Dipartimento Interateneo di Fisica
"M. Merlin"

INFN
BARI
Istituto Nazionale di Fisica Nucleare
Sezione di Bari

2° Congresso di Sezione INFN e Dipartimento di Fisica di Bari

Giacomo Volpe– Università & INFN - Bari

Il secondo evento di questo tipo……..!!

- Qualche numero riguardo la partecipazione
  - Primo giorno:
    - ≅ 30 persone in aula A
    - ≅ 50 persone connesse da remoto
  - Secondo giorno:
    - ≅ 20 persone in aula A
    - ≅ 50 persone connesse da remoto

- Buona partecipazione da parte di dipendenti ed associati

- Quasi nessuna partecipazione da parte degli studenti!
  - Buona occasione per conoscere le attività svolte in sezione
  - Probabilmente alla prossima occasione sarò necessario pubblicizzare l'evento tra gli studenti in maniera più efficiace.

Il secondo evento di questo tipo……..!!

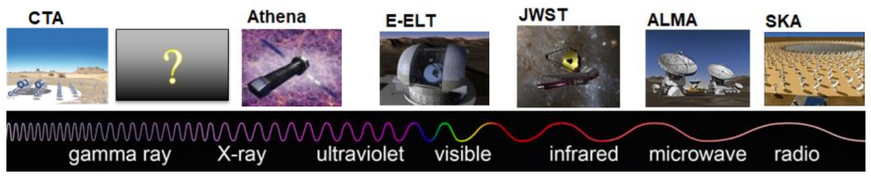
- A nome del comitato organizzatore: Vito, Lucia, gli altri coordinatori locali delle commissioni (Salvatore, Fabio, Antonio e Sonia), Leonardo, Giuseppe e Stefano, ringrazio gli speaker e chi ha con loro collaborato per preparare le presentazioni!

- Abbiamo avuto la possibilità di conoscere gli sviluppi hardware e software/computing in corso in sezione, permettendo lo scambio di informazioni tra gruppi ed eventuali collaborazioni!

Gli sviluppi in corso sono molteplici e variagati…..!

MeV-GeV gamma-ray telescope core science motivation

- Processes at the heart of the extreme Universe (AGN microquasars): prospects for the Astronomy of the 2030s
  - Multi-wavelength, multi-messenger coverage of the sky (with Ligo/Virgo, CTA, SKA, eLISA, …), with special focus on transient phenomena
- The origin of high-energy particles and impact on galaxy evolution, from cosmic rays to antimatter
- Nucleosynthesis and the chemical enrichment of our Galaxy



Fiber based tracking systems for space applications

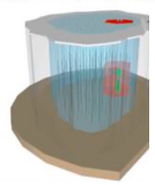
Roberta Pillera

APT

NUSES

Km3Net/IceCube-Gen2 - ν

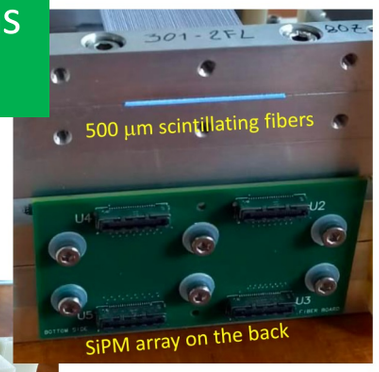
ADAPT

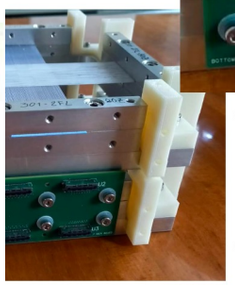


INFN Bari prototype R&D

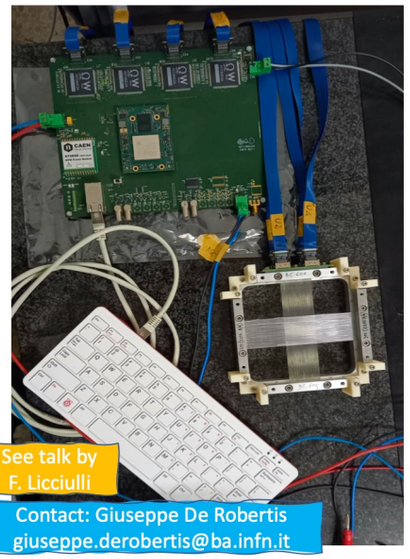
SiPM: Hamamatsu 128-channel 250 µm strip pitch

- The odd channels (top pads) and the even ones (bottom pads) are connected to two different FE ASICs





- Read-out board by INFN Bari
  - 4 Petiroc 2A ASICs
  - CAEN A7585D SiPM voltage module
  - Kintex-7 FPGA module
- DAQ based on the Raspberry Pi4



See talk by F. Licciulli

Contact: Giuseppe De Robertis giuseppe.derobertis@ba.infn.it

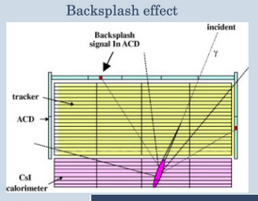
Particle Identification in Astroparticle Physics and for Space Applications

Leonardo Di Venere

Plastic Scintillator Detector (PSD)

- Two main purposes:
  - gamma-ray identification (VETO of charged particles)
  - Charge measurement
- Must be highly segmented to avoid backsplash effect
- Requirements:
  - High efficiency for charged particle identification
  - Good energy resolution and a frontend readout with high dynamic range for charge measurement
  - Low power consumption for space application
- Layout configuration – being studied:
  - Segmented scintillator (tile geometry)
  - Silicon Photomultiplier (SiPM) directly coupled to the scintillator

Backsplash effect



https://doi.org/1

HERD

Di Venere L.

