



Silicon Detector R&D for the CSES missions and beyond

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Particle Physics Seminar @ Uni Bonn, 23/10/2025

Outline

1. CSES-01 mission

- ▶ Scientific objective
- ▶ Main results of 7 years of operation

2. High Energy Particle Detector HEPD-02

- ▶ Tracker based on MAPS
- ▶ FM performance in testbeams

3. Next-generation astro-particle silicon detectors

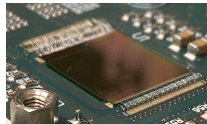
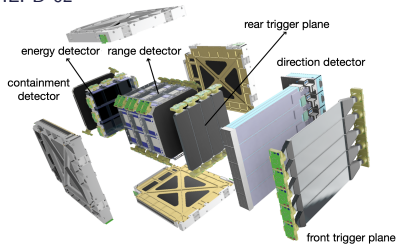
- ▶ Hybrid detector developments
- ▶ ARCADIA project of INFN
 - ▶ CMOS LGADs
 - ▶ chip design for a gamma-ray telescope

4. Outlook

CSES-01



HEPD-02



ARCADIA MD1

China Seismo Electromagnetic Satellite (CSES-01)



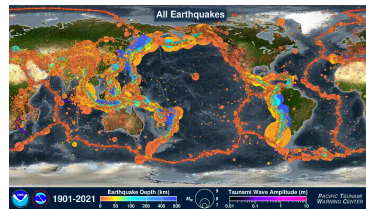
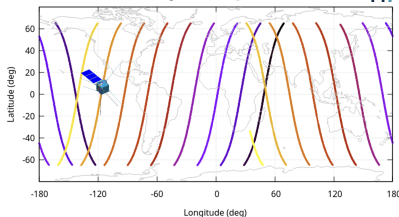
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- ▶ CSES-01 launched 02/02/2018
- ▶ from the Jiuquan Satellite Launch Center in the Gobi Desert (Inner Mongolia)
- ▶ sun-synchronous orbit
- ▶ ~ 500 km altitude
- ▶ Inclination 97°
- ▶ ~ 94 minutes period
- ▶ ~ 5 days return time
- ▶ Mission Life Span ≥ 5 years

main objective:
Detect Earthquakes from Space

1-day footprint



[link to YouTube](#)

Remote sensing of seismic events

How can signal km below ground travel up to 500km?

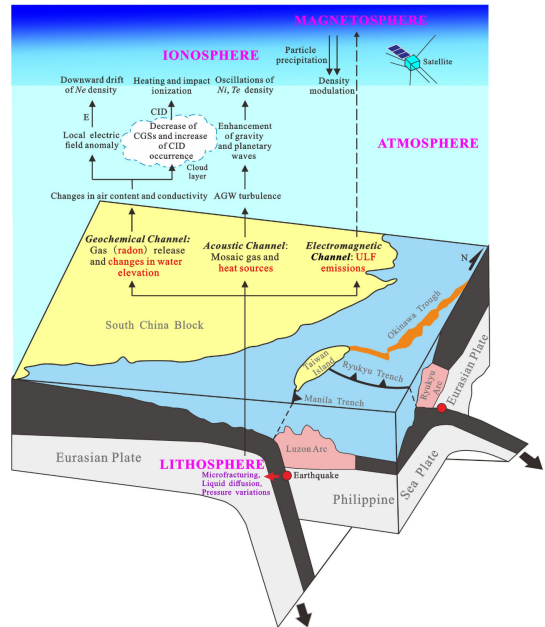
Lithosphere-Atmosphere-Ionosphere Coupling (LAIC)

1. air ionization from the alpha radioactivity of radon
2. EM waves from the cracks in the lithosphere
3. Acoustic Gravity waves (AGW)
4. chemical reactions or others..

single case evidence exists that atmospheric and ionospheric disturbances may precede some earthquakes

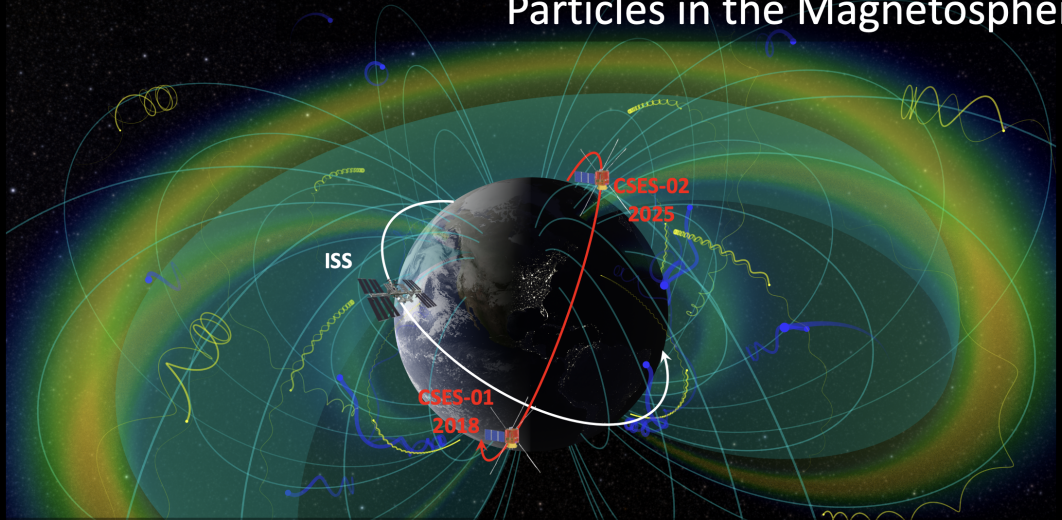
Proof via statistical study very complicated, because

- ▶ lithosphere / atmosphere highly irregular
- ▶ ionosphere very dynamic
- ▶ satellite observations non stationary



[Guo, Y. et al. Atmosphere 2022, 13, 1523.]

Particles in the Magnetosphere



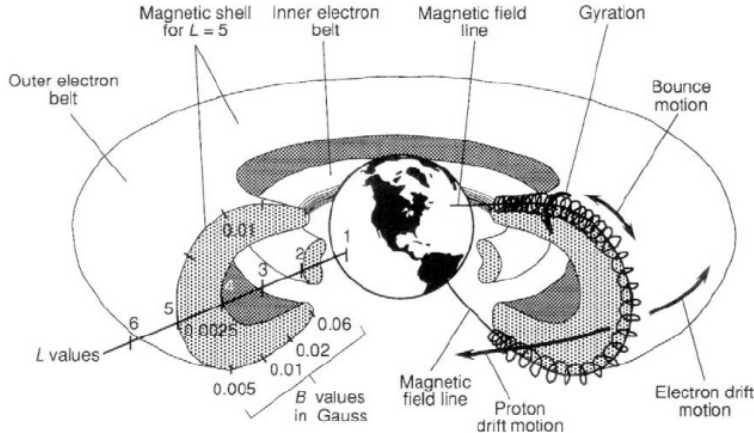
Particles **trapped** in the Earth magnetic field create regions of **high radiation** called **Van Allen belts**. The **CSES constellation** allows for **precision measurement of trapped particles composition and stability** in the energy range from **100 KeV to 300 MeV** complementing the current AMS-02 sensitivity **> 500 MeV** and the previous Pamela data **> 50 MeV**

Motion of charged particles in Earth magnetic field

originating from solar winds and cosmic rays



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3 types of motion:

1. Gyromotion along magnetic field lines
2. Bouncing between mirror points
3. Longitudinal drift
East-wards for negatively charged particles

Inner belt: $(1.5-2)R_E$ in L-shell, electrons $< 1\text{MeV}$

& protons $> 100\text{ MeV}$

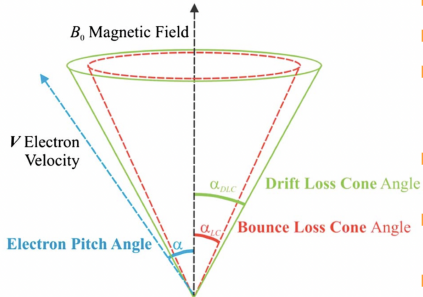
Outer belt: $(4-5)R_E$ in L-shell, electrons $100\text{ keV} - 10\text{ MeV}$

