UNIVERSITÉ
DE GENÈVE
FACULTÉ DES SCIENCES
Département de physique
nucléaire et corpusculaire

Astroparticle Physics in Switzerland

(excluding underground physics activities)

Xin Wu (UNIGE), Adrian Biland (ETHZ), Teresa Montaruli (UNIGE)

CHIPP plenary meeting,
Kandersteg, July 2, 2019

Astroparticle physics ⇔ multi-messenger astrophysics

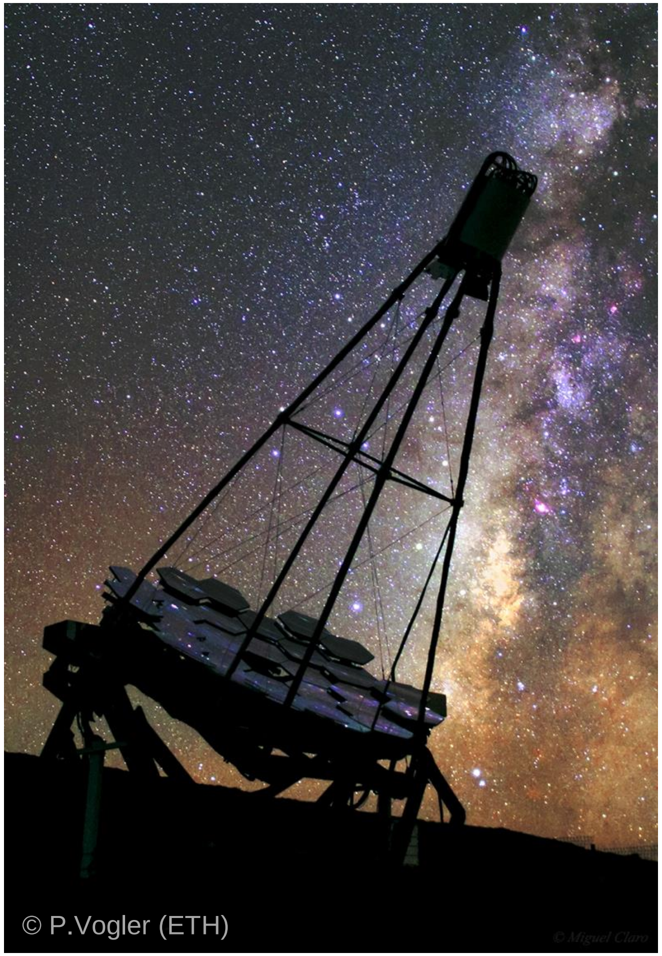
- Multi = 4: **photon, neutrino, cosmic rays, Gravitational Waves**
- Common theme: **Extreme Universe** = study the most extreme processes in the Universe with fundamental physics implications
- **Extreme origin**
  - What is Dark Matter? What is Dark Energy?
- **Extreme energy**
  - How are the particles produced, accelerated and propagated?
- **Extreme objects**: GRBs, BHs, pulsars, neutron stars, AGNs, …
  - What are their roles in particle production/acceleration and cosmology?
- **Extreme gravitation**: G-field around BHs are the strongest in the Universe
  - Would General Relativity still be valid?
- **Extreme magnetic field**: Neutron stars provide the strongest magnetic fields
  - Would QED still be valid? Would vacuum has different property?
- **Extreme density**: matter densities inside neutron stars are the highest
  - What is the state of the matter? Would QCD still be valid?

Multi-messenger astrophysics: CH current activities (experimental)

CHIPP related in bold

- Photons (multi-wavelength astrophysics)
  - VHE gamma-ray: **MAGIC, FAST, CTA**
    - **ETHZ, UZH, UNGE(DPNC**, DA)
  - Gamma-ray space: INTEGRAL, **POLAR(-2), PANGU/eASTROGAM, HERD**, …
    - **UNIGE(DPNC**, DA), **PSI, EPFL**
  - X-ray space: HITOMI/XRISM, **LOFT/eXTP**, ATHENA, THESEUS, …
    - **UNIGE**(DA, **DPNC**)
  - Optical, infrared, … : EUCLID, THESEUS, SPICA, JWST, …
    - ETHZ, UNIGE (DA)
- Neutrino
  - **IceCube**: **UNIGE (DPNC)**
- Cosmic rays
  - **AMS-02, DAMPE, HERD, PAN**: **UNIGE (DPNC)**
  - K-EUSO: UNIGE (DA)
- GW (see talk by Philippe Jetzer)
  - LISA: ETHZ, UZH

Some highlights on recent results and hardware progress will be presented in this talk



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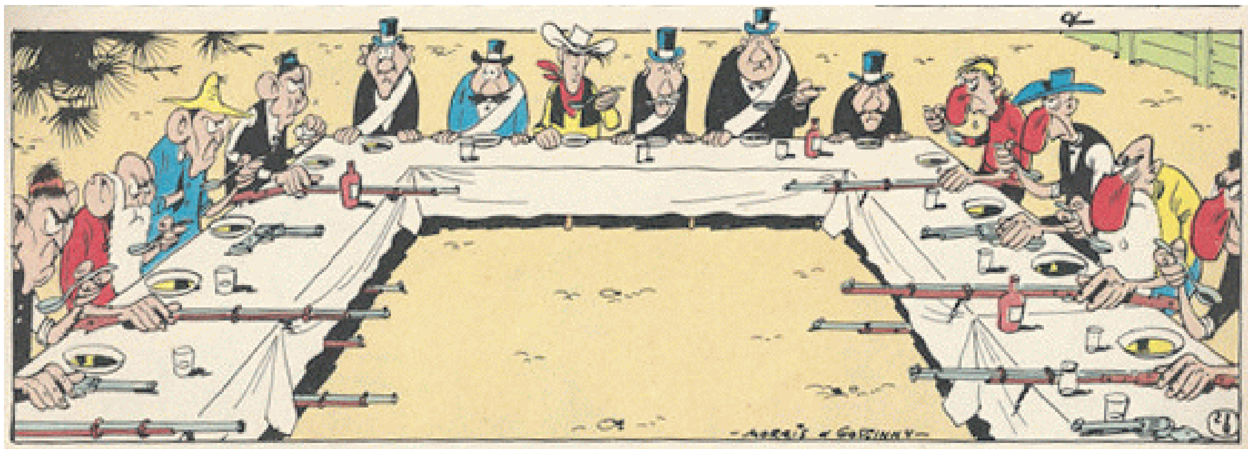
Very High Energy Gamma Ray Astronomy in Switzerland

MAGIC / FACT / CTA

A.Biland, ETHZ (currently chairing MAGIC Meeting in Yerevan)

Selected Management Tasks



A.Biland (ETH Zurich):	Spokesperson FACT; CoChair MAGIC Collab.Board
U.Straumann (UZH):	former Managing Director CTAO GmbH
T.Montaruli (GE DPNC):	Project Leader CTA SST-1M; Chair APPEC
R.Walter (GE ISDC):	former PI Integral Data Center

Canary Island La Palma


international symposium to celebrate 15 MAGIC years
La Palma, June 26-29, 2018

MAGIC status

Continuous improvements:

- some ageing mirror segments replaced
- new trigger added
  ➔ energy threshold lowered to ~30 GeV
- dedicated high-zenith observation
  ➔ extend energy coverage to >100 TeV

➔ After 15 years, MAGIC is in best state ever;
operation of another ~5 years secured
(also due to significant delay of CTA)

MAGIC highlight

First time detection of a GRB at sub-TeV energies; MAGIC detects the GRB 190114C

ATel #12390; ***Razmik Mirzoyan on behalf of the MAGIC Collaboration***
on ***15 Jan 2019; 01:03 UT***
Credential Certification: Razmik Mirzoyan (Razmik.Mirzoyan@mpp.mpg.de)

Subjects: Gamma Ray, >GeV, TeV, VHE, Request for Observations, Gamma-Ray Burst

Referred to by ATel #: 12395, 12475

Tweet

The MAGIC telescopes performed a rapid follow-up observation of GRB 190114C (Gropp et al., GCN 23688; Tyurina et al., GCN 23690, de Ugarte Postigo et al., GCN 23692, Lipunov et al. GCN 23693, Selsing et al. GCN 23695). This observation was triggered by the Swift-BAT alert; we started observing at about 50s after Swift T0: 20:57:03.19. The MAGIC real-time analysis shows a significance >20 sigma in the first 20 min of observations (starting at T0+50s) for energies >300GeV. The relatively high detection threshold is due to the large zenith angle of observations (>60 degrees) and the presence of partial Moon. Given the brightness of the event, MAGIC will continue the observation of GRB 190114C until it is observable tonight and also in the next days. We strongly encourage follow-up observations by other instruments. The MAGIC contact persons for these observations are R. Mirzoyan (Razmik.Mirzoyan@mpp.mpg.de) and K. Noda (nodak@icrr.u-tokyo.ac.jp). MAGIC is a system of two 17m-diameter Imaging Atmospheric Cherenkov Telescopes located at the Observatory Roque de los Muchachos on the Canary island La Palma, Spain, and designed to perform gamma-ray astronomy in the energy range from 50 GeV to greater than 50 TeV.

data analysis going on

Basic MAGIC design optimal to catch GRB

After 15 years, nature kind enough to deliver
➔ first VHE emission from a GRB measured

energy coverage from Radio to TeV

Several high-impact papers in preparation (details under strict embargo)

Press conference(s) later this summer

FACT

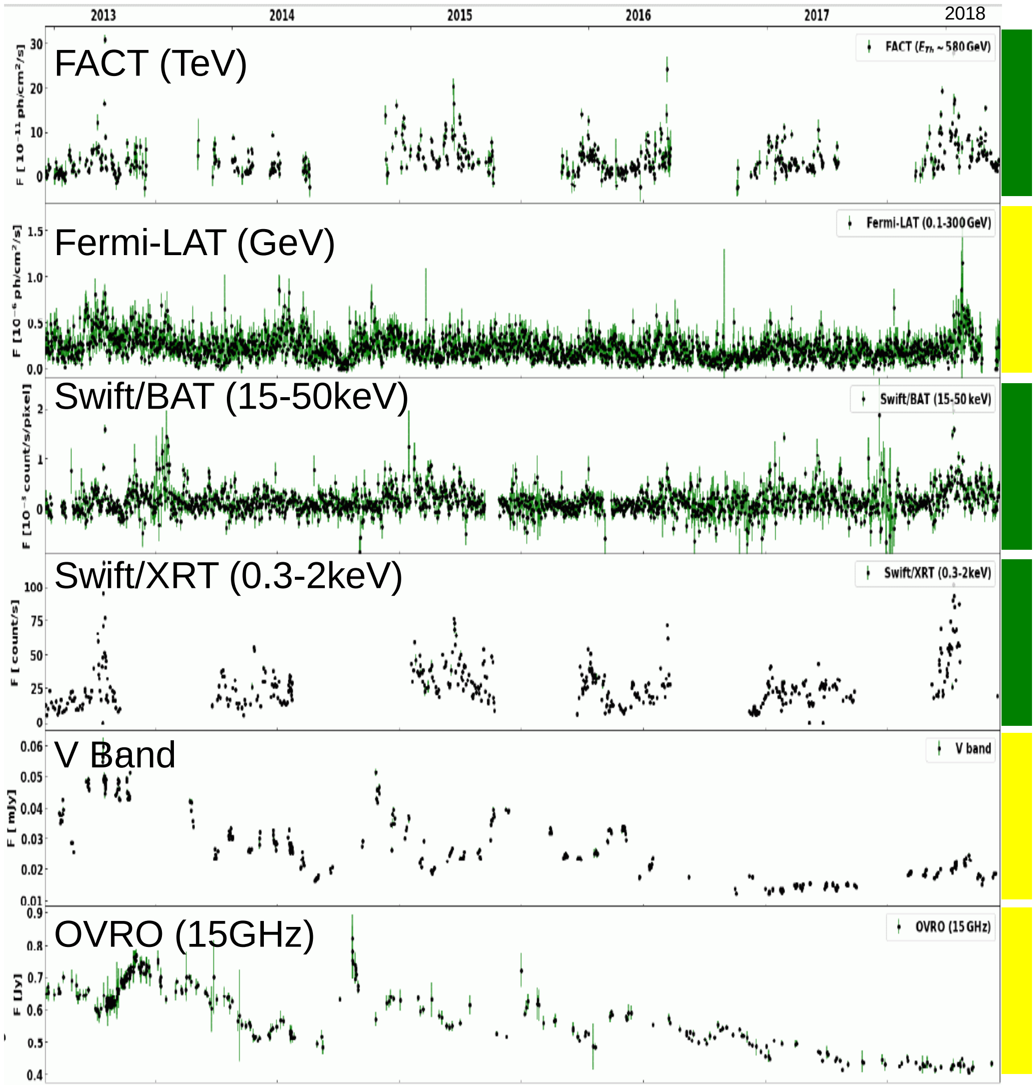
Swiss participation: ETH Zurich, ISDC Geneva

