

# Sezione di Fisica Subnucleare



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Università di Napoli Federico II

Congresso interno del Dipartimento di Fisica

Napoli, 26 Giugno 2019

# Sezione di Fisica Subnucleare: ricerca

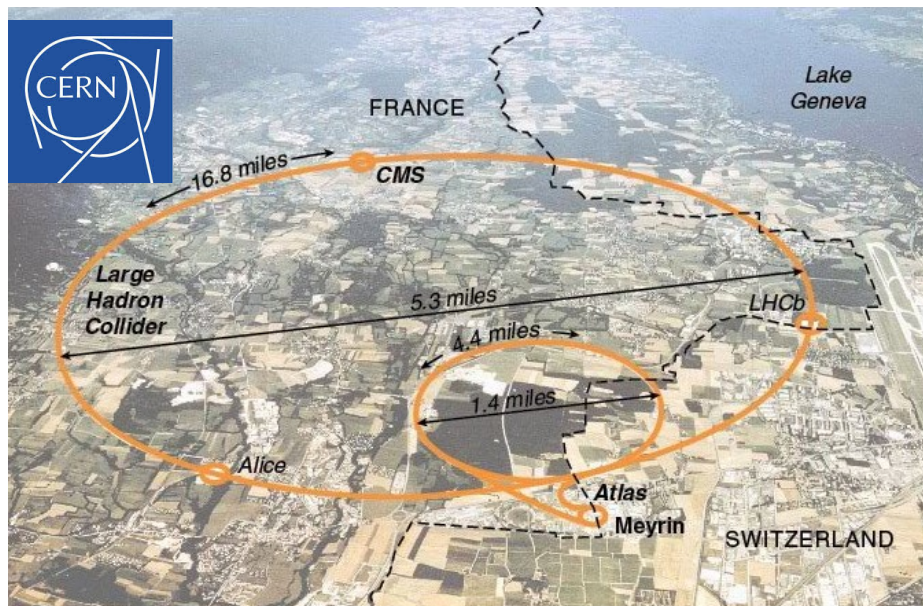
**Ricerca scientifica sperimentale  
nella Fisica delle Particelle Elementari e delle Interazioni Fondamentali**

Area	Esperimenti	Laboratori
Frontiera dell'energia	 	CERN (CH)
Flavour Factory - quark e leptoni pesanti		KEK (JP)
Flavour Factory - kaoni		CERN (CH)
Fisica del Neutrino, dark matter e Hidden Sector	 	CERN (CH), Gran Sasso (IT)



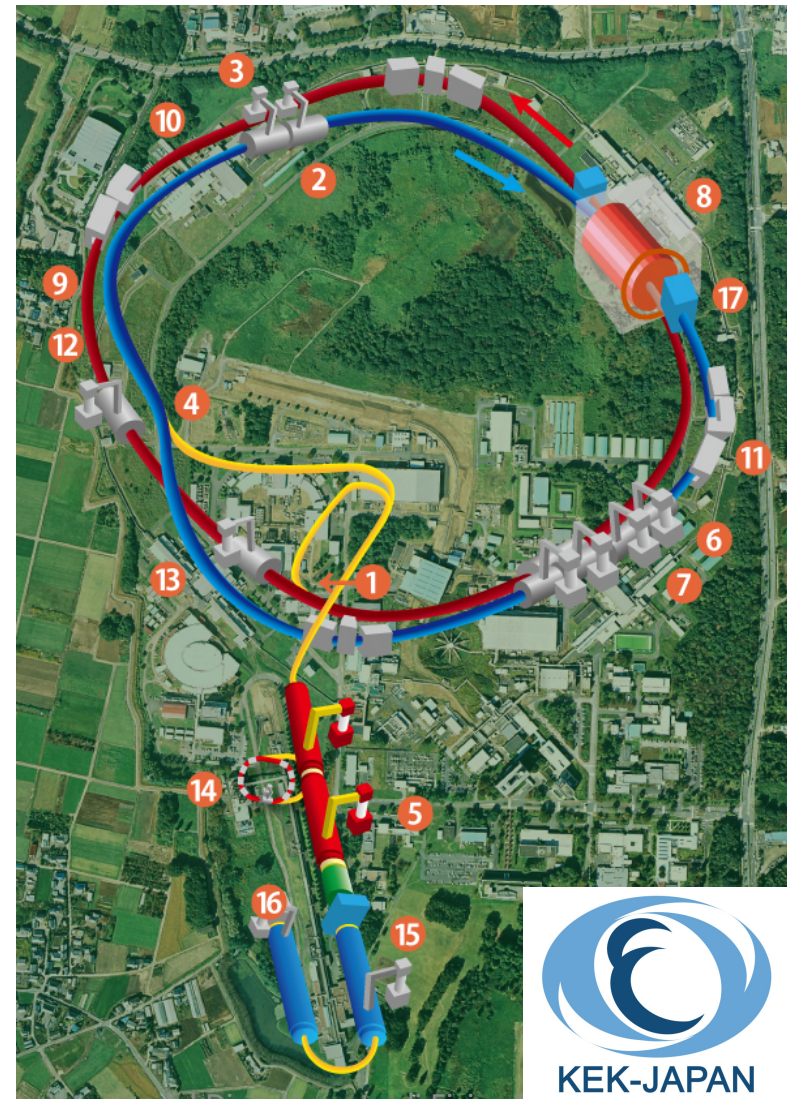
# Programmi sperimentali

Le attività sperimentali si inseriscono in programmi di ampio respiro in laboratori di ricerca internazionali unici nel loro genere



LHC at CERN 7 TeV + 7 TeV p p collider  
(world highest energy)

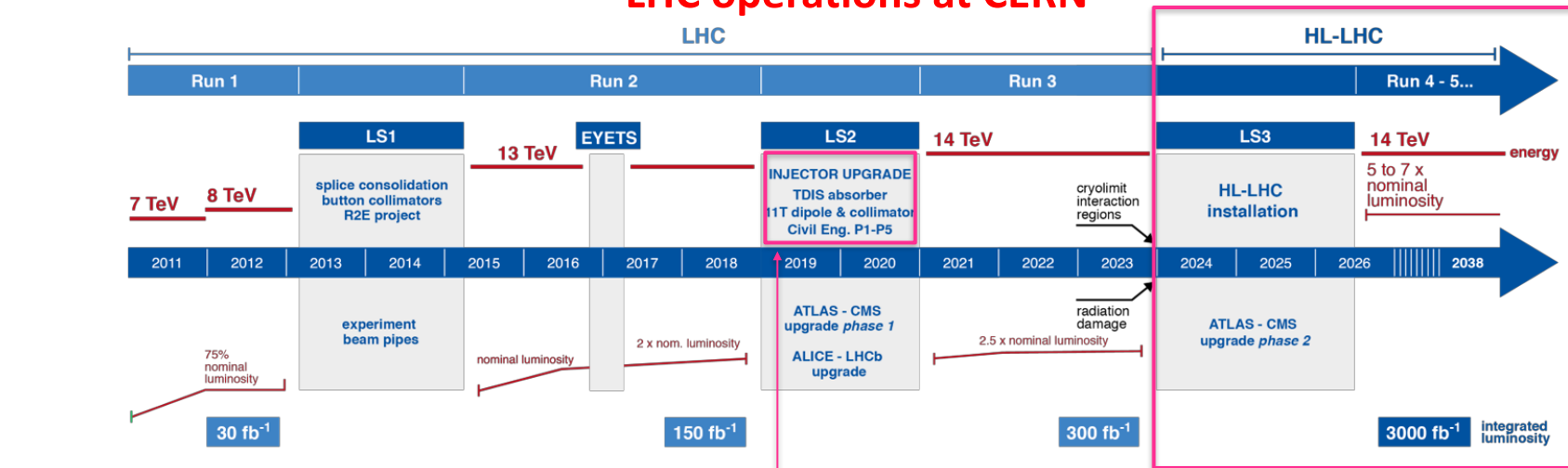
SuperKEKB 7 GeV e<sup>-</sup> on 4 GeV e<sup>+</sup> collider  
(Highest luminosity collider)



# Programmazione

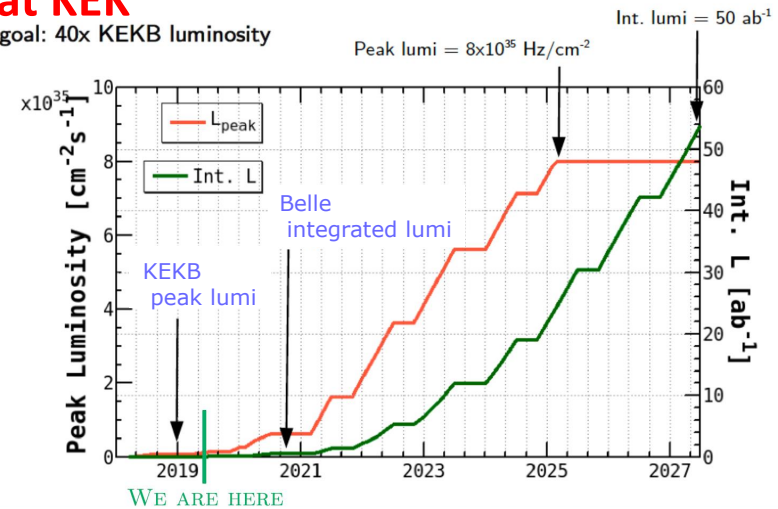
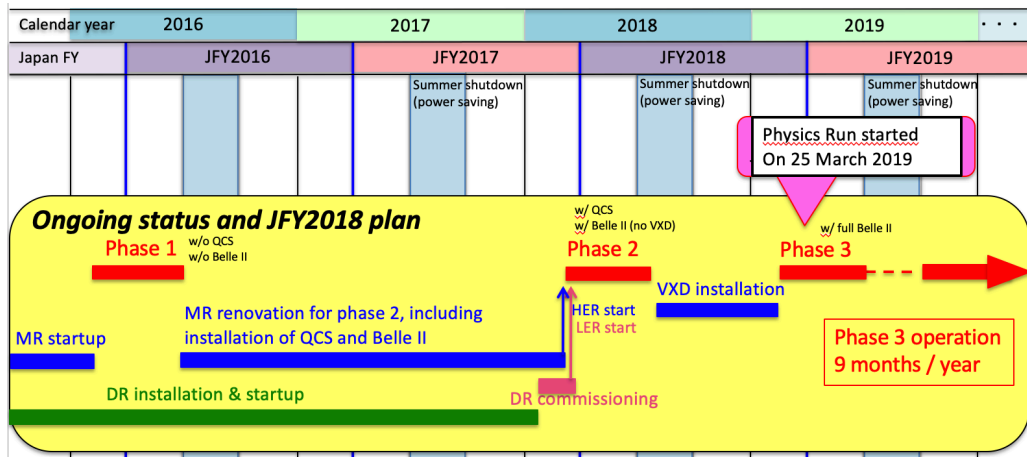
La programmazione scientifica si sviluppa su decine di anni

## LHC operations at CERN



## SuperKEKB operations at KEK

Final goal: 40x KEKB luminosity





# Collaborazioni internazionali

Il massimo livello di internazionalizzazione realizzabile dopo l'ONU

Istituzioni partecipanti all'Esperimento Belle II a KEK (Giappone)



Istituzioni partecipanti all'Esperimento CMS a LHC



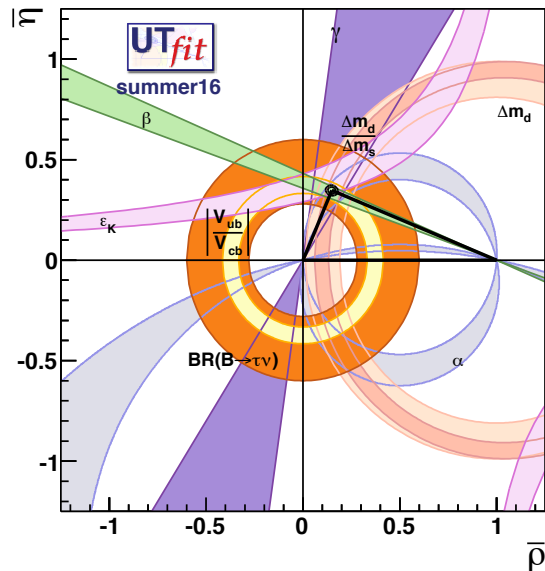


# Premio Nobel

Ricerche sperimentali in Fisica fondamentale

→ High Risk – High Gain → possono portare al premio Nobel

... ai Fisici Teorici



**Successful experimental program**

Established CP violation in B system and remarkable consistency of the Cabibbo Kobayashi Maskawa mechanism of the SM