- pitch angle (electron velocity vector and B field) at mirror point 90°

Pitch angle of trapped particles



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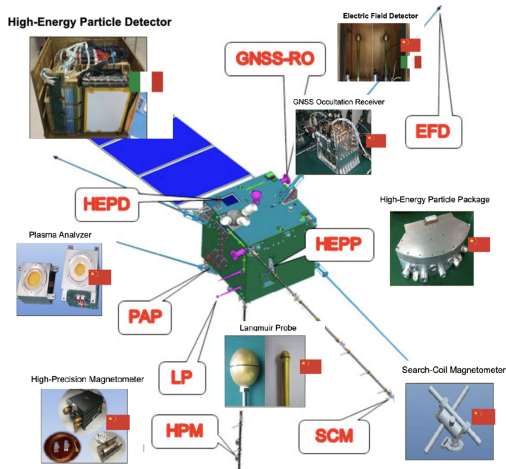
[J.C. Rodger et al., (2013)
doi:10.1002/2013JA019439]

- ▶ pitch angle changes along the magnetic field line
- ▶ locally trapped particle has a pitch angle of 90°
- ▶ trapped particles have a range of pitch angle at the geomagnetic equator from 90° down to the bounce loss cone angle, (α_{BLC})
- ▶ pitch angles are generally referenced to the geomagnetic equator
- ▶ particle whose pitch is smaller than α_{BLC} will mirror at altitudes below ~ 100 km \rightarrow lost through precipitation
- ▶ angular width of the BLC is dependent on the geomagnetic field strength
- ▶ particle with $\alpha_{BLC} < \alpha < \alpha_{DLC}$ drift around world (mirroring above atmosphere)

CSES-01 payloads



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magn. field + EM waves

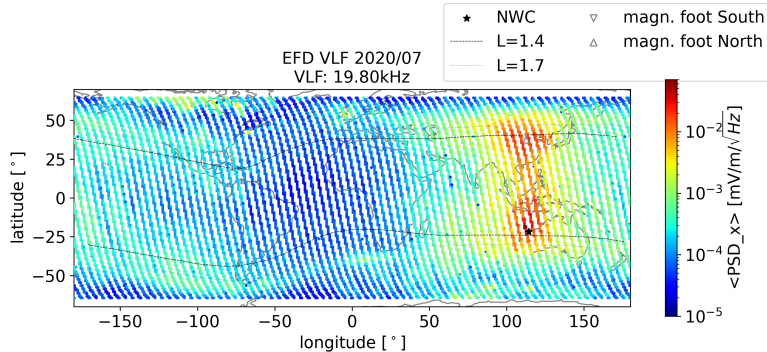
Ionospheric plasma Particles of magnetosphere

Payloads	Parameters
High Precision Magnetometer (HPM) Two flux gate + one coupled dark state magnetometer (CDSM)	DC to 16 Hz
Search-Coil Magnetometer (SCM)	10 Hz ~20 kHz
Electric field detector (EFD)	DC~3.5 MHz
Plasma analyzer package (PAP)	Ion density : $10^2 \sim 10^7 \text{ cm}^{-3}$ Ion temperature: 500~10000 K Ion content: H^+ , He^+ , O^+ Ion drift velocity: V_{xyz}
Langmuir probe (LAP)	Electron density : $10^2 \sim 10^7 \text{ cm}^{-3}$ Electron temperature : 500~10000K
GNSS Occultation Receiver (GOR)	TEC, Ne Profile
Tri-Band Beacon (TBB) : Three bands : 50/400/1066MHz	Air Refraction index, Profile of air temperature and pressure Ionospheric scintillation index
Energetic particle detector (HEPP-H, L, X ray)	Proton flux : 1.5MeV ~ 200MeV Electron flux : $\geq 100 \text{ keV}$ Pitch angle : 5° HEPP-X : 0.9~35 keV
Italian Energetic particle detector (HEPD)	Proton flux: 30- 200 MeV Electron : 30- 100 MeV ;

9 payloads onboard designed to target all possible propagation chains of LAIC

Terrestrial sources – radio transmitters –

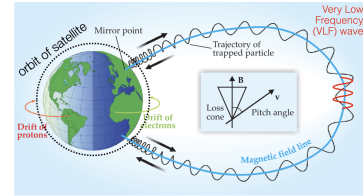
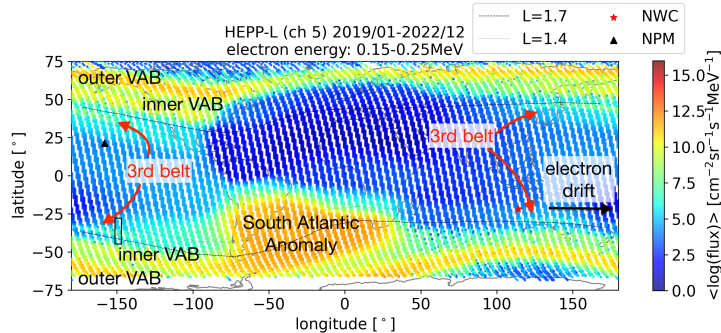
EM wave with Electric Field Detector (EFD)



- ▶ Very Low Frequency (VLF) transmitter NWC (Australia) at 19.8kHz creates 3rd radiation belt
- ▶ Whistler waves in cyclotron resonance cause pitch angle and energy scattering of electrons
→ precipitate to lower L-shell → trapped and drift eastwards

Terrestrial sources – radio transmitters –

150 - 250keV electron flux

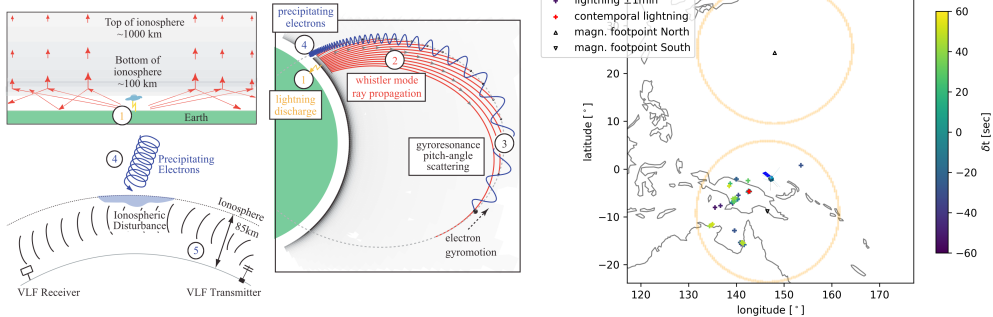


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Lighting-induced Electron Precipitation (LEP)



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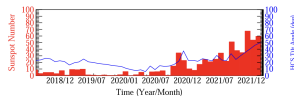
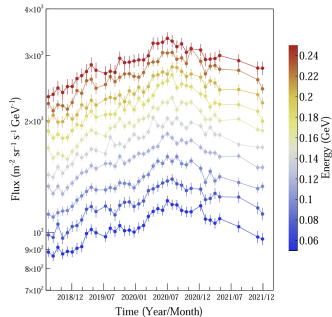
combination of wave and particle observations of CSES-01 + ground-based lightning database:

1. lightning strike
2. VLF wave (1-10 kHz) in 15° cone (possibly conjugate footpoint) in 0 to 200 ms
3. short electron burst within 0 to 9 seconds after

→ 2,311 LEP events in 4 years (publication in collaboration review)