Pioneering usage of SiPM

successful data taking since ~8 years
without any SiPM related problem

First Cherenkov telescope
- not endangered by strong ambient light
- not needing auxiliary calibration devices
- operated from remote (since 2013)
  (no need for expensive data taking crew onsite)
- operated fully robotic since Dec. 2017

First unbiased continuous monitoring of
variable extragalactic VHE sources



FACT highlight

Comparing multi-year lightcurves from the Active Galactic Nucleus Mrk421 in all wavelengths (30 flares detected by FACT)

➔ evidence for strong correlation between

TeV <-> X-ray, time lag 0.26+/-0.46 days

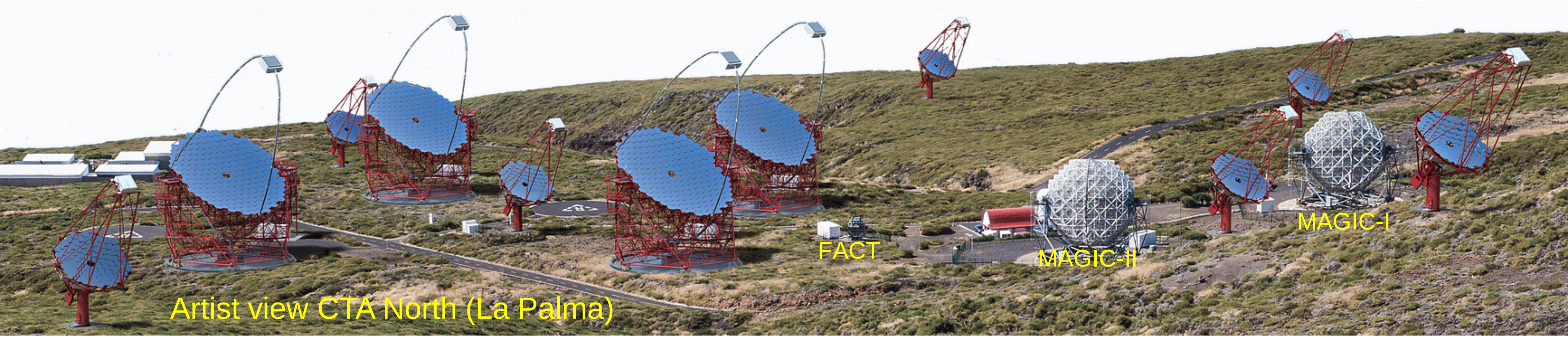
GeV<-> Radio, time lag ~43 days

no correlation TeV <-> GeV

➔ put constraints on cosmic accelerator models (paper submitted)

➔ Unbiased monitoring is important task, but not suited for expensive large arrays; better use dedicated inexpensive telescopes

CTA



Swiss participation: UniGE DPNC, UniGE ISDC(DA), UniZH, ETH Zurich

Dec. 2018: site agreement signed for southern array; need ~3 years to prepare infrastructure
(for northern array, MAGIC paved the way)
April 2019: stage one application for ERIC submitted (large fraction of work done by SERI)
May 2019: First CTA Science Symposium in Bologna
June 2019: CTA Meeting in Lugano (organized mainly by UniGE), including visit to CSCS

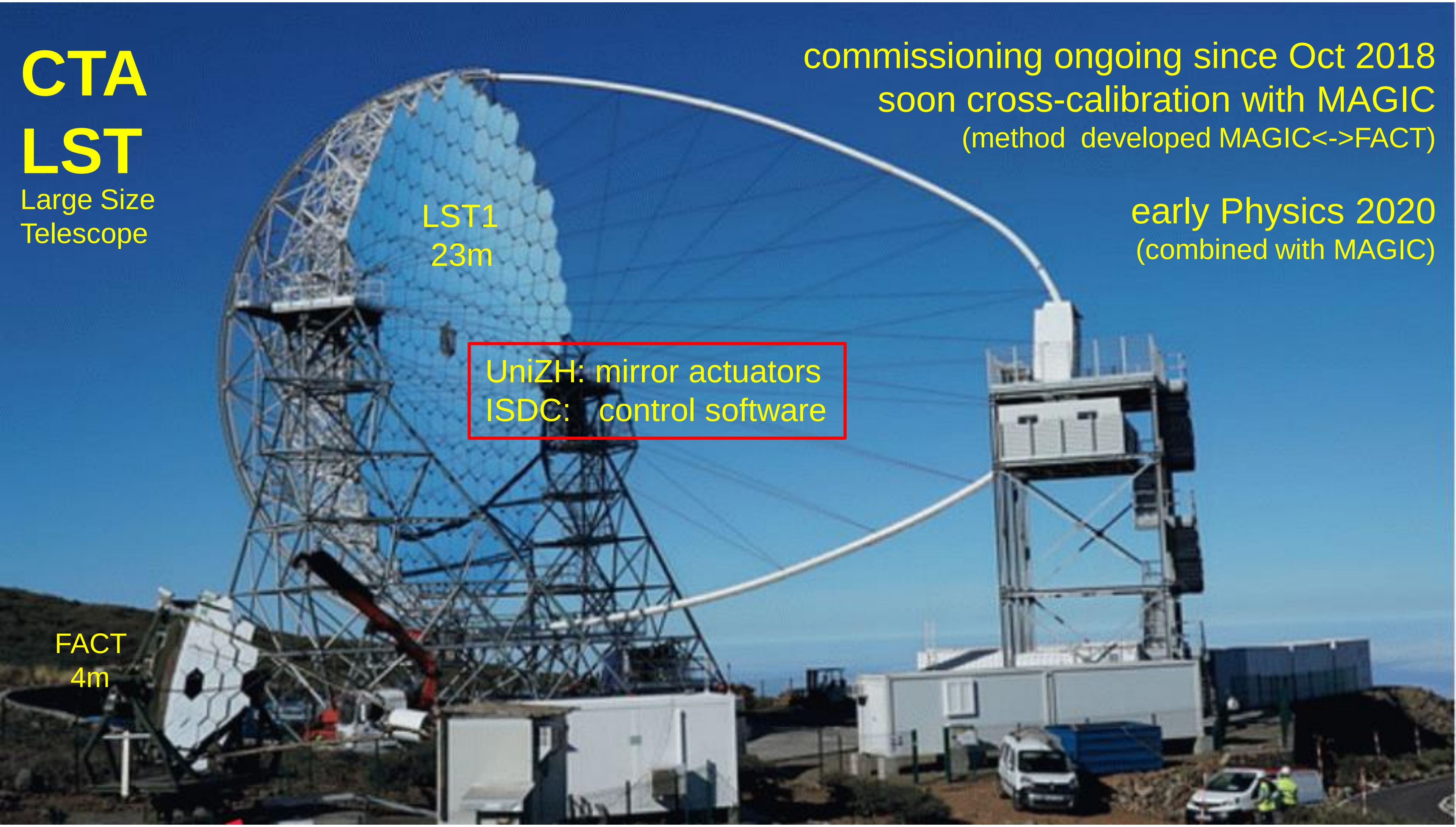
CTA Data Center

CTA shall become open observatory ➔ need different kind of data center

Experience: ISDC Geneva is successfully operating the Data Center for the Integral mission (ESA) since ~20 years (successful user support ➔ >3000 papers)

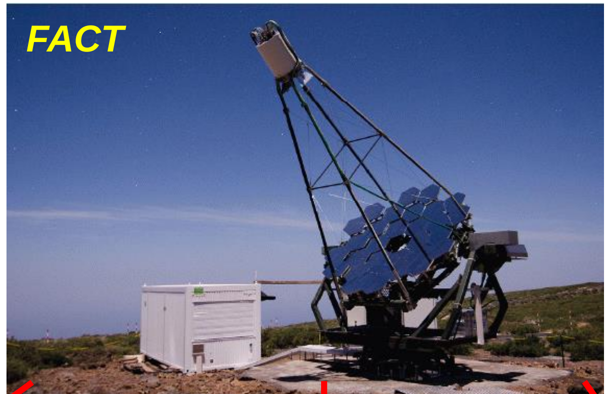
Lot of work done towards special needs of CTA, also using FACT data as testbed

Combine experience from ISDC with resources at CSCS ?
(➔ Synergies with LHC and SKA ?)


