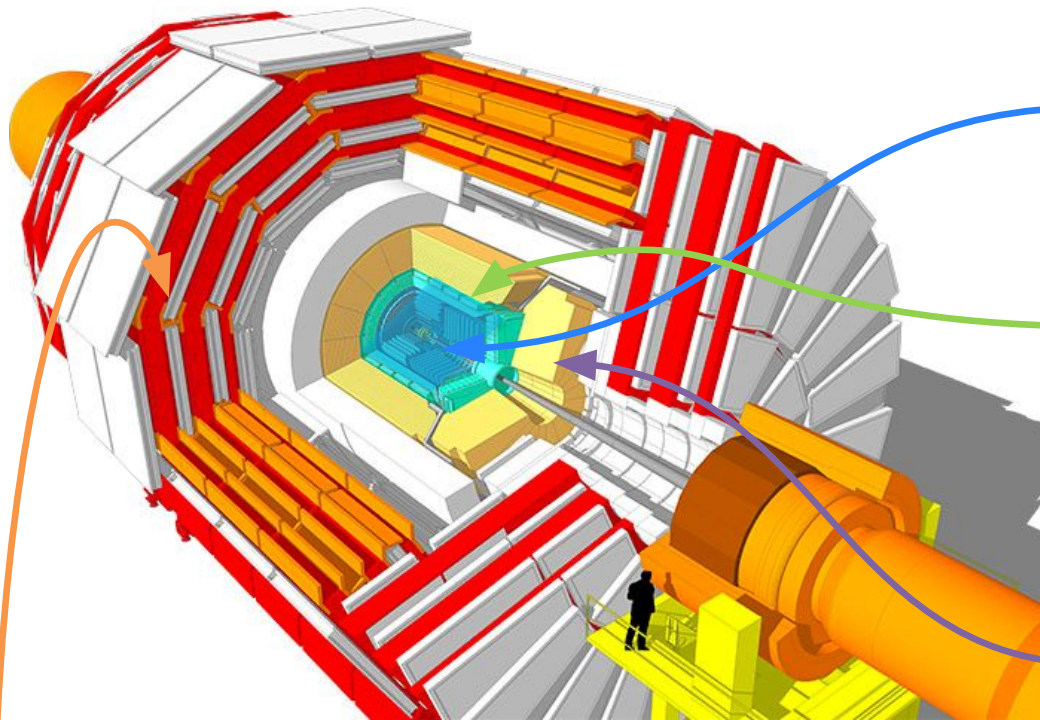


# CMS Inputs for the ESPP

*Rosamaria Venditti per il gruppo CMS Bari*

# Status: CMS Phase II Upgrades

- Il gruppo di Bari ha un forte coinvolgimento nelle attività di Upgrade di fase 2 dell'esperimento
- Siamo coinvolti nella produzione dei moduli per Outer Tracker e sistema a muoni /triple GEM per le stazioni ME0 e GE2/1, contributo al test degli iRPC)



## Tracker

- Increased granularity
- Extended coverage to  $\sim |\eta| 4$
- Designed for tracking in LIT

Bari Group:  
Outer tracker

## New MIP timing detector

- 30 ps timing resolution
- Full coverage to  $|\eta| \sim 3$

## New High-Granularity Endcap Calorimeter (HGECAL)

- Imaging calorimeter
- 3D showers and precise timing

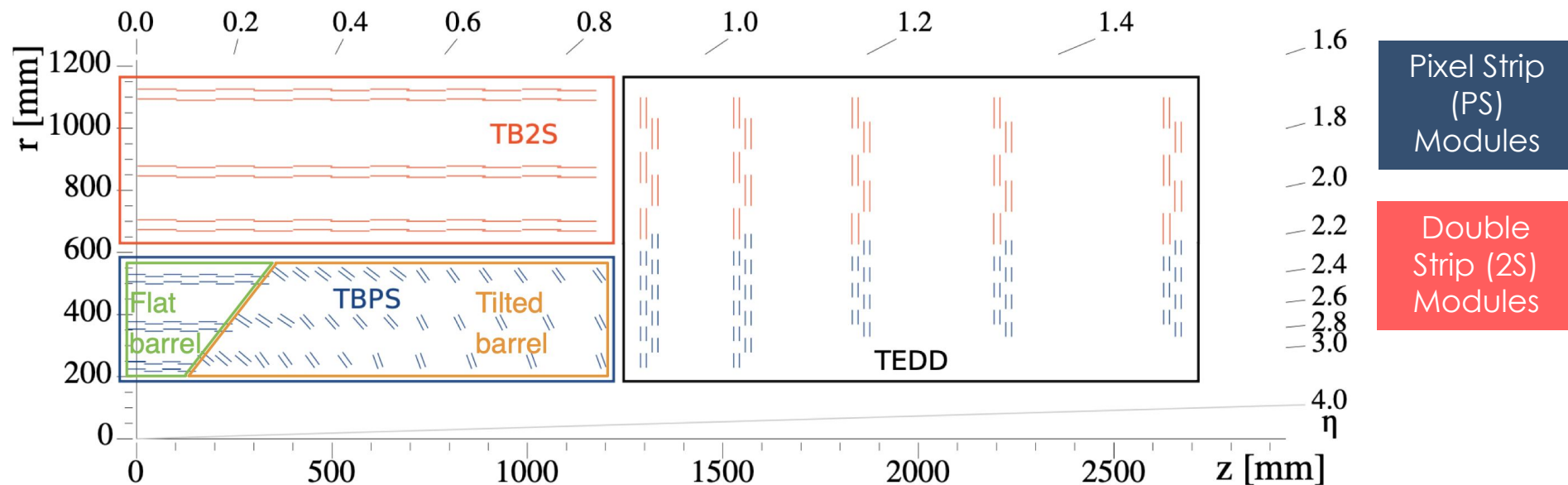
## Muon System

- Extended coverage to  $\sim |\eta| 3$
- Additional station with improved spatial and time resolution

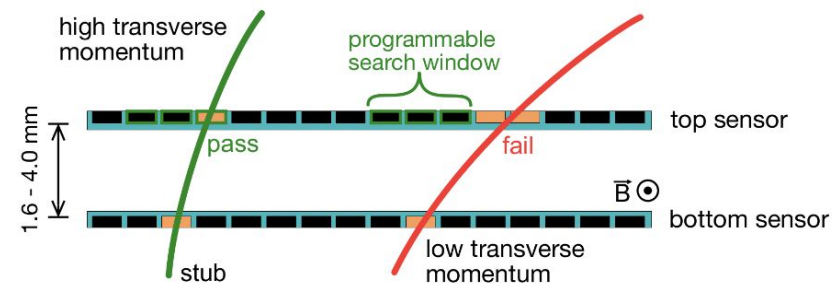
Bari Group:  
GEM Stations,  
iRPC

**CMS-PAS-TDR-15-002**

# CMS Phase II outer tracker



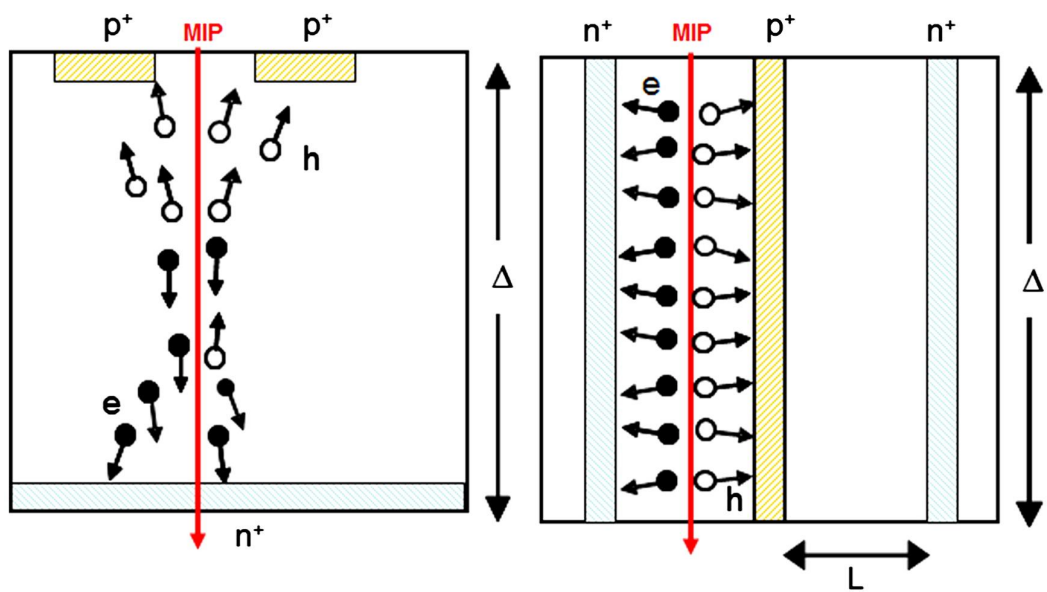
- Cover a total surface of 218 m<sup>2</sup> - 174 million macropixels
- Barrel: 6 layers of **pT modules**
- Endcap: 2x5 disks of **pT modules**
- pT modules: 2 layers of n-in-p silicon
  - 2S: 2 super-imposed strip sensors (90 μm x 5 cm)
  - PS: Macro-pixel sensor (100 μm x 1.5 cm)



