Avalanche Diodes Array – 5D
(ADA_5D)

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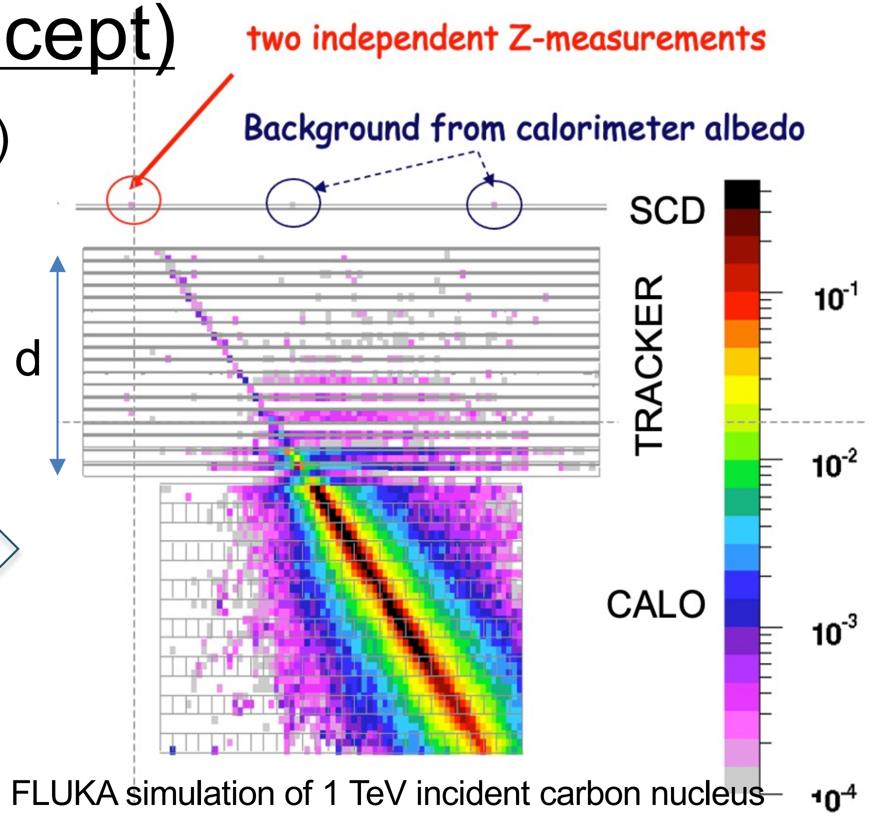
ADA_5D (concept)

CHARGE IDENTIFICATION of cosmic-ray (CR) ions with charge $1 \leq Z \leq 30$ via $dE/dx \propto Z^2$ measurements in a dedicated **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.) + tracker + calorimeter



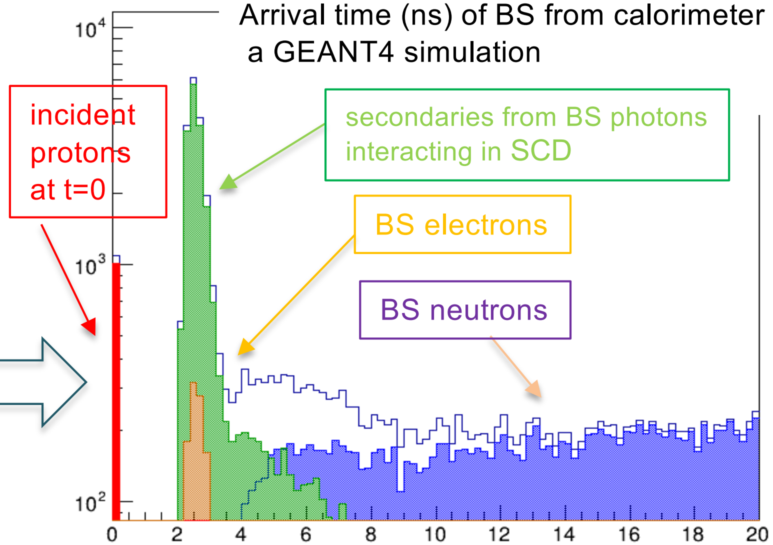
FLUKA simulation of 1 TeV incident carbon nucleus

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

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

ADA-5D concept: BS rejection with a high resolution ToF measurement for the next generation of multi-TeV calorimetric experiments in space