CTA
LST
Large Size
Telescope
commissioning ongoing since Oct 2018
soon cross-calibration with MAGIC
(method developed MAGIC<->FACT)
early Physics 2020
(combined with MAGIC)
LST1
23m
UniZH: mirror actuators
ISDC: control software
FACT
4m

CTA SST

Small Size Telescope



Due to success of FACT, several SiPM based prototypes for CTA-SST

Need to decide for one final design for CTA

CTA
SST

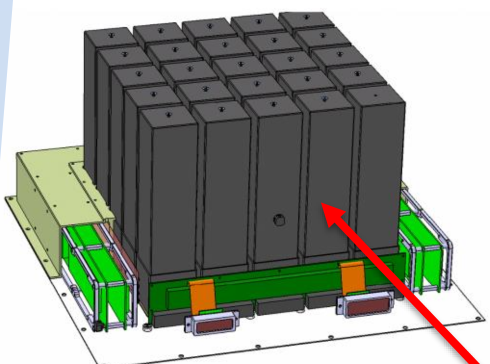
Small Size
Telescope

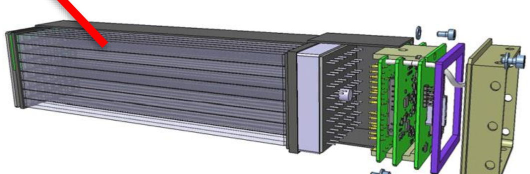
While SST-1M (DPNC+DA of UNIGE, ETHZ) most mature and cost effective, Council decided June 18th 2019 to base final CTA-SST on (significantly to be improved) ASTRI design

Consequences of this decision to be seen …

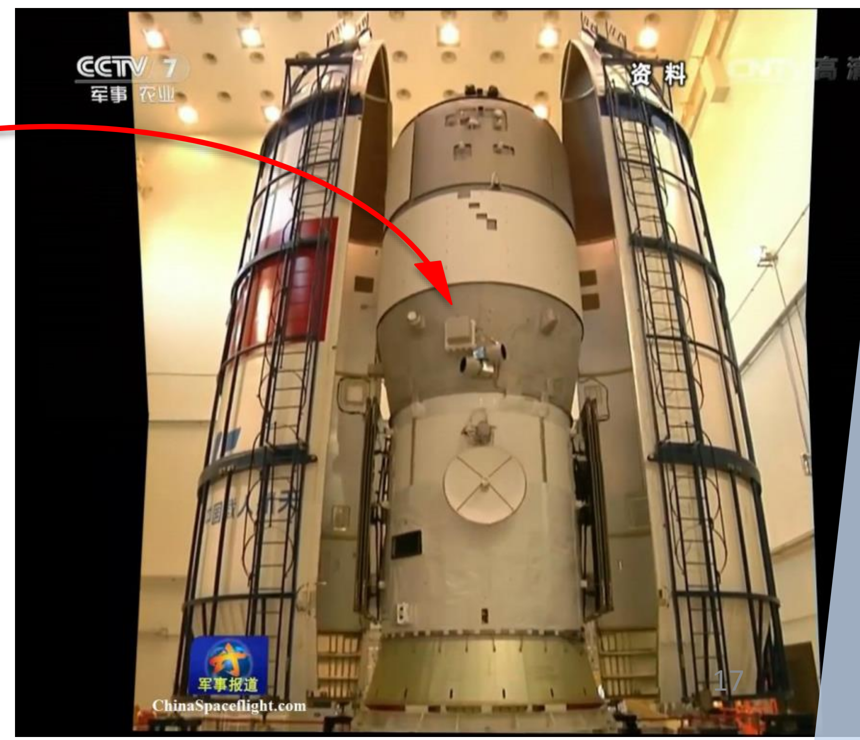
POLAR: first dedicated wide-field GRB polarimeter

- **Switzerland (UNIGE, PSI)** - Poland (NCBJ) – China (IHEP)
  - Hardware development led by UNIGE, financed mainly by SSO
  - Onboard the Chinese TG-2 Spacelab
    - Launched in Sept. 2016, operated for 6 months
  - 55 GRBs detected ➔ largest GRB sample detected by a GRB polarimeter
  - Results of 5 brightest GRBs published in Nature Astronomy in Jan. 2019
  - Several more publications expected in the near future



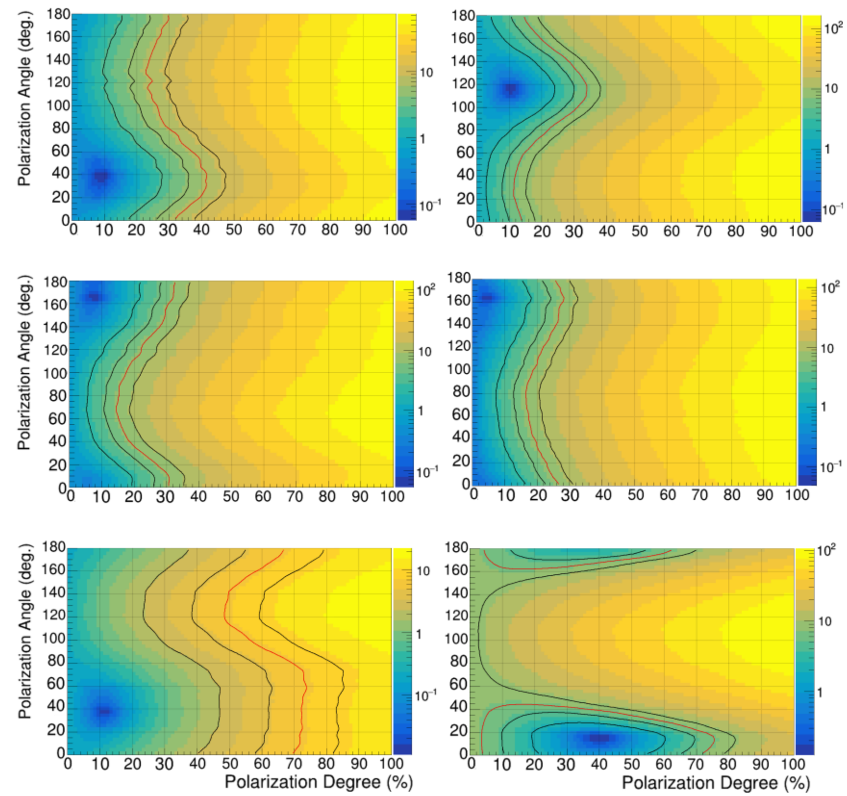


25 modules



First POLAR results published in Nature Astronomy in Jan. 2019

- DPNC (M. Kole) is the co-first author and co-corresponding author
  - POLAR measured a low polarization, against predictions of some popular models
  - Also showed polariza'tion angle evolves with time ⇒ very interesting!
    - Emission mechanism? B-field configuration? Jet geometry?



nature astronomy

Letter | Published: 14 January 2019

Detailed polarization measurements of the prompt emission of five gamma-ray bursts

Shuang-Nan Zhang, Merlin Kole, […] Anna Zwolinska

Nature Astronomy **3**, 258–264 (2019) | Download Citation

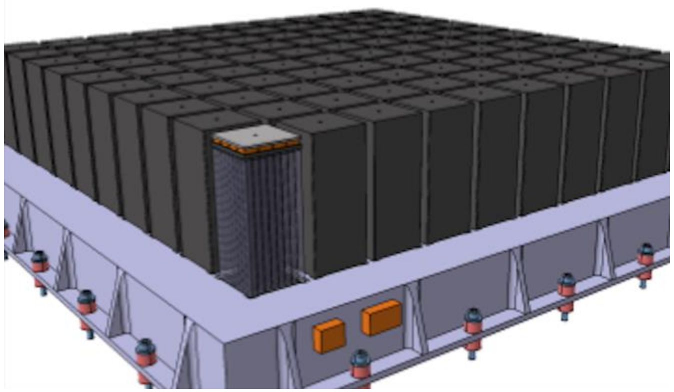
- **But both observations make polarization measurements more difficult**
  - **Need larger detector** to allow time resolved measurements
  - **Need better sensitivity** at low energy to detect Gravitational Wave GRB counterparts which are typically faint and at low energy

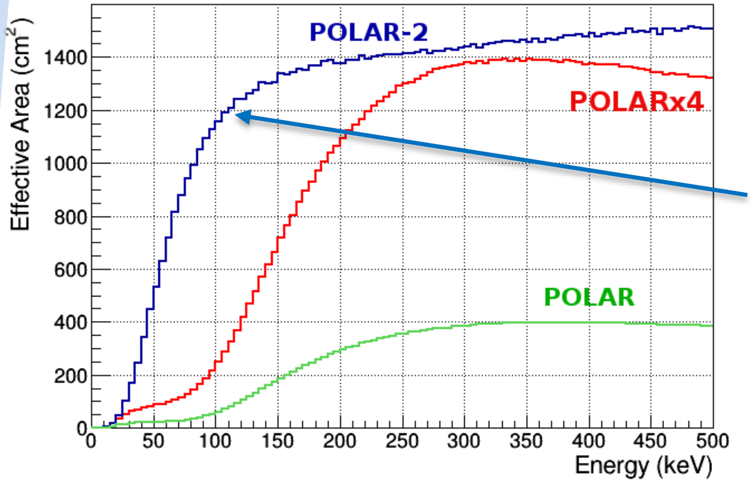
POLAR-2: x10 more sensitive than POLAR

- Main goal: understand the GRB emission mechanism with time resolved and high statistics measurements
  - 30 GRB/year with polarization precision at/above the POLAR's results
  - Time resolved studies of 10 GRB/year
- Detect GRB counterparts of GW events and determine if they are highly polarized
  - Detection limit down to 20 keV
    - POLAR limit was 50 keV
  - Sensitivity is ~10xPOLAR for typical GRBs
- Play an important role in multi-messenger astrophysics by providing alerts to other instruments for even the weakest GRBs
  - Monitoring constantly half of the sky
  - Profit from the resources on the Chinese Space Station and its relay satellites
- Pulsar physics and applications
  - Observation of about 8 pulsars continuously
  - Study pulsar navigation

POLAR-2: baseline design, specification and performance

- 4x larger than POLAR
  - 100 modules, 6400 scintillator bars
  - Total weight ~160 kg
  - Total power consumption ~300 W
  - Data size ~20-40 GB/day





- Energy range: 20 keV - 800 keV (POLAR: 50-500 keV)
- Effective area @100 keV: 1200 cm^2 (POLAR: 100 cm^2)
- Field of View: half the sky (similar to POLAR)
- Time resolution: microseconds (similar to POLAR)

- New features
  - Additional spectrometers for improved polarization measurements
  - Realtime GRB alerts to ground for other instruments
  - Extended observation time: at least 2 years, but can be easily extended

POLAR-2: selected for the Chinese Space Station

- 30 August 2018: POLAR-2 proposal submitted to joint UNOOSA-CMSA Call

UNITED NATIONS
Office for Outer Space Affairs

CMS

United Nations/China Cooperation on the
Utilization of the China Space Station

- 18 February 2019: POLAR-2 has been short-listed
- 20 April 2019 : Implementation Scheme Proposal (ISP) submitted
  - With endorsement letter from the Swiss Space Office
- 12 June 2019: POLAR-2 selected as one of the 9 projects to be implemented
  - First on the list!
- POLAR-2 collaboration: 4 institutes from 4 countries: CH, D, PL, CN
  - UNIGE is the PI (X. Wu) institute

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MPE

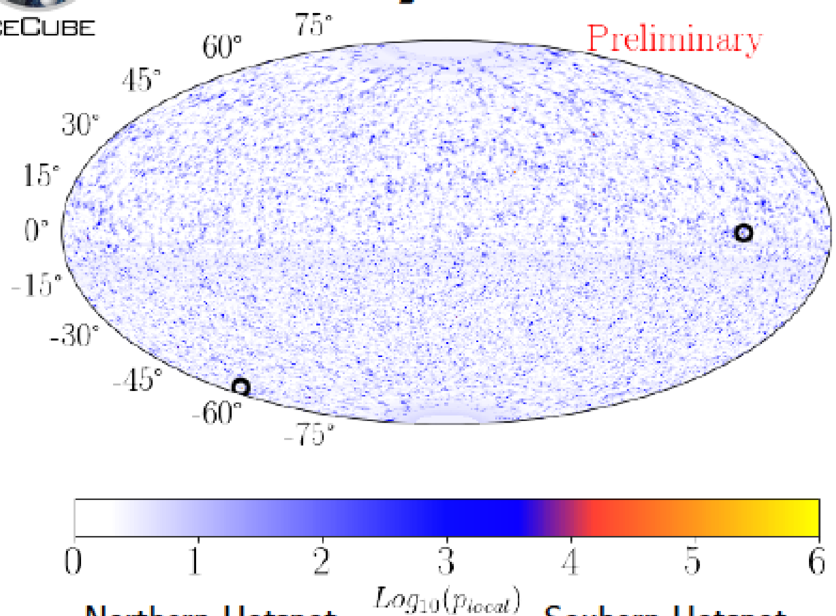
NCBJ

Institute of High Energy Physics
Chinese Academy of Sciences

Launch in 2014!