*p<sub>T</sub> module → provide stubs compatible with tracks p<sub>T</sub> > 2 GeV for L1 trigger rate reduction*

# Rivelatori al silicio: CMS e oltre

- Bari centro di produzione dei moduli Pixel Strip (PS) per la Fase 2 di CMS
  - Assemblaggio e test di validazione in camera pulita
- Interesse per R&D di **sensori al silicio 3D** per sistemi di tracciamento di collisori futuri



# Rivelatori al silicio: CMS e oltre

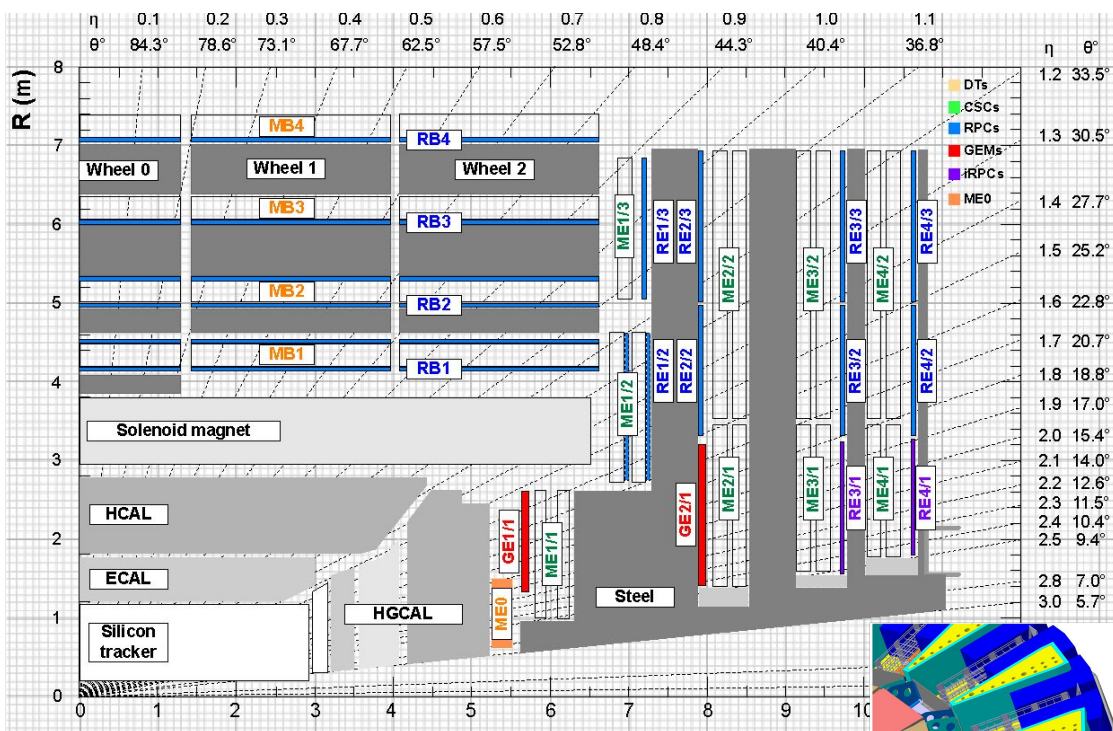
- Coinvolgimento in DRD3, WP 3.2, 3.3
  - R&D di sensori 3D per tracciamento 4D (pos+timing),
    - Spatial resolution: towards 3  $\mu\text{m}$  position resolution
    - Reduction of pixel cell size for 3D sensors
  - studi di resistenza a radiazione per alta fluensa
    - towards  $10^{16}$  neq / $\text{cm}^2$  NIEL and 500 MRa
  - Contatto DRD3: Donato M. Creanza

Workpackage	3.1 Monolithic CMOS sensors				3.2 4D Tracking		3.3 Extreme Fluence			3.4 Intercon.			
Tasks	Spatial resolution	Temporal resolution	Read-out architecture	Radiation Tolerance	3D sensors	LGAD	Wide band-gap materials	Diamond	Silicon	maskless interconnect	in house post-processing	advanced interconnect	mechanics and cooling
Institute													
INFN Bari	X		X	X	X				X			X	

[Link a DRD3 Proposal](#)

# CMS Phase II Muon System

New stations to increase coverage, improve momentum resolution, trigger and track reconstruction



**GE2/1**

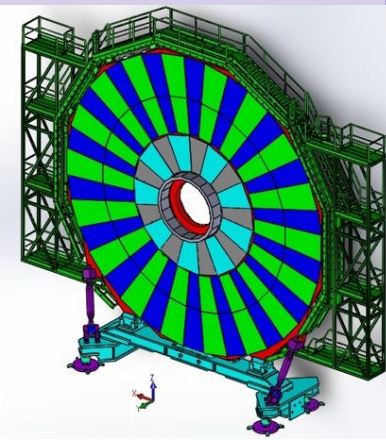
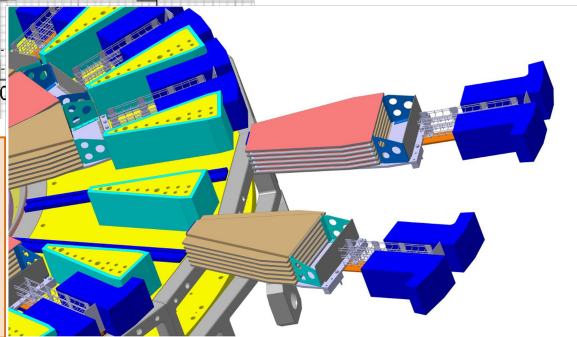
- $1.6 < |\eta| < 2.49$
- 2 rings of two layers of **triple GEMs**
- Additional stub in the muon trigger and offline

**RE3/1-RE4/1**

- $1.9 < |\eta| < 2.4$
- 2 stations of **improved RPC**
- time and position for trigger and track reconstruction

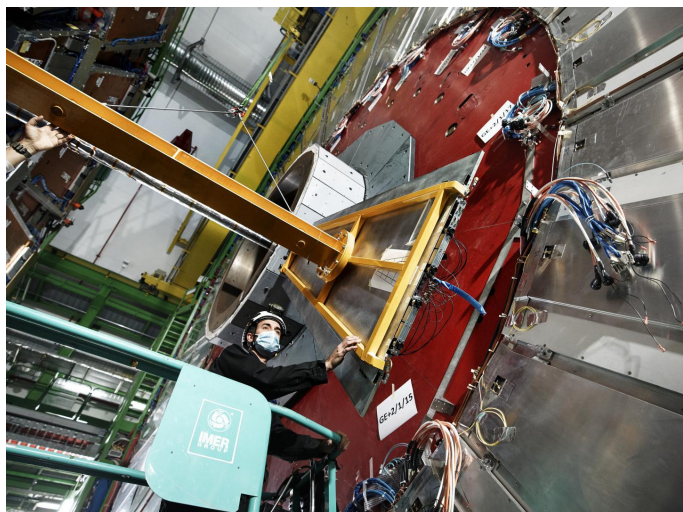
**ME0-Muon near-tagger**

- $2 < |\eta| < 2.8$ ,  $O(100 \text{ kHz/cm}^2)$  background
- 6-layers of **triple-GEM**
- additional information to the tracker