**2008**

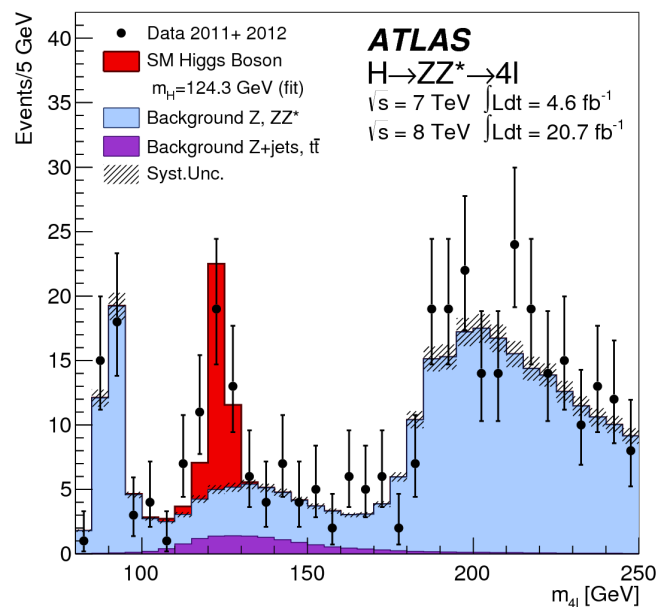


Kobayashi e Maskawa

# Ricerche sperimentali in Fisica fondamentale

→ High Risk – High Gain → possono portare al premio Nobel

... ai Fisici Teorici









**LHC experiments found a new particle a 125 GeV**  
Established the existence of the Higgs boson

2013

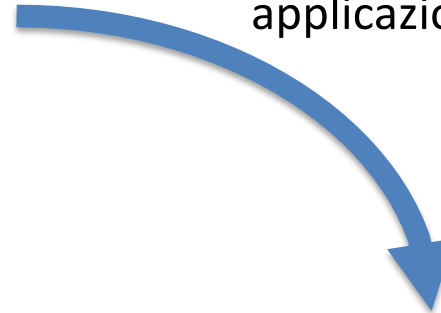


Peter Higgs

# Applicazioni

Area	Esperimenti	Laboratori
<u>Frontiera dell'energia</u>	 	CERN (CH)
<u>Flavour Factory - quark e leptoni pesanti</u>		KEK (JP)
<u>Flavour Factory - kaoni</u>		CERN (CH)
<u>Fisica del Neutrino, dark matter e Hidden Sector</u>	 	CERN (CH)

Ricerca e sviluppo con applicazioni a più ampio spettro



## Applicazioni

**Rivelatori di radiazione innovativi**

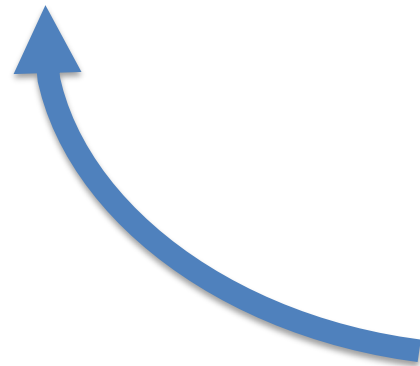
**Data Science: infrastrutture di calcolo e tecniche di analisi dati**

**Elettronica innovativa**

**Dosimetria**

**Muografia**

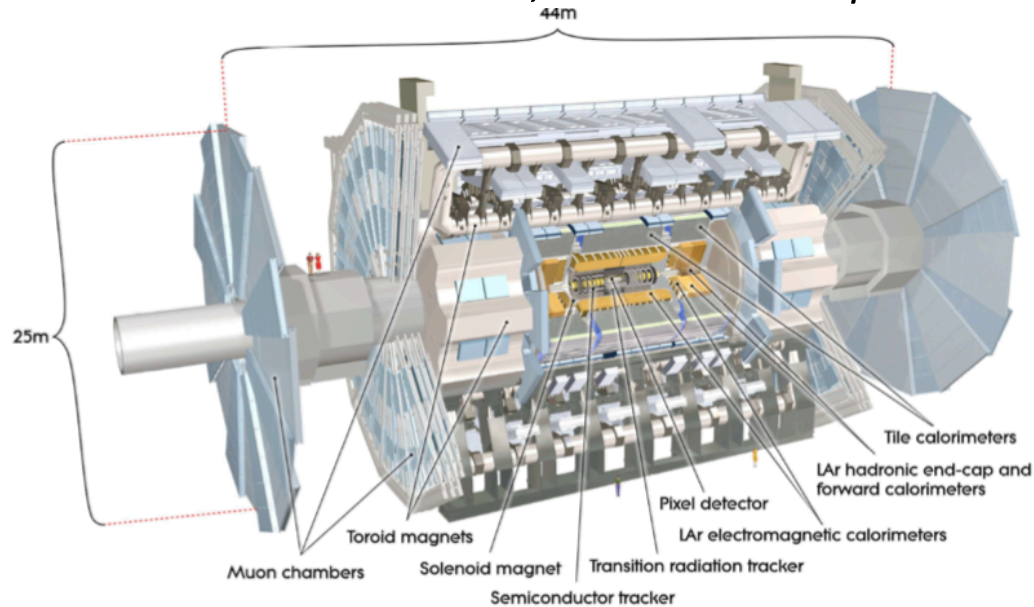
Forniscono le tecnologie cutting edge necessarie agli esperimenti





# Esperimento ATLAS

A.Aloisio, M. Alviggi, V. Canale, M. Della Pietra, P. Massarotti, L. Merola, E. Rossi,  
G.Russo + collaboratori INFN, Univ Parthenope



Numerose responsabilità:

Management del Calcolo dell'esperimento  
Sviluppo e operations del Trigger di muoni  
R&D e produzione delle small wheel  
(Micromegas) per l'upgrade dell'apparato  
Analisi dei dati sperimentali

## Attività del gruppo

Sistema di trigger di muoni di I livello:

- RPC detectors
- Trigger e DAQ

Fase 1 - New Small Wheel:

- Micromegas detectors

Fase 2 - High Eta Muon Tagger

Analisi dei dati sperimentali:

- Higgs: misura parametri risonanza
- Ricerche di Particelle oltre il Modello Standard

Computing

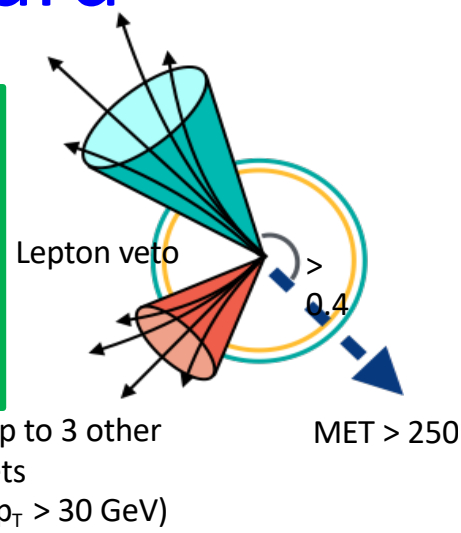
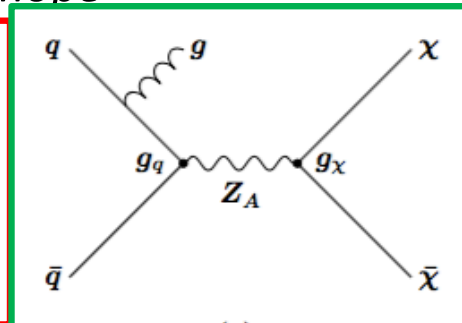
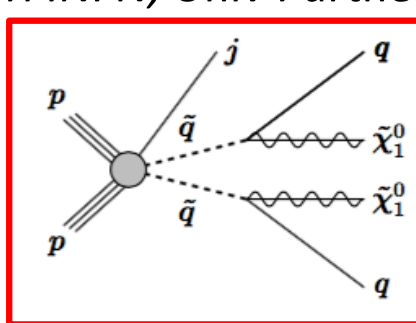
- Tier2 del calcolo offline

# Ricerca di Fisica oltre il modello standard

L. Merola, E. Rossi + collaboratori INFN, Univ Parthenope

1. **Invisible particles** recoiling against a high-momentum jet

Test: Dark Matter, SUSY...



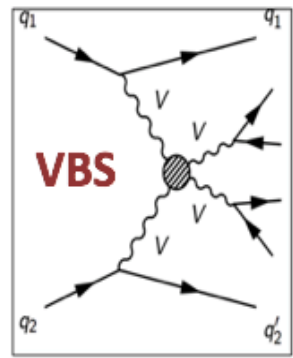
2. Search for **new particle in diboson processes (with semi-leptonic final states)**  
 Combined **0/1/2-lepton channels** ( $ZV \rightarrow \nu\nu qq$ ,  $WV \rightarrow l\nu qq$  and  $ZV \rightarrow ll qq$ )

Focus on **Machine Learning application:**  
**Recurrent Neural Network (RNN)** for the VBF/ggF signals classification.

**parametrised Deep Neural Network (pDNN)** for signal/bkg event classification.

3 Search for the electroweak diboson production in association with a high-mass dijet system (Vector Boson Scattering)

Test: accoppiamenti anomali tra bosoni di gauge



# Contributi ai rivelatori e elettronica associata

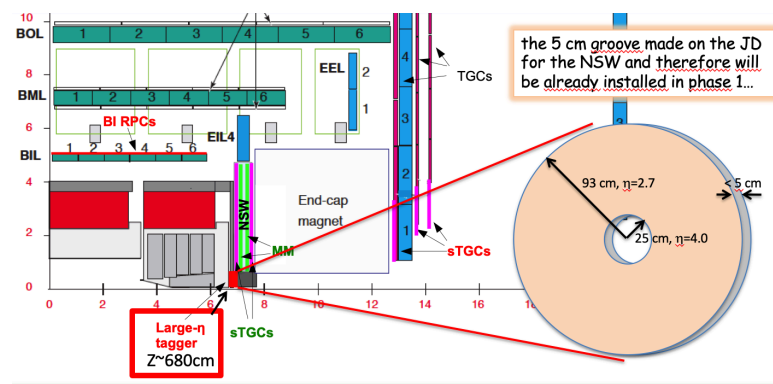
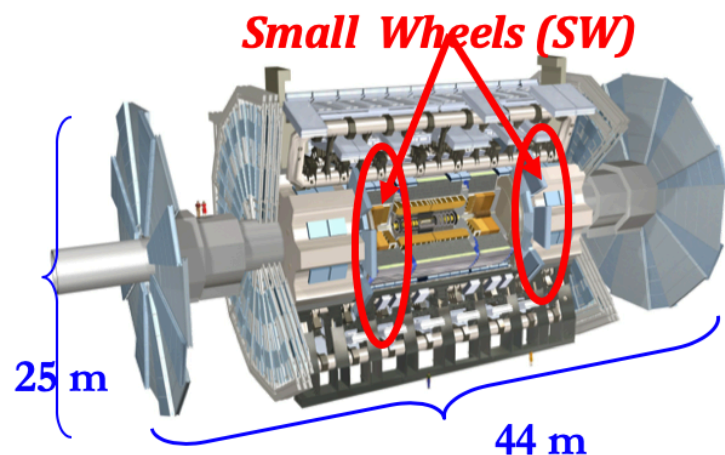
A. Aloisio, M. Della Pietra, R. Giordano, E. Rossi + collaboratori INFN

- Rivelatori Resistive Plate Counters + DAQ
- schede ROD e link ottici per dati di trigger
- **Level 1 Muon Trigger Operations:**
- **monitoring online per Data Quality**
- **maintenance trigger e DAQ**

## Upgrade del Muon detector

M. Alviggi, V. Canale, P. Massarotti + collaboratori INFN

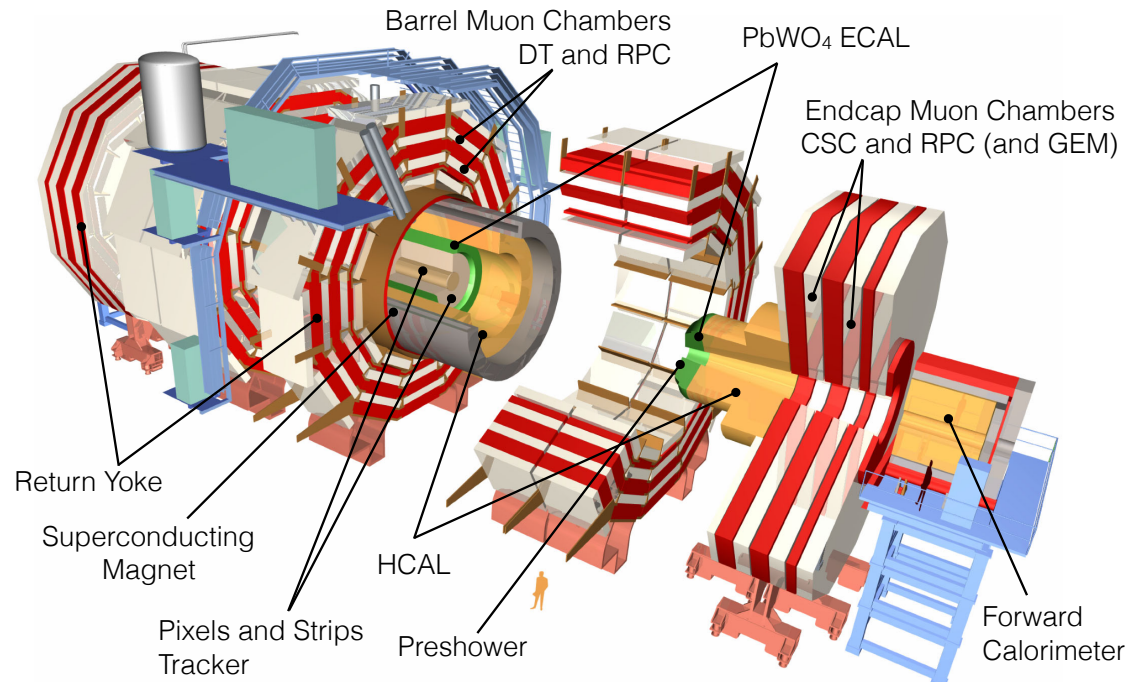
Aumentare la capacità di Trigger dell' esperimento da muoni in avanti





# Esperimento CMS

*O. Iorio, L. Lista + collaboratori INFN*



Sistema di trigger e identificazione dei muoni (RPC) e suo upgrade

Analisi dei dati sperimentali :

- Misura di precisione di Fisica del quark top
- Ricerche di leptoquark e nuovi bosoni intermedi

## Marie Sklodowska-Curie International Training Network INSIGHTS

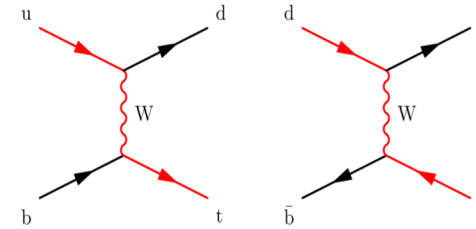
sviluppo di tecniche statistiche avanzate, in particolare Machine Learning, per la fisica delle particelle, e loro applicazioni.