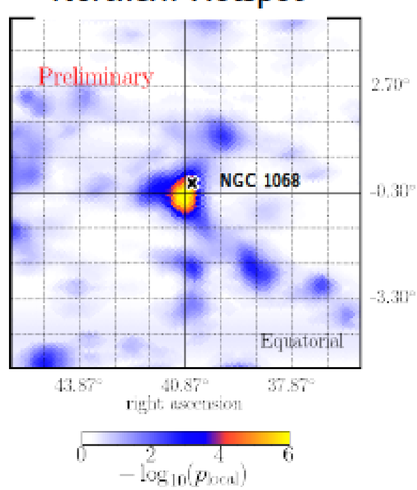
IceCube/DPNC

10 year All-Sky Scan Results

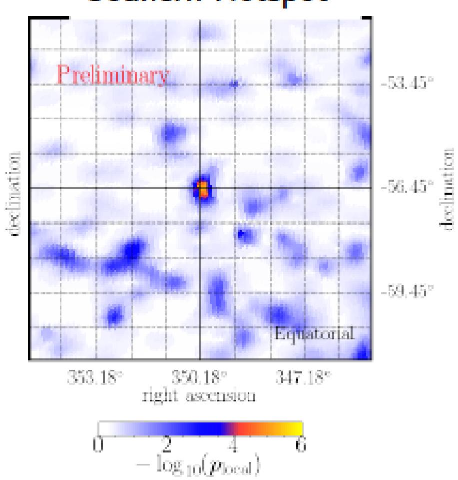


- Scan the entire sky and evaluate the likelihood of signal over background.
- The position with the smallest p-value in each hemisphere is taken as the hottest spot.

Northern Hotspot



Souhern Hotspot



Hottest Point in Northern Hemisphere :

($\delta \geq -5^o$)

RA = 40.87° , Dec = -0.30°

n_{signal} = 61.45 , γ= 3.411

$P_{pre\text{-}trial} = 10^{-6.45}$, TS = 25.34 ⇒ $\boxed{\text{9.9\% post-trial}}$

Hottest Point in Southern Hemisphere :

($\delta < -5^o$)

Ra = 350.18° , Dec -56.45°

n_{signal} =17.75, γ = 3.34

$P_{pre\text{-}trial} = 10^{-5.37}$, TS= 19.95 ⇒ 75% post-trial

$\boxed{\text{T. Carver PhD Thesis.}}$ Presentation at SPS by A. Barbano,PRL being submitted

Most significant Source List Results

IceCube/DPNC

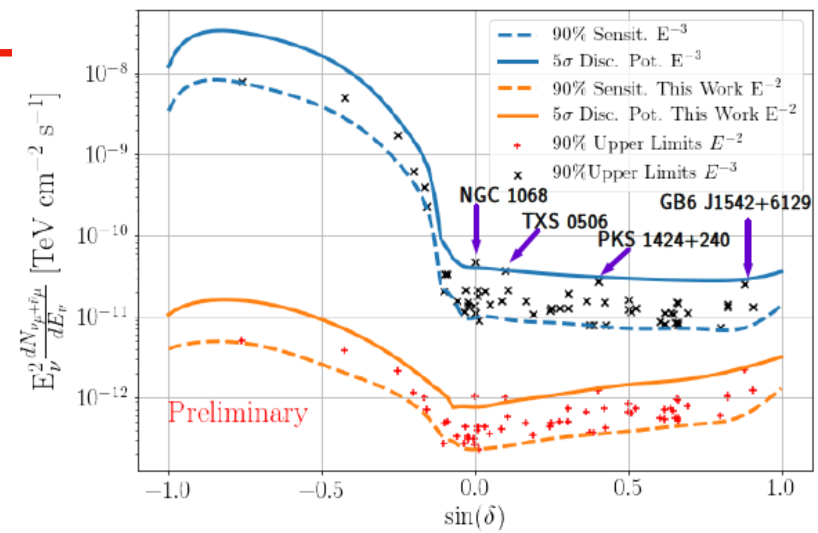
Name	Ra (°)	Dec (°)	TS	n_{signal}	γ	$-\log_{10}(p_{local})$	Pre-trial σ
NGC 1068	40.67	-0.01	17.04	50.4	3.16	4.74	4.13
TXS 0506+056	77.35	5.70	13.05	12.32	2.08	3.72	3.55
PKS 1424+240	216.76	23.8	9.88	41.47	3.94	2.8	2.95
GB6 J1542+6129	235.75	61.50	9.29	29.72	3.02	2.74	2.91
MGRO J1908+06	287.17	6.18	3.48	4.22	1.96	1.42	1.77
PKS 1717+177	259.81	17.75	2.96	19.82	3.65	1.32	1.66
PKS 2233-148	339.14	-14.56	2.8	5.32	2.80	1.26	1.6
B2 1215+30	184.48	30.12	2.67	18.60	3.39	1.09	1.4
M 31	10.82	41.24	2.11	10.99	4.0	1.09	1.4
4C +55.17	149.42	55.38	1.61	11.88	3.27	1.02	1.31

- Evidence for a flaring Blazar from a flare in 2014. (M. G. Aartsen et al. 2018)

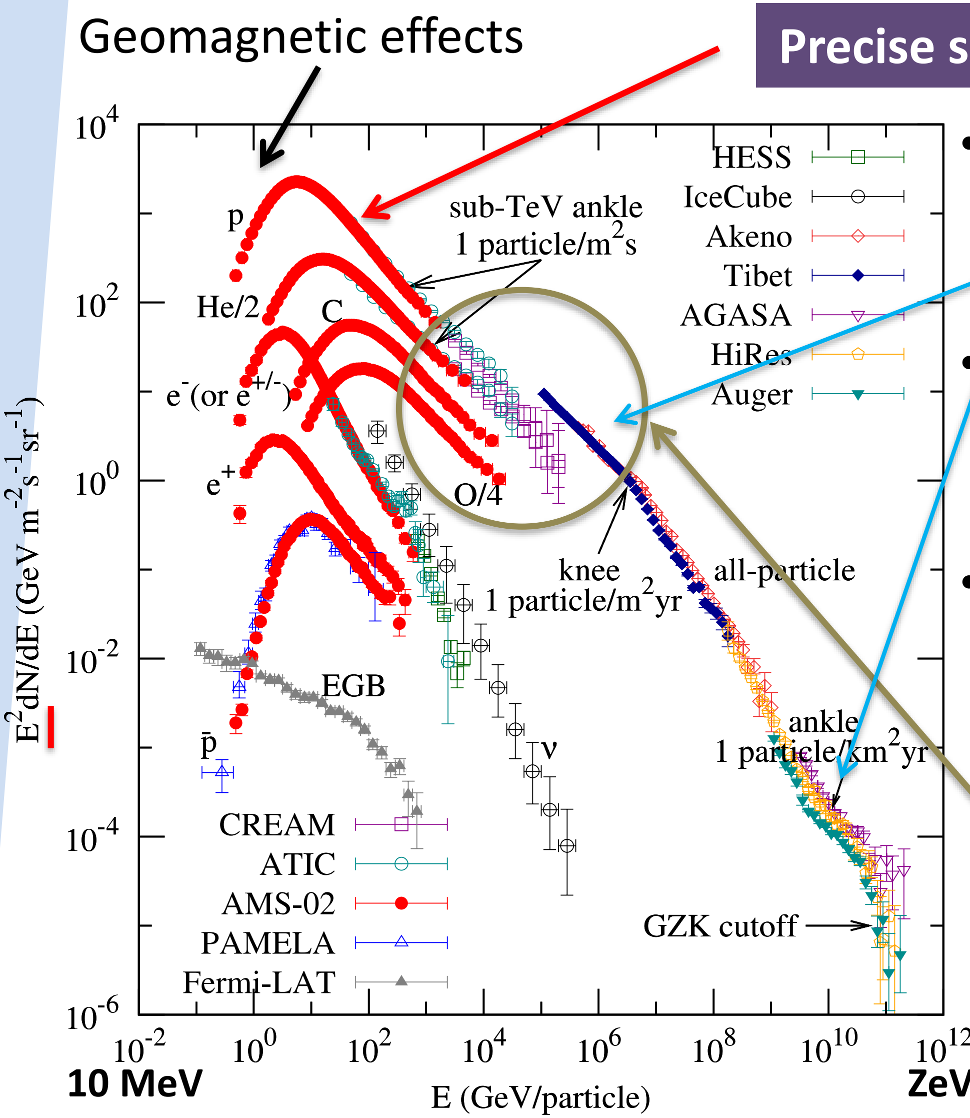
- Most signifcant excess in the Northern Source List. $\rightarrow$ **2.9σ post-trial**
- **0.35°** from the hottest point in the sky.

Four sources (NGC 1068, TXS 0506+056, PKS 1424+240,GB6 J1542+6129) with inconsistent background at 3.3σ post-trial level

Time dependent study of this excess ongoing (A. Barbano, F. Lucarelli) Correlation of neutrinos of IceCube + ANTARES and UHECRs (Telescope Array and Pierre Auger) to be presented at ICRC2019



Particles in the Universe



balloon and space

ground-based

- **From afar**, flux follows a power law $F(E) \propto E^{-\gamma}$, γ ~ 2.7 up to the "knee" at ~PeV, then an "ankle" at ~EeV
- Above ~PeV: Need to use ground experiments because of low rate
  - Only measure all-particle flux
- Below the "knee region": balloon and satellite experiments
  - Measure total flux and chemical composition

New generation of space experiments (DAMPE, HERD, …) extends into the "knee" region to connect to ground measurements

Major current and future astroparticle missions

Mission	Years	E Measuring Technology	GF m^2sr	Energy Reach	$X_0(\lambda)$
FERMI	since 2008	total absorption calorimeter (2.8 tons)	10 (for γ)	~ TeV	10
AMS-02	since 2011	magnetic spectrometer (8.5 tons)	0.12	~ 1 TeV/Z	16
NUCLEON	since 2015	target + sampling calorimeter (360 kg)	0.2	~10 TeV	15(0.9+0.23)
CALET	since 2015	total absorption calorimeter (2.5 tons)	0.12	~10 TeV	30(1.2)
DAMPE	since 2015	total absorption calorimeter (1.45 tons)	0.3	~100 TeV	32(1.6)
ISS-CREAM	since 2017	target + sampling calorimeter (1.3 tons)	0.2	10 TeV	21(0.7+0.5)
HERD	2025	3D total absorption calorimeter (~4 tons)	~3	> PeV	55(3)