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



example:
d = 30 cm

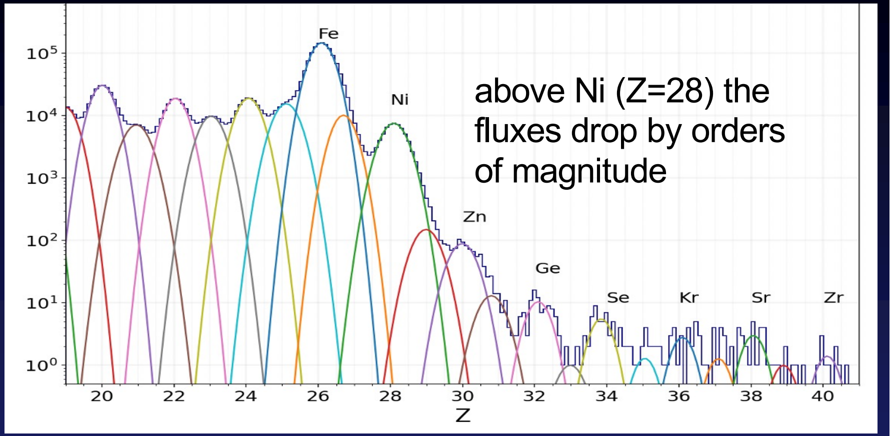
total delay
$\Delta t \sim 2$ns

Charge measurement requirements

- DYNAMIC RANGE

  baseline: O(1000) MIP from p to Zn ($1 \leq Z \leq 30$)

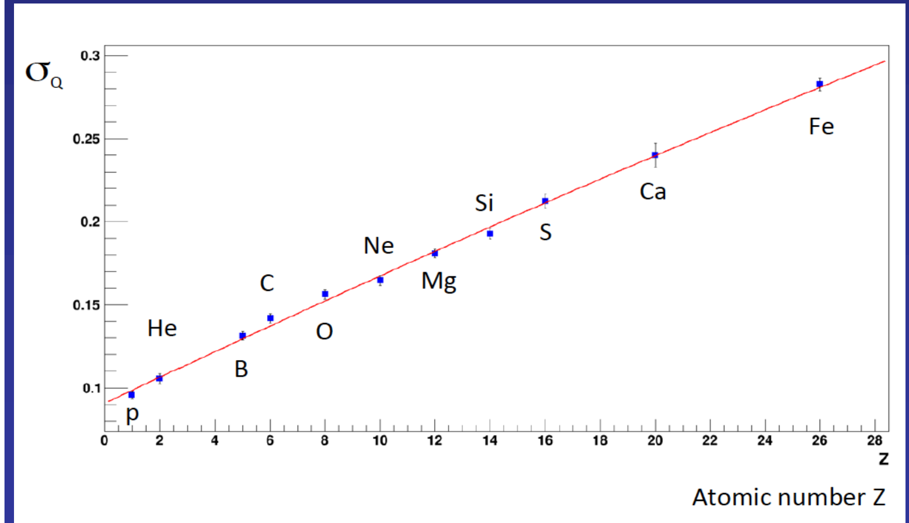
  extension (TBD) to trans-iron Z<40 => 1600 MIP

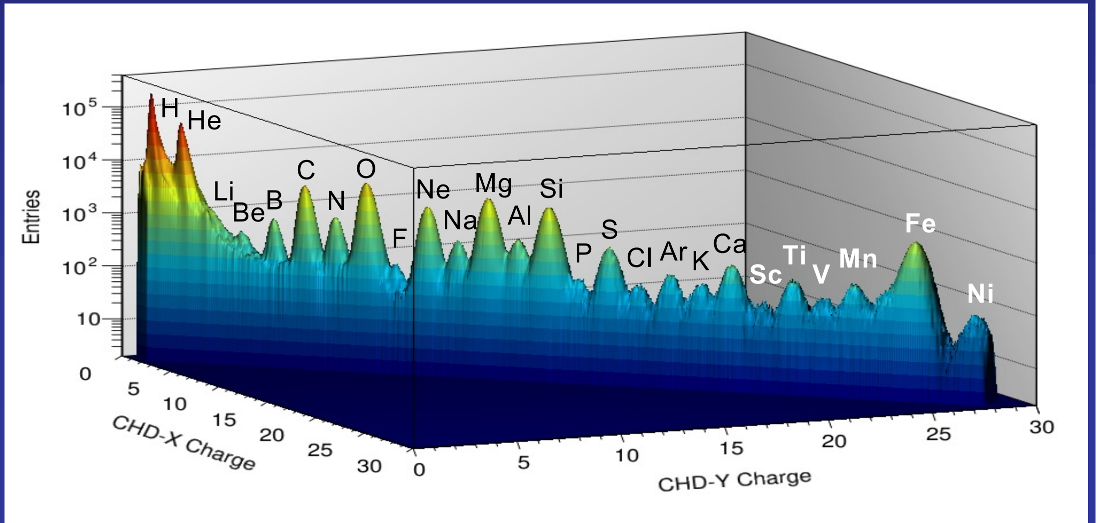


- CHARGE RESOLUTION

  200-300 um thick LGA to reduce the Poissonian fluctuations on the PRIMARY ionization

