Proposta di nuova iniziativa (2022-2025)

Avalanche Diodes Array – 5D

(ADA-5D)

University of Padova & INFN Padova
University of Pavia & INFN Pavia
University of Pisa & INFN Pisa
University of Siena & INFN Pisa
University of Trento & TIFPA
Fondazione Bruno Kessler (FBK – Trento)

CHARGE IDENTIFICATION of cosmic-ray (CR) ions with charge $1 \leq Z \leq 30$ with $dE/dx \propto Z^2$ measurements in a **charge detector** (SCD) at the top of the instrument

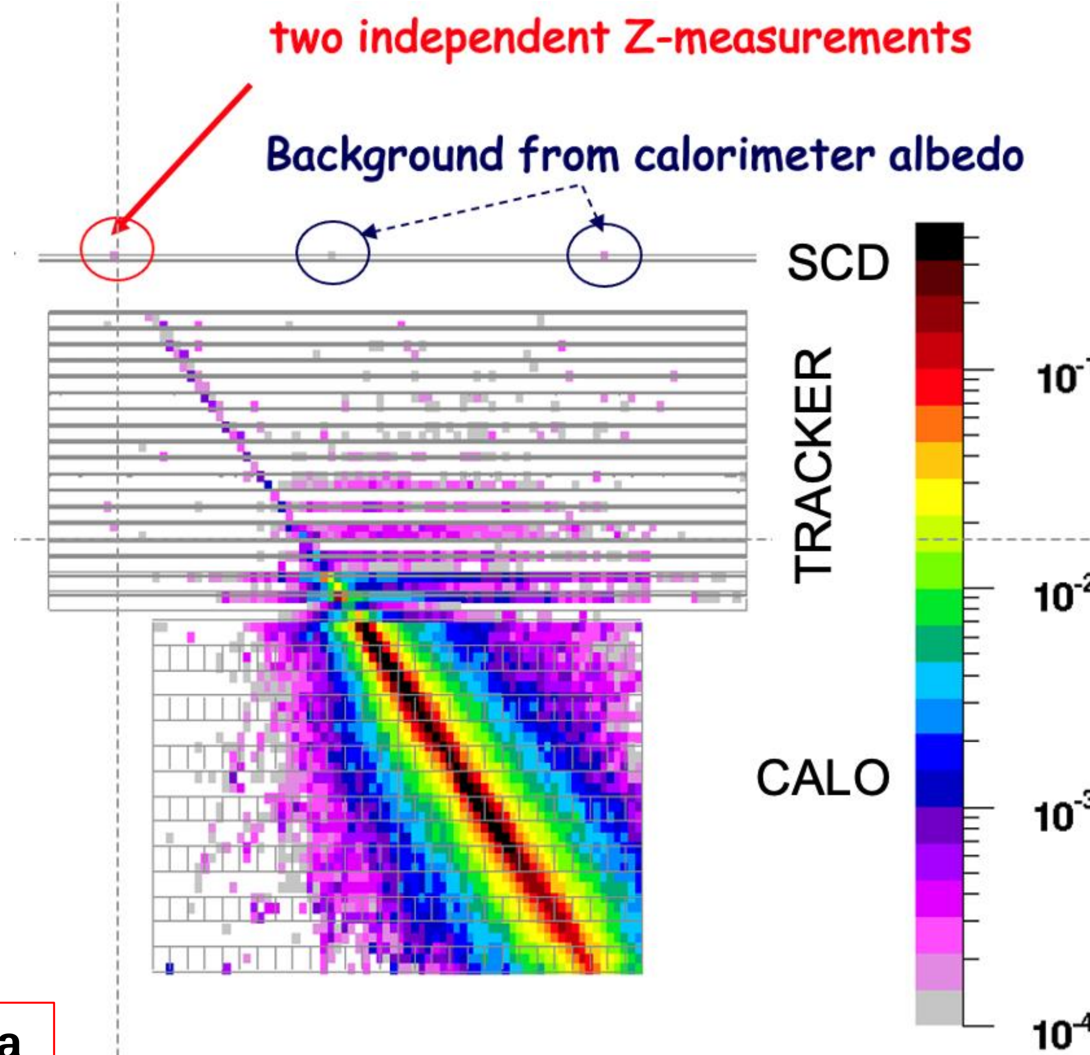
Example of a typical space-borne CR experiment with a generic charge detector (silicon pixels, scintillator paddles/tiles, etc.)