Radioactive gamma-ray sources identification

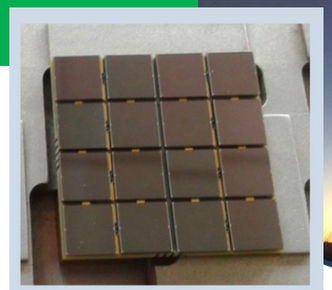
- Gamma-ray detection is hot topic in several fields
  - Homeland security
  - Safety control in industrial environment
  - NORM and TENORM environmental monitoring
  - Survey of areas from UAVs
- Gamma-ray detection requirements:
  - High sensitivity
  - Gamma spectroscopy over a wide energy range (100 keV – 3 MeV)
  - Source localization
  - Fast response

Gate monitoring for homeland security

Nuclear waste drums

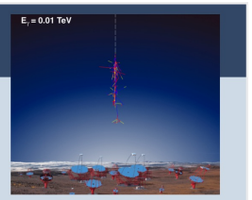
Fly coal ash (example of TENORM)

Di Venere L.



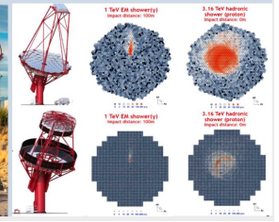
The Cherenkov Telescope Array

- Gamma-rays and cosmic rays produce particle showers in atmosphere
- Cherenkov telescopes reconstruct shower images to identify and measure the primary particle
- INFN Bari involved in the Schwarzschild-Couder dual mirror optics Medium Size Telescope
  - Joint effort of US and Italian institutes
  - Dual mirror optics designed to cancel aberration and de-magnify images
  - compatible with compact high-resolution SiPM camera
  - Improved angular resolution
  - 3M$ MRI&INFN funded project ongoing



Credits to Pillera R.

CTA



Di Venere L. Contact: Giordano F.

Gli sviluppi in corso sono molteplici e variagati.....!

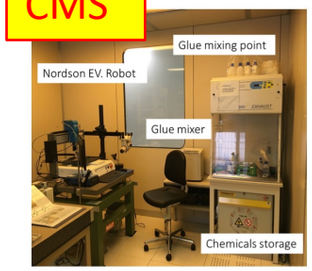
Solid state tracker

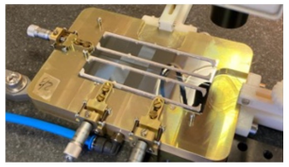
Silicon trackers for CMS and ALICE
Domenico Colella

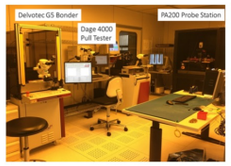
CMS

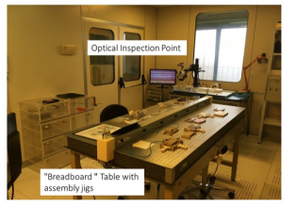
CMS tracker - Outer Tracker (OT)

- INFN strong commitment in the assembly of TBPS (1920 PS modules, ≈ 40 m² detector surface)
- Big effort in **Bari** and **Perugia** to complete the assembly line
  - New Glue dispensing robot, Nordson EV
  - New bonding machine
  - Vacuum line and assembly workflow optimisation
  - Jigs production and testing
- **2019** mainly dedicated to mechanical prototype construction
  - Alignment based and sensor dicing, lower precision obtainable with mechanical parts
  - Waiting for dummy sensors (MaPSA)
- **2020** mainly dedicated to build dummy modules and validate the procedures
  - Received 2 dummy sensors (MaPSA) per center
- **2021** first functional modules assembling
  - Foreseen in 2020 and delayed due to material procurement difficulties
  - Stringent constraints on sensor-to-sensor alignment and rotation

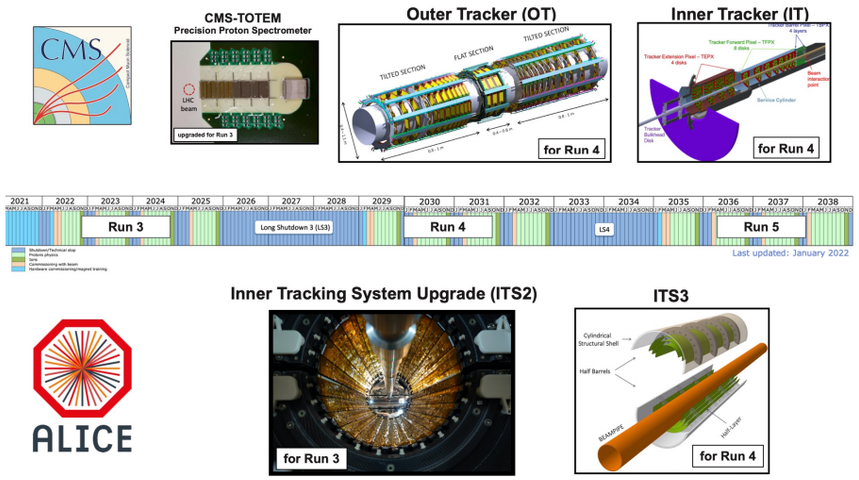








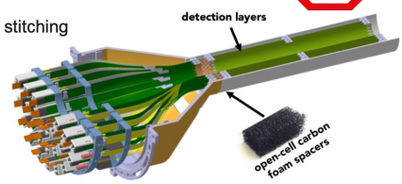
LHC schedule and silicon tracker upgrades