Space Weather – proton flux –

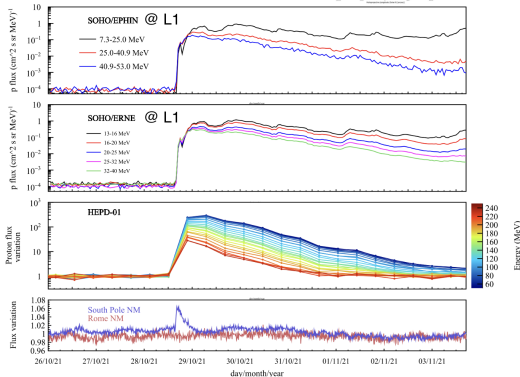
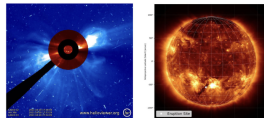
Galactic cosmic ray proton modulation with Sun
- maximum flux at solar minimum



[M. Martucci et al. 2023 ApJL 945 L39]

- ▶ selection galactic protons >50 MeV ($L > 7$)
- ▶ excluding high solar activity periods and solar energetic particle (SEP) events

long duration
X1 solar flare



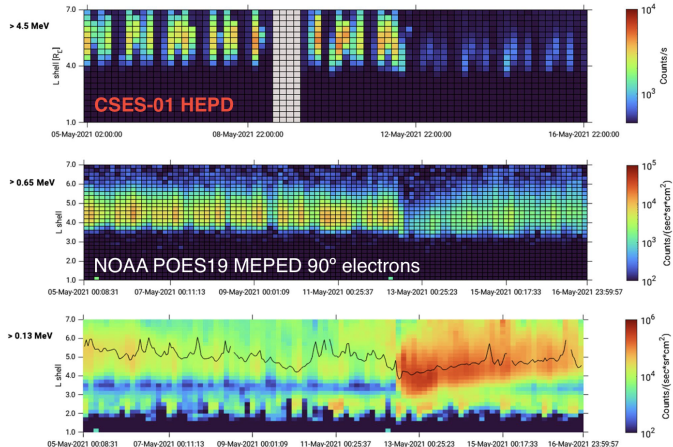
- ▶ caused Ground Level Enhancement (showers detected by ground-based neutron monitors)
- ▶ HEPD-01 provides spectral information



[M. Martucci et al. Space Weather, 21]

Space Weather – geomagnetic storm –

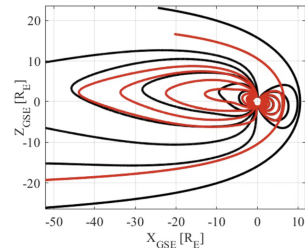
On May 12, 2021, a Coronal Mass Ejection (CME)



CME emitted on May 9 from a filament on the Sun's surface

— Before the IPs
— After the IPs

TS04 - Magnetospheric field line configuration



- ▶ primary impact of the storm: rapid loss of relativistic electrons from the outer radiation belt (magnetospheric shadowing)



TIFPD

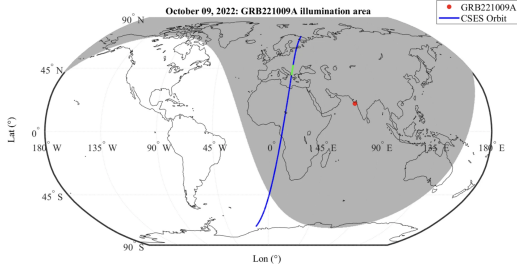
[M. Piersanti et al. Space Weather, 2021]

Brightest Of All Times (BOAT) Gamma Ray Burst (GRB)

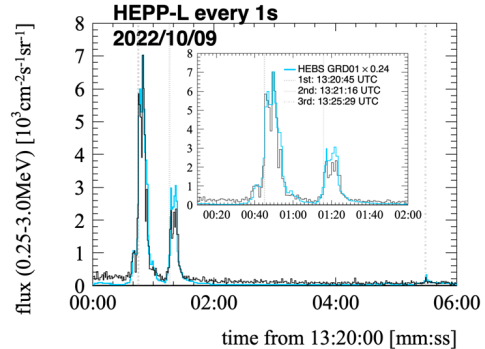
October 9th 2022: *GRB221009A*



- ▶ a massive star undergoing a supernova
- ▶ photons with energies above 10 TeV
- ▶ HEPP-L measures electrons produced through photon absorption in surrounding passive materials
→ impressive agreement in time evolution



[Piersanti, M., et al. doi:10.1038/s41467-023-42551-5]



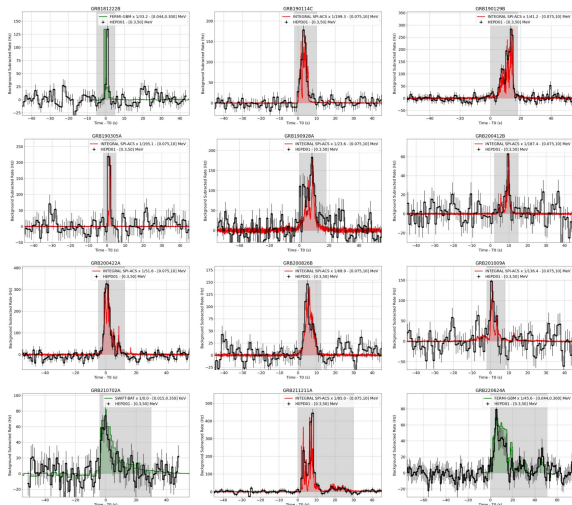
[R. Battiston et al, 2023 ApJL 946 L29]

- ▶ PBs detected well above 3σ
- ▶ here example of lowest/highest energy bins

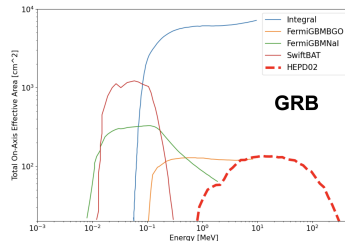
GRB detection with HEPD-01



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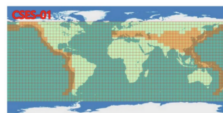
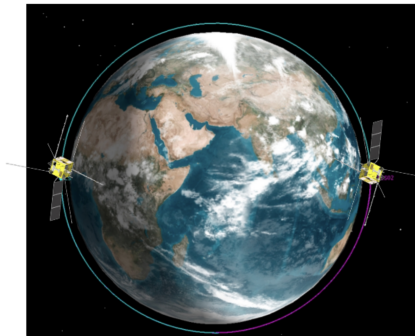
- ▶ GRBs no target for CSES-01 mission
- ▶ found 12 GRBs with HEPD rate meter (1st Scintillator trigger plane)
- ▶ automated detection of GRBs above background modelled over ± 16 days in 60s windows
- ▶ from 08/2018 to 06/2022
- ▶ HEPD-02 includes trigger configurations targeting GRBs



[F. Palma et al 2024 ApJ 960 21]

[S. Bartocci et al 2024 ApJ 976 239]

- ▶ Launched June 14th, 2025
- ▶ Same DFH CAST-2000 platform of CSES-01 with some upgrades
- ▶ Earth oriented 3-axis stabilization system with orbit manoeuvre capability
- ▶ X-Band Data Transmission 120Mbps → 150Mbps
- ▶ Storage 160Gb → 512Gb
- ▶ Total Mass: 730kg → 900kg
- ▶ Peak Power Consumption: 900W
- ▶ Design Life-span: 5 years → 6 years
- ▶ Complementary Ground Track wrt CSES-01
- ▶ Identical Orbit Plane
- ▶ **180° Phase Difference**
- ▶ Track interval: $5^\circ \rightarrow 2.5^\circ$
- ▶ Return cycle: 5 days → 2.5 days
- ▶ **Operation mode: Full time operational**