Backscattering (BS) from the calorimeter generates fake hits in the charge detectors and in the tracker.

The tracker back estrapolates to the SCD with an impact point IP resolution ~ 150 - 200 um

BS increases with energy and deteriorates the charge ID of individual CR elements.

ADA-5D concept: reject BS with a high resolution ToF measurement



FLUKA simulation of 1 TeV incident carbon nucleus

Charge & Timing 5D detector: x,y,z, charge, time

VERY stringent requirements for a space experiment:

Charge measurement:

- large dynamic range > 1000 m.i.p.
- charge resolution for proton < 0.1 => 200-300 μm sensors for primary ionization

Timing measurement:

- sub-ns resolution (e.g., for 10 – 20 cm flight path → 100 ps)

Space resolution and granularity:

- modest granularity (3mm x 3mm pixels) to cover large O(m^2) sensitive area
- an independent TRACKER is in charge of the fine spatial resolution

Power budget:

- VERY challenging < 150 W/m^2

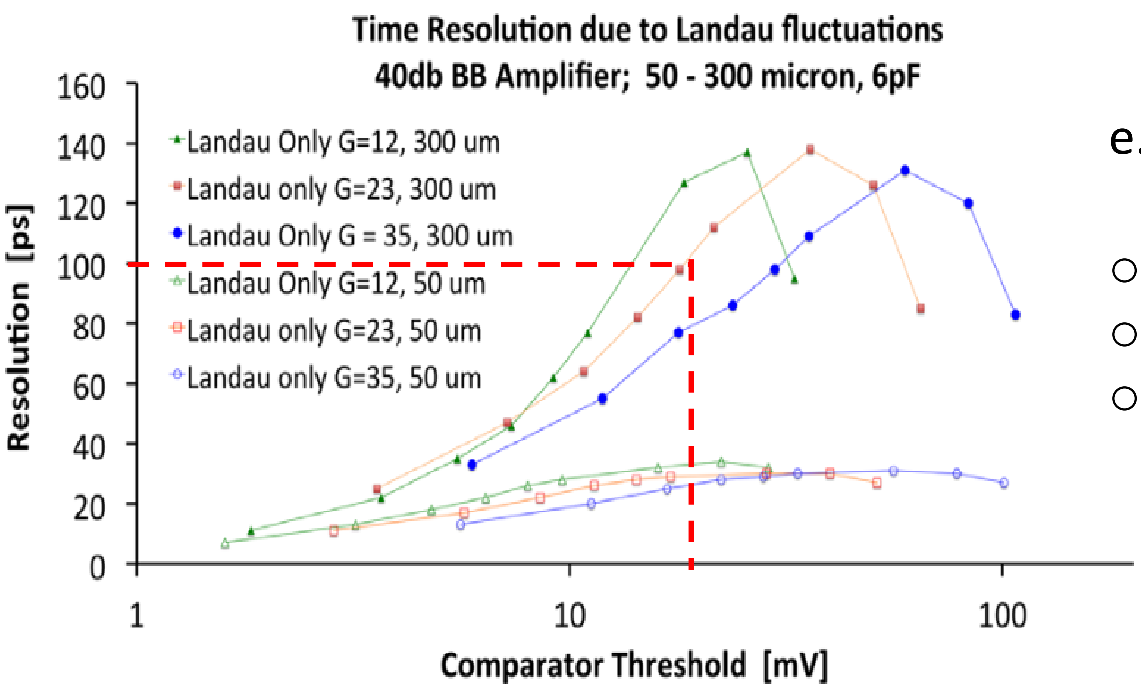
Radiation hardness:

- modest problem for space experiments < 10^{11} 1 MeV neq (TID ~100 krad)

Proposed development of LGADs for ADA-5D at FBK

- large pixels (e.g.: 3mm x 3mm)
- sensor thickness 200-300 um

with G~ 10-20 the dominant term for the time resolution is the jitter => 100 ps feasible with a low threshold (realistic as S/N>30 for 1 m.i.p)



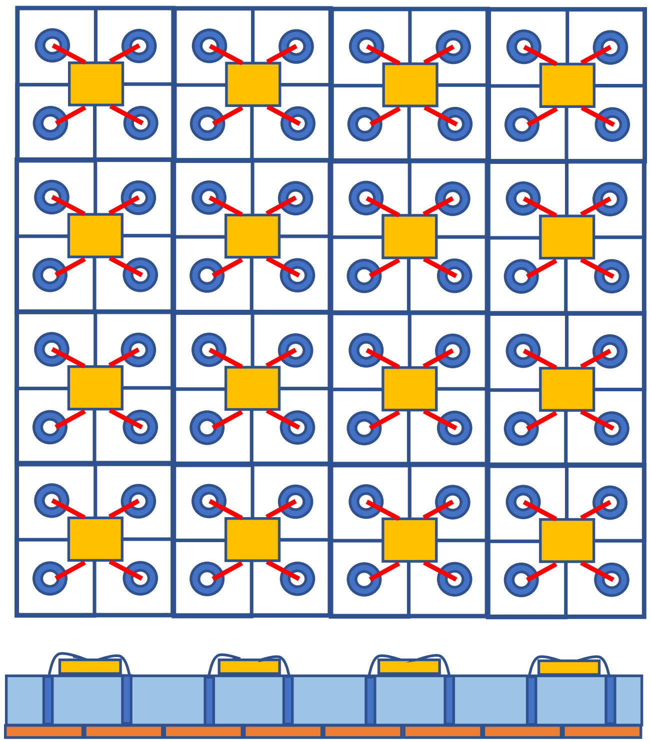
e.g.: 100 ps resolution with:

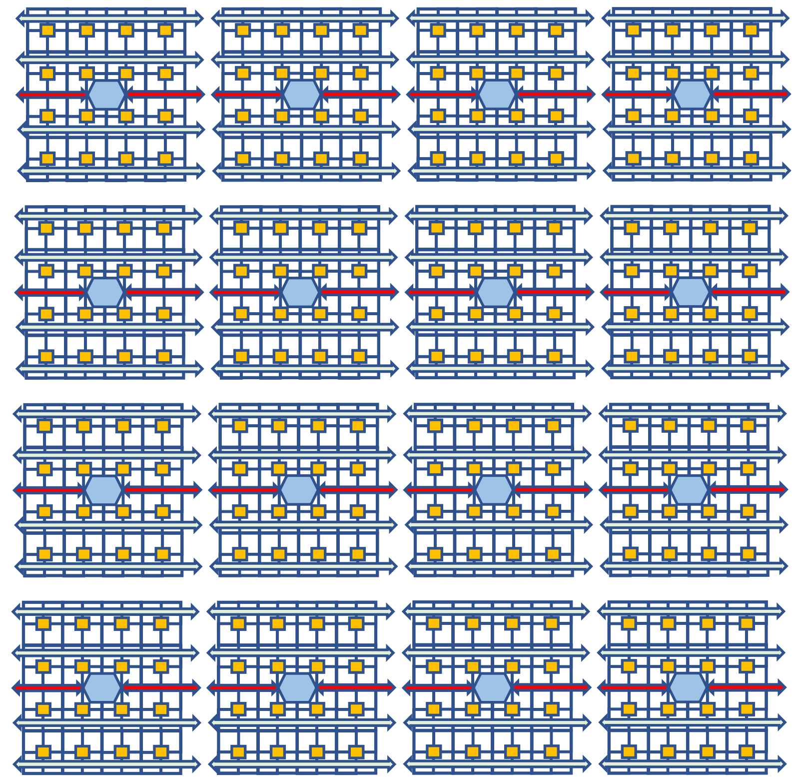
- 300 um thickness
- G=23
- threshold ~ 20 – 30 mV