ALICE

ALICE tracker - ITS3 detector concept

Key ingredients
» Wafer-scale chips (up to ~28x10 cm), fabricated using stitching
» Sensor thickness 20-40 μm
» Chips bent in cylindrical shape at target radii
» Si MAPS sensor based on 65 nm technology
» Carbon foam structures
» Smaller beam pipe diameter and wall thickness (0.14% X_0)



The whole detector will comprise six chips (current ITS IB: 432) and barely anything else!

Key benefits
» Extremely low material budget: 0.02-0.04% X_0
» Homogeneous material distribution: negligible systematic error from material distribution

Beam pipe inner/outer radius (mm)	16.0/16.5		
IB Layer Parameters	Layer 0	Layer 1	Layer 2
Radial position (mm)	18.0	24.0	30.0
Length of sensitive area (mm)	300.0		
Pseudo-rapidity coverage	±2.5	±2.3	±2.0
Active-area (cm²)	610	816	1016
Pixel sensor dimension (mm²)	280 × 56.5	280 × 75.5	280 × 94
Number of sensors per layer	2		
Pixel size (μm²)	O (10 x 10)		

ITS3 project R&D lines

Chip design
New, stitched sensor in 65 nm technology on 300 mm wafers

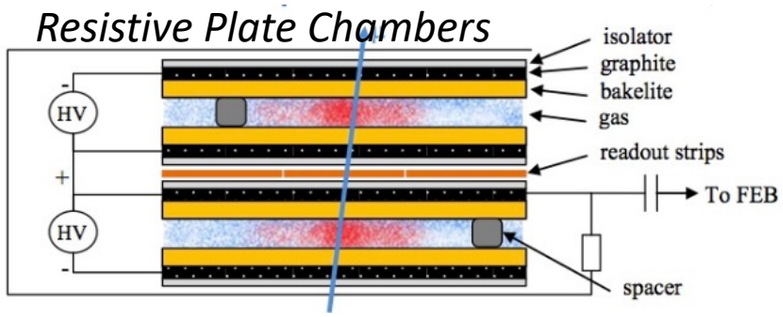
Sensor performance
Tests with existing bent ALPIDE chips (ITS2) for (in-beam) performance assessment

Detector Integration
Tests with wafer-scale dummy chips for mechanical integration