→ [Max Plank Institut für Physik](#), Munich, per lo sviluppo di strumenti di analisi Bayesiana usando come metro di paragone misure di CMS

→ [Istituto Nazionale di Geofisica e Vulcanologia \(INGV\)](#), Naples, per l'applicazione di metodi statistici tipici della fisica delle alte energie a dati di sismologia e vulcanologia.

# CMS – Analisi dei dati sperimentali

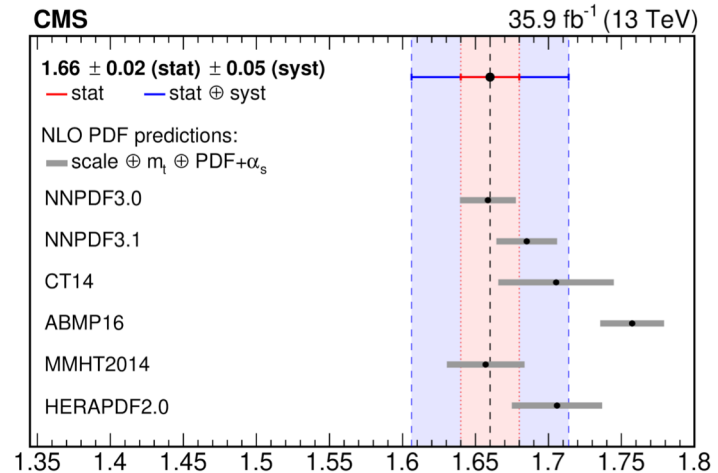
## Produzione di top quark singolo in collisioni pp:



Canale elettrodebole, con vertice tWb in produzione

Misure di precisione:

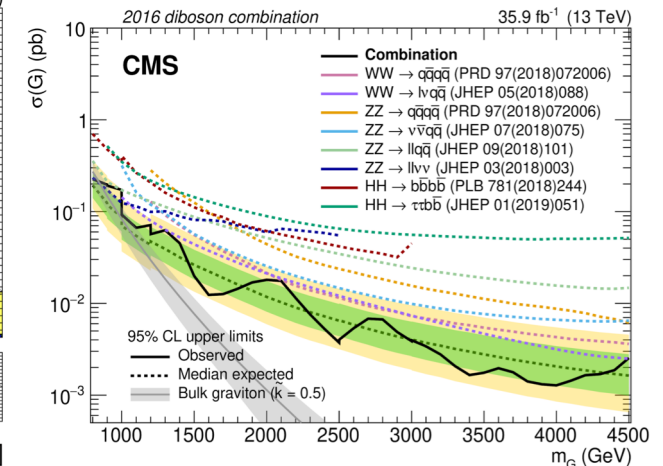
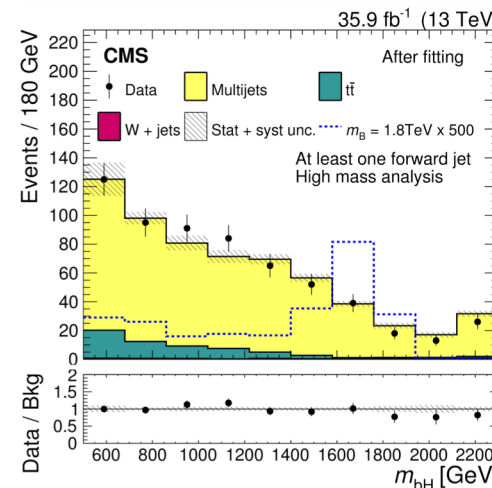
- Elementi di matrice CKM:
- Asimmetria top quark-antiquark
- Parton-Distribution functions



## Fisica oltre il Modello Standard

Ricerche di nuove famiglie di quark, Leptoquark e di bosoni vettori aggiuntivi

Responsabilità sotto-Gruppo “beyond 2 generations”



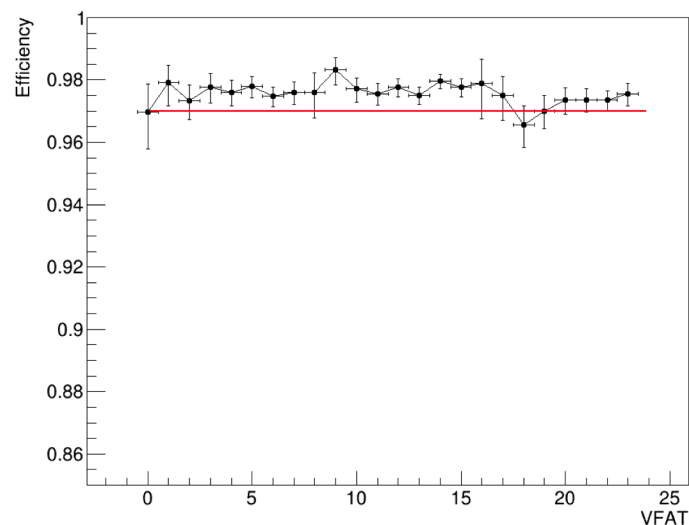
# CMS – Upgrade sistema di rivelazione muoni

Upgrade del sistema di tracciamento muoni in avanti con rivelatori GEM

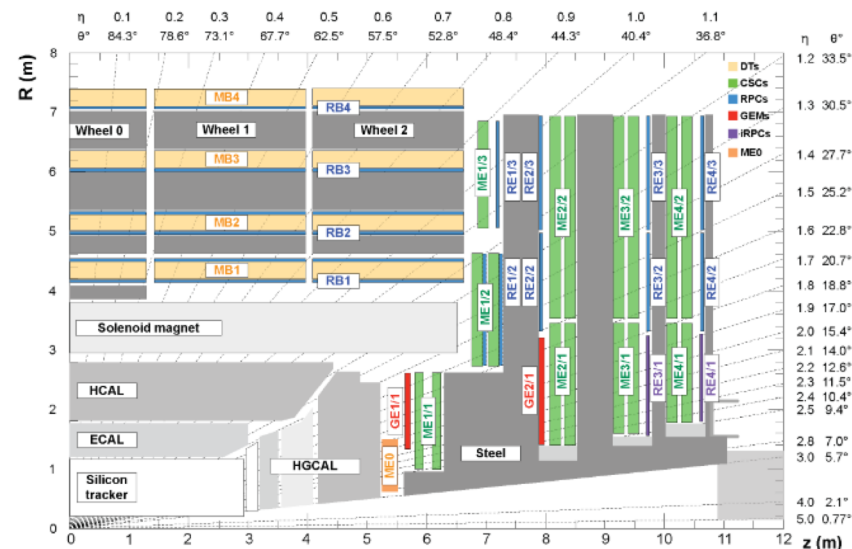
- Partecipazione Test effettuato con supercamere durante il RunII-2018
- Responsabilità nel Quality Control per la validazione delle supercamere
- Progettazione del sistema di alta tensione e sviluppo di strumenti di diagnostica di alta precisione (picoamperometro)

Partecipazione alle operations del Sistema con RPC e al suo upgrade

Plot di efficienza per ognuna delle 24 FVAT (pad di lettura) di una camera.



Layout dell'esperimento dopo l'upgrade in corso, in rosso le GEM, zona dell'upgrade a GEM-RPC tratteggiata





# NA62: the CERN kaon factory



*F. Ambrosino, P. Massarotti,  
G. Saracino + collaboratori  
INFN*

**Kaon physics with fixed target  
experiments at CERN SPS**

**Currently in NA62:  
~200 participants  
29 institutions from 13 countries**

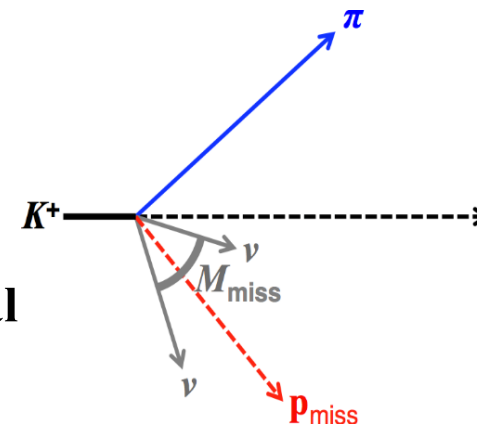
**NA62 Main Goal: 10% precision  $BR(K^+ \rightarrow \pi^+ \nu \bar{\nu})$  measurement**

## **Technique:**

**75 GeV  $K^+$  decay in flight**  
**O(100 ps) timing between detectors**  
 **$K^+/\pi^+$  PID**  
**Photon/Muon veto**  
**Beam related activity veto**

## **Signal:**

**$BR_{SM} = (0.84 \pm 0.10) \times 10^{-10}$**   
 **$K^+$  track in,  $\pi^+$  track out**  
 **$(P_K - P_\pi)^2$  used to**  
**kinematically separate signal**  
**from background.**

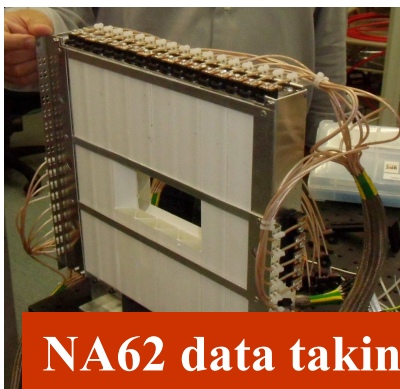


# NA62: the CERN kaon factory

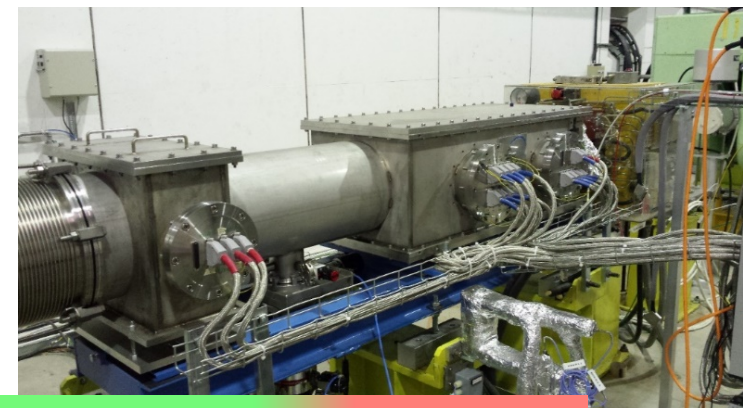
CHANTI Detector is fundamental to veto beam related activity background.

Proposed in 2009. **Designed and built entirely in Naples.** Installed at CERN in 2014.