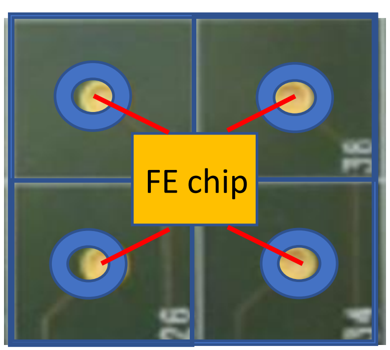
Nuclear Instruments and Methods in Physics Research A 845 (2017) 47–51

mini-TILE (2.4cm x 2.4 cm):
16 FE = 8 x 8 LGADs

TILE (9.6 cm x 9.6 cm): 16 mini-tiles
= 256 FE = 16 x 8 x 8 = 1024 LGADs

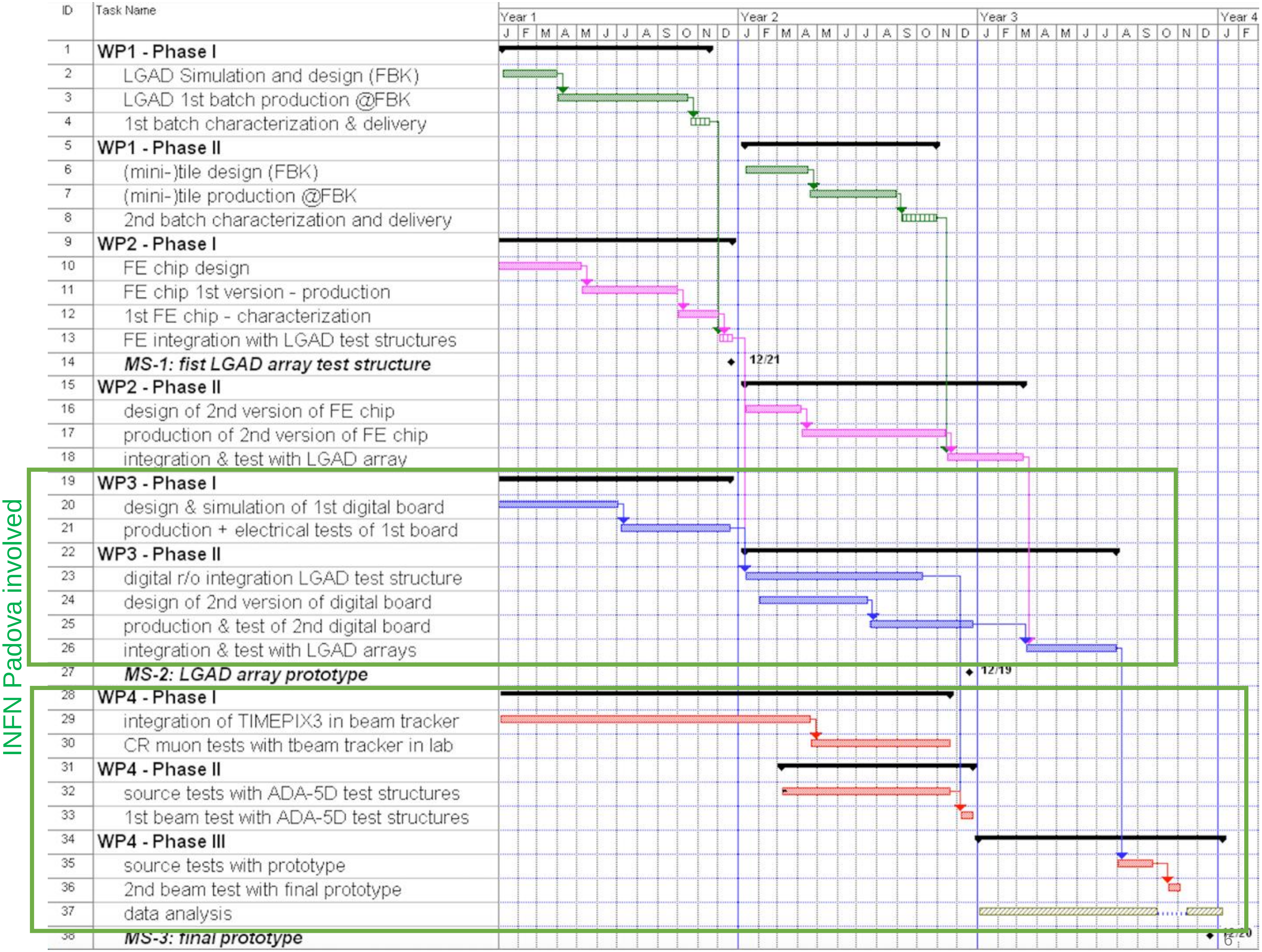






Each FE chip, connected to 4 LGADS, implements:

- double gain linear range to cover > 1000 m.i.p.
- internal ADC
- internal TAC + ADC conversion
- Track & Hold


ID
Task Name
Year 1
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1 WP1 - Phase I
2 LGAD Simulation and design (FBK)
3 LGAD 1st batch production @FBK
4 1st batch characterization & delivery
5 WP1 - Phase II
6 (mini-)tile design (FBK)
7 (mini-)tile production @FBK
8 2nd batch characterization and delivery
9 WP2 - Phase I
10 FE chip design
11 FE chip 1st version - production
12 1st FE chip - characterization
13 FE integration with LGAD test structures
14 MS-1: fist LGAD array test structure
12/21
15 WP2 - Phase II
16 design of 2nd version of FE chip
17 production of 2nd version of FE chip
18 integration & test with LGAD array
19 WP3 - Phase I
20 design & simulation of 1st digital board
21 production + electrical tests of 1st board
22 WP3 - Phase II
23 digital r/o integration LGAD test structure
24 design of 2nd version of digital board
25 production & test of 2nd digital board
26 integration & test with LGAD arrays
27 MS-2: LGAD array prototype
12/19
28 WP4 - Phase I
29 integration of TIMEPIX3 in beam tracker
30 CR muon tests with tbeam tracker in lab
31 WP4 - Phase II
32 source tests with ADA-5D test structures
33 1st beam test with ADA-5D test structures
34 WP4 - Phase III
35 source tests with prototype
36 2nd beam test with final prototype
37 data analysis
38 MS-3: final prototype
12/20
INFN Padova involved

Developments @ INFN Padova

Digital RO board (collaboration with w/ INFN Pisa)

- ADC & TDC information from O(1000) channels
- Small FPGA + fast links

Fast timing silicon pixel telescope (for test beams)

- Based either on TimePix4 or on TimeSpot
- Synergies with Medipix4/INFN Ferrara & TimeSpot/LHCb being investigated

Resources @ INFN Padova

- G.Collazuol - 20 %
- Michelangelo Pari (PostDoc) – 20 %
- Matteo Feltre (PhD) - 20%
- Marco Mattiazzi (PhD) - 80%