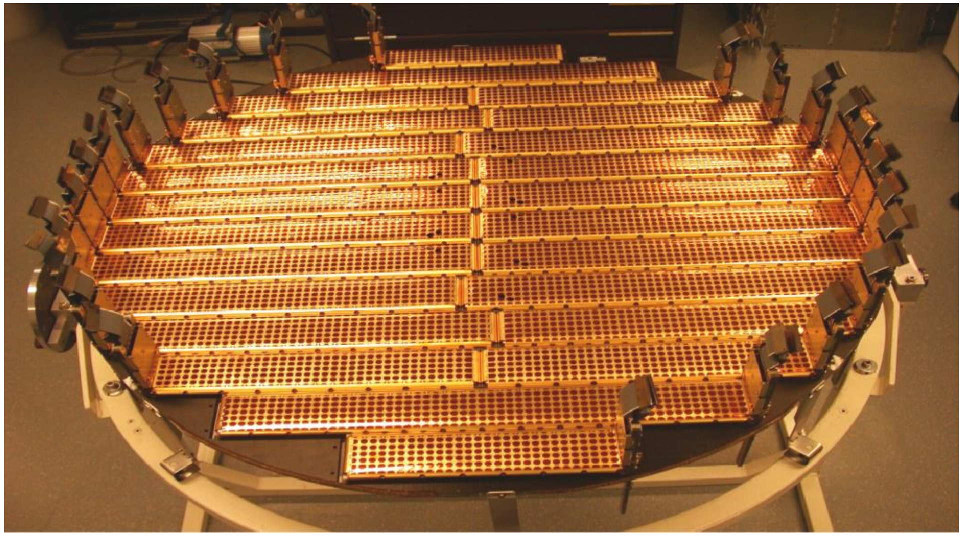
- Up tp ~1 TeV, well covered by AMS-02
- Up to 100 TeV, well covered by DAMPE
- HERD will extend the reach to >PeV (knee)

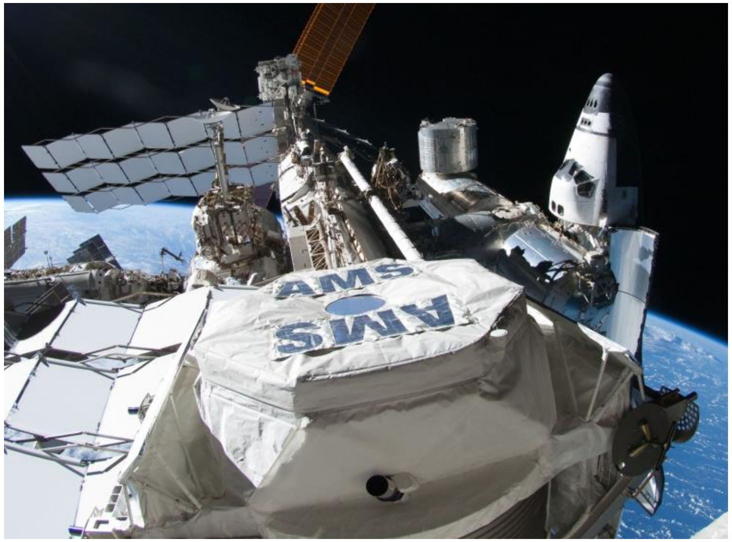
DAMPE/HERD are "general purpose": e, γ, p, nuclei

RED: with major CH contributions

AMS-02: Large magnetic spectrometer in space

- Major CH (UNIGE, ETHZ) contributions to the silicon tracker construction



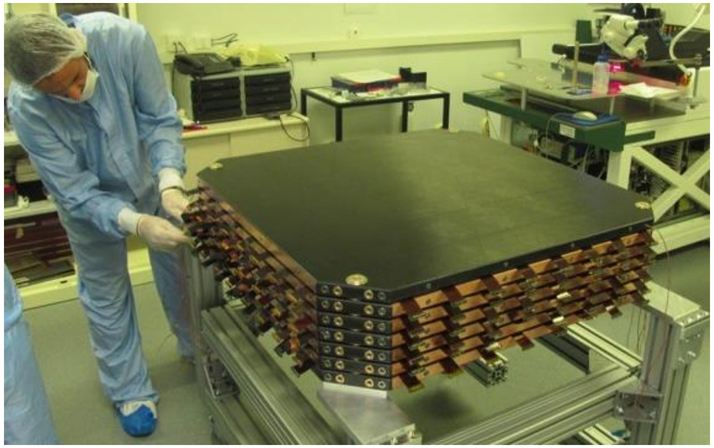


Launched May 2011, in operation until at least 2024

- In cosmic ray observation: **features are physics (first "what" then "why")**
  - AMS-02 high precision direct cosmic ray detection in GeV – TeV allowed to observe many features or "surprises"
  - Positron fraction "anomaly", proton and light nuclei spectral breaks, flattening antiproton fraction
- UNIGE data analysis focus: Si, Mg, Al flux, Be isotopes
  - Important for the study of propagation effects -> background to DM search

DAMPE: high precision direct cosmic ray detection TeV - 100 TeV

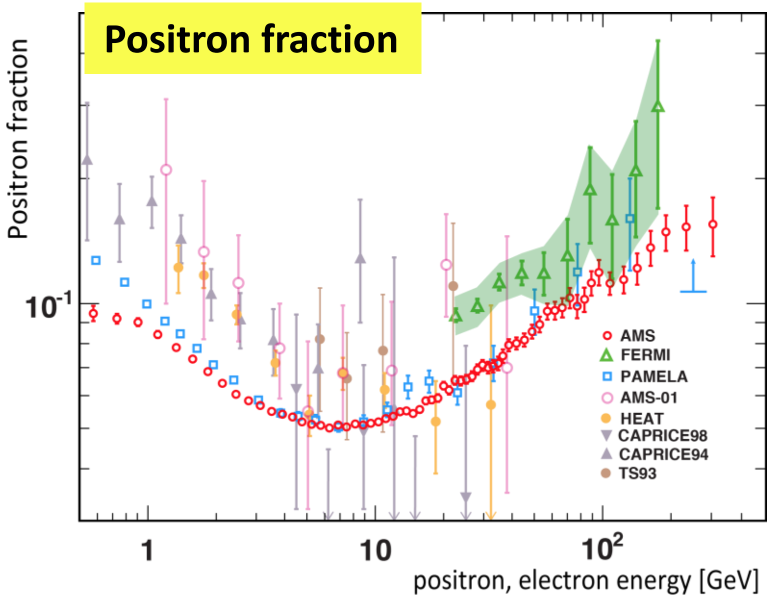
- Major UNIGE contributions (hardware, software and data analysis)
  - Proposer and leading institute for the Silicon-Tungsten Tracker (STK)
  - STK monitoring, calibration, alignment and track reconstruction
  - Lead contributor to the electron flux measurement published in **Nature**
  - Key contributor to the proton flux analysis, accepted by **Science Advances**
  - Current focus: electron ID with ML for electron flux update, Helium flux, proton anisotropy, pulsar analyses …



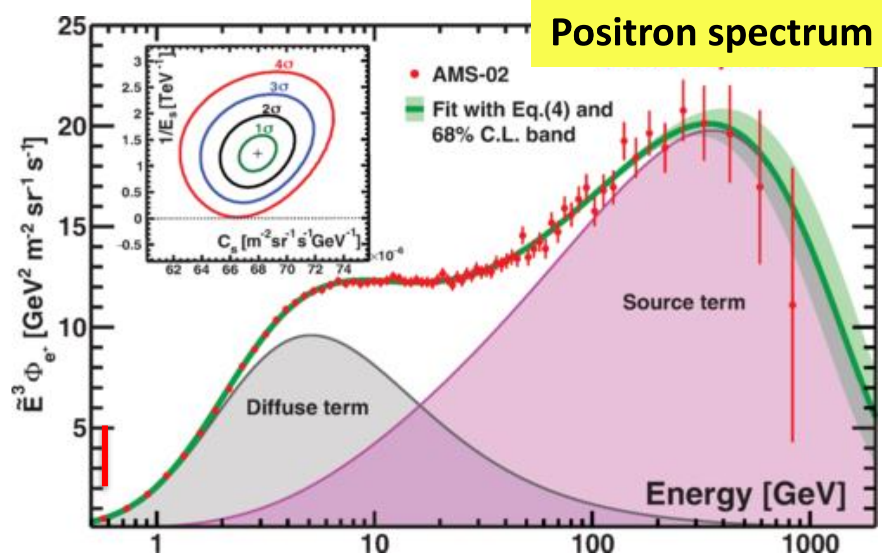
Launched Dec. 2015, in excellent condition, will run for many more years

AMS: Positron fraction "anomaly" ⇒ positron flux cut-off

- Positrons were expected to be mainly secondary ⇒ single power law
  - from cosmic rays interacting with Interstellar medium (ISM)
- AMS-02 revealed that positrons have primary contribution(s)!
  - EM cascade in pulsar magnetic field or through pion production in shock acceleration (pulsar, SNR)? Or DM?



AMS 1.5 years of data



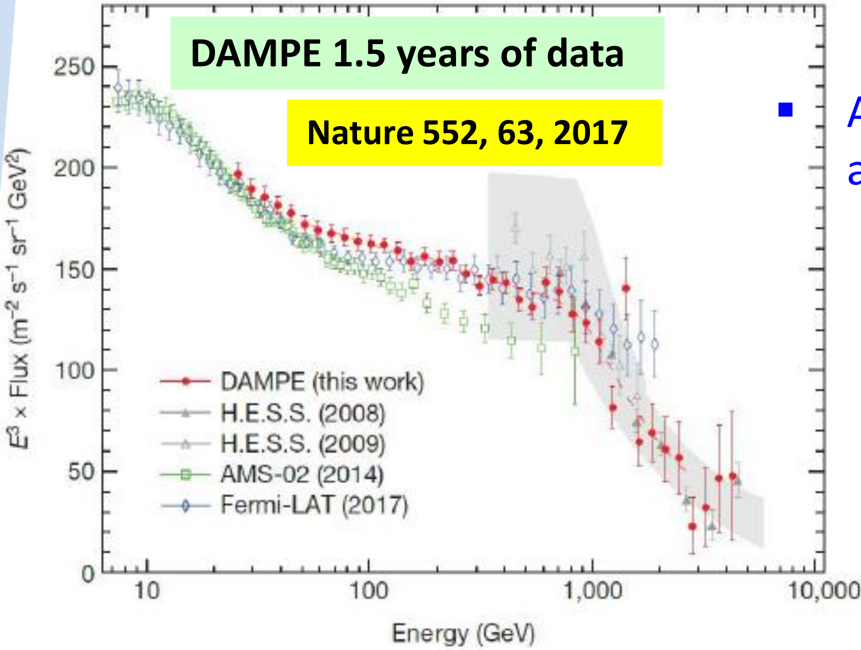
AMS 6.5 years of data

PRL 122, 041102 (2019)