**2016 JINST 11 P03029**



**NA62 data taking**



2014

Pilot Run

2015

Commissioning

2016

Commissioning +  
Physics Run

2017

Physics Run

2018

Physics Run

2019-2020

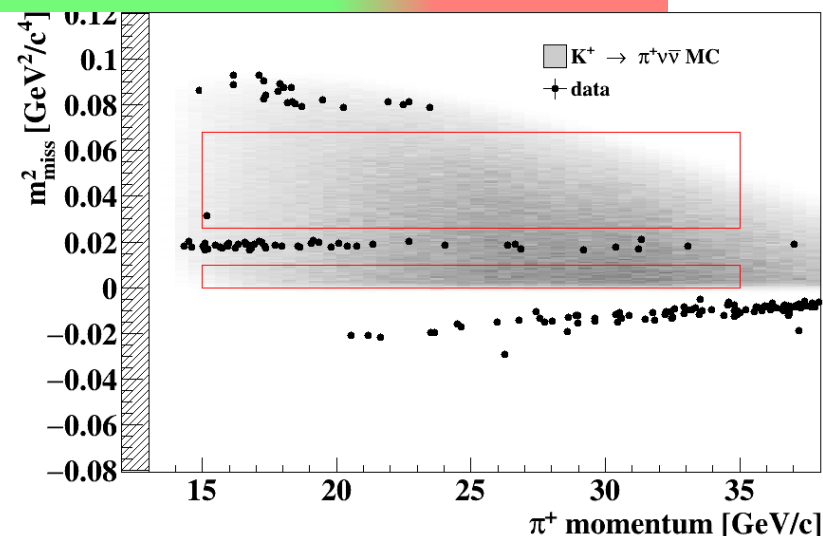
LS2 Long  
shutdown 2

One event observed in 2016 data

$BR(K^+ \rightarrow \pi^+ \nu \bar{\nu}) < 11 \times 10^{-10}$  at 90% CL  
compatible with SM

Phys. Lett. B 791 (2019) 156-166

In 2017 expected single event sensitivity  $\sim 10 \times$   
2016. Analysis ongoing



# NA62: the CERN kaon factory

Search for production of an invisible dark photon in  $\pi^0$  decays

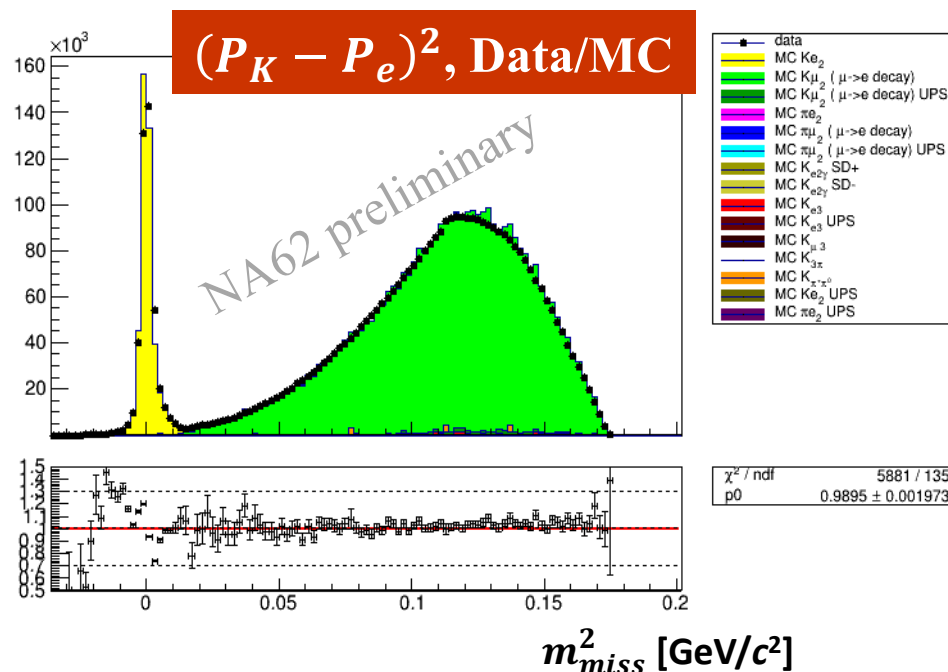
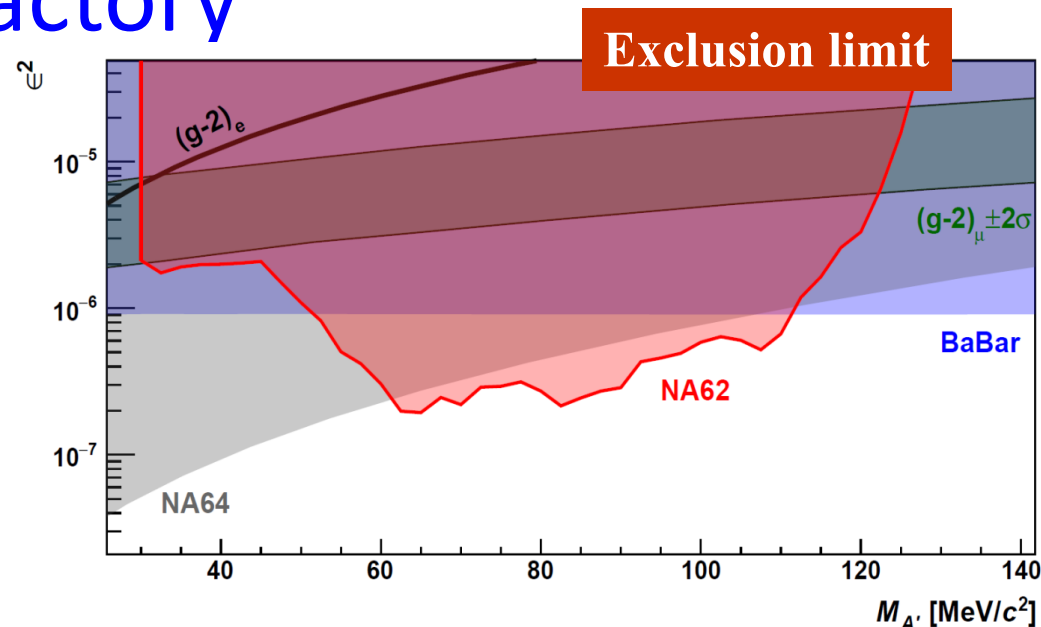
$$K^+ \rightarrow \pi^+ \pi^0, \pi^0 \rightarrow A' \gamma, A' \rightarrow \textit{invisible}$$

JHEP 05 (2019) 182

Lepton flavour universality test

$$R_K = \frac{\Gamma(K^+ \rightarrow e^+ \nu_e)}{\Gamma(K^+ \rightarrow \mu^+ \nu_\mu)}$$

Analysis ongoing

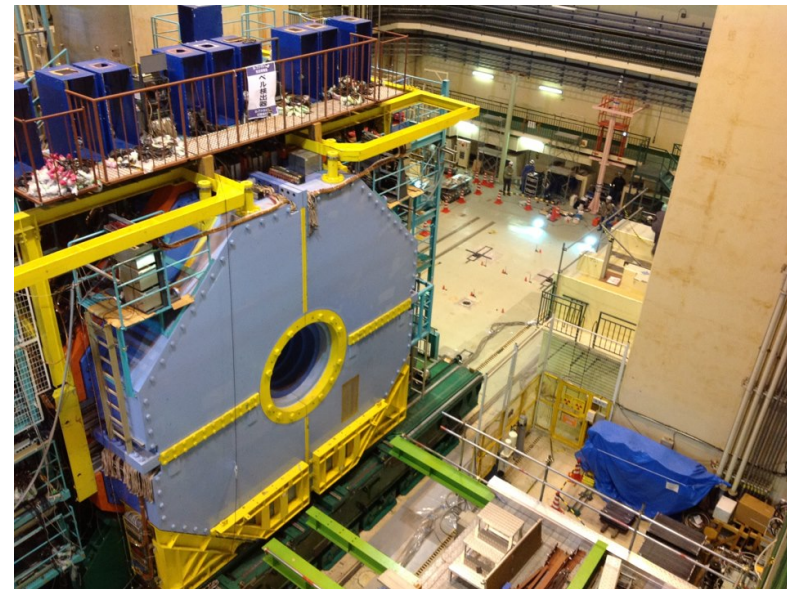
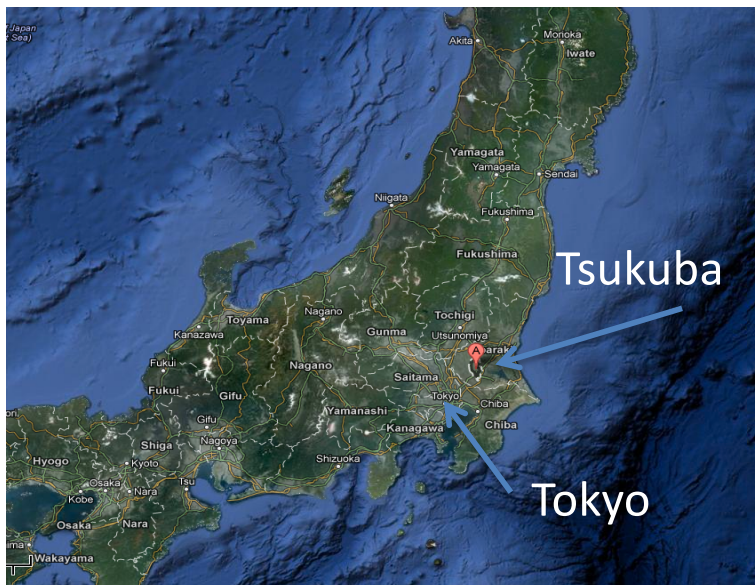




# Belle II @ KEK (Tsukuba, Japan)

*G. De Nardo, A. Aloisio, F. Di Capua, R. Giordano, G. Russo + M. Merola (Dip. Agraria) + collaboratori INFN*

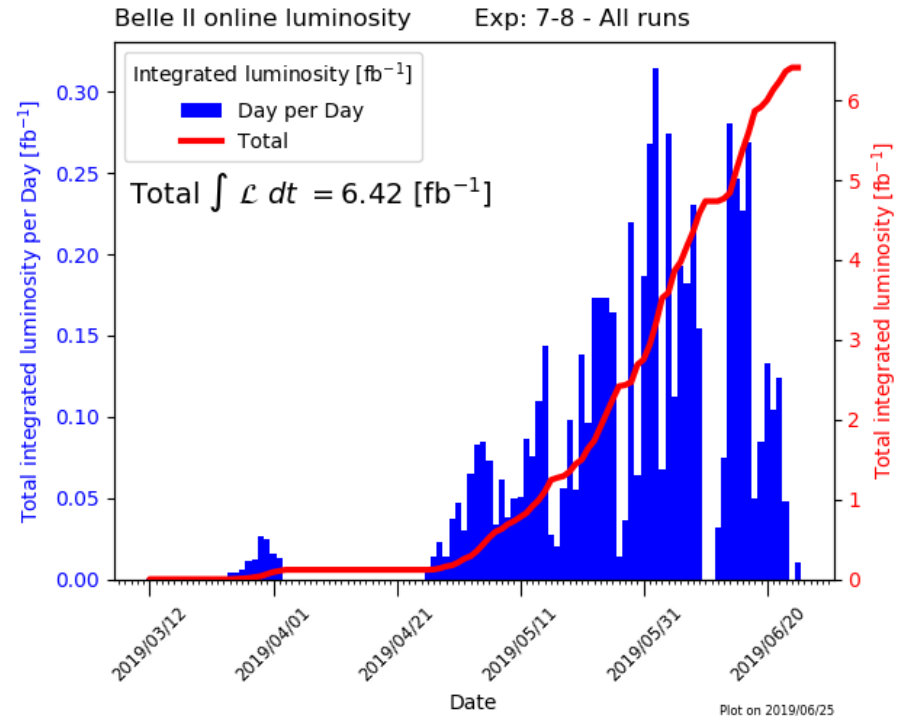
Fisica del Flavour nei decadimenti del beauty, charm e leptoni  $\tau$ .  
Ricerca di Fisica oltre il modello standard  
*complementare alle ricerche all' LHC*



KEK: High Energy Accelerator Research Organization  
Circa 900 collaboratori in America, Europa ed Asia



# Belle II @ KEK (Tsukuba, Japan)



Run di Fisica appena iniziato (marzo 2019)

Napoli è entrata nella collaborazione Belle II nel 2013.

Il periodo 2013-18 è stato di costruzione, installazione e commissioning dell'apparato, sviluppo del software e studi di Fisica su simulazioni.