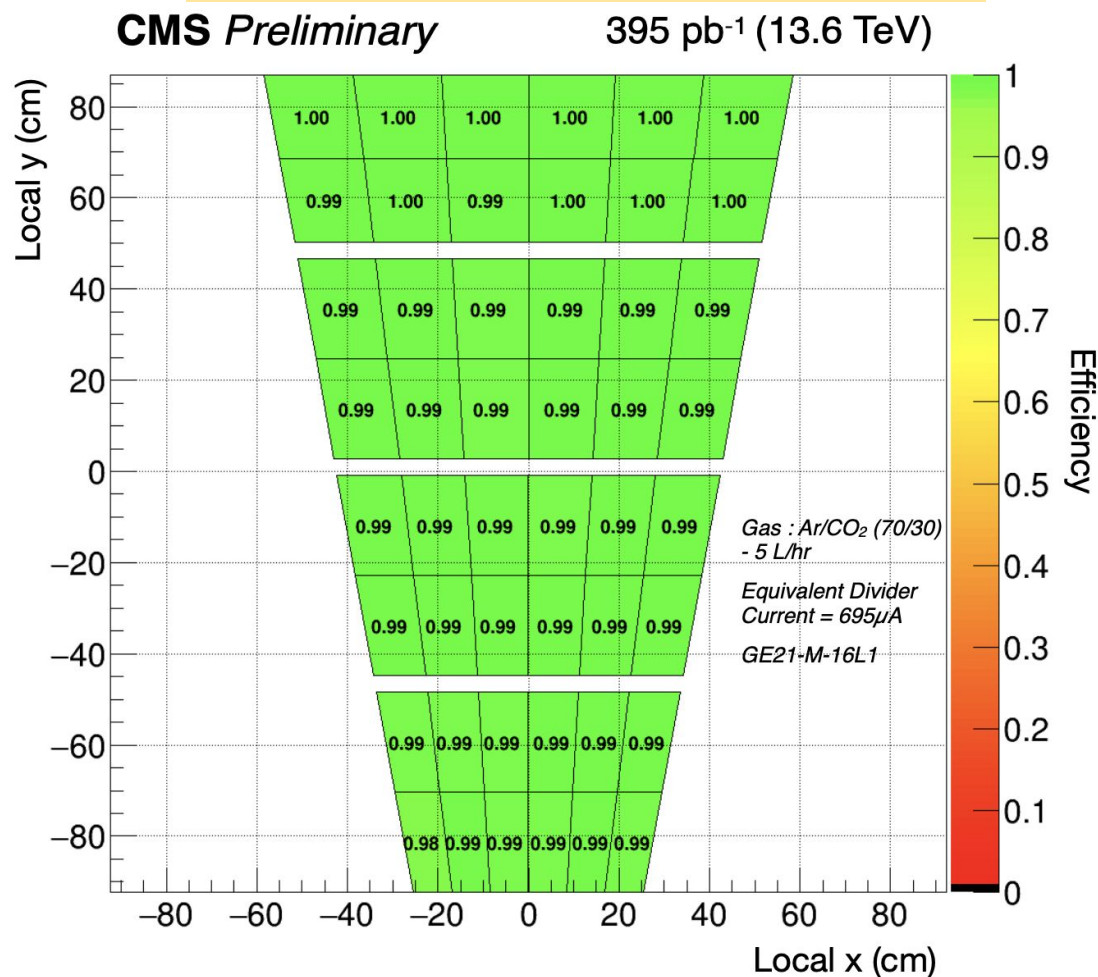


# The GE2/1 station

- Triple GEM is a mature technology based on mechanical foil stretching
- Additional stub measurement
- 3 GE2/1 chambers installed and integrated in data taking
  - gain operational experience
  - occupancy, noise, Dead channel, Cross talk
- Efficiency shows the expected performance



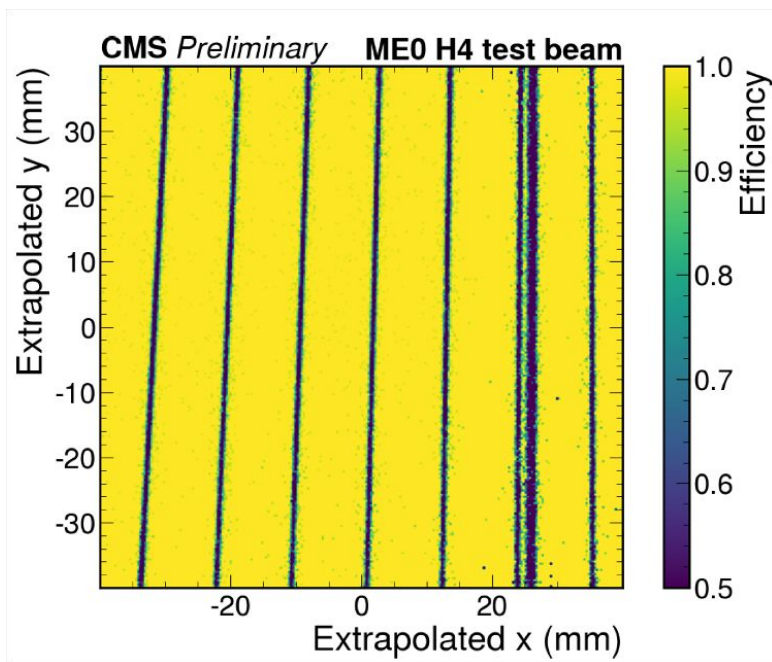
## Detector prototype performance



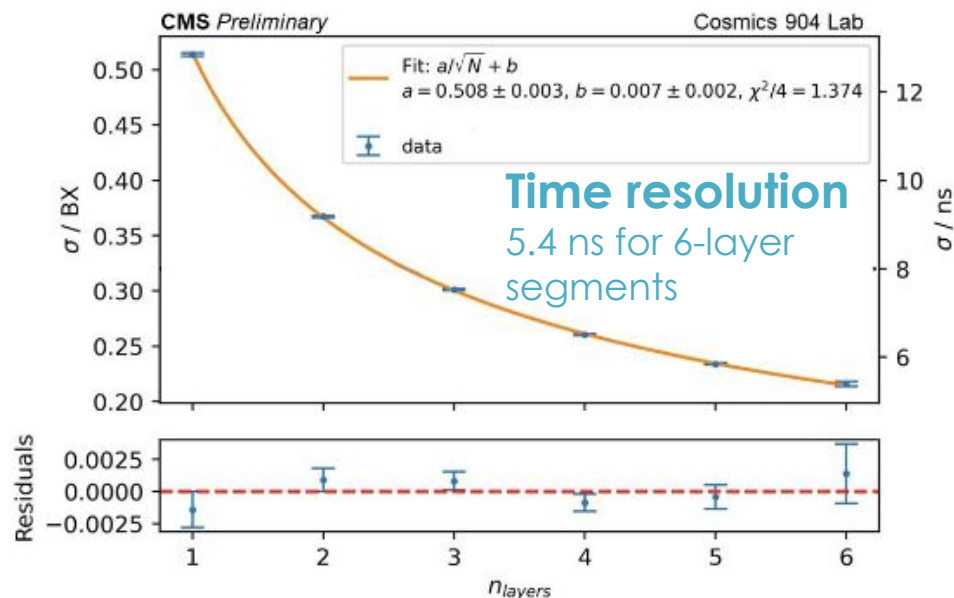
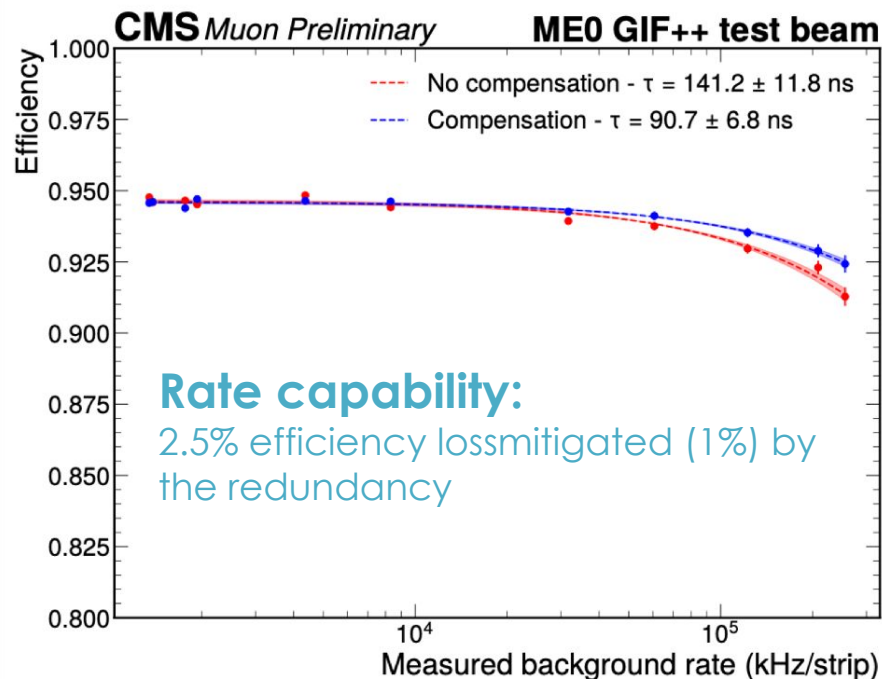
# The ME0 station