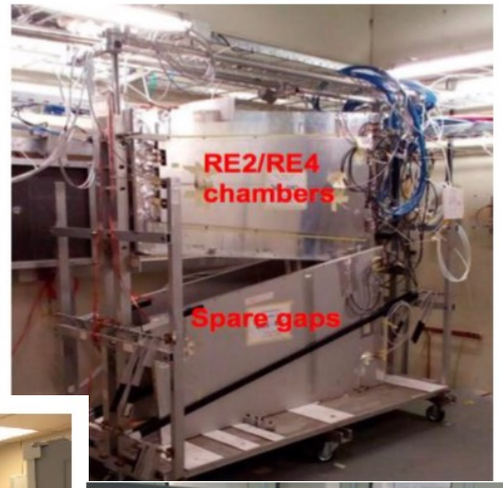
Gaseaus tracker

Rivelatori di tracciamento a gas per CMS e LHCb
Piet Verwilligen

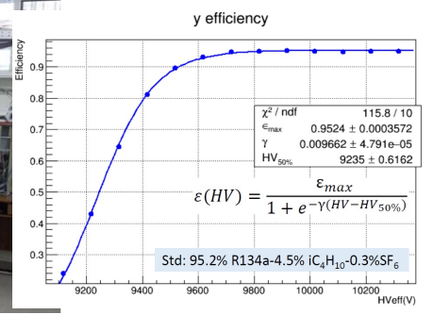
Resistive Plate Chambers



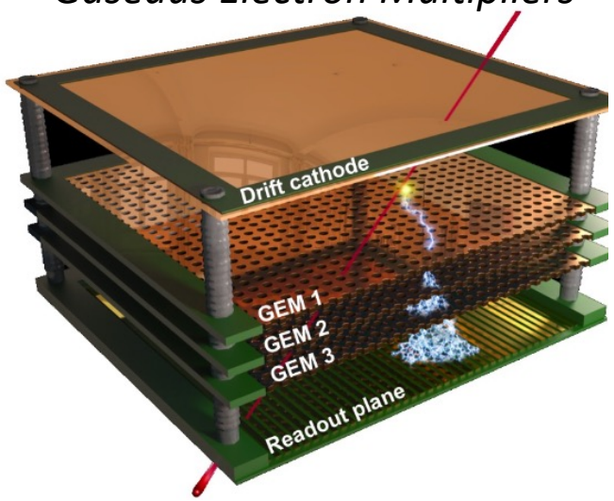
CMS



LHCb

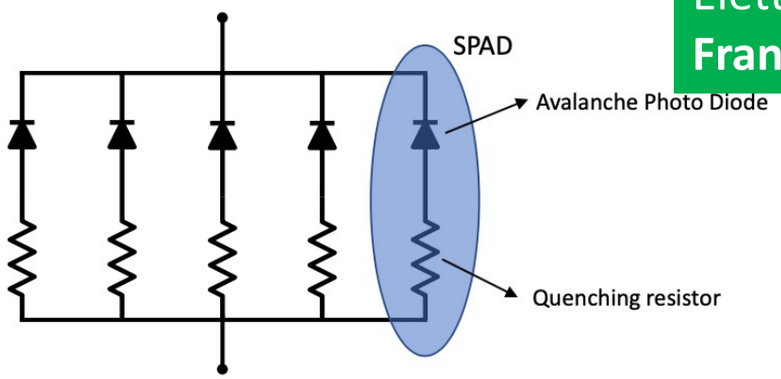


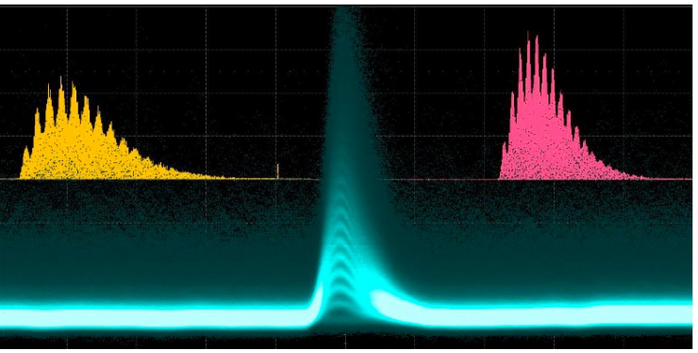
Gaseaus Electron Multipliers



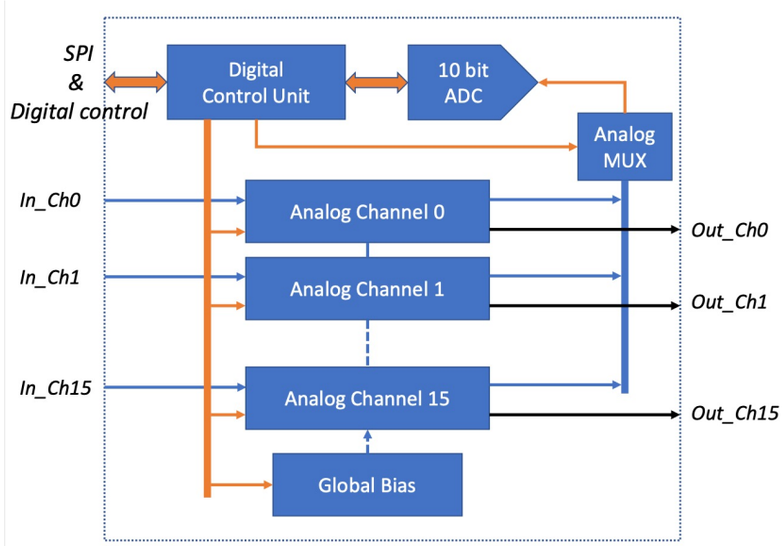
Gli sviluppi in corso sono molteplici e variagati…..!

Elettronica di readout per foto-rivelatori al silicio
Francesco Liciulli

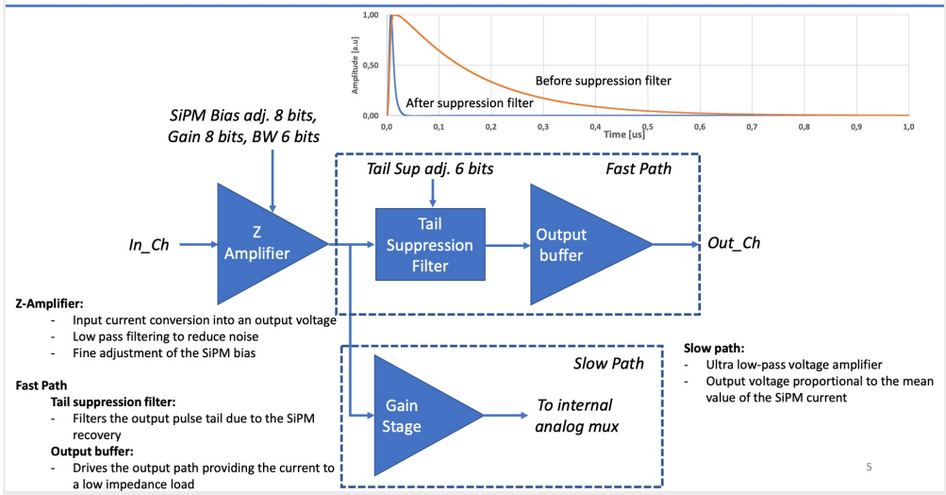




SMART2: ASIC architecture overview

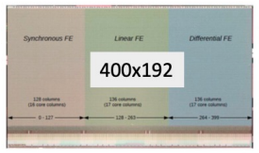


SMART2: Channel architecture overview

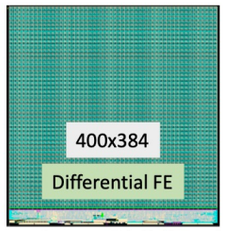


RD53 pixel chips for the CMS and ATLAS CMS Phase-2 upgrades at the High Luminosity LHC
Flavio Loddo