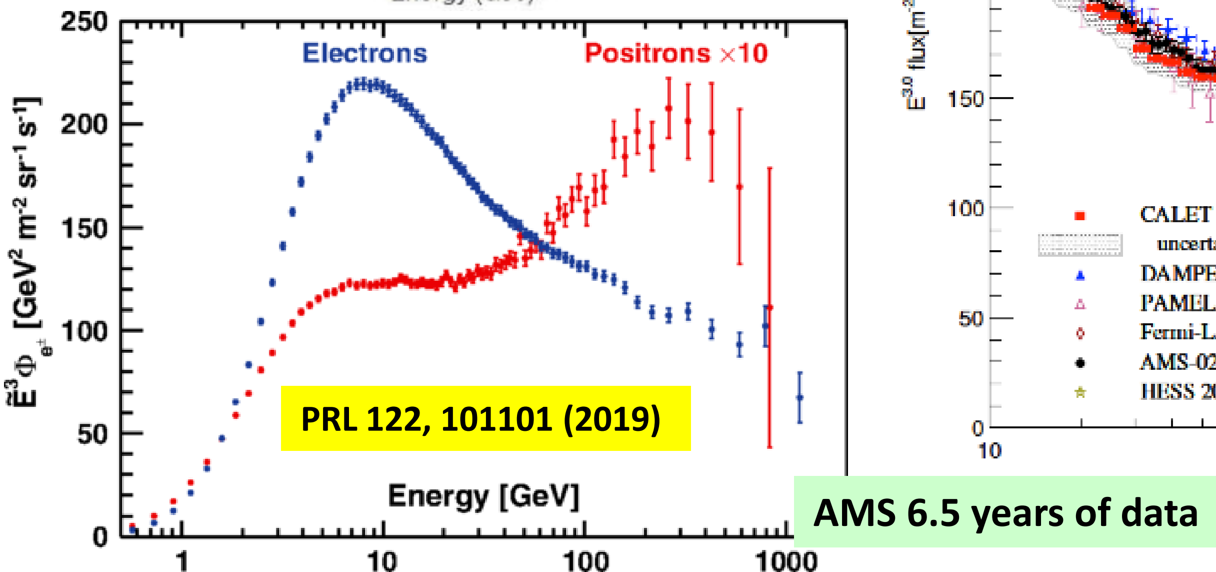
Charge confusion increase with energy, ~18% at 700 -1000 GeV, lack of statistics ~1 TeV ⇒ DAMPE complementary for e^++e^- flux above 1 TeV

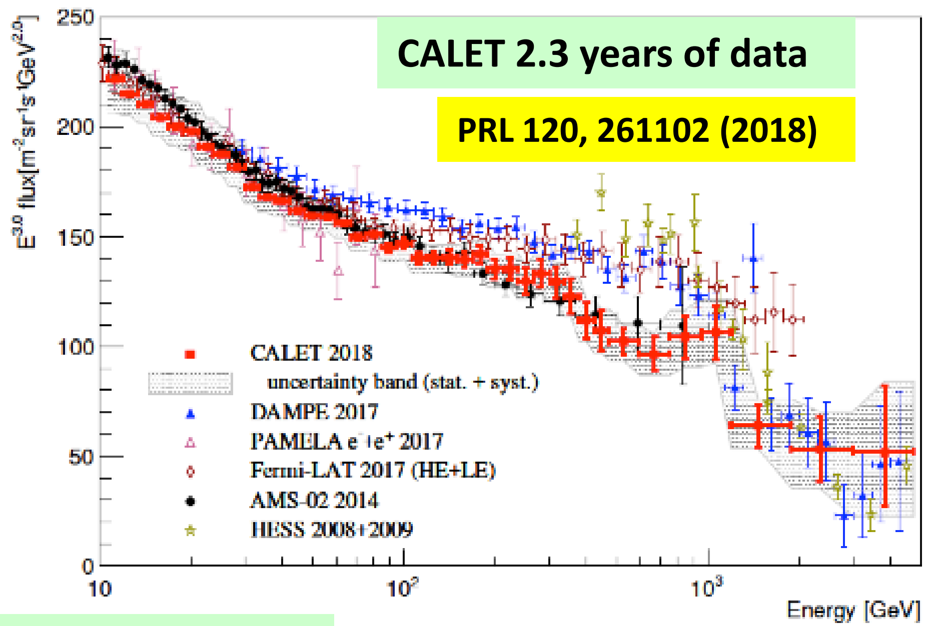
DAMPE: Precise CRE (electron + positron) measurement ~TeV

- DAMPE: precise flux measurement up to ~5 TeV, observed a spectral break at ~1TeV



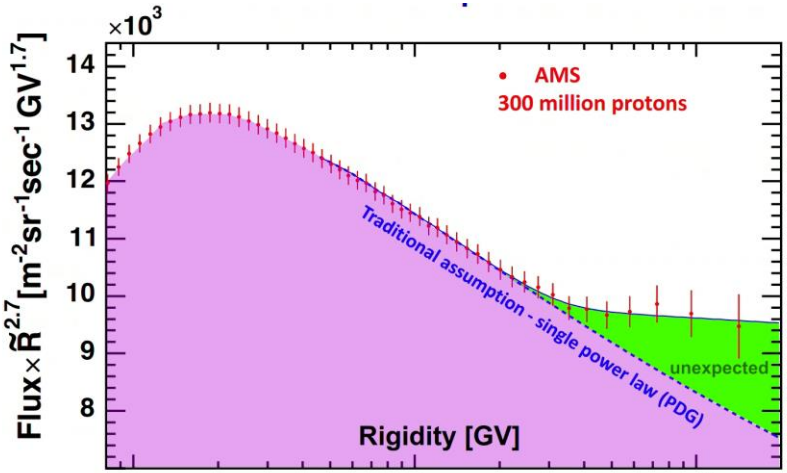
- A spectral softening is not contradicted by CALET and AMS (both have large systematics at ~TeV)
  - Nearby pulsar(s), or DM, or propagation effect?
  - More data from DAMPE, and eventually from HERD, will help to clarify the situation

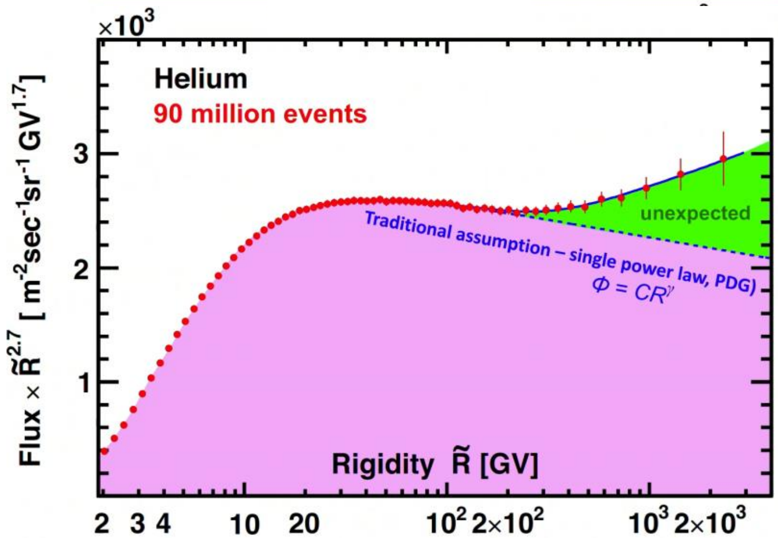


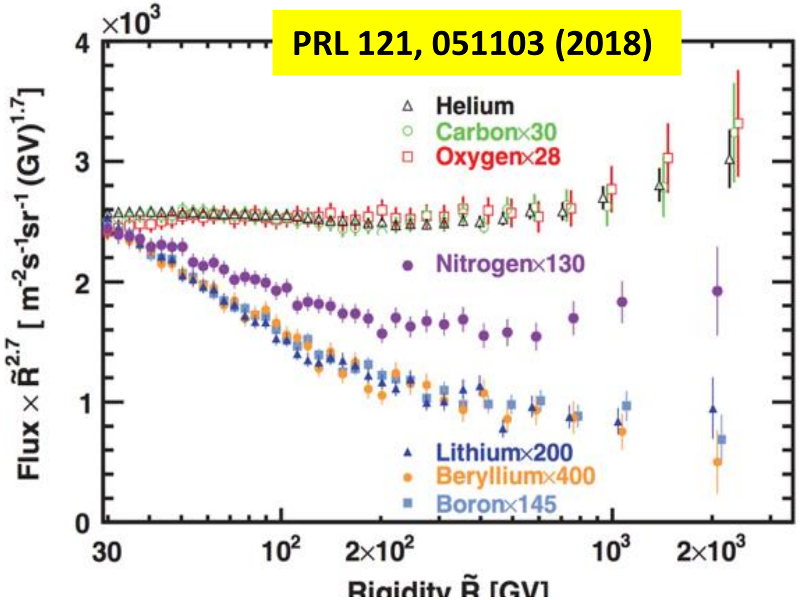


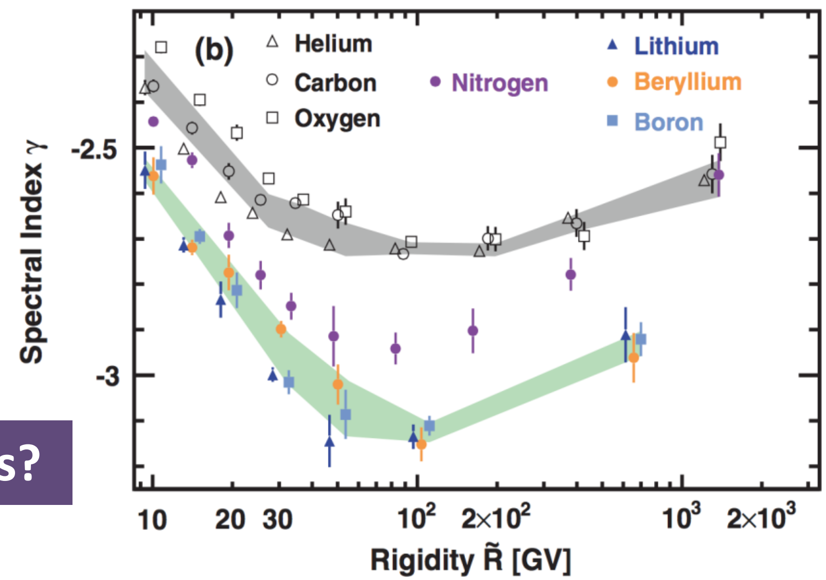
AMS: Proton and light nuclei rigidity spectra, up to ~TV

- There is a general single power law breakdown around 200 GV!