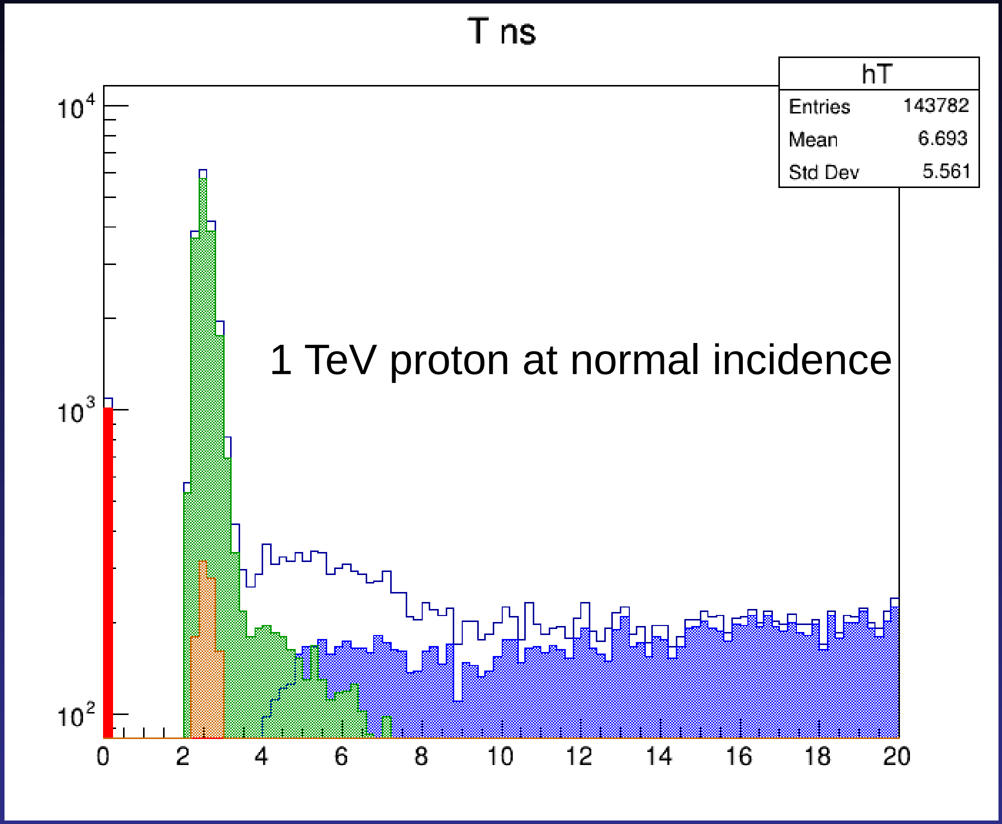
Richieste:

- Consumo per circa 10kEuro
- Missioni per circa 4kEuro

- Servizi Tecnici ed Elettronici
  progettazione scheda RO ~ 3m.p.
- Servizio Elettronica
  programmazione FPGA TP4/TS ~ 3m.p.
- Servizio Progettazione Meccanica
  setup telescopio ~ 1m.p.
- Servizio Officina Meccanica
  meccanica telescopio ~ 1m.p.

Additional material

Arrival time (ns) of BS from calorimeter on SCD: a GEANT4 simulation



Geometry

Calorimeter: 50x50 cm^2 Pb 30 X_0

300 micron Silicon array (50x50 cm^2)

e.g.: 30 cm distance to calorimeter

- ToF of incident particle to CALO ~ 1ns
- BS flight time:
  - ~ 1ns for ultra-relativistic particles (e, γ)
  - > 1ns for NR (neutrons)