Confined Areas Observation

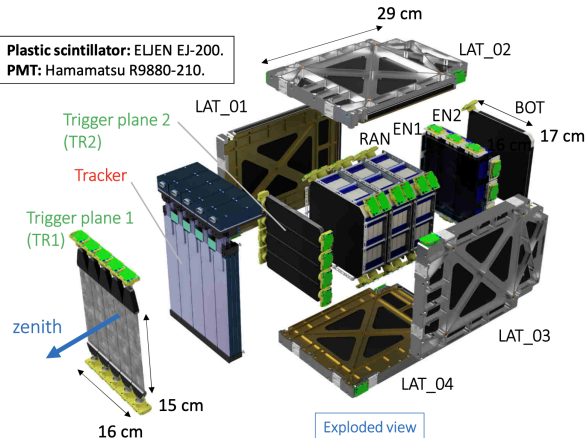


Global Wide Observation

R. Iuppa @ CRIS-MAC13

The HEPD-02 instrument

- **1/5. Trigger detectors (TR1, TR2).**
 - **Plastic scintillators / PMTs:** 2 planes, 5+4 mutually orthogonal bars.
 - HEPD-01 had a single plane.
- **2/5. Particle tracker.**
 - **Si Monolithic Active Pixel Sensors (MAPS):** 3 planes in 5 adjacent "turrets".
 - HEPD-01 had double-sided Si microstrips, 2 planes.
- TR1 and tracker **tightly packed together**, matching active area and segmentation.
 - **Asymmetric wave-guide read-out** on opposite ends of TR1 bar.
- **TR1 thickness minimized to 2 mm** (mechanically challenging).
 - This **reduces multiple scattering** before tracker **and energy threshold** for coincidence with TR2.



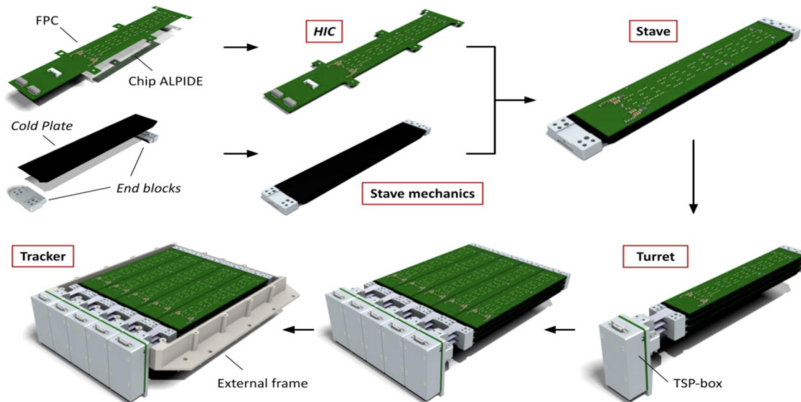
SB Ricciarini - PM2024

7

S. Bruno Ricciarini @ PISA2024

HEPD-02 tracker

a 80 megapixel CMOS camera for charged radiation



10 chips per stave → 3 staves per turret → total 5 turrets: 150 chips
everything × 2 for QM & FM

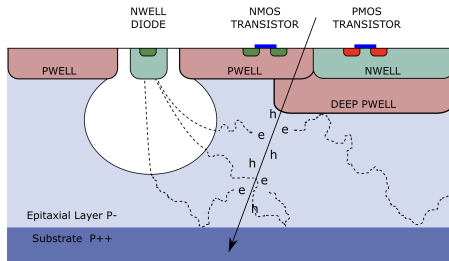
[R. Iuppa et al. PoS(ICRC2021)070]

ALTAI – updated ALICE ALPIDE chip

Monolithic Active Pixel Sensor (MAPS) [NIM A 824 (2016) 434–438]



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- ▶ integrated readout electronics
- ▶ CMOS 180nm technology from Tower Jazz
- ▶ non-depleted → charge collection by diffusion

Advantages

- ▶ reduces systematic uncertainties
- ▶ cheaper than standard microstrips
- ▶ extremely low material budget

Parameter

Values

Detector size [mm ²]	15 x 30
Columns x rows	1024 x 512
Pixel size [μm x μm]	26.9 x 29.2
Detector thickness [μm]	50
Spatial resolution [μm]	5
Detection efficiency	>99%
Fake hit rate [evt ⁻¹ pixel ⁻¹]	<10 ⁻⁷
Integration time [μs]	~2
Power density [mW/cm ²]	<50

70k chips produced and tested for 10m² active silicon area, 12.5 × 10⁹ pixels at ALICE ITS

Challenges

1. limited power budget
2. heat dissipation
3. rigidity to withstand launch acceleration and vibrations
4. digital readout: limited info on charge

Space qualification MAPS



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Solutions

1. mitigating power consumption to target of ~ 13 W

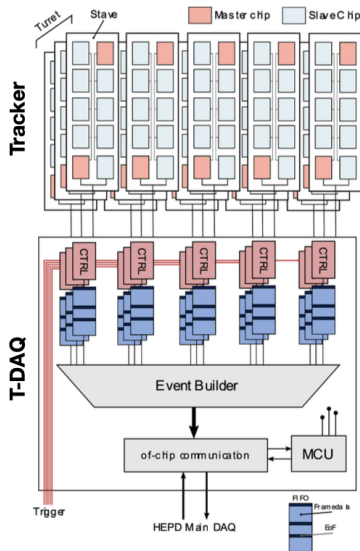
ALICE ITS OB Master-slave architecture (1 master out of 5 chips) with sequential slave

Permanent switch-off of fast data transmission unit (DTU) and read-out through serial slow-control line.

- ▶ Acceptable increase of dead time, given the relatively low trigger rate (up to few kHz).

Clock gating: clock normally off, set on with trigger

- ▶ trigger: clock on (17 mW/cm²);
- ▶ wait for signal digitization;
- ▶ transmit data to control/read-out electronics;
- ▶ clock off (7 mW/cm²): wait for new trigger



Solutions

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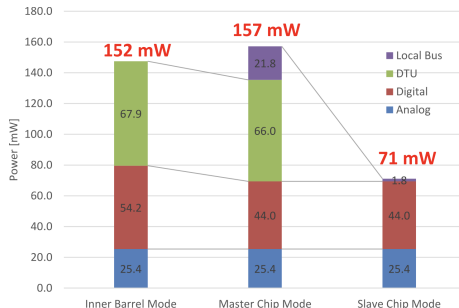
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Solutions

2. heat dissipation and mechanical support

Mechanical support

Conditions:

- ▶ vacuum of $6.65 \cdot 10^{-3}$ Pa
- ▶ repeated thermal cycles from -30° to $+50^{\circ}$
- ▶ needs to resist 10G

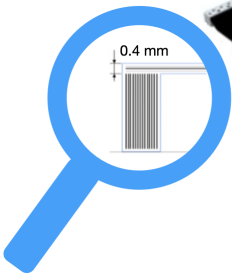


TARGET: stiffness and thermal drain

Cooling is granted by material thermal conductivity
support has to be **stiff** enough to resist to 10G
the **material budget** has to be minimized

Material budget of STAVEs

STAVE element	material	thick [μm]	rad.length X ₀ [%]
FPC board	capton	135	0.048
FPC tracks	Cu	36	0.251
glue	ARALDITE 2011	130	0.029
ALTAI	Si	50	0.053
cold plate	Carbon fiber + epoxy resin	350	0.134
Total:			0.515



C-shaped carbon fiber
(400 μm thick)

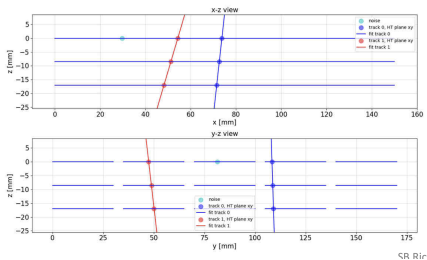
aluminum
end blocks

[E. Serra et al. 2022 Conf. Ser. 2374 012049]

Performance of HEPD-02 tracker – testbeams



- ▶ noisy pixels of ~ 1 k over 80 M
- ▶ "non-noisy" hit pixels are clustered (DBSCAN) and track seeds are identified (Hough transform)
- ▶ residual noise clusters are easily identified by requiring 3-planes tracks