# Belle II @ KEK

## Calorimetro Elettromagnetico

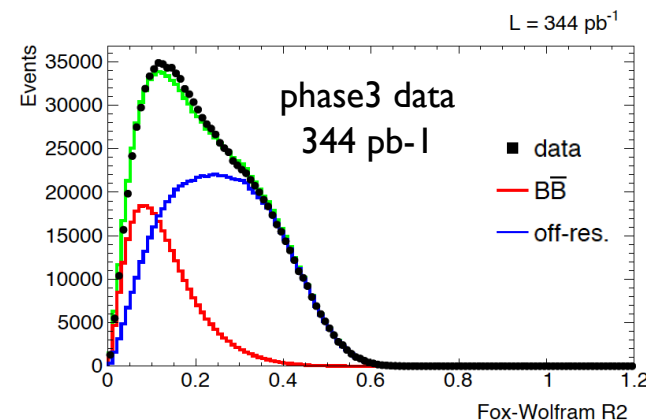
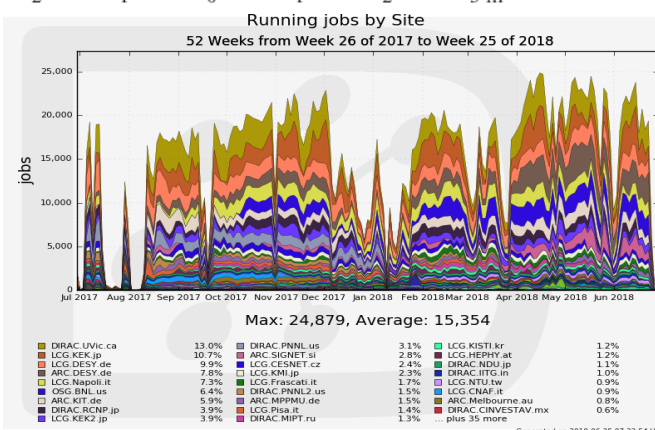
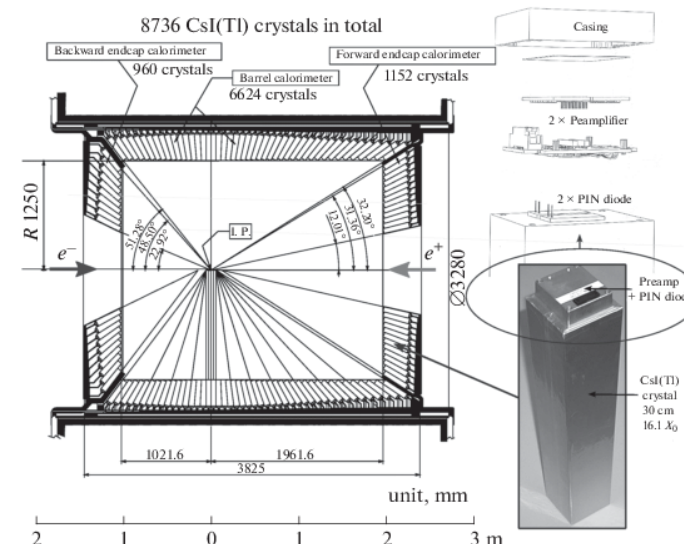
operations del rivelatore  
 software di digitalizzazione e ricostruzione  
 Responsabilità del sistema di monitoraggio  
 temperatura e umidità

## Calcolo

Attività di produzione di simulazioni MC  
 (data center ReCaS a Napoli è tra i siti più attivi)  
 Coordinamento attività networking

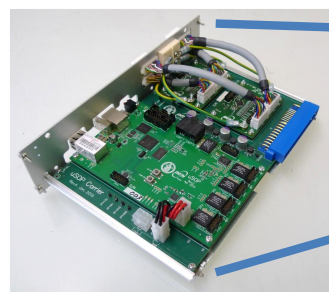
## Analisi dei dati

Leadership nei decadimenti semileptonici e leptonici del mesone B  
 Collaborazione flavour changing neutral currents e ricerche di dark matter  
 Sviluppo del core software identificazione elettroni  
 Studio delle Performances del rivelatore sui primissimi dati



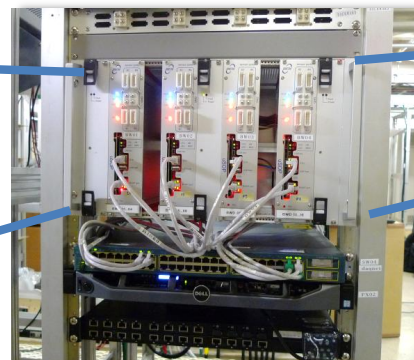
# Il sistema di monitor del calorimetro Belle II

- uSOP: un single board computer basato su processor ARM, sviluppato dal gruppo di Napoli, in sinergia con la Sezione INFN

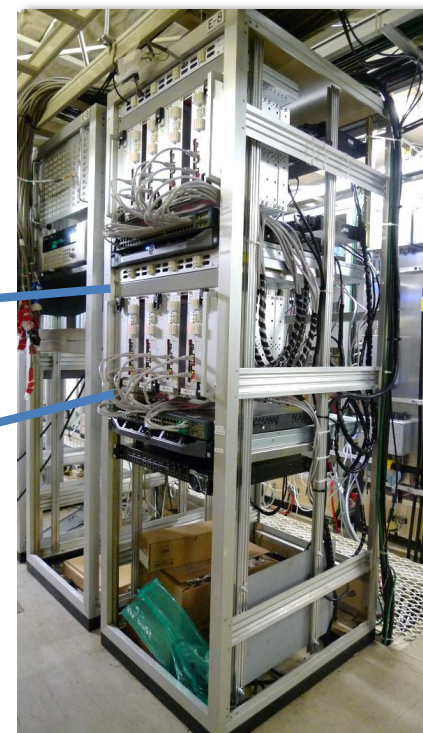


uSOP board

uSOP crate nella sala di KEK

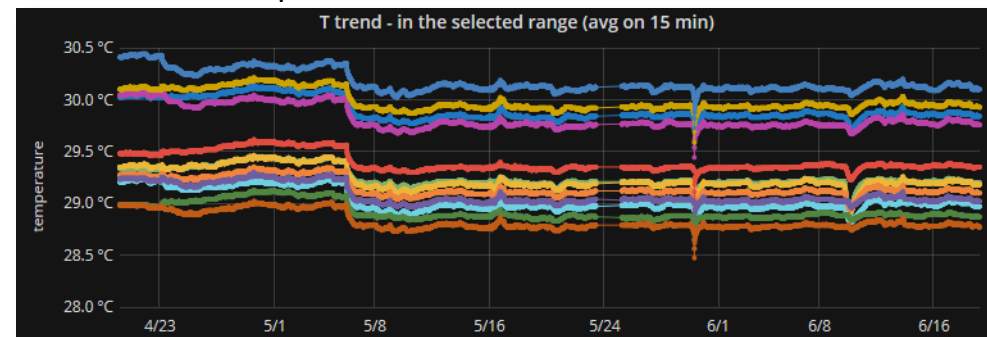


Vista della sala di acquisizione, con il sistema di monitoring in primo piano



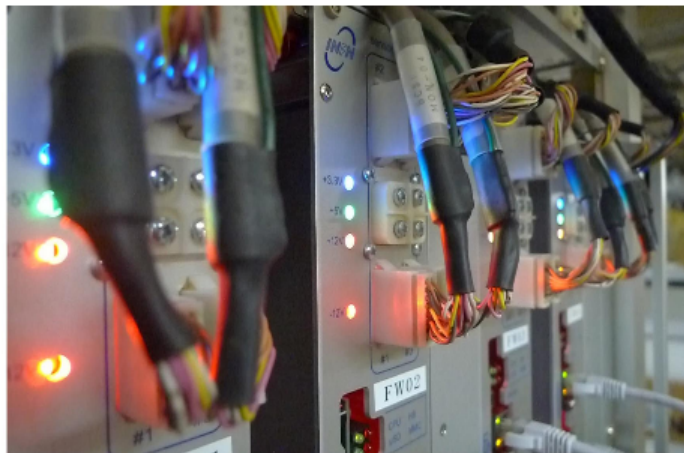
- Il Sistema di monitoring delle parti 'endcap' del calorimetro elettromagnetico (CsI(Tl) letti da fotodiodi) è basato su uSOP e acquisisce temperature e umidità relativa nel rivelatore con risoluzione e accuratezza pari o superiori a quelle offerte da strumentazione da laboratorio
- I dati sono integrati nel framework software dell'esperimento, permettendo la correzione della resa di luce in funzione della T

Last 6 month Temp record



# Art & Science at KEK

## Belle II



- Una foto del sistema di monitoring progettato e costruito a Napoli ha vinto un premio fotografico della collaborazione Belle2
- La foto e' stata selezionata per il calendario ufficiale di Belle2 del 2018
- Insieme con altre, la foto ha fatto parte di una mostra itinerante esibita in molti laboratori giapponesi ed europei



# Nuclear emulsion group

*G. De Lellis, A. Di Crescenzo, A. Lauria, M.C. Montesi + collaborators*

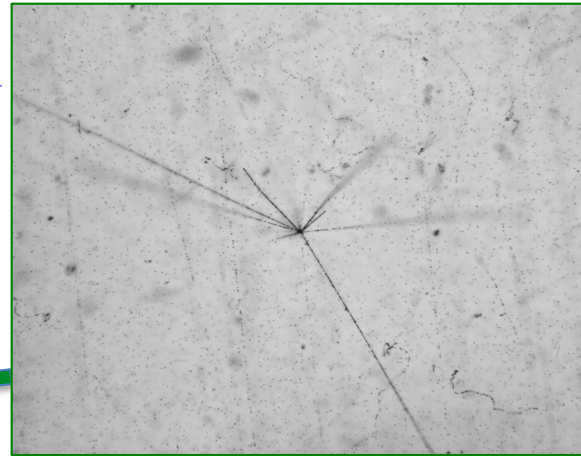
External funds from:

Russian Ministry of Education  
Japan Society for Promotion  
of Science  
European Community

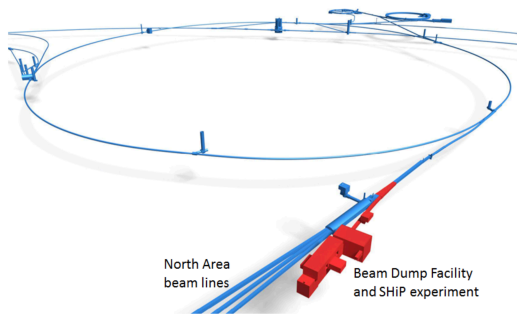
Dip. Fisica & INFN group.

Collaborators from:

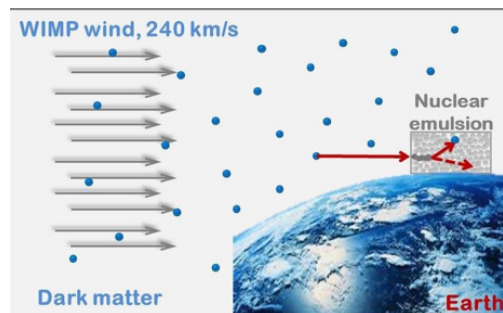
- Dip. Chimica
- DIETI
- Dip. Strutture Ingegneria
- CNR ISASI
- Università Marconi



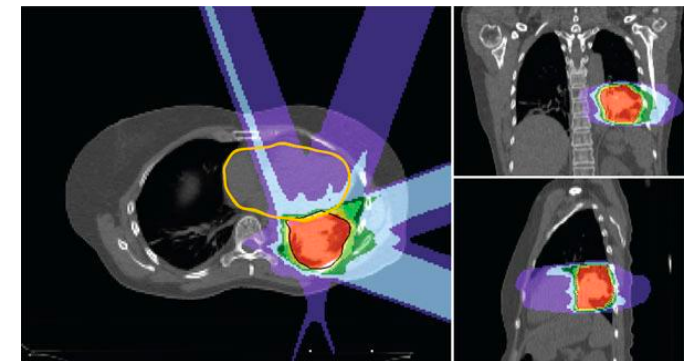
Neutrino Physics and Hidden Sector  
search @CERN SPS



Directional dark matter search  
@ Gran Sasso Lab



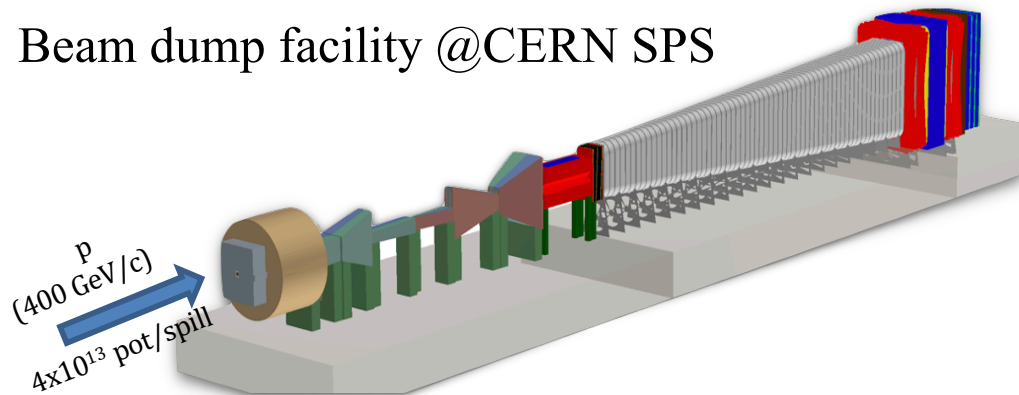
Nuclear fragmentation for hadron therapy and  
space radioprotection





# SHiP Experiment: Search for Hidden Particles

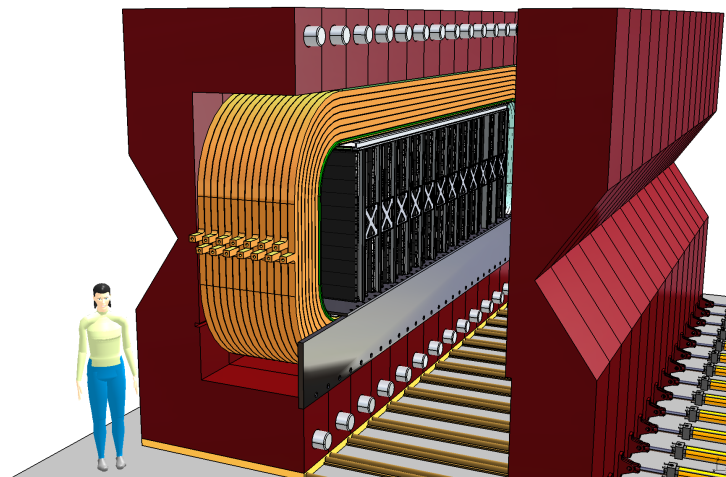
Beam dump facility @CERN SPS



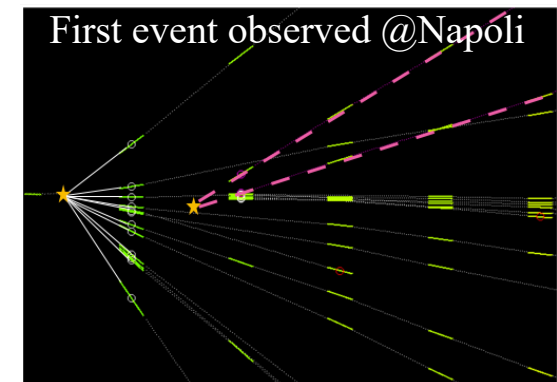
- **April 2015:** Technical and Physics proposals submitted to CERN SPS Committee, [*arXiv:1504.04956*], *Rep. Prog. Phys.* 79 (2016) 12
- **January 2016:** positive recommendations from SPSC
- **March 2016:** SHiP motivated the setting-up of the Physics Beyond Colliders working group at CERN
- **Comprehensive Design Report** in November **2019**. Recommendation by the European HEP strategy in Spring **2020**