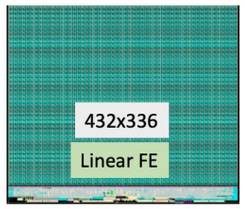
https://cds.cern.ch/record/2663161



RD53A
- **Half-size demonstrator**
- Size: 20 x 11.5 mm2
- 3 Analog Front-Ends
- 2 readout architectures
- submitted in August 2017



RD53B-ATLAS (ItkPix_V1)
- submitted in March 2020
- size: 20 mm x 21 mm



RD53B-CMS (CROC_V1)
- submitted in June 2021
- size: 21.6 mm x 18.6 mm

RD53C-ATLAS: April 2022
RD53C-CMS: Sept/Oct 2022

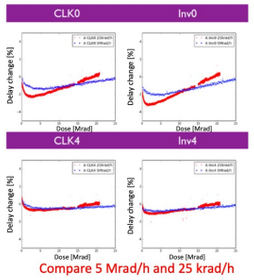
Manpower:
- G. De Robertis
- F. Loddo

Design activity:
- Chip floorplanning
- Rad-hard 10-bit Digital-to-analog converter
- Analog bias network
- Power distribution
- Scan-chain architecture for easier production testing (Design for Testability)
- Sign-off verifications

Responsibilities
- Since June 2016: F. Loddo is the RD53 Project Engineer
- Since May 2018: F. Loddo is the CMS Phase2 Inner Tracker ASIC project coordinator

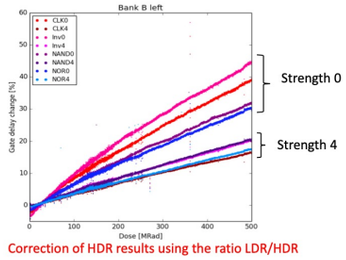
Radiation hardness

- Extensive TID X-ray tests done in the past years on RD53A, RD53B and small prototypes to qualify IPs, analog FEs and digital standard cells
- The TID damage concerns essentially the digital design because of the small area devices
- Tests done at low temperature (-20°C) and high dose rate show that the RD53 chips are operating correctly at least up to 1 Grad
- From measurements on Ring Oscillators (RD53A and RD53B): **gate delay degradation roughly x2 larger for low dose-rate (LDR)**



Compare 5 Mrad/h and 25 krad/h

ROSC	Delay slope [%/MRad]		
	HDR	LDR	Ratio
CLK 0	0.051	0.121	**2.34**
CLK 4	0.012	0.026	**2.32**
Inv 0	0.076	0.176	**2.31**
Inv 4	0.029	0.055	**1.94**
NAND 0	0.034	0.085	**2.52**
NAND 4	0.008	0.016	**1.91**
NOR 0	0.051	0.097	**1.91**
NOR 4	0.031	0.051	**1.61**



Correction of HDR results using the ratio LDR/HDR

- Irradiation corner models and extreme corners from the foundry were used to predict the TID effect and design to guarantee good timing for the digital design. These corners resulted to be more pessimistic than the extrapolations of low dose-rate tests to 500 Mrad
- These tests, together with the policy to **avoid minimum size digital cells**, give confidence that RD53B chips will meet TID specifications if **operated at cold temperature**. Irradiated chips must be cooled while under power, **since room or high temperature annealing is detrimental**

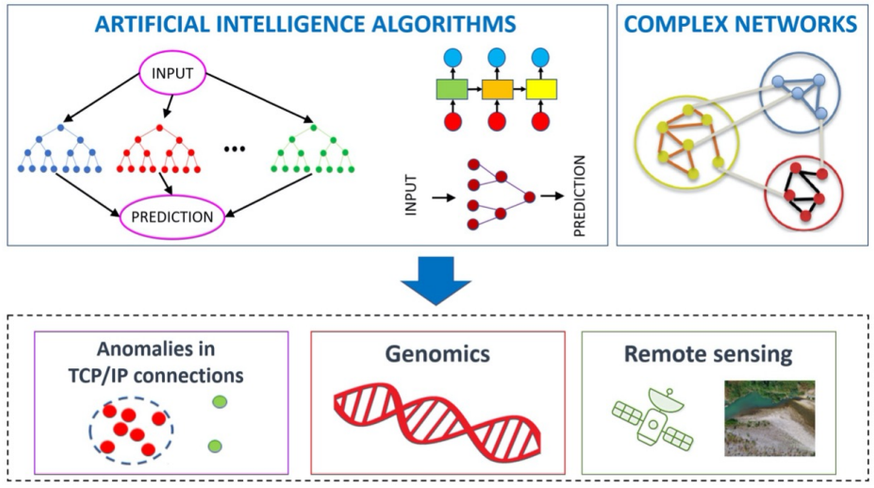
Congresso INFN-Bari 3-4 Feb. 2022 F. Loddo INFN-Bari 7

Gli sviluppi in corso sono molteplici e variagati.....!