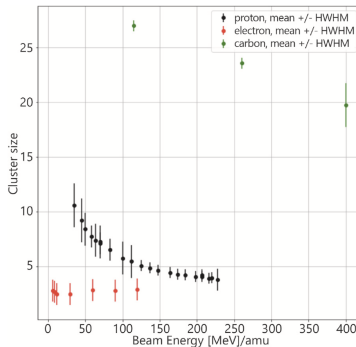
S. Bruno Ricciarini @ Pisa Meeting 2024

Electrons: 30-450MeV @ BTF, Frascati

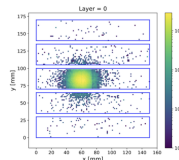
Electrons: 6-12MeV/ γ @ Medical LINAC

Protons: 20-230MeV @ Proton Terapia

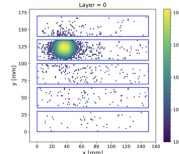
Carbon: 115-400MeV/amu @ CNAO, Pavia



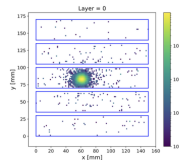
Protons - 70 MeV



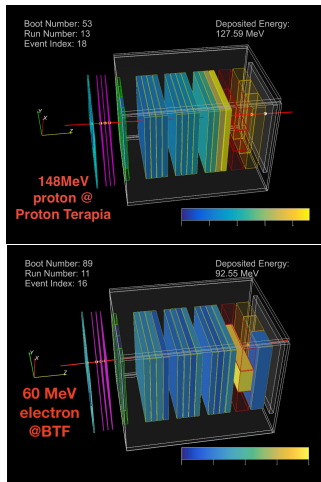
Protons - 164 MeV



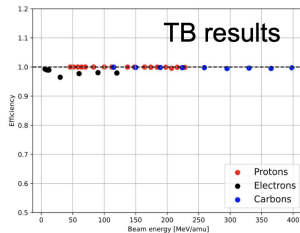
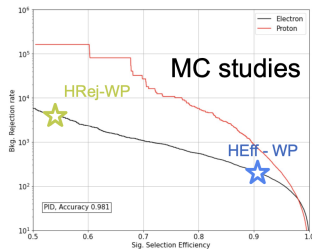
Protons - 228 MeV



Performance of HEPD-02 – particle identification



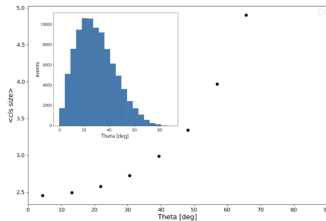
Courtesy of F. M. Follega



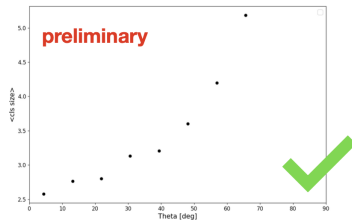
- ▶ PID results obtained using a DNN, combined inputs of cross-correlation between release in front (TR2) and inner (RAN) scintillator layers
- ▶ PID efficiency in TB tested to be $> 95\%$ for low energy electrons

Performance of HEPD-02 tracker – cosmic muons

Cosmic rays data acquisition
before integration in CSES-02
statistics: about 117,000 events



Cosmic rays data acquisition
after integration in CSES-02
after vibrational tests
statistics: about 7,000 events



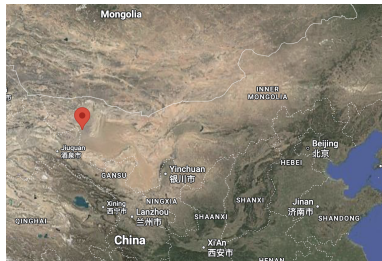
U. Savino @ CRIS-MAC13

Launch of CSES-02 on 14/06/2025

from Jiuquan Satellite Launch Center, 1,600 km from Beijing



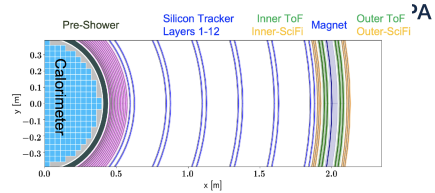
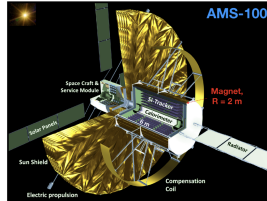
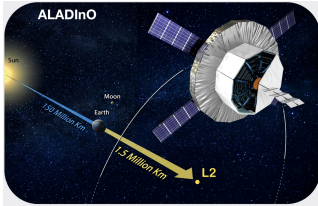
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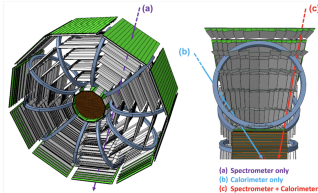
- ▶ ignition of HEPD-02 on 20/06/2025 07:50
- ▶ all detector sub-systems functional
- ▶ **commissioning ongoing..**

Play video
[from this website](#)

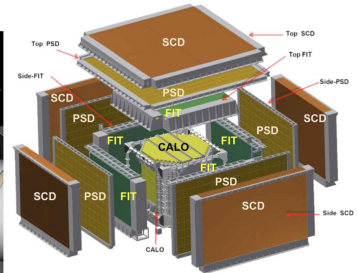
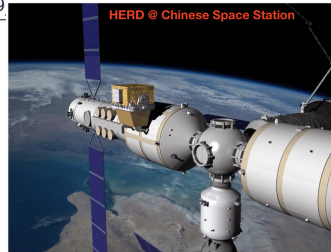
Next generation Astro-particle experiments



[O. Adriani, et al. Instruments 2022, 6(2),19]



[R. Battiston, et al. Exp Astron 51 (2021)]



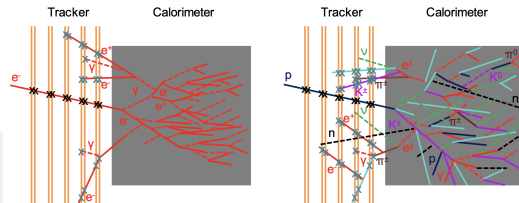
Requirements on tracking detectors

Operating Missions						
	Mission Start	Si-Sensor Area	Strip-Length	Readout Channels	Readout Pitch	Spatial Resolution
Fermi-LAT	2008	$\sim 74 \text{ m}^2$	38 cm	$\sim 880 \times 10^3$	228 μm	$\sim 66 \mu\text{m}$
AMS-02	2011	$\sim 7 \text{ m}^2$	29–62 cm	$\sim 200 \times 10^3$	110 μm	$\sim 7 \mu\text{m}$
DAMPE	2015	$\sim 7 \text{ m}^2$	38 cm	$\sim 70 \times 10^3$	242 μm	$\sim 40 \mu\text{m}$
Future Missions						
	Planned Operations	Si-Sensor Area	Strip-Length	Readout Channels	Readout Pitch	Spatial Resolution
HERD	2030	$\sim 35 \text{ m}^2$	48–67 cm	$\sim 350 \times 10^3$	$\sim 242 \mu\text{m}$	$\sim 40 \mu\text{m}$
ALADInO	2050	$\sim 80\text{--}100 \text{ m}^2$	19–67 cm	$\sim 2.5 \times 10^6$	$\sim 100 \mu\text{m}$	$\sim 5 \mu\text{m}$
AMS-100	2050	$\sim 180\text{--}200 \text{ m}^2$	$\sim 100 \text{ cm}$	$\sim 8 \times 10^6$	$\sim 100 \mu\text{m}$	$\sim 5 \mu\text{m}$

- ▶ large area
- ▶ high number of readout channels
→ clever readout architectures for low power
- ▶ 5D tracking = position + charge + **timing**

hit time resolution of $\sim 100 \text{ ps}$:

- improves track reconstruction (mitigate ghost hits & backscattered particle contamination)
- provide Time of Flight (ToF) measurement
- improves e/p separation



- affect tracking efficiency by tens % at 1 TeV

[M. Duranti et al. Instruments 2021, 5, 20]