## Requirements :

- Rate capability: 150 kHz/cm<sup>2</sup>
- 97% module efficiency
- < 500  $\mu$ rad resolution
- 10 ns time resolution



- **Hit Efficiency: 99%**
- **Spatial Resolution: 240  $\mu$ rad**



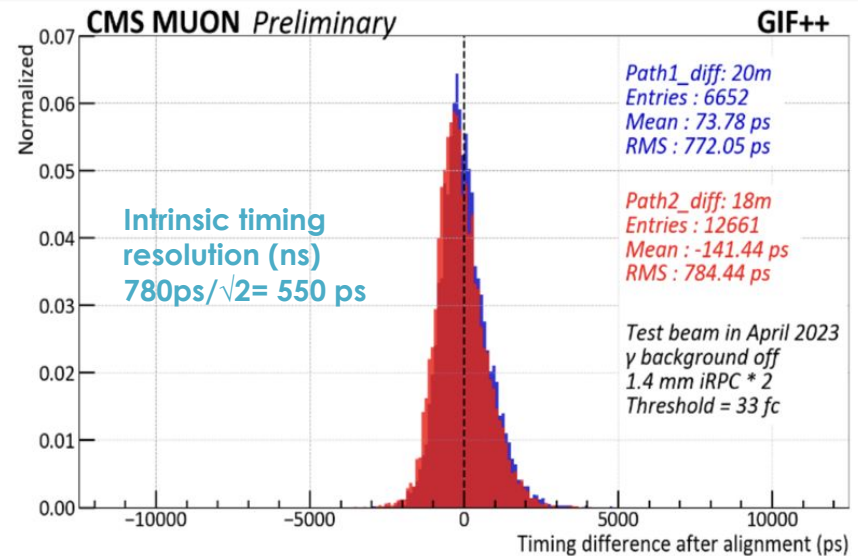
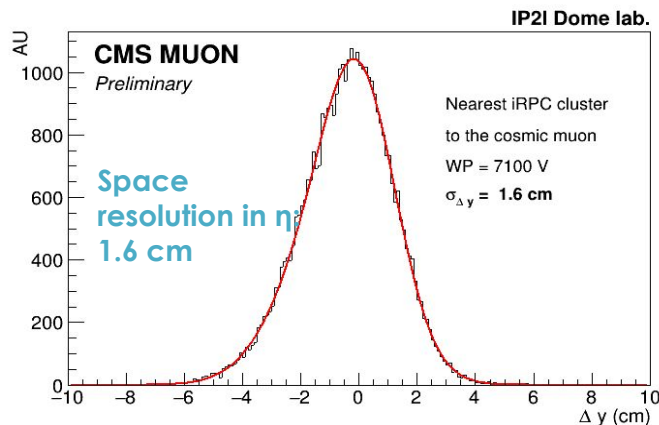
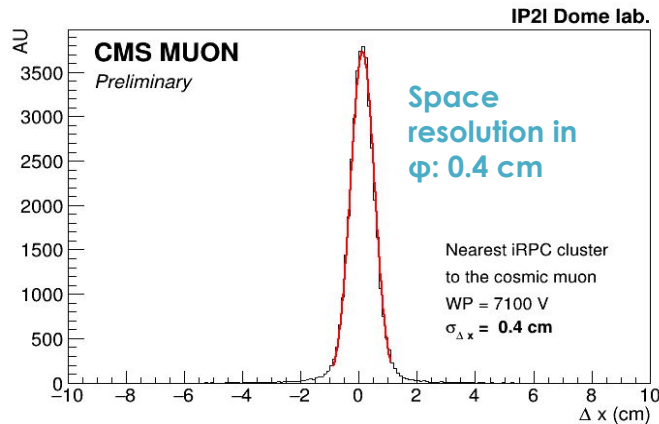


# Improved RPC for RE3/1 RE4 / 1

- Reduced gap thickness and resistivity → improvement in spatial and time resolution
- Double readout in the strips high and low radius

	RPC	iRPC
HPL thickness (mm)	2	1.4
Gas gap thickness (mm)	2	1.4
Resistivity ( $\Omega\text{cm}$ )	$1 - 6 \times 10^{10}$	$0.9 - 3 \times 10^{10}$
Charge threshold (fC)	150	30 - 40
Space resolution in $\eta$ (cm)	20 - 28	1.5
Space resolution in $\phi$ (cm)	0.8 - 1.9	0.3 - 0.6
Intrinsic timing resolution (ns)	1.5	0.5

Detector prototype performance



# Rivelatori a ionizzazione: CMS e oltre

- Bari centro di produzione di rivelatori a tripla GEM
  - Assemblaggio in camera pulita e test di validazione in laboratorio
- Interesse per R&D di rivelatori **MPGD resistivi e iRPC** per future colliders
  - Calorimetro adronico (MuColl)
  - Sistema a muoni (FCC)
- Coinvolgimento in DRD1- WP1, WP5, WP7
  - sviluppo miscele eco-friendly, rivelatori di grande area con alta granularità per calorimetria, studi di timing, di elettronica di lettura
  - [Link a DRD1 Proposal](#) (vedi talk di Alessandra)
  - [Link al proposal per Snowmass](#)