Sviluppi e applicazioni di algoritmi di Intelligenza Artificiale
Loredana Bellantuomo

METHODS

APPLICATIONS



New GPU Cluster @ ReCaS-Bari

All the applications shown in the following are based on the **ReCaS-Bari high-performance computing** capability

ReCaS upgrade → new GPU Cluster [more details in Gioacchino Vino's talk]

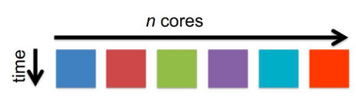
- Currently, the cluster is composed of:
  - 38 GPUs (18 Nvidia A100 and 20 Nvidia V100)
  - 1755 CPU cores
  - 13.7 TB RAM
  - 55 TB Disk Space
- Thanks to the high number of cores, the GPUs allow the running of high-performance **parallel algorithms reducing the overall execution time**
- The configured cluster is able to run batch jobs or open **interactive environments** where users are able to write code and test it in real time

Supporto all'HPC e utilizzo di GPU per applicazioni scientifiche
Gioacchino Vino

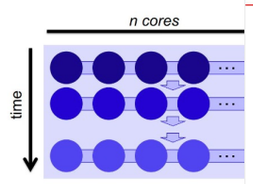
Computing: HTC vs HPC

There are two different approaches to scientific computing:

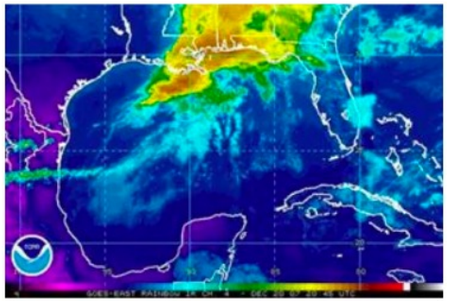
- **High-throughput computing (HTC)**
  - Large workflows of numerous, small and independent tasks
  - Executes on physically distributed resources using grid-enabled technologies

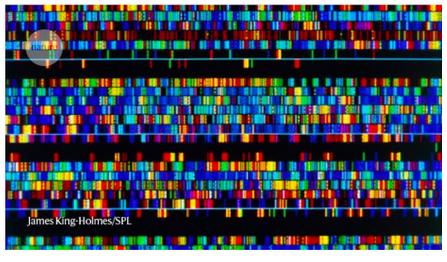


- **High-performance computing (HPC)**
  - Large workflows of highly-interdependent sub-tasks
  - Frequent and rapid exchanges of intermediate results is required to perform the computations
  - Parallel processing over many processors



2° Congresso INFN e Dipartimento di Fisica / Bari / 4Feb2022 / Gioacchino Vino





Graphical Processing Unit (GPU):

- Massively parallel hardware architecture (> 5000 cores)
- High performance of floating point arithmetic

Make them suited for many scientific workloads on HPC clusters

Use case: Multi-charm reconstruction with ML in ALICE 3

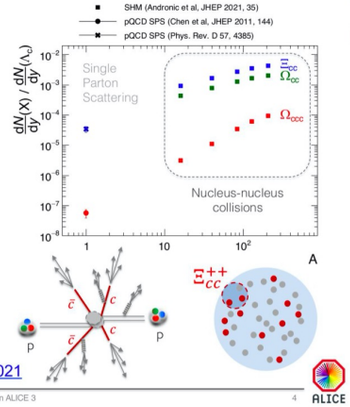
Motivation and challenges

Working Team:

- Domenico Elia
- Annalisa Mastroserio
- Domenico Colella
- Gioacchino Vino
- David Chinellato

Multi-charm baryons: from low to high density QCD

- Charm production in general: almost exclusive to hard scatterings due to large mass (~1275 MeV/c^2)
- Formation of Ξ_{cc}^{++}, Ω_{cc}^{+}, Ω_{ccc}^{++}: extremely unlikely in single parton scattering (unlike e.g. J/ψ)
- Multi-parton interactions and multi-charm: multiple charm quarks combine into hadrons
- In nuclear collisions:
  - High density of charm quarks leads to much larger multi-charm population
  - Described by SHM (g_c) and coalescence
  - Enormous dynamic effect!



D. D. Chinellato, ALICE 3 workshop 18-19.10.2021

Multi-charm baryons in ALICE 3 4 ALICE 2

2° Congresso INFN e Dipartimento di Fisica / Bari / 4Feb2022 / Gioacchino Vino 12

ReCaS HPC/GPU Cluster

Gli sviluppi in corso sono molteplici e variagati…..!