- Design and construction of tau neutrino detector
- Optimization for Light Dark Matter search
- Design of the Neutrino Detector Magnet

Magnet surrounding the neutrino detector



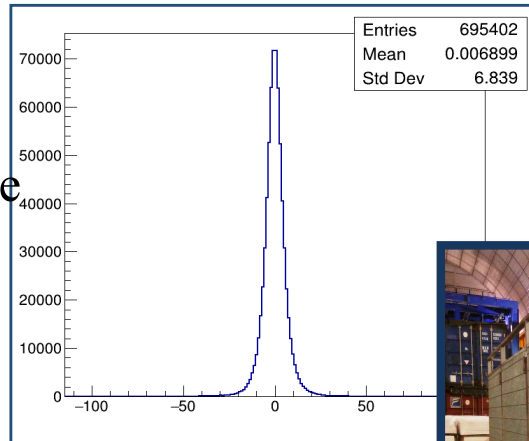
Measurement of **charm production** induced by 400 GeV proton interactions, Summer 2018



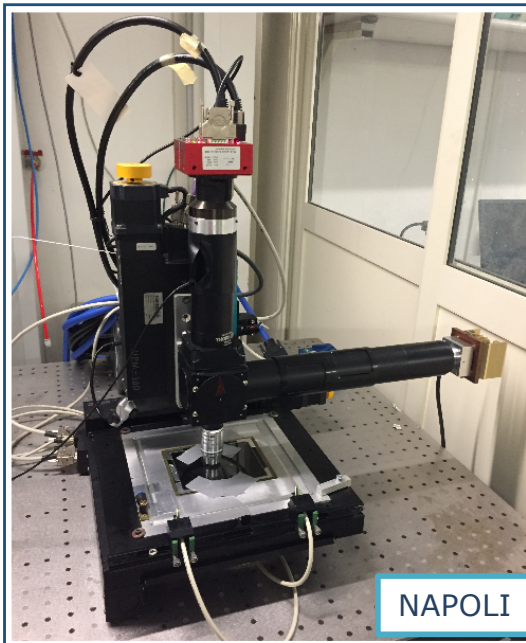
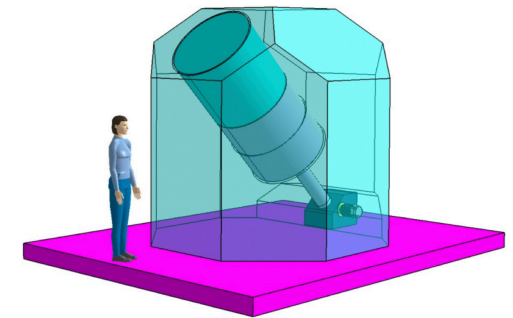


# NEWSdm experiment: Nuclear Emulsions for WIMP Search with directional measurement

- Prototype microscope in Napoli equipped with liquid crystal polarizer: **6 nm** resolution achieved



- Emulsion production facility @LNGS installed and commissioned
- 10 g test in progress @LNGS
- TDR for 10 kg experiment to be submitted in 2019
- First experiment will act as a demonstrator to further extend the mass range and the NEWS sensitivity towards **the neutrino floor**

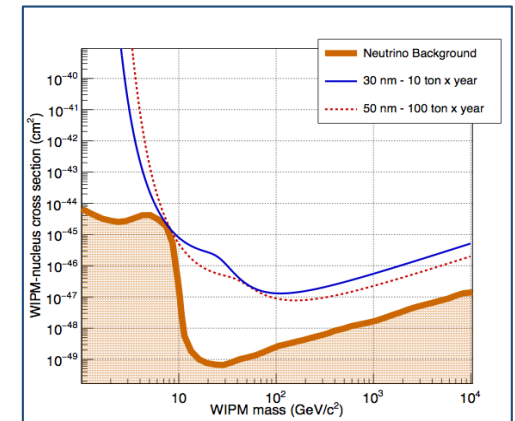


Patent for 3D readout:

- Dec 2016 - N. 102016000132813 - A. Alexandrov, G. De Lellis, V. Tioukov, N. D'Ambrosio

Recent papers:

- "Measurement of intrinsic neutron background in nuclear emulsions", *Astropart. Phys.* 80 (2016) 16
- "Discovery potential for directional dark matter detection with nuclear emulsions", *EPJ C* 78 (2018) n.7, 578





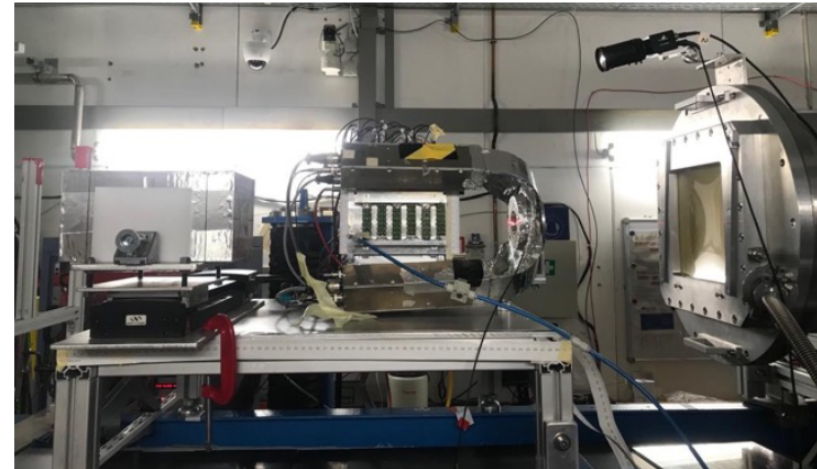
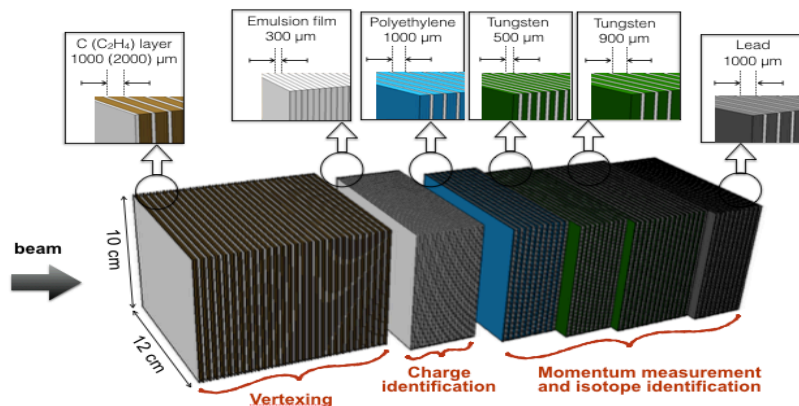


# The FOOT experiment: FragmentatiOn Of Target



- Study of nuclear fragmentation for particle therapy
- Data taking and test beams performed in several hadron therapy centers in Europe
- Emulsion detector designed and constructed in Naples
- Recent papers:
  - “Measurement of  $^{12}\text{C}$  ions beam fragmentation at large angle with an Emulsion Cloud Chamber”, JINST 11 (2017) P08013
  - M.C. Montesi et al. Ion charge separation with new generation of nuclear emulsion films, Open Phys. 2019; 17:233–240

## Emulsion chamber designed in Naples



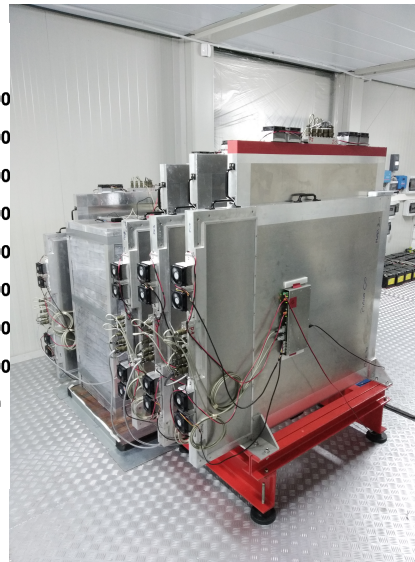
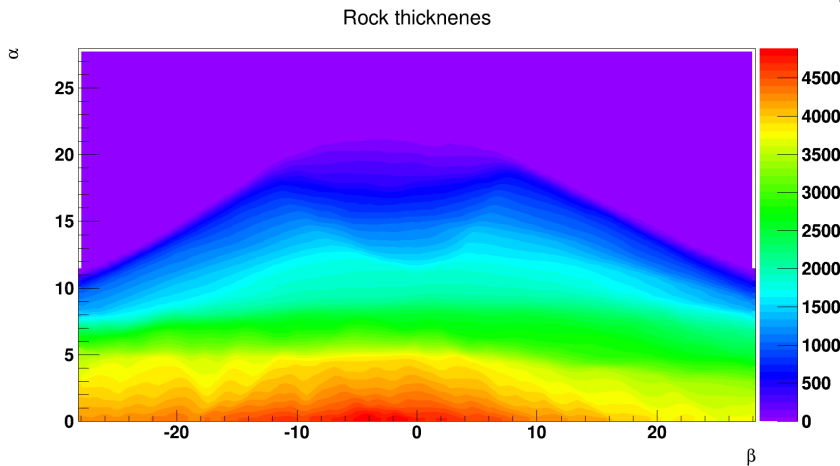
Set up for the emulsion detector data taking in GSI (April 2019)



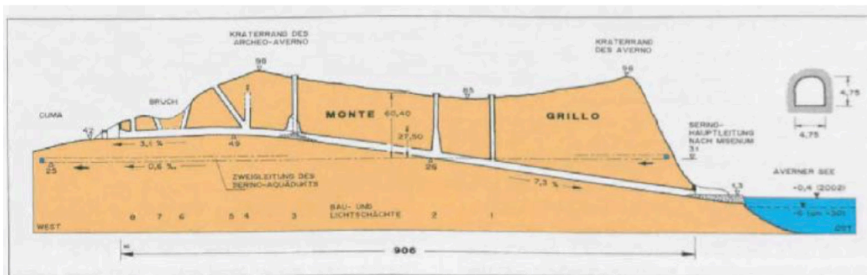
# Radiografia muonica

G. Saracino, F. Ambrosino, L. Cimmino + collaboratori

Progetto premiale MURAVES (INFN e INGV):  
studio del Gran Cono del Vesuvio

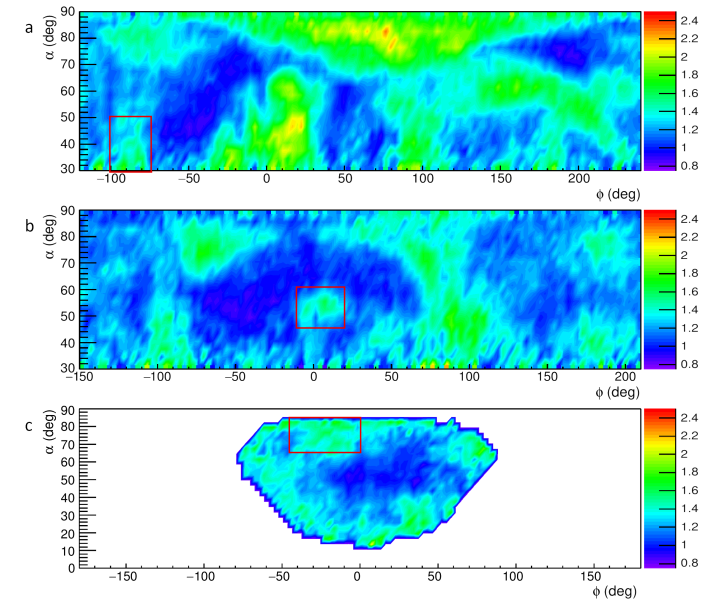


In progetto: parco archeologico di Cuma



Grotta di Cocceio e Acquedotto - Schema

Studio delle cavità al monte Echia



Alcuni articoli recenti

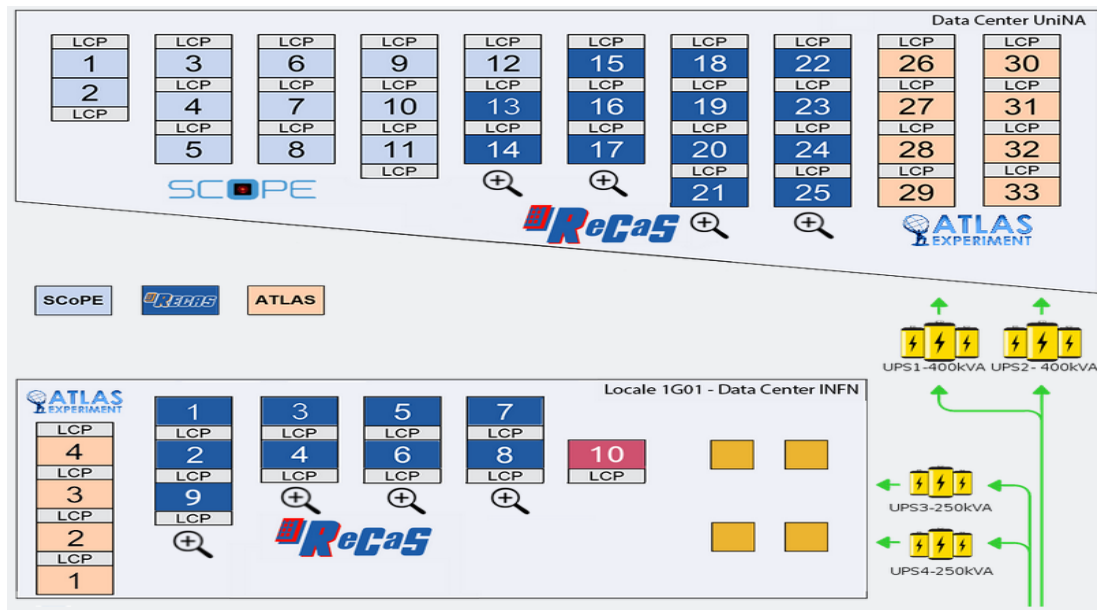
- 2019: L. Cimmino et al:  
**3D Muography for the Search of Hidden Cavities**  
Scientific Report

-2018: G. Saracino et al  
**Applications of muon absorption radiography to the fields of archaeology and civil engineering**  
Philosophical Transactions of the Royal Society A, vol. 377, issue 2137.