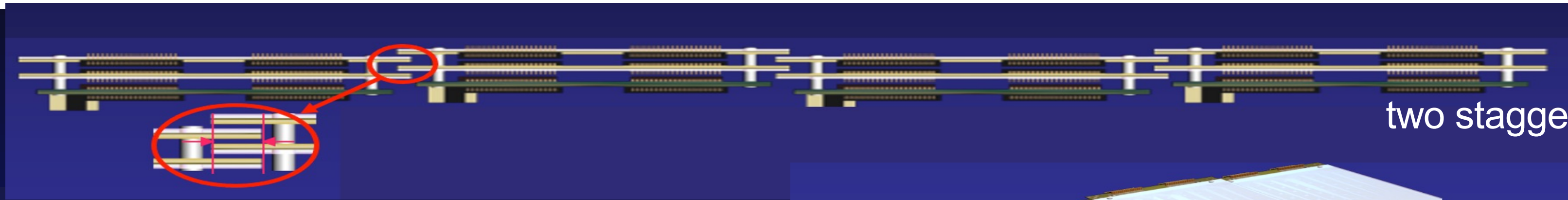
  An example from CALET (plastic scintillator paddles) on the ISS since 2015:
  charge resolution: proton ~0.1 -> Fe, Ni ~ 0.28 (charge units)



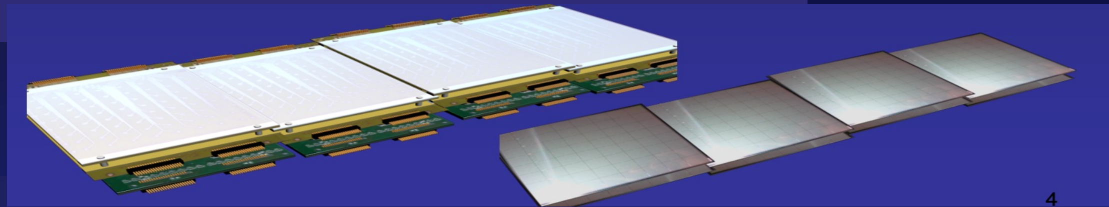


ADA_5D Charge & Timing 5D detector: x,y,z, time, charge

Development of a pixelated ToF detector with 100 ps time resolution (based on **LGAD** sensors) for the charge identification of CR elements up to Z=40



two staggered layers



- Charge measurement:

  very large dynamic range O(1000) MIP (for $1 \leq Z \leq 30$, 1600 MIP for trans-iron Z<40)

  charge resolution for proton < 0.1 => 200-300 um sensors for primary ionization

- Timing measurement:
  sub-ns resolution (e.g., for 10 cm flight path → needs 100 ps resolution)

- 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)