MPGDs for tracking and Muon detection at future high energy physics colliders

Snowmass Instrumentation Frontier: MPGD White paper 5

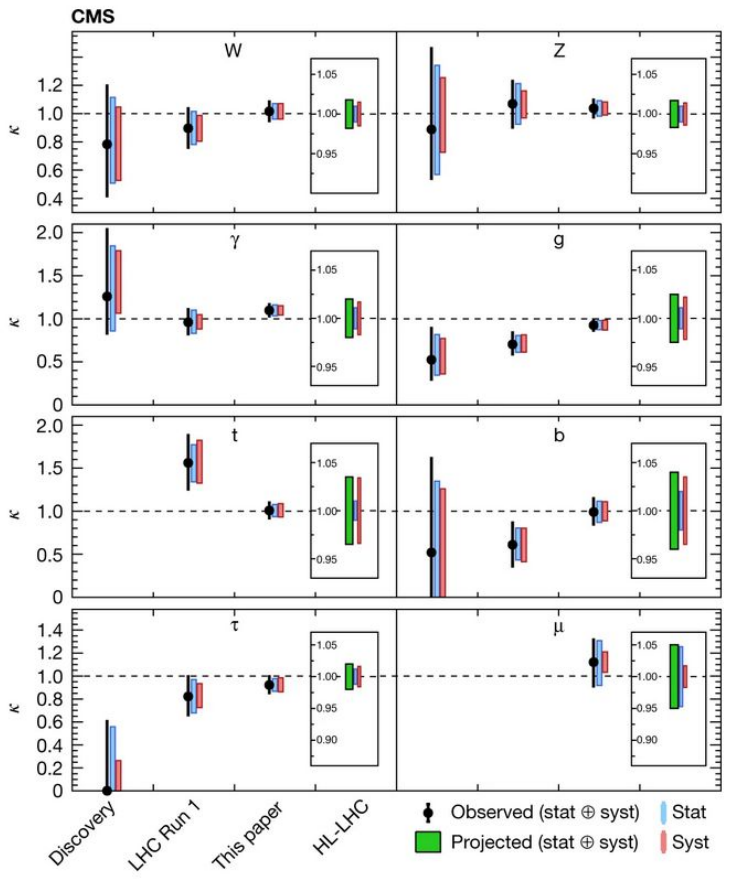
K. Black (Coordinator)<sup>1</sup>, A. Colaleo (Coordinator)<sup>2</sup>, C. Aimè<sup>3</sup>, M. Alviggi<sup>4</sup>, C. Aruta<sup>2</sup>, M. Bianco<sup>5</sup>, I. Balossino<sup>6</sup>, G. Bencivenni<sup>7</sup>, M. Bertani<sup>7</sup>, A. Braghieri<sup>8</sup>, V. Cafaro<sup>9</sup>, S. Calzaferri<sup>8</sup>, M. T. Camerlingo<sup>10,5</sup>, V. Canale<sup>4</sup>, G. Cibinetto<sup>6</sup>, M. Corbetta<sup>5</sup>, V. D'amico<sup>10</sup>, E. De Lucia<sup>7</sup>, M. Della Pietra<sup>4</sup>, C. Di Donato<sup>4</sup>, R. Di Nardo<sup>10</sup>, D. Domenici<sup>7</sup>, F. Errico<sup>2</sup>, P. Everaerts<sup>1</sup>, F. Fallavollita<sup>11</sup>, R. Farinelli<sup>6</sup>, G. Felici<sup>7</sup>, D. Fiorina<sup>8</sup>, I. Garzia<sup>6</sup>, M. Gatta<sup>7</sup>, P. Giacomelli<sup>9</sup>, M. Giovannetti<sup>7</sup>, S. Gramigna<sup>6</sup>, R. Guida<sup>5</sup>, M. Hohlmann<sup>12</sup>, P. Iengo<sup>13,5</sup>, M. Iodice<sup>14</sup>, L. Lavezzi<sup>15</sup>, M. Maggi<sup>16</sup>, B. Mandelli<sup>5</sup>, M. Melchiorri<sup>6</sup>, J. A. Merlin<sup>17</sup>, G. Mezzadri<sup>6</sup>, P. Montagna<sup>3</sup>, G. Morello<sup>7</sup>, G. Papalino<sup>7</sup>, A. Pellicchia<sup>2</sup>, F. Petrucci<sup>10</sup>, M. Poli Lener<sup>7</sup>, R. Radogna<sup>2</sup>, C. Riccardi<sup>9</sup>, M. G. Rigoletti<sup>5</sup>, P. Salvini<sup>8</sup>, M. Scodreggio<sup>6</sup>, G. Sekhniaidze<sup>13</sup>, M. Sessa<sup>10</sup>, F.M. Simone<sup>16</sup>, A. Sharma<sup>5</sup>, A. Stameria<sup>2</sup>, I. Vai<sup>8</sup>, R. Venditti<sup>2</sup>, P. Verwilligen<sup>16</sup>, P. Vitulo<sup>3</sup>, and A. Zaza<sup>2</sup>

12 Mar 2022

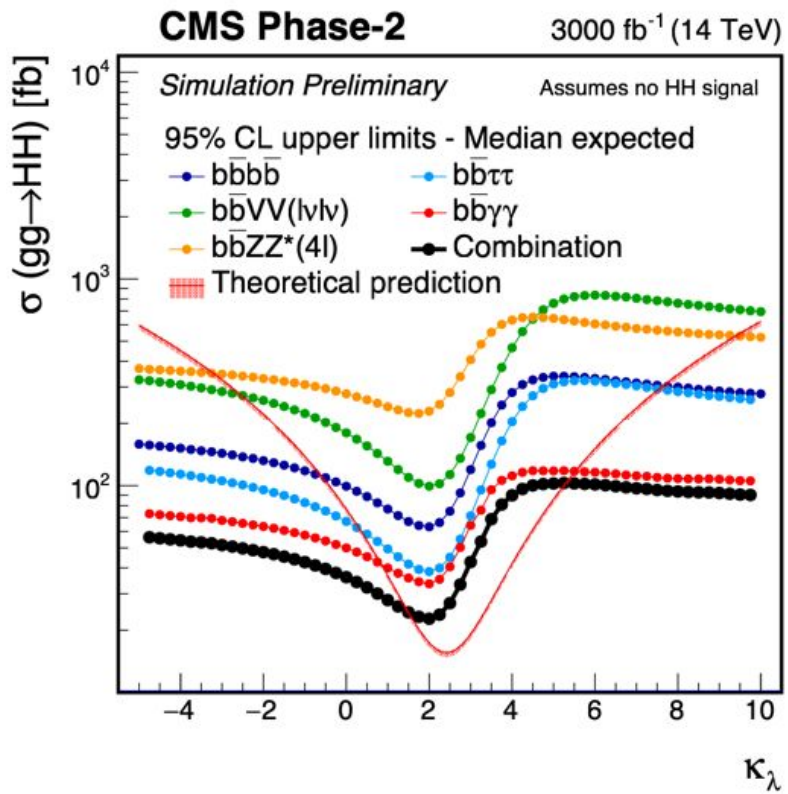
# HL-LHC Physics Motivation - Higgs

- Precisely test the Standard Model, including Higgs boson
- Searches for rare processes  $H \rightarrow cc, HH$

A portrait of the Higgs boson by the CMS experiment ten years after the discovery. [Nature 607, 60–68 \(2022\)](https://arxiv.org/pdf/1902.10229).



Extrapolation of Run2 analyses ( $35.9 \text{ fb}^{-1}$ )  
**O(few %) reached on SM couplings**



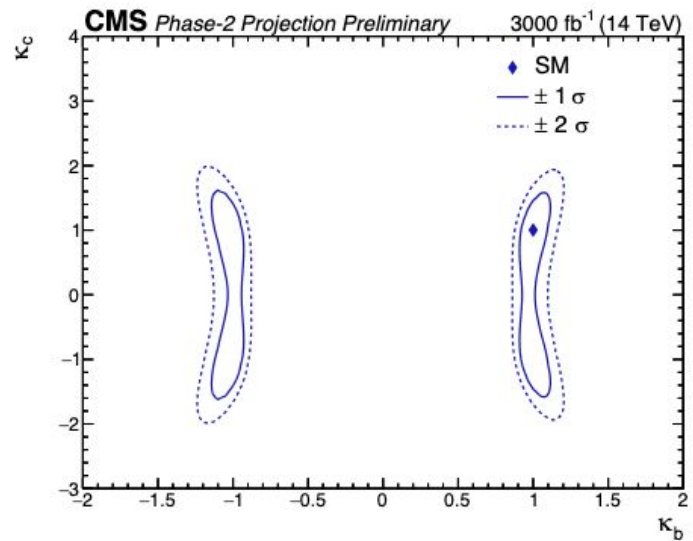
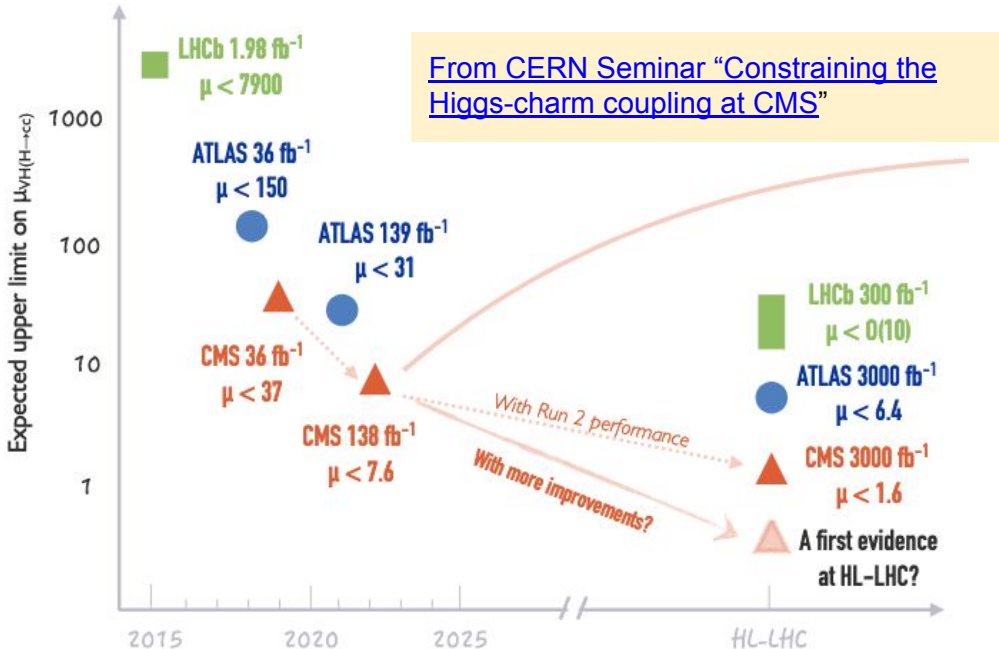
<https://arxiv.org/pdf/1902.10229>