-2017 G. Saracino et al:  
**Imaging of underground cavities with cosmic-ray muons from observations at Mt. Echia (Naples)**  
Scientific Report

# Infrastruttura di calcolo (IBISCO)

*L. Merola, G. Russo + INFN*



## INFRASTRUTTURA ATTUALE

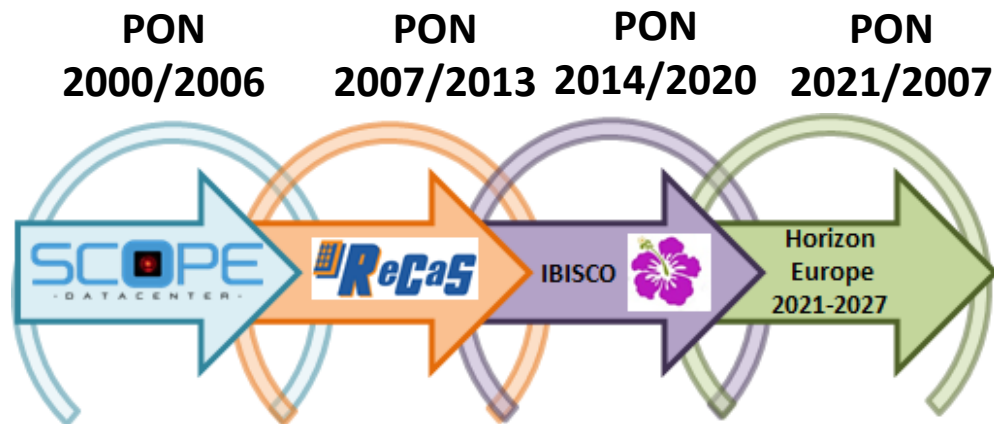
- >5000 Core
- 3 PB Disco
- 10 Gbit/s LAN
- 20 Gbit/s GARR WAN

## Applicazioni

- Tier2 di Atlas
- Regional Data Center Belle II

## Potenziamento IBISCO

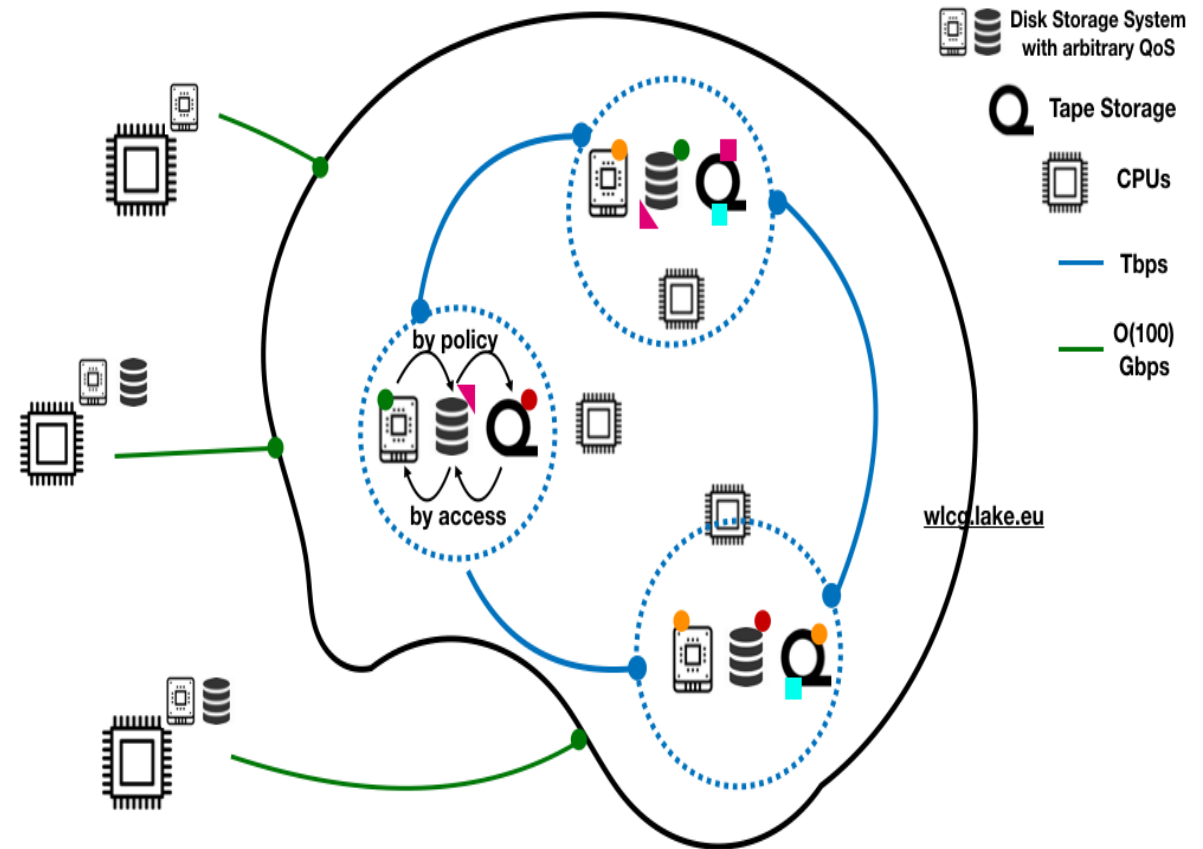
- Oltre 300 server Multicore
- GPU Cluster con Infiniband
- 10 PB Disco
- Reti a 100Gb



# R&D su tecnologie di storage (data lake)

Studio del Nuovo modello di data management DATA LAKE finalizzato a integrare risorse eterogenee ovunque distribuite, ottimizzando l'utilizzo del disco e introducendo elementi di storage dinamici (CACHE, Cloud Storage)

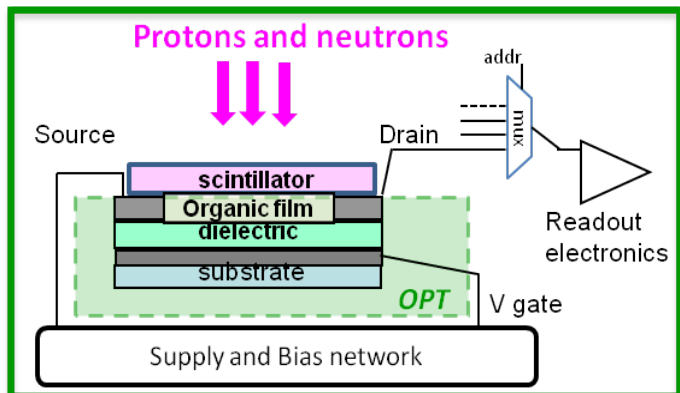
- Progetto INFN IDDLs (DDLs: Italian Distributed Data Lake for Science.)
- Progetto europeo XDC
- Working Group WLCG
- Working Group all'interno di esperimenti



# Flexible organic ionizing radiation detector

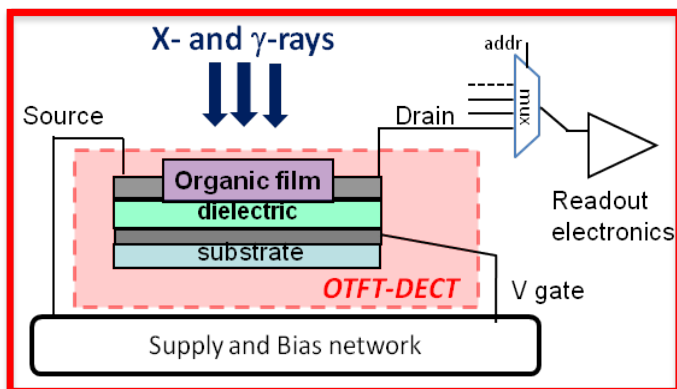
A. Aloisio, F. Di Capua

## INDIRECT DETECTING SINGLE PIXEL (NEPRO)



- fotosensori organici per rivelazione di protoni, neutroni, X e  $\gamma$
- Progetto INFN in collaborazione con sezioni INFN TIPFA, LNL, Bologna, Roma 3 e CNR
- A Napoli: elettronica a basso rumore per il read-out e la caratterizzazione dei dispositivi e dei materiali

## DIRECT DETECTING SINGLE PIXEL (PHOX)

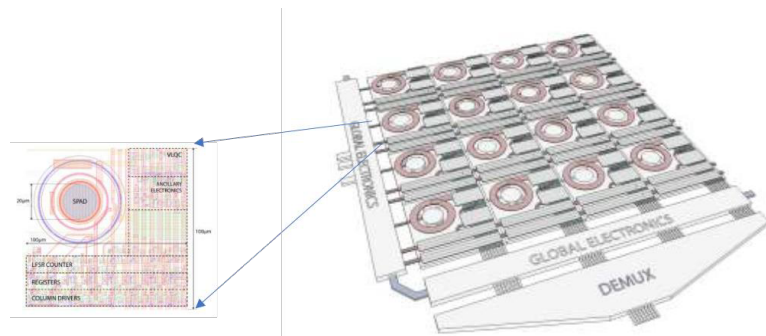


Marie Curie Action EU-Japan Jennifer 2: Work Package su Innovative Detectors e Task su Organic Photosensors  
Academical Agreement tra UNINA-INFN-CNR-NIMS (JP)-KEK(JP)  
Proposta di Bilateral Program CNR-JSPS (Japanese Society for Promotion of Science)



# Studio di Single Photon Avalanche Diodes

F. Di Capua

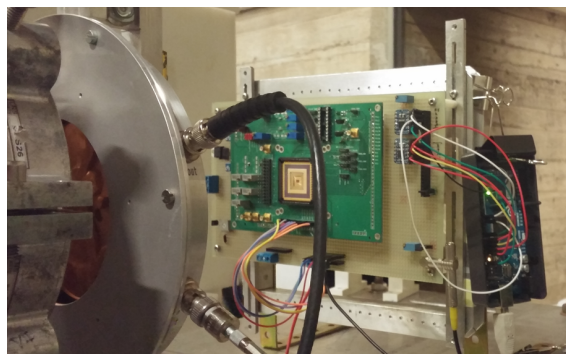


Progetto INSIDE

**Meccanismi alla base del Dark Count Rate**

**Effetto delle radiazioni sul DCR**

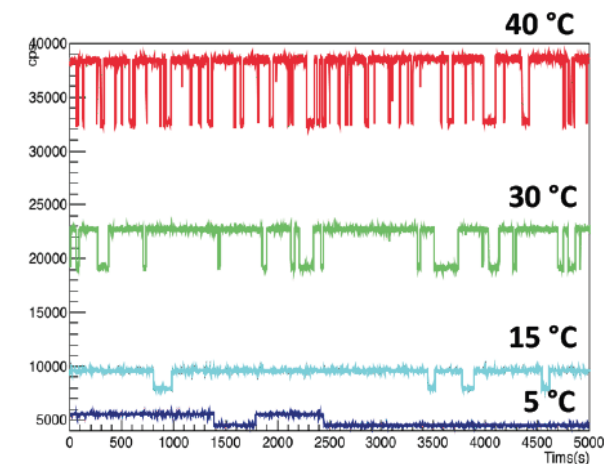
**Osservazione e Studio del Random Telegraph Signal del DCR**



Irraggiamenti presso acceleratori di elettroni e protoni: studio del degrado del Dark Count Rate per diversi tipi di giunzioni e geometrie di SPAD