Orchestrazione di risorse Cloud e implementazione di cluster complessi per l'analisi dati
Marica Antonacci

Cos'è il cloud computing

*Cloud computing is a model for enabling ubiquitous, convenient, **on-demand** network access to a **shared pool of configurable computing resources** (e.g., networks, servers, storage, applications, and services) that can be **rapidly provisioned and released** with minimal management effort or service provider interaction.*

NIST Definition
https://doi.org/10.6028/NIST.SP.800-145
(September 2011)

INFN

Le opportunità per il calcolo scientifico

- Grandi e piccoli esperimenti possono trarre vantaggio dalla facilità d'uso e dalle interfacce semplificate dei servizi cloud di alto livello
  - in particolare in piccole collaborazioni, e/o dove c'è carenza di specifiche competenze sul calcolo distribuito e/o manpower
- Le soluzioni a livello PaaS semplificano la migrazione delle applicazioni (anche legacy) in ambiente cloud

INFN Cloud - obiettivo

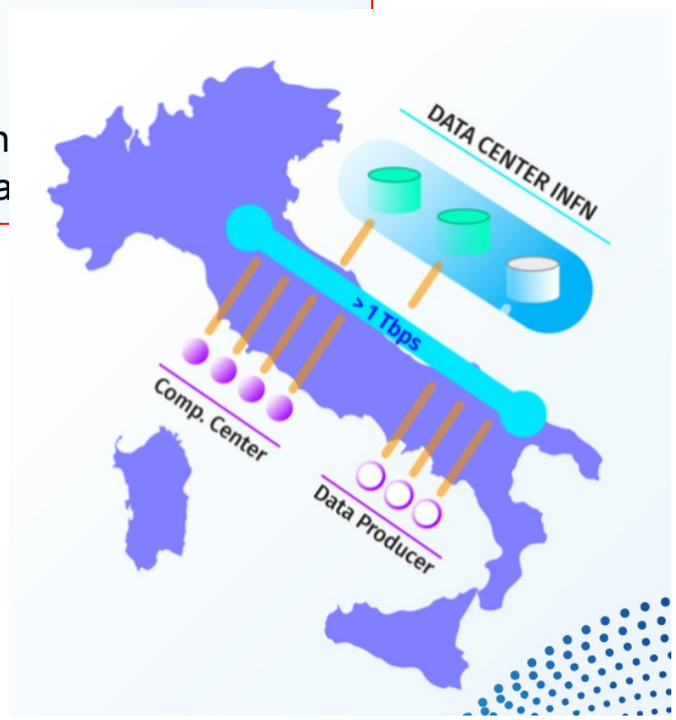
Fornire un insieme di **servizi** di cloud computing per la comunità INFN a supporto di

- **calcolo scientifico**
- **sviluppo software**
- **training**

partendo dalle soluzioni sviluppate e dal kn
durante i progetti e le iniziative a cui l'ente ha pa

Progetti e iniziative

INFN



Gli sviluppi in corso sono molteplici e variagati…..!

Trasferimento tecnologico
Cosimo Pastore

Trasferimento Tecnologico

valorizzazione di idee e tecniche innovative che nascono nell'ambito della **ricerca di base**

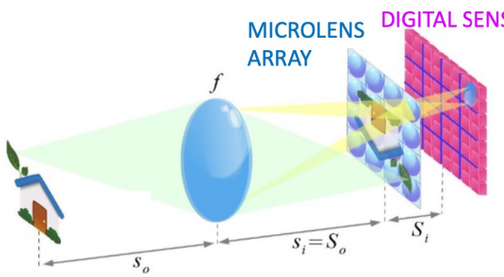
nuove tecnologie possono così trasformarsi in **beni e servizi fruibili dalla collettività**

Focus sulle tecnologie quantistiche
Milena D'Angelo

Quantum imaging in Bari

Plenoptic imaging: working principle

Ng 2005



retrieves BOTH the image AND the ***propagation direction*** of light

A 16 Megapixel camera, behaves as a 4 Megapixel

- Trade-off between resolution and depth-of-field → NO diffraction-limited resolution
- Sacrificed change of perspective limits the 3D imaging capability

Can quantum imaging help?

Trasferimento tecnologico con focus sulle tecnologie ottiche quantistiche - Milena D'Angelo

The adventure in TT

IP needs to be «valorized»

1° patent → «**Borsa della ricerca**», Salerno 2017

Lesson 1: IT patent is useless, go for **International patent**

Lesson 2: «come back next year with a **prototype»**

Lesson 3: search for a ***killer application*** - study the *mom's test*

Lesson 4: protect your patent with many «daughter patents»

Young researcher project - INFN CSN5: PICS (PI: Francesco Pepe)
Main goals:
- Develop CPI in the framework of **microscopy**, of particle tracks in emulsions and biomed ap
- Design of the **prototype** of a CPI microscope
- Protect INFN **IP** → 3° patent application

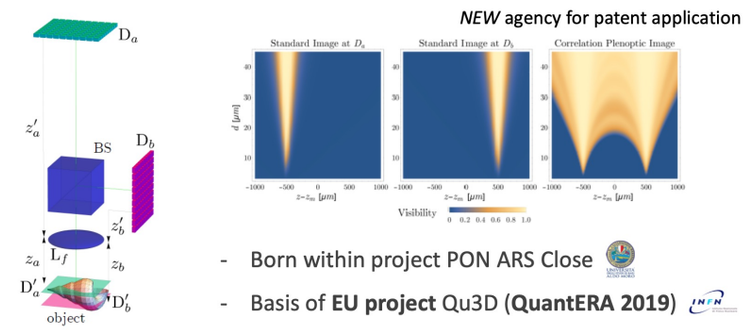
Trasferimento tecnologico con focus sulle tecnologie ottiche quantistiche