Possible realisations of 5D tracking detectors



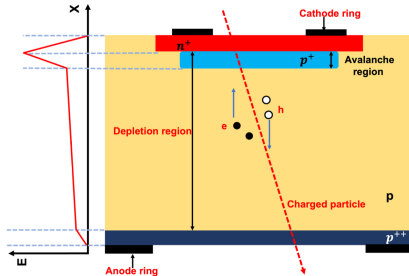
TIFPA

timing layers within Si micro-strip detector: Low Gain Avalanche Diodes (LGADs)

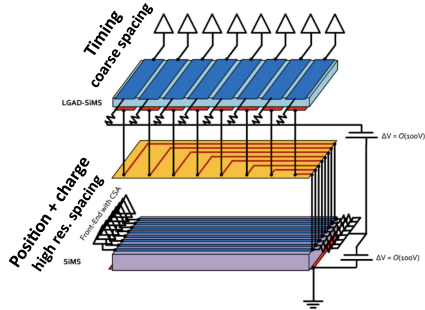
- ▶ development of large area Low Gain Avalanche Diodes (LGADs)

challenges:

- ▶ long strips/large channel size \rightarrow large capacitance: decreases S/N ratio
- ▶ signal propagation: delay (30ps \sim 1cm@c) & signal distortion
- ▶ gain uniformity



[A. Bisht et al. Instruments 2024,8,27.]



M. Duranti @ TREDI25

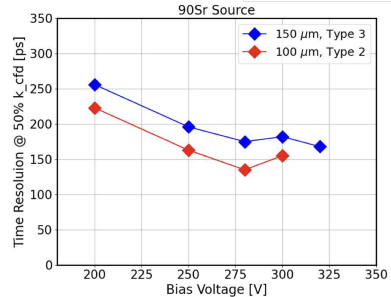
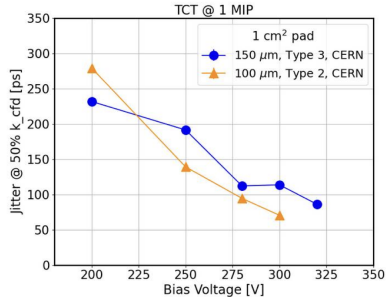
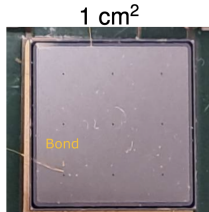
LGADs for Space @ FBK

strategy: increase signal with thicker substrate and higher gain

[L. Cavazzini TREDI2025]



TIFPA



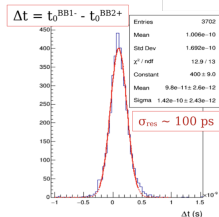
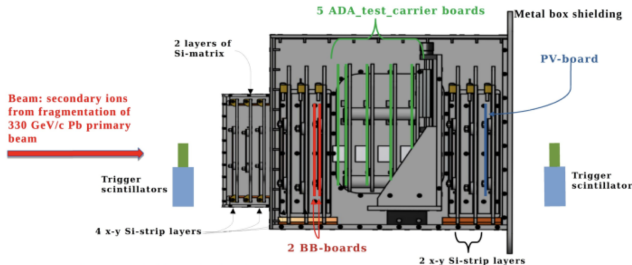
- Signal propagation and gain variation expected to account for 32 ps
- **Time resolution of 135 ps on 1 cm², 100 μm thick sensor**
- Expected improvement with different electronics
- Next batch for: gain tuning, signal propagation studies

Avalanche Diodes Array (ADA_5D)

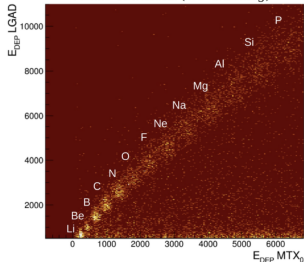
[P. Brogi TREDI2025]



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LGAD vs Matrix (NO-tracking)



- 5th dimension is charge
- Atomic number ID from charge deposit \Rightarrow thicker sensors
- Mixed ions beam
- Data analysis ongoing
- **Time res. 100 ps on $3 \times 3 \text{ mm}^2$ channel, $150 \mu\text{m}$ thick**
- Charge correlation between LGAD and other sensors

M. Centis Vignali @ VCI25

Developments of MAPS for space

Spoke 4 -Next Generation Detectors of Ionizing Radiation and Fields for Remote Sensing



WP 4.2 High-density, low-power silicon sensors for tracking ionizing particles in space

- Sensor design and fabrication
- Data Acquisition systems and Back End Electronics
- TRL assessment
- Sensor performance calibration

L: INFN, TL: UNIFI, UNITN, Others: FBK, UNITO (Art.15)

WP 4.3 SiPM based detectors for ionizing radiation in space

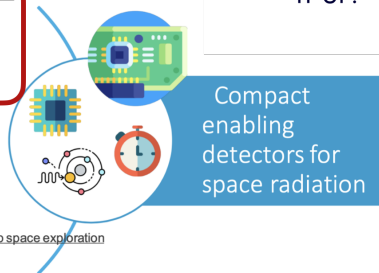
- Detector design and characterization
- Readout and Data Acquisition Electronics
- Prototype Integration
- Tests and TRL assessment

L: GSSI, TL: UNINA, Others: FBK, INAF, TASI

WP 4.6 New time and frequency references for detector synchronization and deep space exploration

- Analysis of requirements for microfabricated clock in space
- Analysis and design of critical components
- Critical components procurement, fabrication and testing

L: INRIM, Others: TASI, GSSI, INFN

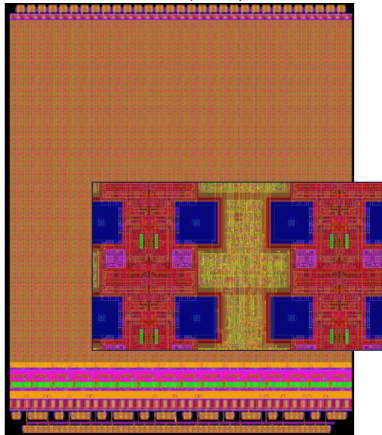


Compact enabling detectors for space radiation

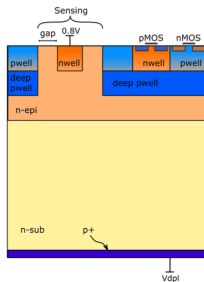
Embedded electronics, less components and connectors:

- ▶ no need for costly fine-pitched flip-chip assembly
- ▶ less (failing) connectors and lower material budget
- ▶ cost reduction for large productions

Main Demonstrator (MD1)

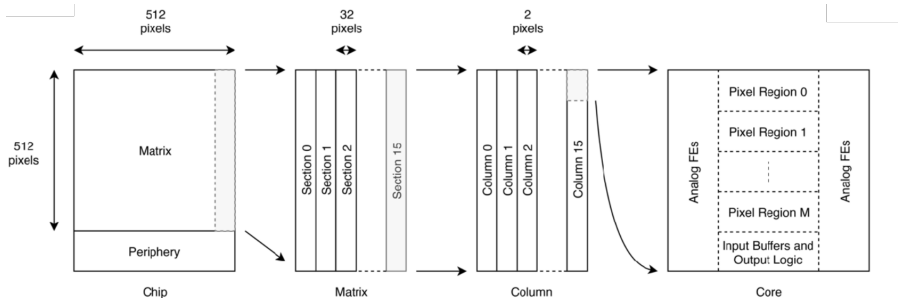


M. Rolo, INFN Torino



- ▶ 110 nm CMOS process with 1.2 V transistors, developed between INFN and LFOUNDRY
- ▶ fully depleted, charge collection by drift
- ▶ backside processing (diode+GR)
- ▶ low resistivity epi-layer for delayed on-set of punch-through currents
- ▶ matrix core 512×512 pixels of $25 \mu\text{m}$ pitch
- ▶ trigger-less and binary readout
- ▶ matrix and EoC architecture, data links and payload ID: scalable to 2048×2048 pixels
- ▶ pixels are $\sim(50/50)\%$ analog/digital
- ▶ sensor diode about 20% of total area
- ▶ 'side-abutable' to accommodate a 1024×512 silicon active area ($2.56 \times 1.28 \text{ cm}^2$)