- 4 -

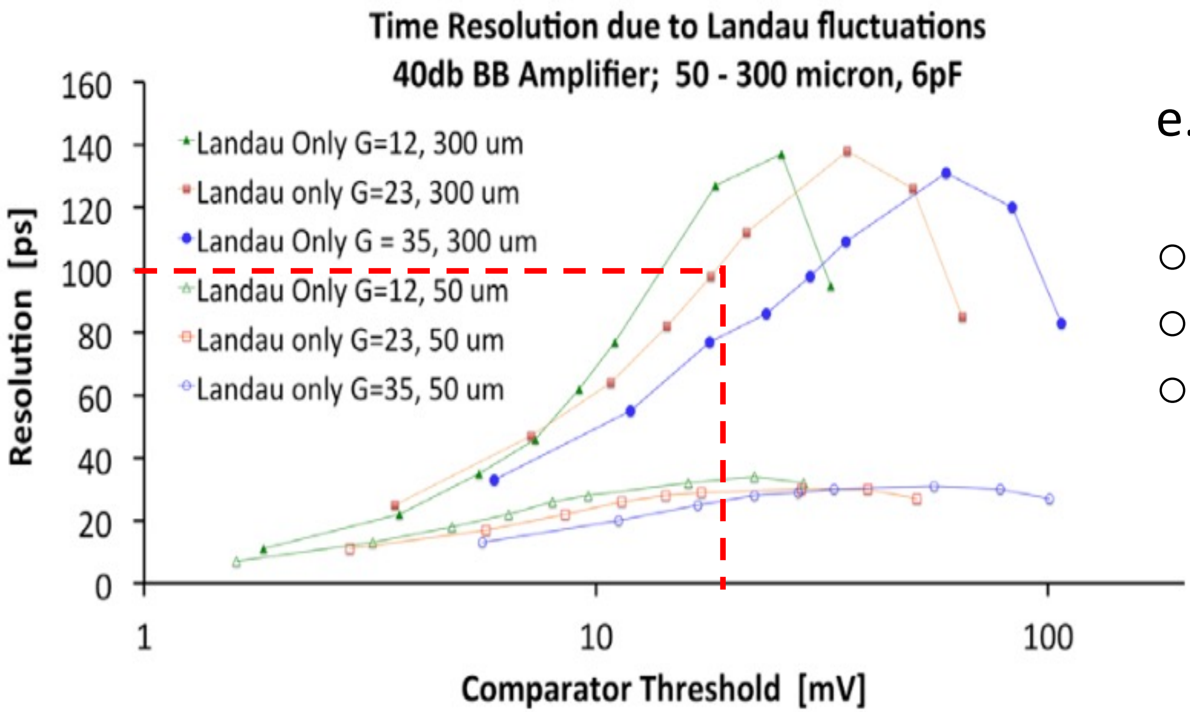
Timing measurement :

proposed development of LGADs for ADA_5D at FBK with:

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

with G~ 10-20 the time resolution is dominated by the jitter term

=> 100 ps resolution is feasible with a low threshold (realistic as S/N>30 for 1)



e.g.: 100 ps resolution with:

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

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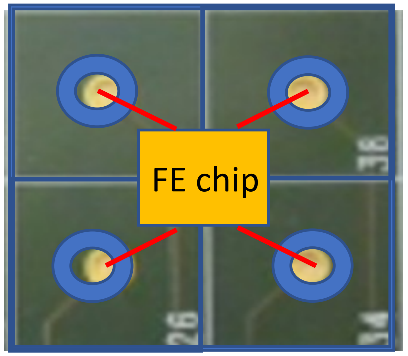
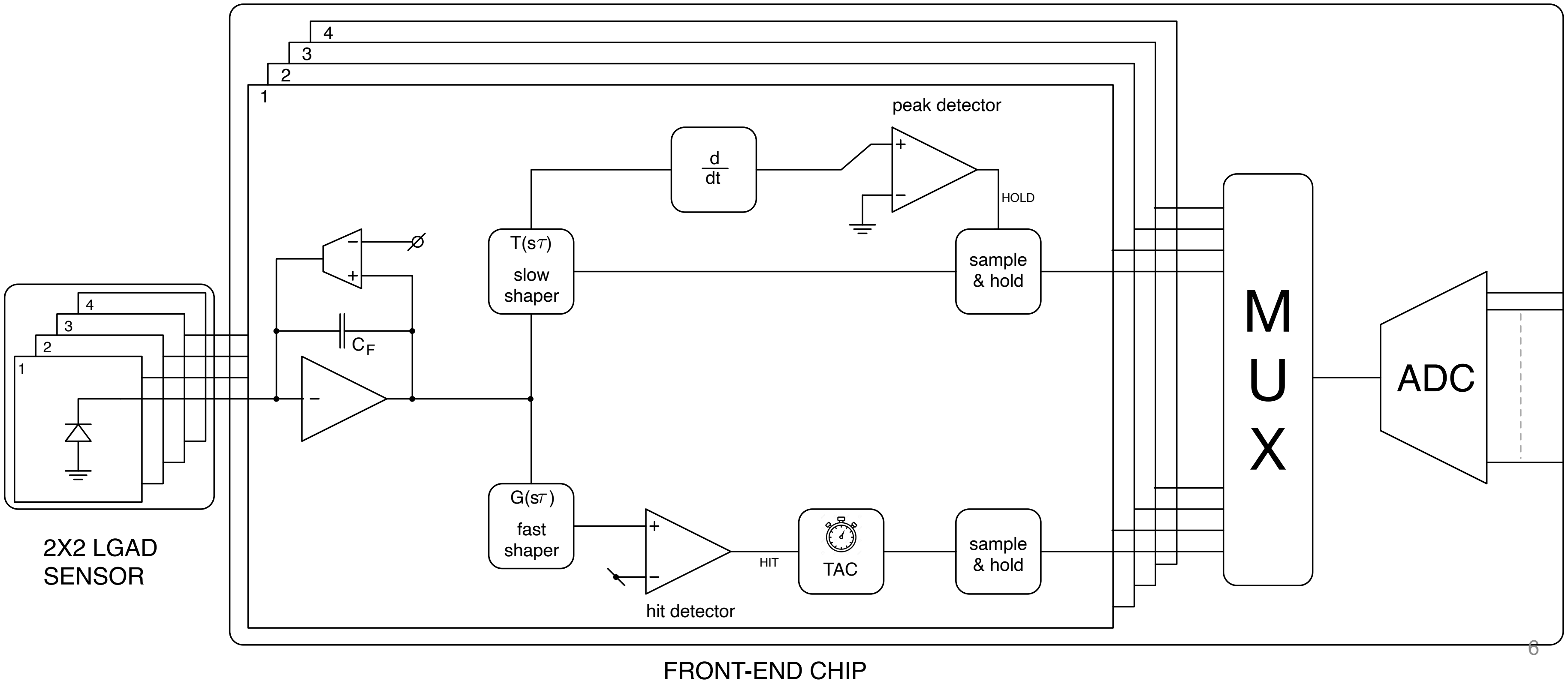