The adventure in TT

Two more patents

PCT/2019: **CPI –AP** (original idea by Francesco Di Lena, PhD thesis)

NEW agency for patent application



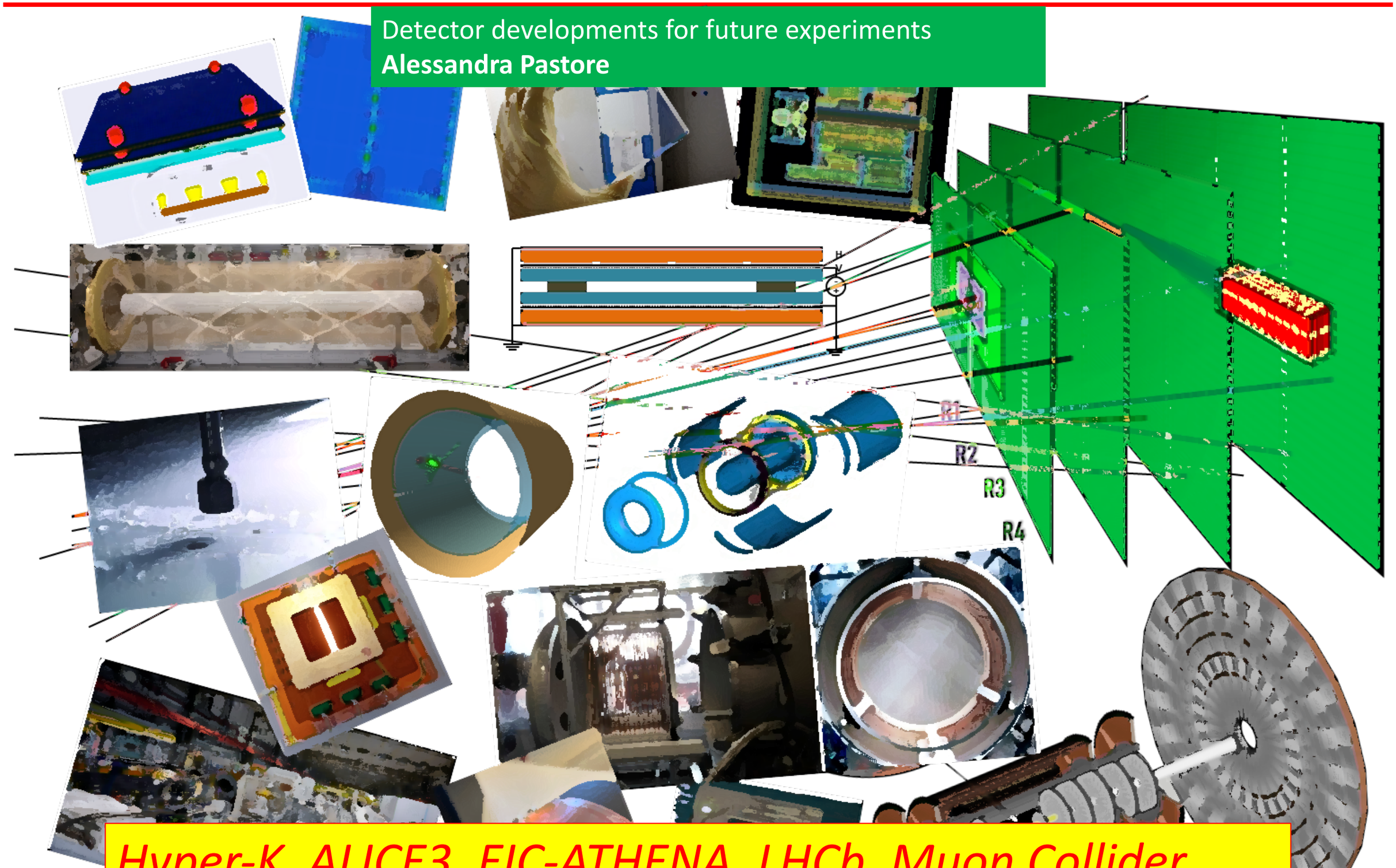
- Born within project PON ARS Close
- Basis of **EU project** Qu3D (**QuantERA 2019**)

PCT/2020: Hyperstecral imaging by correlations (G. Massaro, PhD thesis)

??? Basis of **QEO**, ind. partner: Planetek (RIPARTI, Reg. Puglia '21)

Trasferimento tecnologico con focus sulle tecnologie ottiche quantistiche - Milena D'Angelo

Gli sviluppi in corso sono molteplici e variagati…..!



Hyper-K, ALICE3, EIC-ATHENA, LHCb, Muon Collider, FCC, ASTROGAM, AMEGO, ….

Prossimo evento

- Prossimo congresso a Giugno, il terzo di questo tipo, e sarà dedicato ai risultati di fisica.

- Vi ricordo che ovviamente suggerimenti/commenti relativi a questo congresso e per il prossimo sono benvenuti.
  - potete inviarli via e-mail in modo tale che li possiamo valutare all'interno del comitato organizzatore