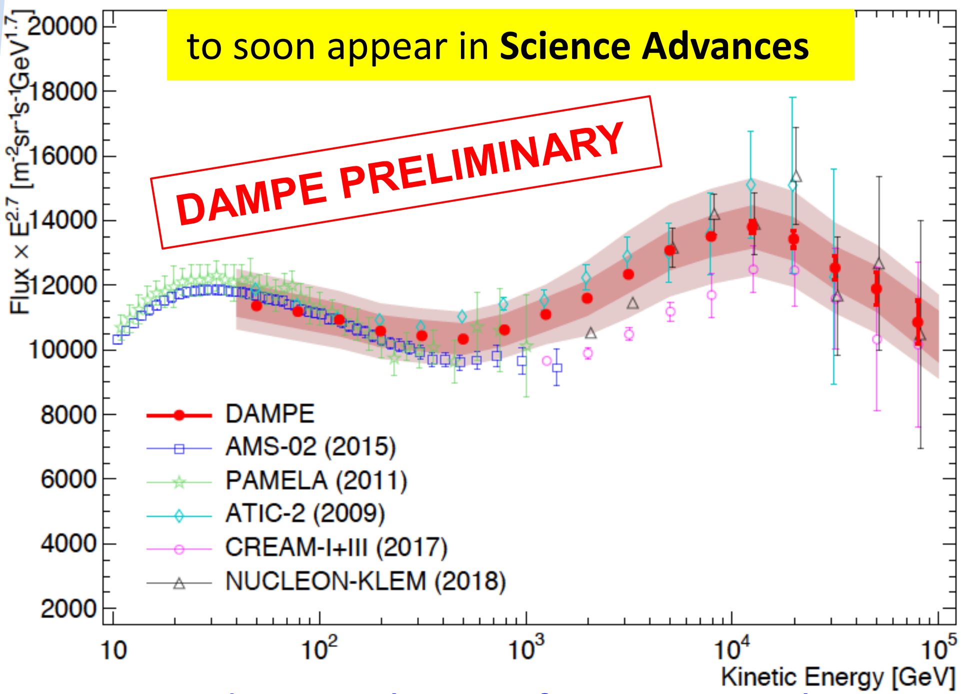


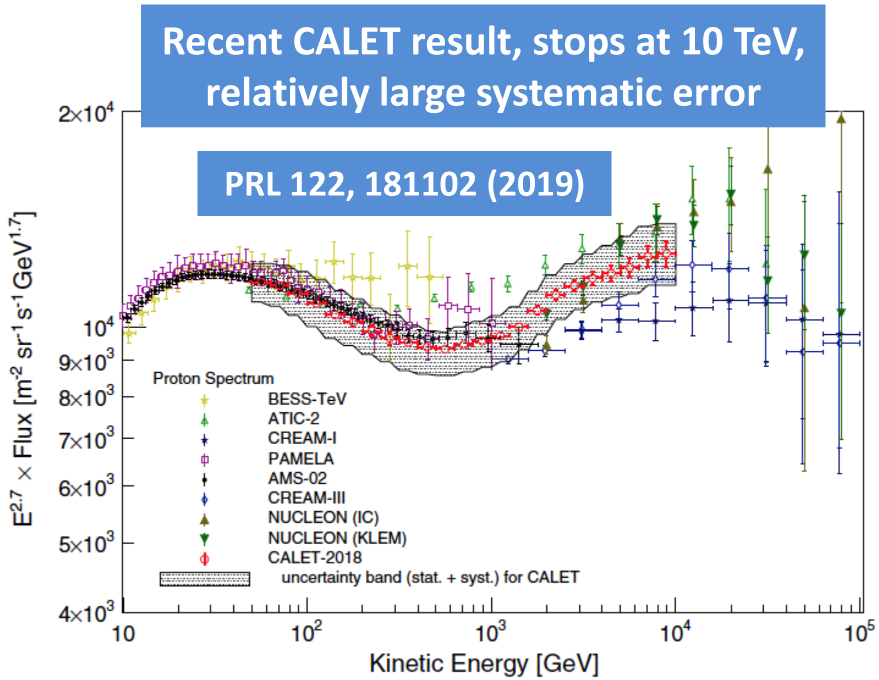


Acceleration? Propagation? Local sources?

DAMPE: Precise proton (and soon He) flux, up to ~100 TeV

- Direct detection of cosmic protons up to 100 TeV with high precision
  - Accepted, soon to appear on **Science Advances**
  - Confirms the hardening at a few hundreds GeV observed by AMS
  - Strong evidence of softening at ~10 TeV



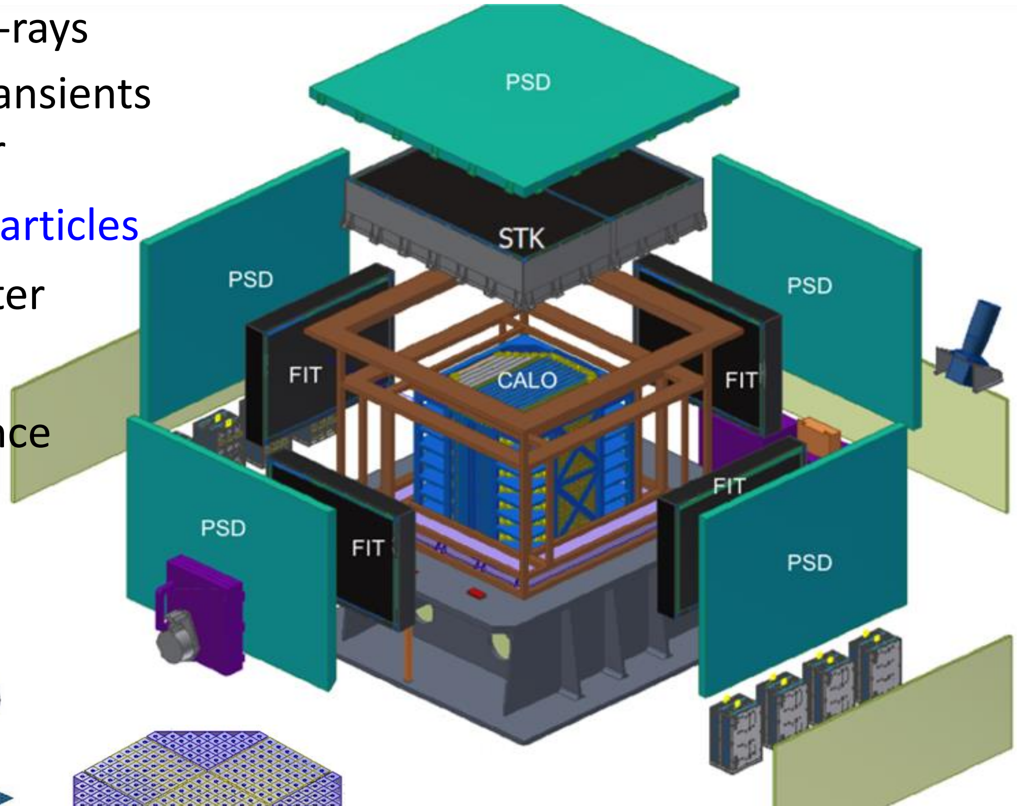


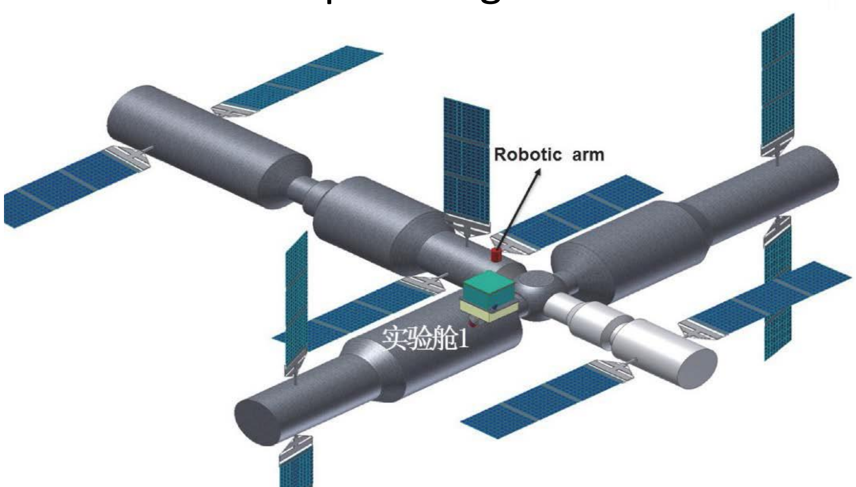
- Hardening then softening, similar to positron and electron
  - local sources? multiple sources? Propagation?

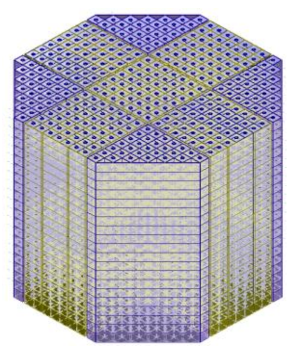
With HERD, compatibility with ground-based all particle data at the knee will soon become a key challenge to models

HERD: next generation particle detector on board the CSS

- 5-side sensitive for large acceptance, ⇒ **~3 m^{2}sr**
  - Larger statistics for CR up to multi-PeV: spectra, composition, anisotropy!
  - DM search with electrons and γ-rays
  - γ-ray astronomy: high energy transients monitoring and sub-GeV imager
- Most precise detector for TeV-PeV particles
  - LYSO cube 3D imaging calorimeter
  - Si and Fiber tracker
  - Plastic scintillator anti-coincidence
  - Multiple charge measurements







~7500 LYSO crystals ⇒ 55 X_0 and 3 λ !

Payload ~4T (~0.5 AMS)

main participants: CN, IT, CH, E, launch ~2025

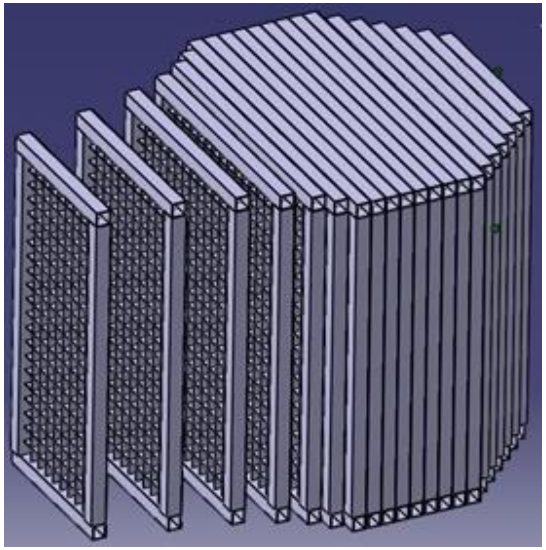
HERD: Expected Performance

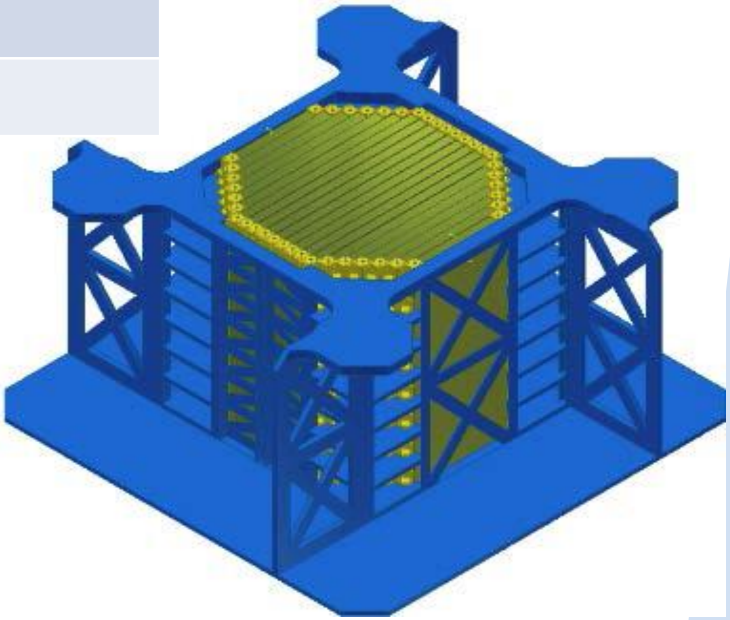
e/γ energy range	**10 GeV – 100 TeV**
γ low energy range	0.5 (0.1) GeV -10 GeV
Nuclei energy range	**30 GeV - 3 PeV**
e/γ angular resolution	0.1°@10 GeV
Nuclei charge resolution	10-15% for Z=1-26
e/γ energy resolution	<1%@200 GeV
Proton energy resolution	**20%@100 GeV - PeV**
e/p separation power	$>10^6$
Electron effective GF	$>3\ m^2sr$@200 GeV
Proton effective GF	$>2\ m^2sr$@100 GeV