Caratterizzazione e indagini sulle origini di effetti di Random Telegraph Signal del DCR: misure delle probabilità di switching in

funzione della temperatura, studio per diversi profili di drogaggio, identificazione dei difetti tramite annealing

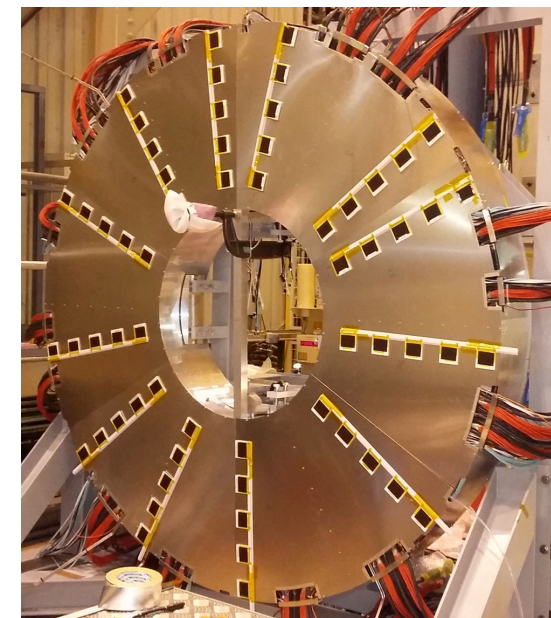
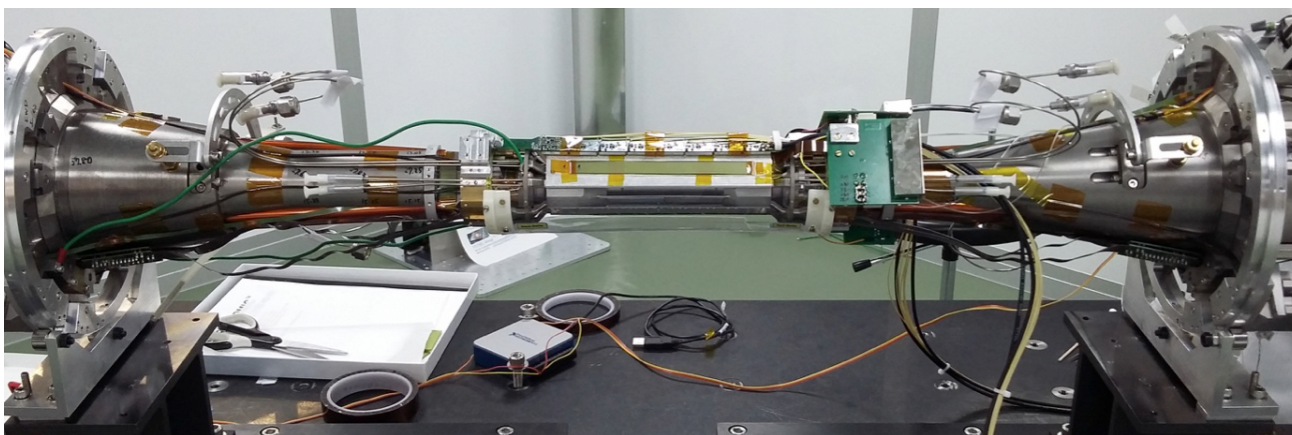


# Radiation Monitoring with radio-chromic film

- Understanding of experiment lifetime
  - Understanding of beam-induced background
- Films positioned on electron-positron collision region

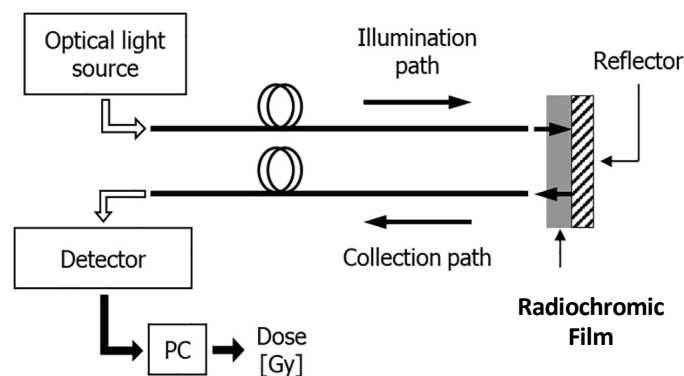
*F. Di Capua*

Films on ECL forward calorimeter

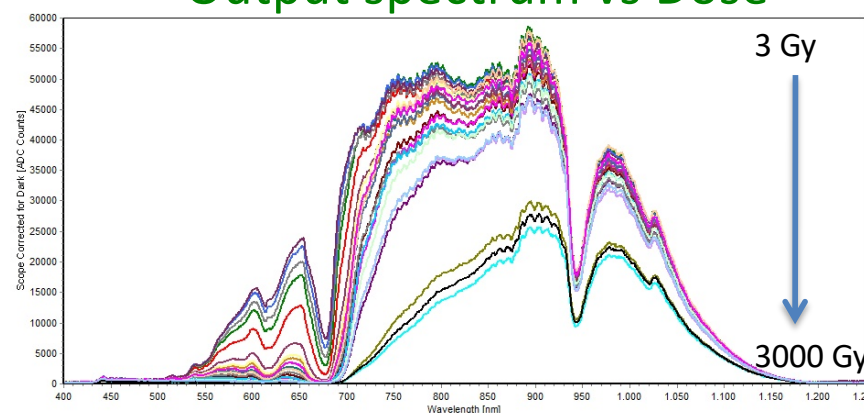


**Future plan: real time continuous reading of the films**

## Conceptual idea



## Output spectrum vs Dose



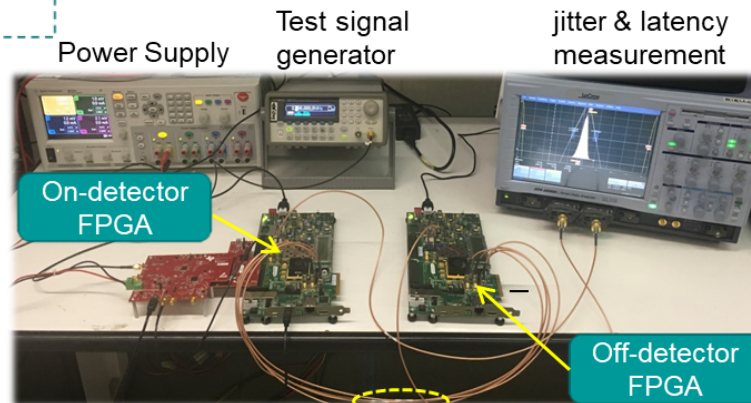
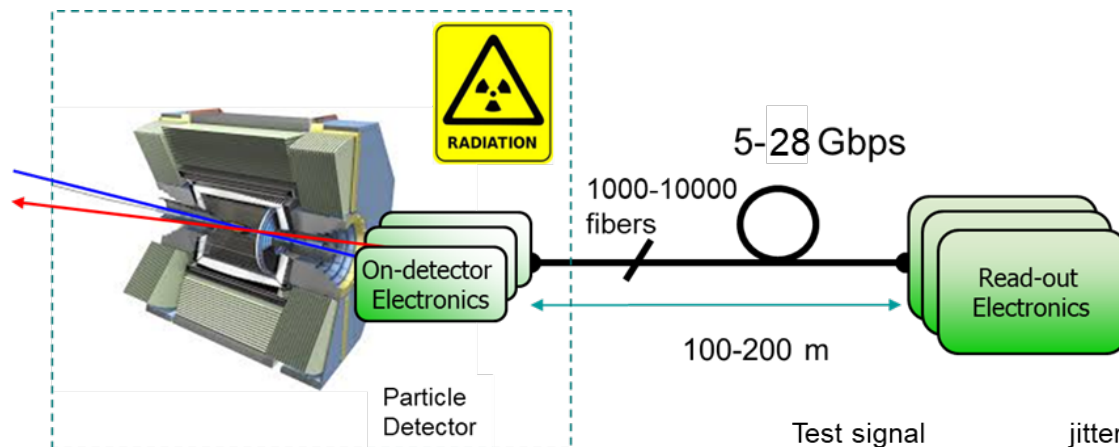
# The ROAL project

R. Giordano



- Funded by SIR excellence program of MIUR and supported by
  - INFN Sezione di Napoli (Naples, Italy)
  - INFN Laboratori Nazionali del Sud (Catania, Italy) – RARO irradiation program
  - Belle2 experiment (KEK, Japan)
  - ATLAS experiment (CERN, Geneva)

- Goal: high-speed links for trigger and data acquisition systems of High-Energy Physics experiments
  - Based on latest generation programmable logic devices (Field Programmable Gate Arrays)
  - Development of novel techniques for mitigation of radiation effects
  - Latest tests show successful data transfers with fixed-latency at 28 Gbps



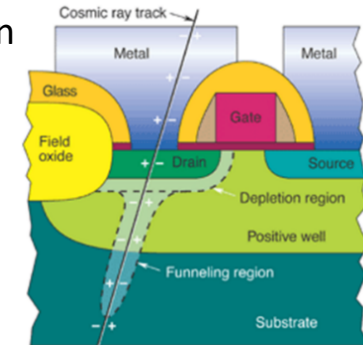
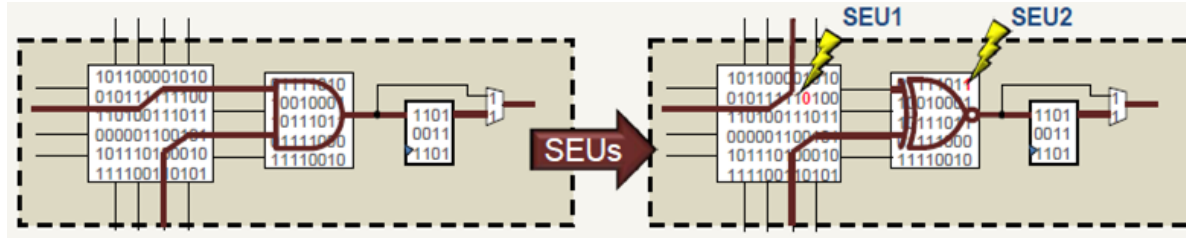
[www.roalproject.it](http://www.roalproject.it)

- So far 9 talks at international conferences, 5 papers on int'l journals, 1 book chapter, 1 patent (Italian, International, U.S.)
- Two papers being prepared for submission

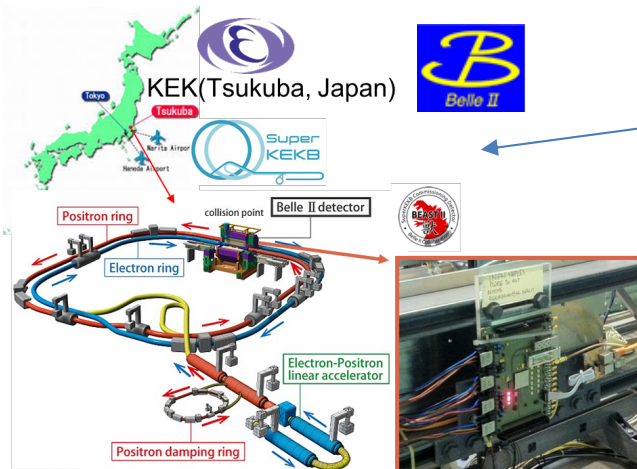


# Configuration Self-Repair

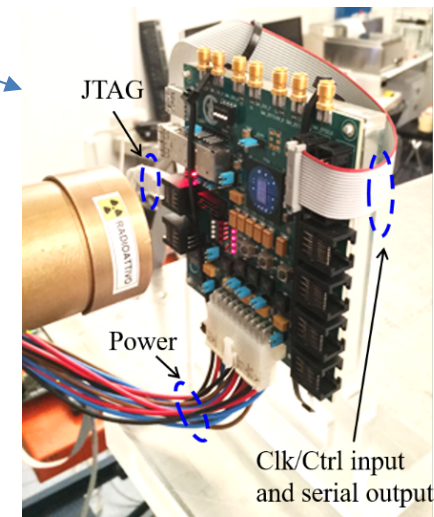
- Configuration Single event upsets (SEUs) are among the main causes of malfunction FPGAs in radiation environments



- Development of FPGA-based self-repairing circuits [1]
  - Detect and correct configuration, based on induced redundancy
  - Patented a novel methodology [2] for redundancy generation, proven on 7-Series Xilinx FPGA



- Irradiation testing w/ 62-MeV protons at LNS...
- ...and in Belle2 radiation environment during Phase-1, -2 and -3 (data taking in progress)
- Results show our self-repair solution 20+ times more effective than commercially-available ones
- Recently designed and tested a new board based on Xilinx Ultrascale+ devices
  - Test bed for development of new self-repair techniques and high-speed links



[1] R. Giordano et al., "Configuration Self-Repair in Xilinx FPGAs" IEEE Trans. On Nucl. Sci., Vol. 65, no.16, Oct. 2018, DOI: 10.1109/TNS.2018.2868992  
 [2] R. Giordano, "Method for Generating Redundant Configuration in Field Programmable Gate Arrays", PCT Application no. PCT/IB2018/060461