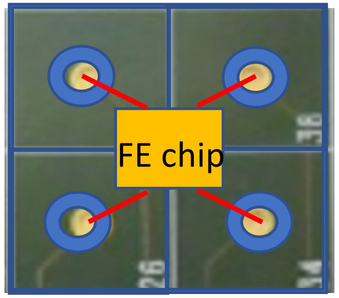
2x2 LGADs unit

Modular LGAD arrays based on a 2x2 building block

- each FE chip is connected to 4 LGADs (3x3 mm each)
- charge: slow shaper O(100ns) + sample & hold
- timing: fast shaper O(10ns) + TAC
- MUX x 8 digitization of time & charge via on-chip ADC
- **power requirement: <1.5 mW**

PIXEL FRONT-END ASIC (concept)

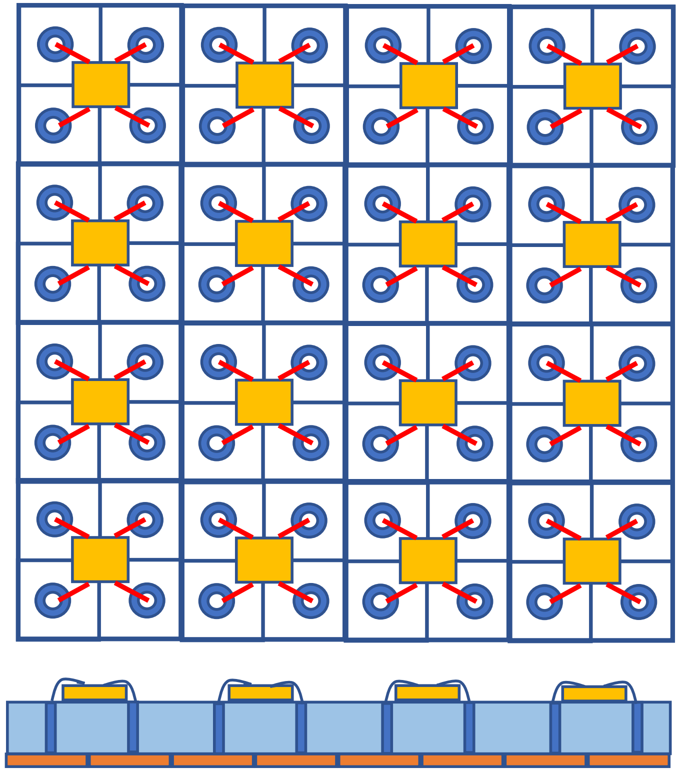




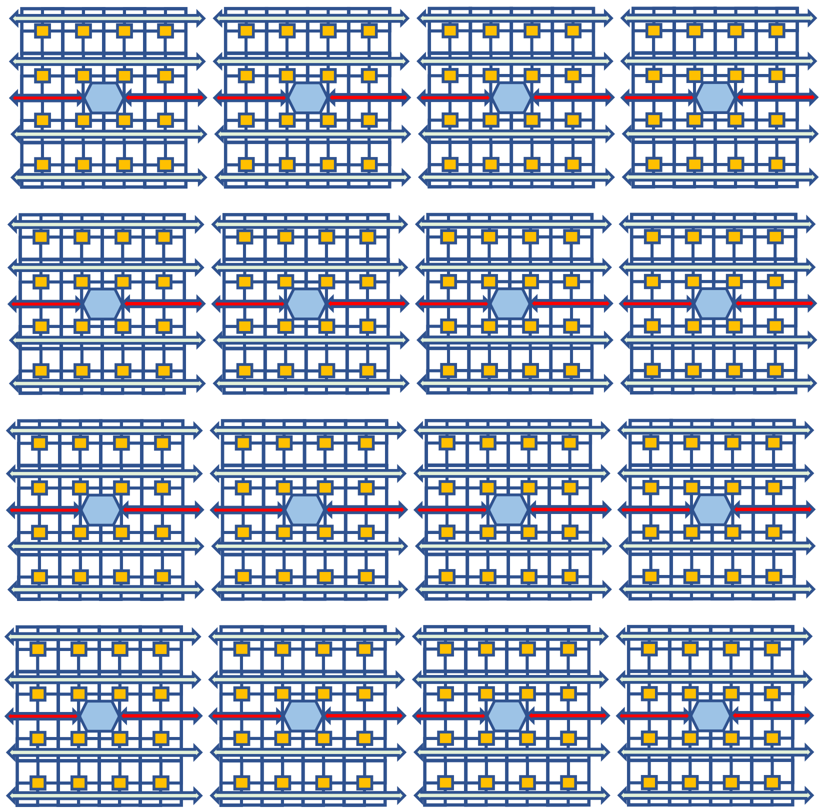
LGAD arrays in order of complexity

2x2 unit (6mm x 6mm) >> mini-TILE(64) >> TILE(1024) LGADs

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



ADA_5D: FTE a Pisa

PI/SI		**ADA_5D 2024**
Bigongiari Gabriele	PA Univ. di Siena + INFN Gruppo Collegato	**0.6**
Brogi Paolo	RTDB Univ. di Siena + INFN Gruppo Collegato	**0.8**
Checchia Caterina	Assegno di ricerca - Univ. di Siena - Associaz. INFN Pisa	**0.6**
Maestro Paolo	PA Univ. di Siena + INFN Gruppo Collegato	**0.4**
Marrocchesi Pier Simone	PO Univ. di Siena + INFN Gruppo Collegato	**0.7**
Stolzi Francesco	RTDA Univ. di Siena + INFN Gruppo Collegato	**0.6**
Messineo Alberto	PA (UNIPI) - Associaz. INFN Pisa	**0.1**
MIna Maghami Moghim	Dottoranda - UNISI - Associaz. INFN Pisa	**1.0**
TOTALE FTE		**4.8**
Basti Andrea	Tecnologo UNIPI	0.1