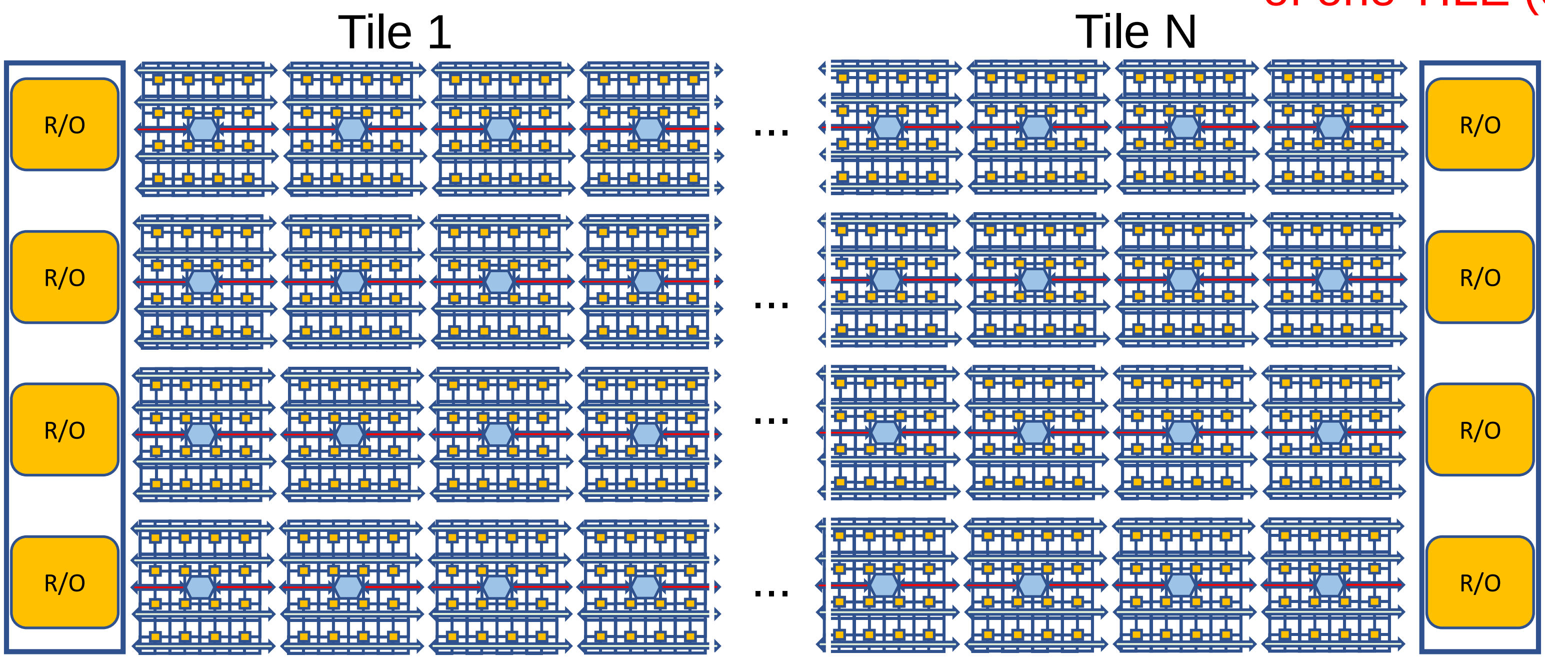
Total time > 2ns

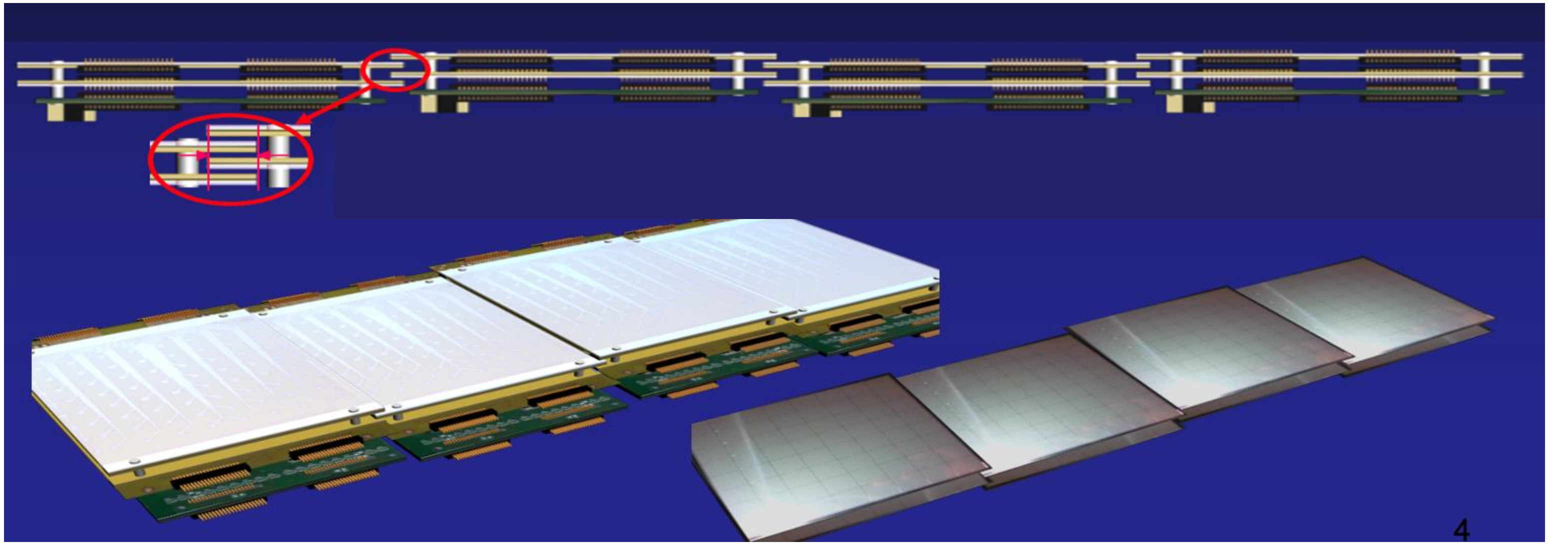
- filled-green: back-scattered **photons** (create ionizing secondaries → fake hits in SCD);
- filled-blue: back-scattered **neutrons**;
- filled-orange: back-scattered **electrons** depositing energy in the charge detector;
- filled-red: **incident protons** on charge detector (generated at t=0);
- blue non-filled: histogram inclusive of all above..

LARGE AREA DETECTOR concept: N tiles per row x M rows

Example of 1 row equipped with N tiles and readout on either side

ADA-5D goal is limited to the development of one TILE (or mini-TILE)





overlapping staggered layers

	ADA-5D 2023 - FTE	PI/SI	PV	TIFPA	PD
Pier Simone Marrocchesi	PO Univ. di Siena + INFN Gruppo Collegato	0.7			
Paolo Maestro	PA Univ. di Siena + INFN Gruppo Collegato	0.4			
Gabriele Bigongiari	PA Univ. di Siena + INFN Gruppo Collegato	0.6			
Caterina Checchia	Assegno di ricerca - Univ. di Siena - Associaz. INFN Pisa	0.6			
Mina Maghami Moghim	Dottoranda Univ. di Siena - Associaz. INFN Pisa	1.0			