2.6 sigma expected significance on HH  
**95% CL intervals for  $\kappa_\lambda$ : [-0.18, 3.6]**

# Ricostruzione, computing, analisi

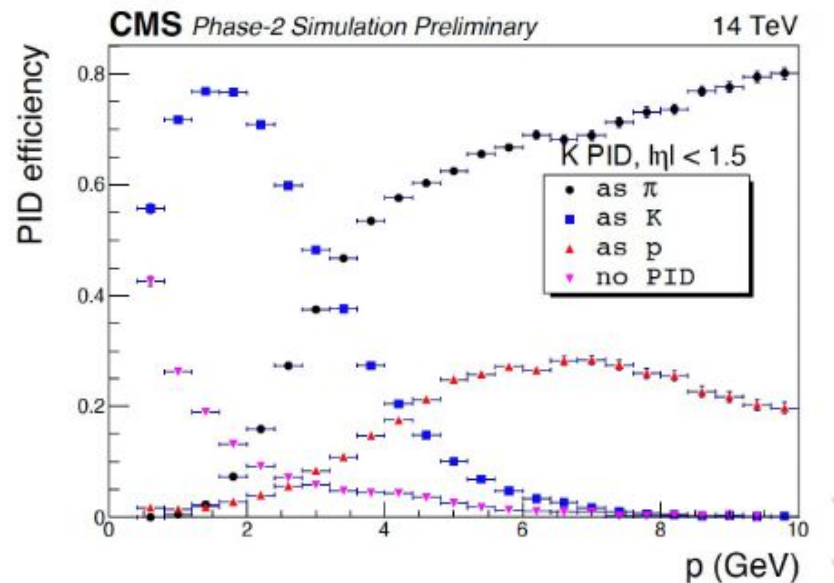
Misura dell'accoppiamento di Yukawa dell'higgs con con quark della seconda generazione:  $H \rightarrow cc$

- CMS Run3: ricerca di VBF  $H \rightarrow cc$  ongoing
- L'estrapolazione delle misure attuali porta a un UL  $\mu < 1.6$  a HL-LHC (CMS only)
- Con miglioramenti sull'analisi: evidenza al Run3 (con ATLAS) e osservazione a HL-LHC?
- Stima della precisione a livello sub-per cento a futuri collisori



# HL-LHC Physics Motivation - Flavor

- Fisica del Flavor: *spettroscopia*, *LFV anomalies*
  - Confermato interesse per HL-LHC: queste ricerche trarranno enormi vantaggi dall'upgrade di tracciatore, sistema a muoni e inclusione di MTD
- Software/computing: interesse nello sviluppo di ricostruzione di tracce, muoni e jet a futuri collisori
  - algoritmi di deep learning per flavor tagging, identificazione dei muoni
  - architetture ibride (con GPU e FPGA) per la ricostruzione di tracce e jet



Snowmass 2021 (DPF Community Planning Exercise)



May 5, 2022

## Review of CMS contribution to Hadron Spectroscopy (White Paper)

Ruslan Chistov<sup>1</sup>, Vaia Papadimitriou<sup>2</sup>, Sergey Polikarpov<sup>1</sup>,  
Alexis Pompili<sup>3</sup>, Alberto Sanchez-Hernandez<sup>4</sup>

<https://arxiv.org/pdf/2204.06667>

# Summary

Il gruppo CMS Bari è impegnato nelle attività per l'Upgrade di Fase 2 di CMS

- Produzione di moduli PS di outer tracker
- rivelatori a tripla GEM per ME0 e GE2/1

Impegno nelle attività di R&D per:

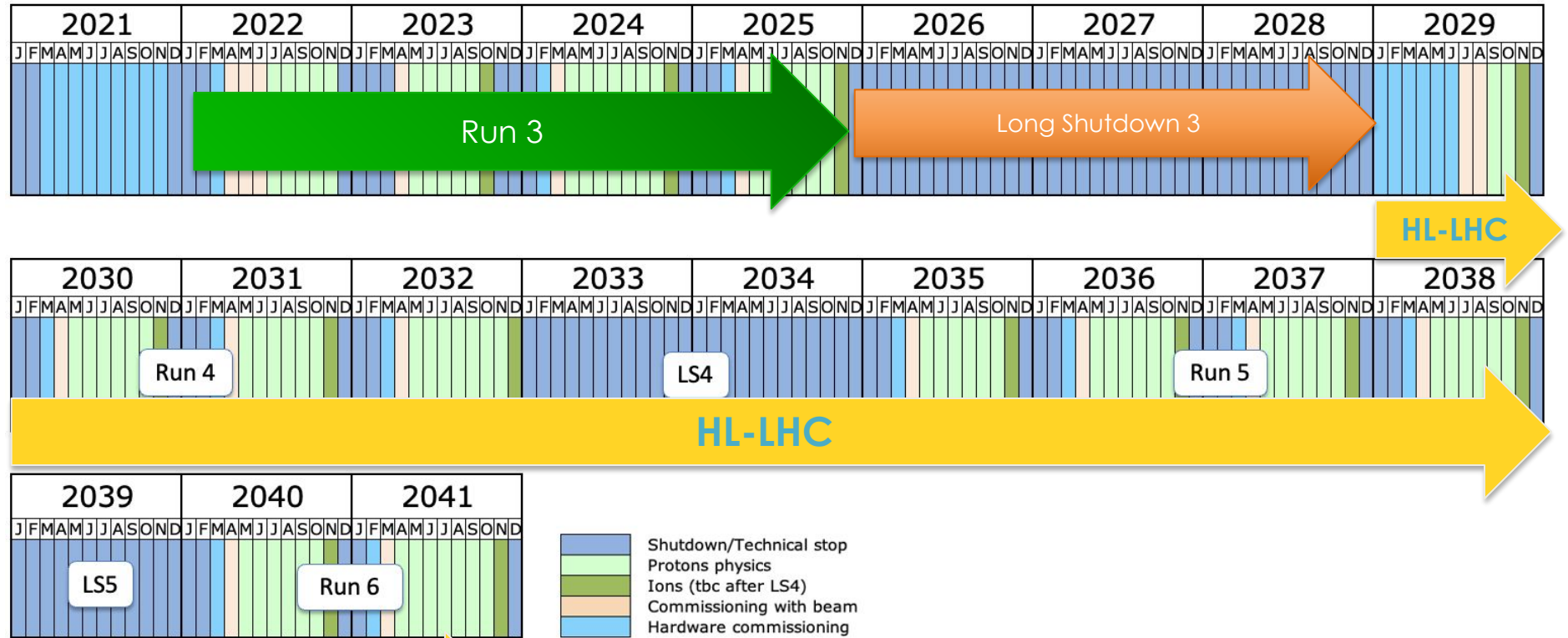
- sviluppo di sistemi di tracciamento: R&D Rivelatori al silicio 3D
- sistemi a muoni, calorimetro adronico: R&D Rivelatori MPGD resistivi

Fisica e computing/ricostruzione: sviluppo analisi e tecniche nel Run3, in preparazione a HL-LHC e future colliders

- Misure di precisione di Hcc coupling
- Fisica del flavor: LFV e spettroscopia
- sviluppo di ricostruzione di tracce, muoni e jet a futuri collisori
  - algoritmi di deep learning per flavor tagging, identificazione dei muoni
  - architetture ibride (con GPU e FPGA) per la ricostruzione di tracce e jet

# Backup

# Towards HL-LHC



	Run 3	Run 4,5,6
Inst. Lumi ( $\text{sec}^{-1} \text{cm}^{-2}$ )	$2 \times 10^{34}$	$5-7 \times 10^{34}$
Target int. lumi ( $\text{fb}^{-1}$ )	250	3000-4000
Pile up	~50	~140-200