Morsani Fabio	Tecnologo INFN Pisa	0.1
Stiaccini Leonardo	Tecnico Università di Siena	0.5

	ADA_5D preventivi 2024 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			
Alberto Messineo	PA Univ. di Pisa + INFN Pisa	0.1			
Lodovico Ratti	PO Univ. di Pavia		0.4		
Piero Malcovati	PO Univ. di Pavia		0.3		
Marco Grassi	RTDB Univ. di Pavia		0.4		
Fatemeh Shojaei	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	PO Univ. di Trento			0.1	
Thomas Corradino	Dottorando (associato TIFPA)			0.3	
Gregorio Giovanazzi	Laurenado UniTN (associato TIFPA)			0.5	
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	Dottoranda (associata sez. Padova)				0.7
Matteo Feltre	Post-doc (associato sez. Padova)				0.3
TOTALE FTE	**11.2**	**4.8**	**3.5**	**1.7**	**1.2**

	ADA_5D 2024 - PREVENTIVI	PI/SI	PV	TIFPA	PD	TOT
Missioni	missioni in Italia (beam test sj nel 2024)	12	2	2	2	18
Consumo	2nd lotto FBK + 2nd run FE ASIC + r/o boards	9	32	30.5	10	81.5
Costruzione Apparati	FE ASIC (PV)		2			2
Inventariabile		8				8
TOTALE richieste x 2024		**29**	**36**	**32.5**	**12**	**110**

ADA_5D: Richieste di servizi in sezione per il 2024

- Supporto gruppo alte-tecnologie (micro-bonding)
- Supporto progettazione elettronica (2 mesi uomo)
- Supporto progettazione e stampa 3D (A.Basti)