Paolo Brogi	RTDA Univ. di Siena + INFN Gruppo Collegato	0.8			
Francesco Stolzi	RTDA Univ. di Siena + INFN Gruppo Collegato	0.6			
F.Morsani	Tecnologo INFN Pisa	0.1			
Lodovico Ratti	PO Univ. di Pavia		0.3		
Piero Malcovati	PO Univ. di Pavia		0.3		
Marco Grassi	RTDB Univ. di Pavia		0.5		
Joana Minga	Dottoranda (associata sez. Pavia)		1.0		
Simone Giroletti	Dottorando (associato sez. Pavia)		1.0		
Carla Vacchi	RC Univ. di Pavia		0.4		
Lucio Pancheri	PA Univ. di Trento			0.4	
GianFranco Dalla Betta	PA Univ. di Trento			0.1	
Thomas Corradino	Dottorando (associato TIFPA)			0.5	
Alberto Taffelli	Dottorando (associato TIFPA)			0.8	
Maurizio Boscardin	FBK Ricercatore Senior (associato TIFPA)			0.1	
Matteo Centis Vignali	FBK (associato TIFPA)			0.1	
Omar Hammad Ali	FBK (associato TIFPA)			0.2	
Gianmaria Collazuol	PA Univ. di Padova				0.2
Marco Mattiazzi	Dottorando (associato sez. Padova)				0.7
Matteo Feltri	Dottorando (associato sez. Padova)				0.3
TOTALE FTE	**11.7**	**4.8**	**3.5**	**2.2**	**1.2**