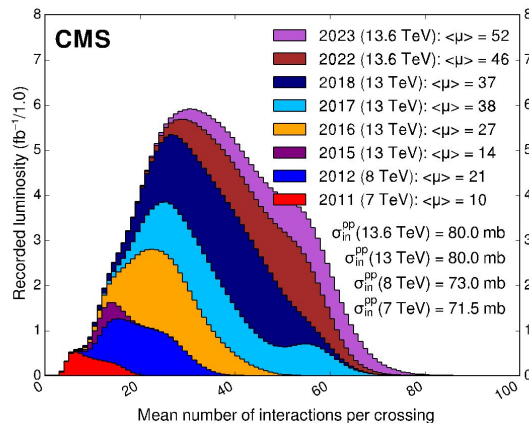
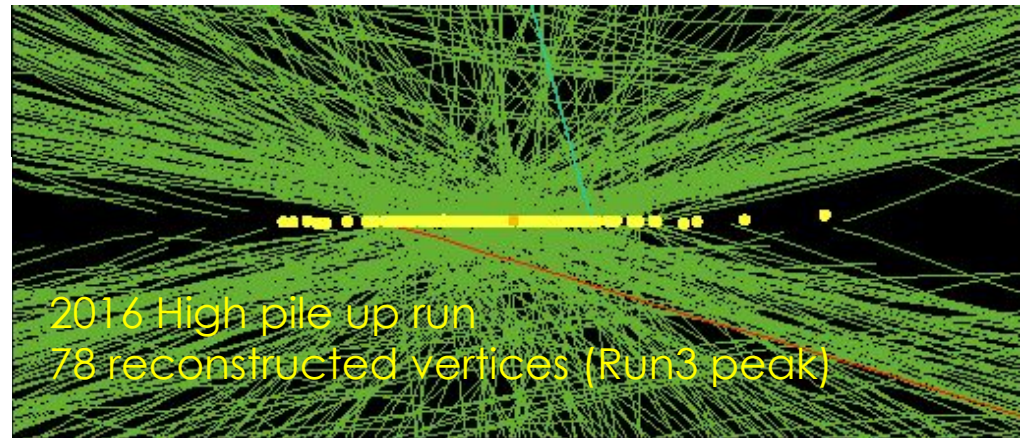
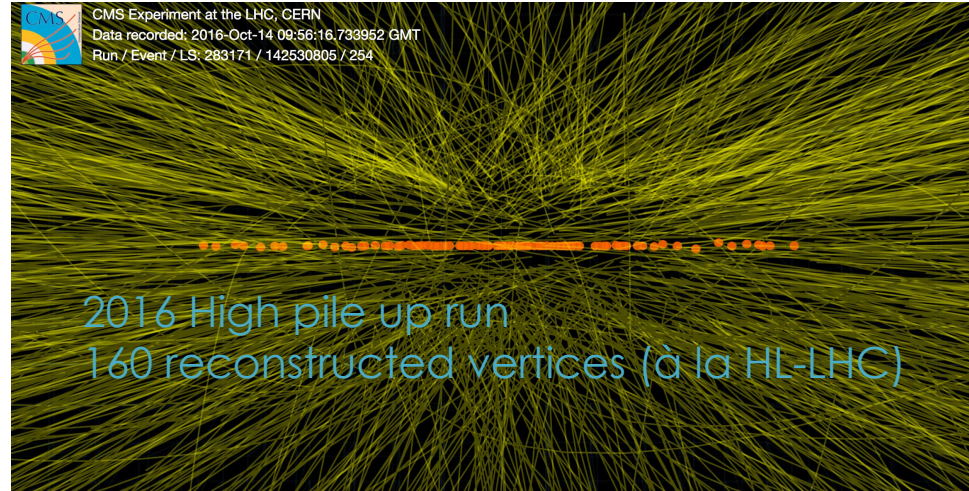
# Towards HL-LHC

## HL-LHC: challenging data taking conditions

- Detector operations
- event reconstruction
- particle densities x5-10
- Radiation damage x10

## Requirements for experimental apparatus

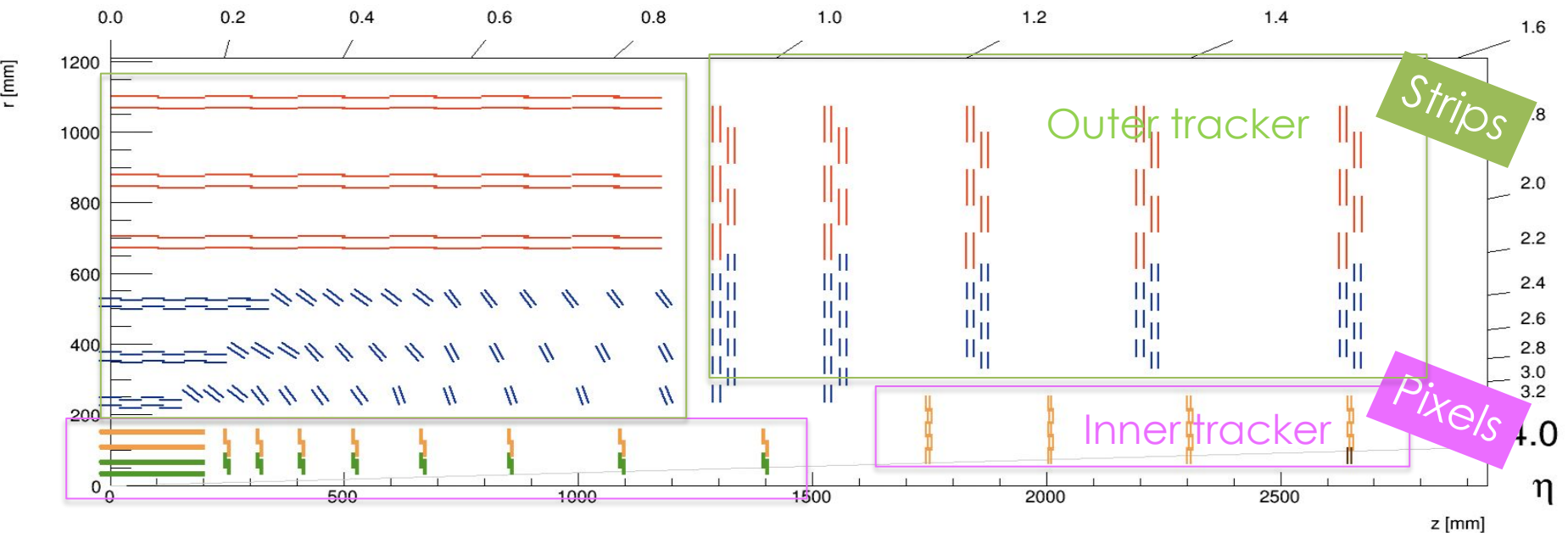
- Increased detector granularities
- Significant use of (fast) timing
- Radiation hardness



# CMS Phase II tracker project

## Requirements:

- Radiation hardness: Max fluence up to  $O(10^{16}) n_{eq}/cm^2$
- Preserve  $\geq 98\%$  efficiency
- Preserve spatial resolution
- Increased granularity: 1200 tracks / unit of  $\eta$
- Reduced material: Preserve calorimetric resolution
- Contribution to the L1 trigger

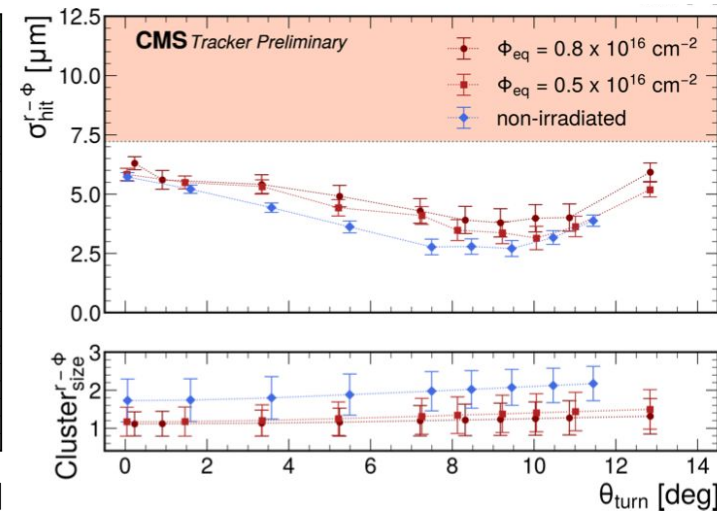
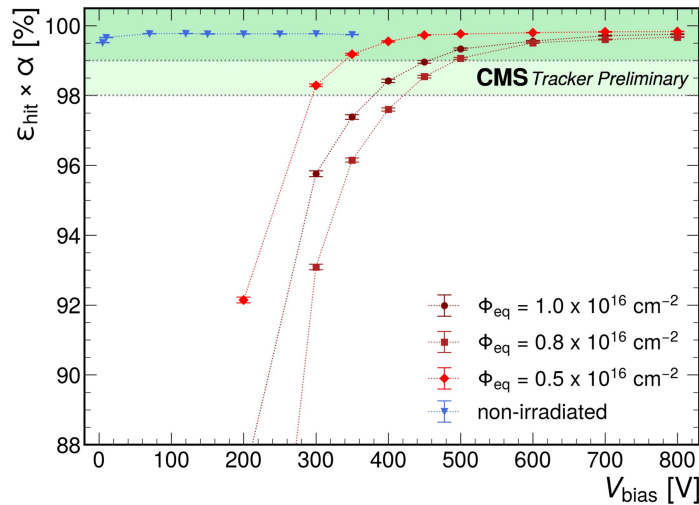