MD3 chip architecture

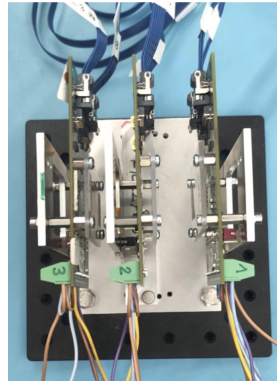
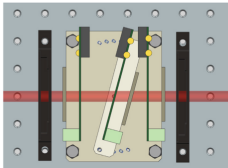
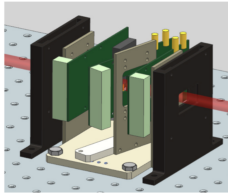


- * Pixel size $25\ \mu\text{m} \times 25\ \mu\text{m}$, Matrix core 512×512 , $1.28 \times 1.28\ \text{cm}^2$ silicon active area, side-abutable
- * Trigger-less data-driven readout and low-power asynchronous architecture with clock-less pixel matrix
- * Event rate up to $100\ \text{MHz/cm}^2$ (design post-layout simulations)
 - High-rate operation (16 Tx): $17\text{-}30\ \text{mW/cm}^2$ depending on transceiver driving strength (measured)
 - Low-power operation (1 Tx): $10\ \text{mW/cm}^2$ (all data conveyed in 1 transceiver, others turned-off)

Courtesy of M. Rolo

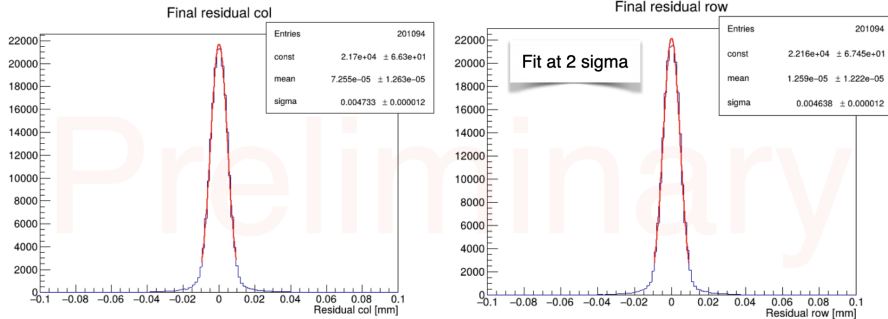
MD3 at test beam

- Test beam at FNAL (120 GeV protons): very good results from data analysis ongoing
- mini-telescope with 3 ARCADIA-MD3 200 μm thick sensors
- Threshold, sensor HV and incidence angle parametrisation: study of cluster size, collection efficiency, spatial resolution



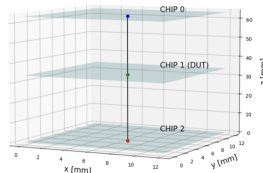
Courtesy of M. Rolo

Spatial resolution



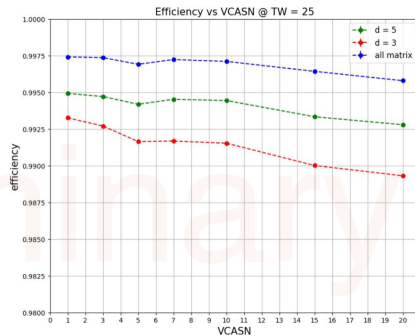
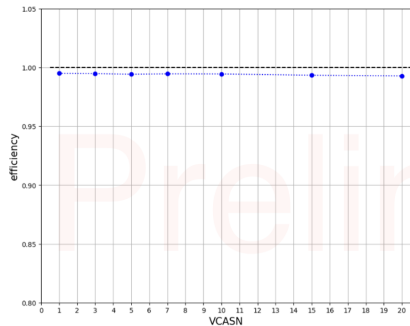
- Residuals plots @VCASN = 5 ($\sim 600\text{ e}^-$), still includes contributions from tracking planes
- angle of tilt = 0°
- Data with 1 cluster per plane, excluding clusters with multiplicity above 20

Single-point resolution $\sim 4.7\text{ }\mu\text{m}$



Courtesy of M. Rolo

Efficiency



- Efficiency plot vs. Threshold, scanned from 800 down 300 e⁻
- Time Window = 5 μ s, Spatial cut = 5 [pixels]

average efficiency 0.9941 +/- 0.0003

- d = spatial cut on DUT hits (pixel)
- d = 5 \rightarrow 11x11 matrix
- d = 3 \rightarrow 7x7 matrix

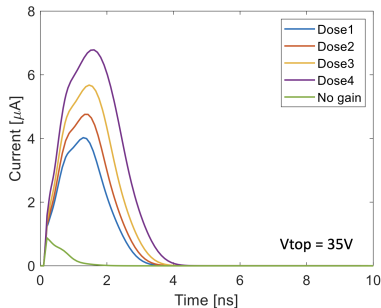
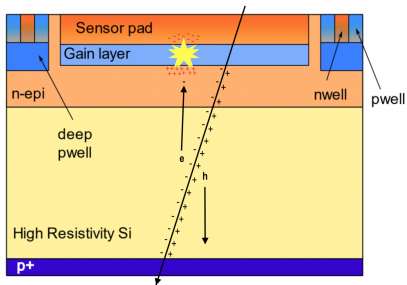
Courtesy of M. Rolo

Current R&D: ARCADIA CMOS LGADs

passive and active pixel matrices included in 3rd ARCADIA run



TIFPA



Courtesy of L. Pancheri

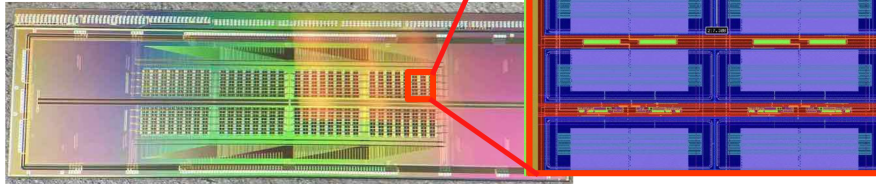
- ▶ $250 \times 100 \mu\text{m}^2$ pixels in active (8×8) and passive (2×4) matrices
- ▶ gain layer biased from top, depleted from bottom
- ▶ expected gain 10-30
- ▶ highly doped p+ layer below the collection n-well results in high electric field that accelerates arriving electrons which creates a cascade of charge carriers
- ▶ 4 dose splittings with 3 wafers per dose

MadPix chip

Monolithic CMOS Avalanche Detector PIXelated Prototype

- ◆ **MadPix** prototype with gain layer and integrated electronics
- ◆ first small-scale demonstrator $4 \times 16 \text{ mm}^2$;
- ◆ 8 matrices (64 pixel pads each) implementing different sensor and front-end flavours;
- ◆ $250 \times 100 \mu\text{m}^2$ pixel pads;
- ◆ 64 analogue outputs on each side, rolling shutter of single matrix readout;

U. Folto, S. Durando,
G. Gioachin, C. Ferrero



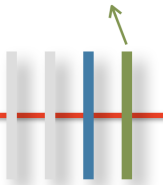
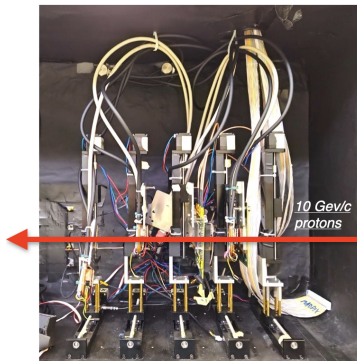
MadPix test beam



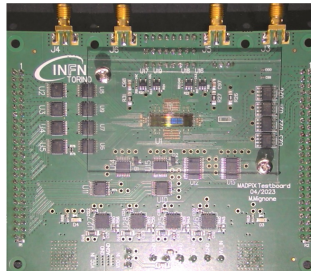
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ALICE3 TOF Test beam @ CERN PS - October 2024

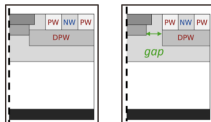
Trigger:
LGAD 1x1 mm 50 μ m
reference (28 ps r.m.s.)