# Silicon modules performance

doi/10.22323/1.449.0578

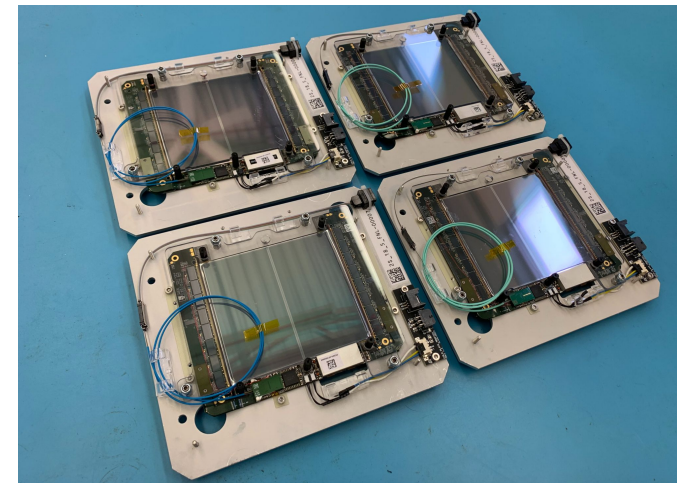
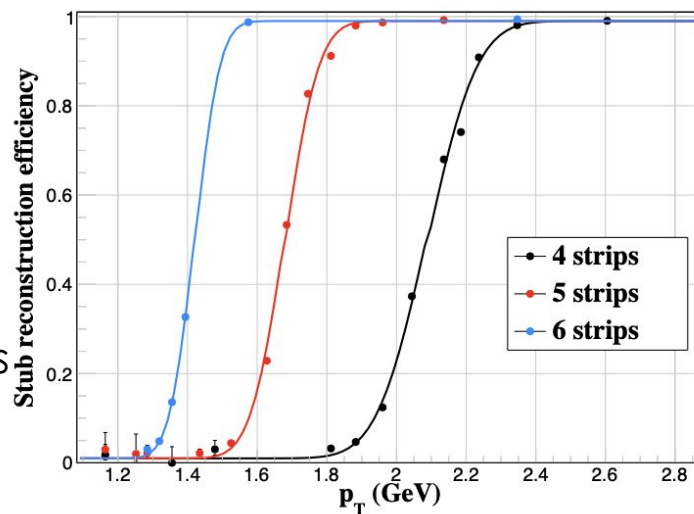
## Pixel prototypes

- Single chip assemblies irradiated at CERN
- Performance measured with test beam at DESY
- Hit efficiency  $> 98\%$  for high irradiation
- Spatial resolution below the single-pixel cluster limit  $7.2 \mu\text{m}$  ( $r-\phi$ )

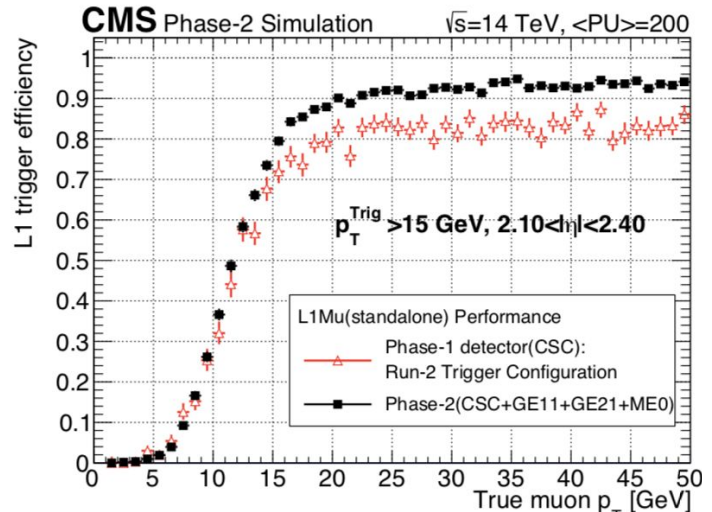


## pT modules prototypes

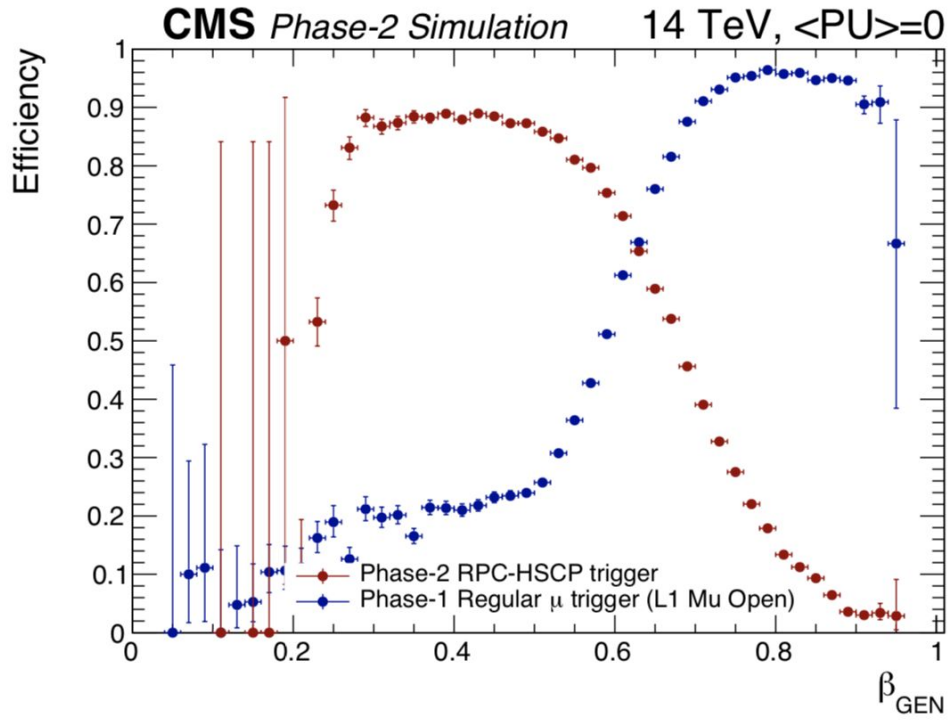
- More than 60 modules built across the various production centers
- Expected performance confirmed



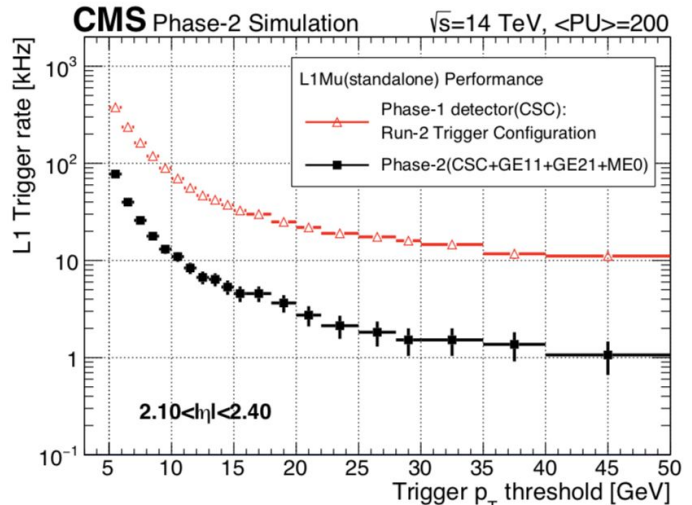
# Phase II Muon System motivations



Recover L1 trigger efficiency wrt Phase 1



Sensitivity new physics, e.g. heavy stable charged particles



Reduce L1 endcap trigger rate wrt Phase 1

**Muon system overview in G. Pugliese talk**