MadPIX

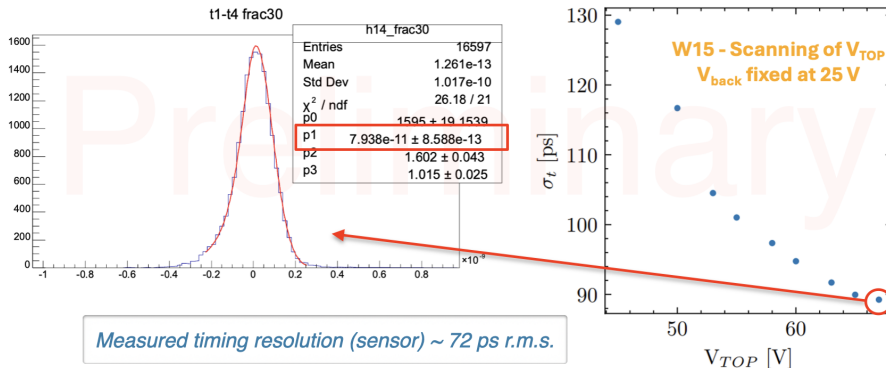


- 3 Test boards
- 2 Flavours
 - A1 and A2
- 4 Pixels
 - J3, J4, J5, J6



Courtesy of M. Rolo

MadPix performance



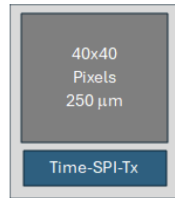
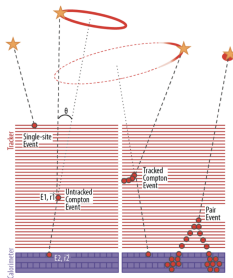
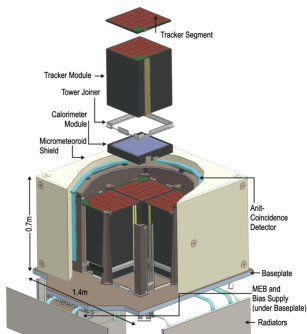
- ◆ Gain layer implemented (5-15) with very good matching with TCAD simulation framework
- ◆ MadPix test beam just concluded, timing resolution measured < 75 ps (very preliminary results)
- ◆ 48 μm thick active layer on a p+ substrate, timing resolution is sensor limited (FEE jitter ~ 20 ps r.m.s.)
- ◆ Up next: new short-loop with ARCADIA mask set and thinner n-epi active layer, start full-chip IP design for ALICE3 TOF

Courtesy of M. Rolo

Coming up...

CMOS and Sensor design for next generation Gamma-ray telescope:
2 ARCADIA runs with specialised chips

- ▶ Pilot run with thick ($600\text{ }\mu\text{m}$) wafers scheduled for Q2, FZ substrates procured and delivered – awaiting arrival
- ▶ demonstrator chip: $250\text{ }\mu\text{m}$ pixels + $\sim 1\text{mW}/\text{cm}^2$ power + analog readout (peak) + ADC on pixel + asynchronous readout to periphery



L. Latronico @ TREDI25

Conclusions Take home messages



TIFPA

- ▶ Space experiments at LEO like CSES need versatile set of detectors for identification of signal sources (terrestrial/solar/galactic)
- ▶ HEPD-01 has demonstrated capabilities of GRB detection
→ exploited further with CSES-02
- ▶ HEPD-02 detector is the first space experiment with MAPS tracker

Future space experiments...

- ▶ need large area, low power, 5D tracking detectors
- ▶ technologies to be ready in order to pass all qualification tests in time!
- ▶ profit from technology platforms like ARCADIA allow for parallel development for diverse applications

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Thank you for your attention!

Acknowledgments & References



Thanks to all collaborators from the CSES-Limadou and the ARCADIA collaboration!

Especially: Roberto Battiston, Roberto Iuppa, Matteo Martucci, Umberto Savino, Francesco Follega, Manuel Rolo, Matteo Duranti, Matteo Centis Vignali, Alessio Perinelli, Ester Ricci e Lucio Pancheri

Links to presentations:

[R. Iuppa @ CRIS-MAC13]

[E. Ricci @ TREDI18]

[S. Bruno Ricciarini @ Pisa Meeting 2024]

[U. Savino @ CRIS-MAC13]

[M. Duranti @ TREDI25]

[L. Cavazzini @ TREDI25]

[L. Latronico @ TREDI25]

[G. Gioachin @ IFD 2025 – INFN Workshop on Future Detectors]

[M. Centis Vignali @ VCI25]

BACKUP

Correlation search for co-seismic signal

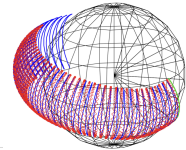
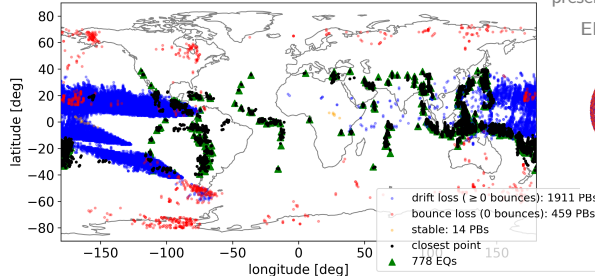
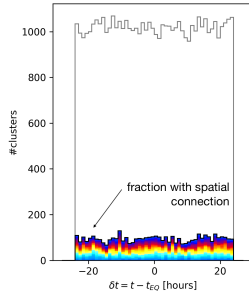
NOAA POES-19 PBs: electrons $> 110\text{keV}$, telescope 0°



TIFPA

presented at

EMSEV2022



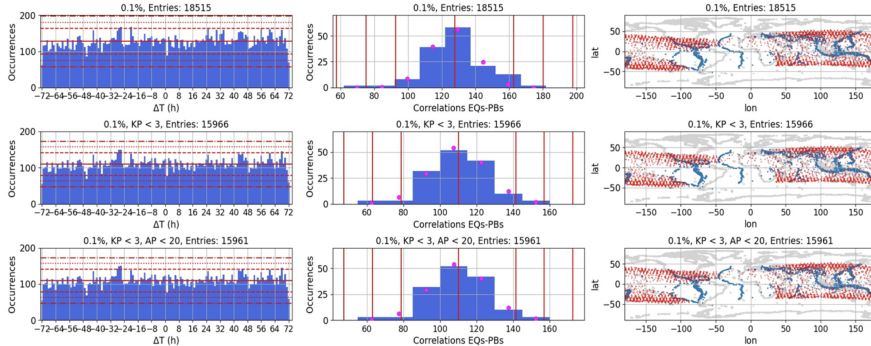
- ▶ tested: 913 EQ in three years (Magn. > 5.5 , $\pm 40^\circ \lambda$, max. depth 100 km, isolated)
- ▶ followed approach of [R. Battiston, V. Vitale, doi:10.1016/j.nuclphysbps.2013.09.002.] with much less statistics
- ▶ classified PBs by possible EQ origin, evaluated with back-tracing algorithm
- ▶ no significant excess in δt distribution found

Correlation search for precursor signal

HEPD-01 PBs: $3 \text{ MeV} < \text{electron energies} < 15 \text{ MeV}$



TIFPA



- ▶ tested: 8293EQ in four years (Magn. >4.5 , max. depth 100 km, $L_{eq} \leq 2$)
- ▶ following approach of [V. Sgrigna, et. al., doi:10.1016/j.jastp.2005.07.008]
- ▶ no significant excess in δt distribution found