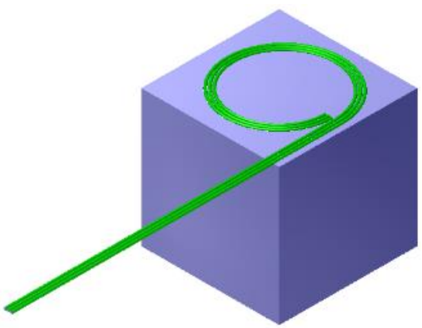
- Acceptance and nuclei energy reach: >10x of previous/current experiments
- Best energy resolution and particle ID for TeV-PeV electron, photon and nuclei

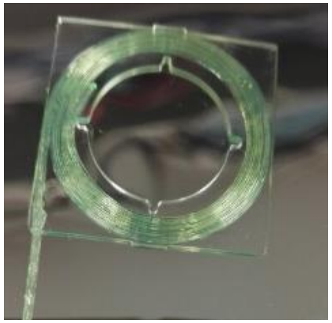
HERD: LYSO 3D Calorimeter

Crystal dimensions	~3x3x3 cm^3	
Number of crystals	~7500	
Radiation length	55	~21 LYSO crystals
Nucl. inter. length	3	
Fiber readout	3 WLSF/crystal (low & high range, trigger)	
Non-uniformity in, between crystal	<5%, <30%	
Space between crystal	<4,4,8 mm	
Alignment	< 0.5 mm	





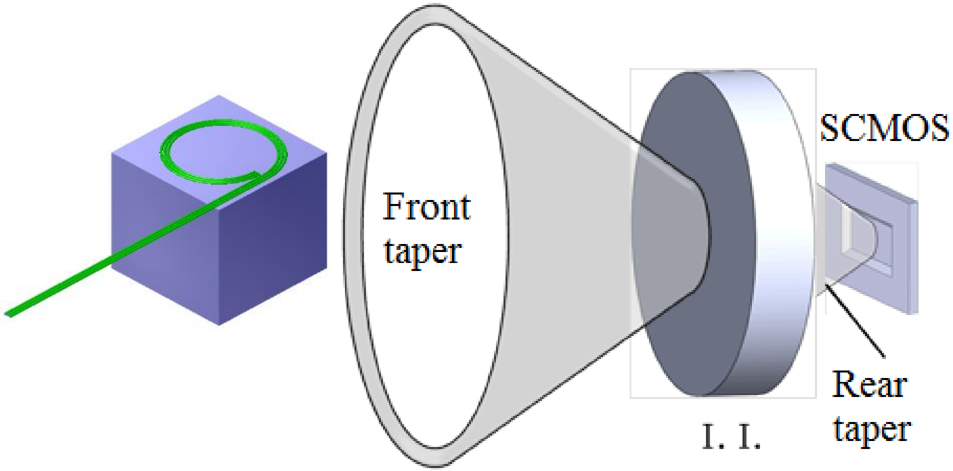




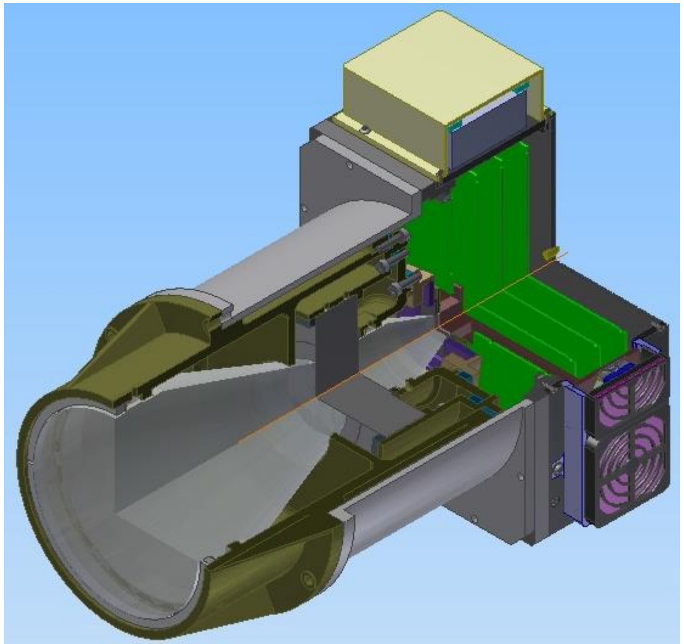
HERD: Calorimeter ISCMOS Readout

- Image intensifier (I.I) + sCMOS camera

Range	2, low and high
Input fibers	~7500/range
Dynamic range	~10^7 (30-10^8p.e)
Frame rate	500 fps
Energy resolution	~1%@200 GeV
ADC resolution	22 bits (2x11-bits)



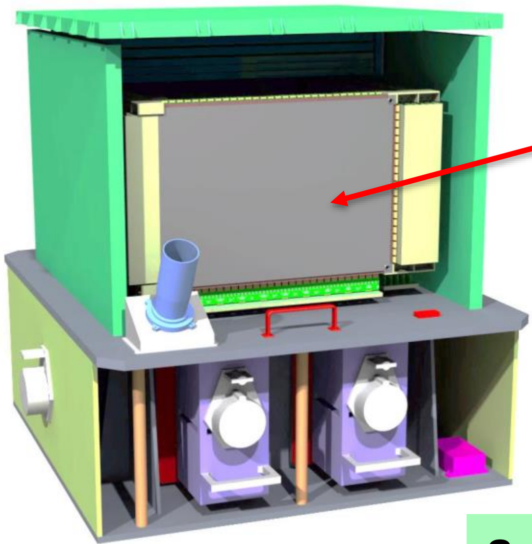
- ISCMOS camera prototype module
  - Size: 40x30x30 cm3
  - Weight: ~15kg
  - Power consumption: ~100W
  - Rad-soft, replaceable on CSS

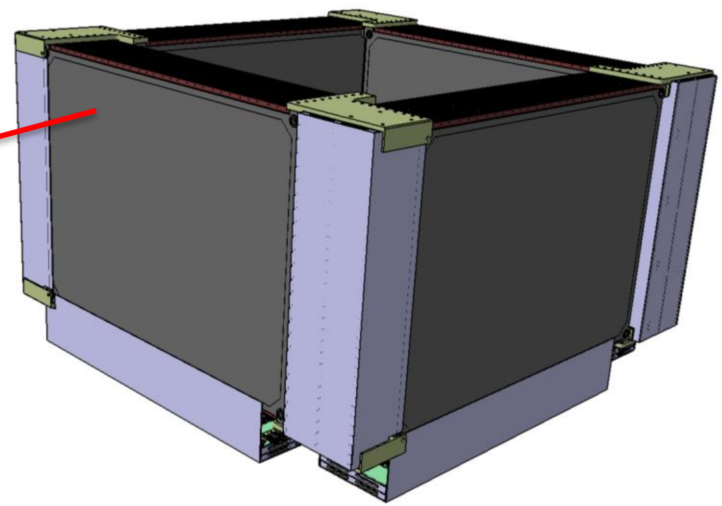


Prototypes tested at CERN in 2017 and 2018

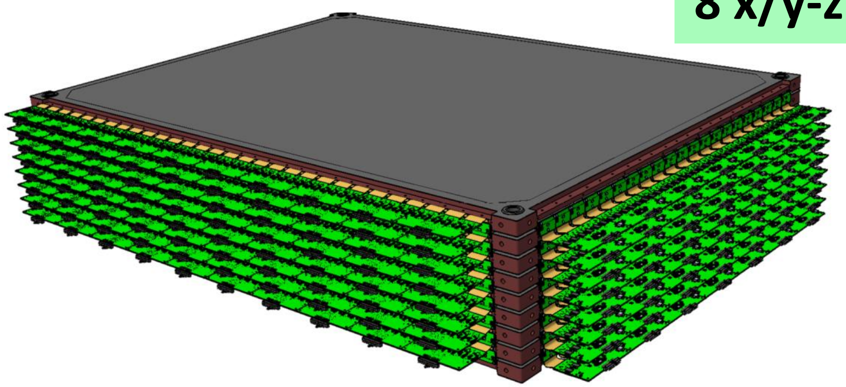
HERD CH contribution: Scintillating Fiber Tracker (FIT)

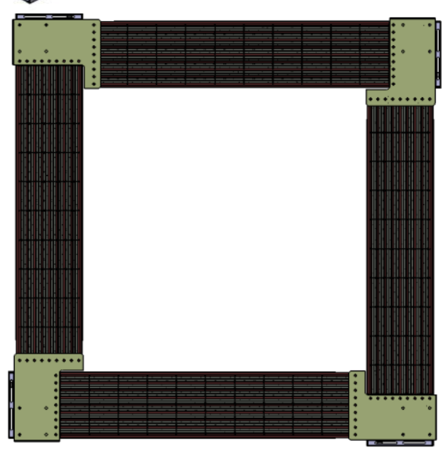
- Use fibers on 4-sides: beside tracking and charge measurement, also allows to use many tracking layers without converter to achieve unprecedented angular resolution at 100 MeV - 1 GeV range!





8 x/y-z SciFi layers



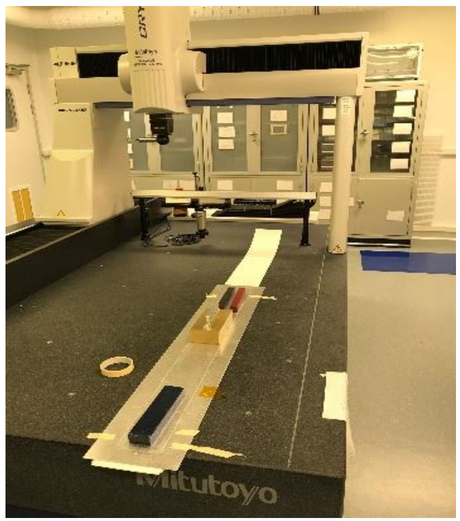


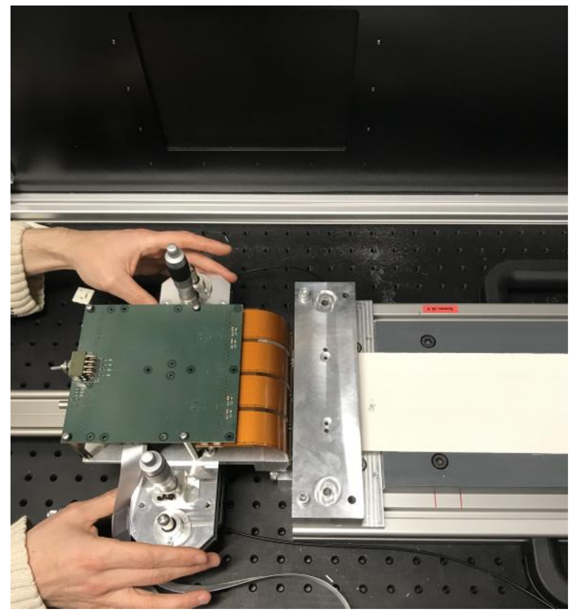
UNIGE (DPNC+DA), with strong support from EPFL

FIT Phase B R&D progress

Supported by the Swiss Space Office

- Several fiber mats provided by EPFL/LHCb, sufficient for Phase B
    - End-piece designed and fiber module assembly procedure established
        - Optical scan and light yield tests done at EPFL



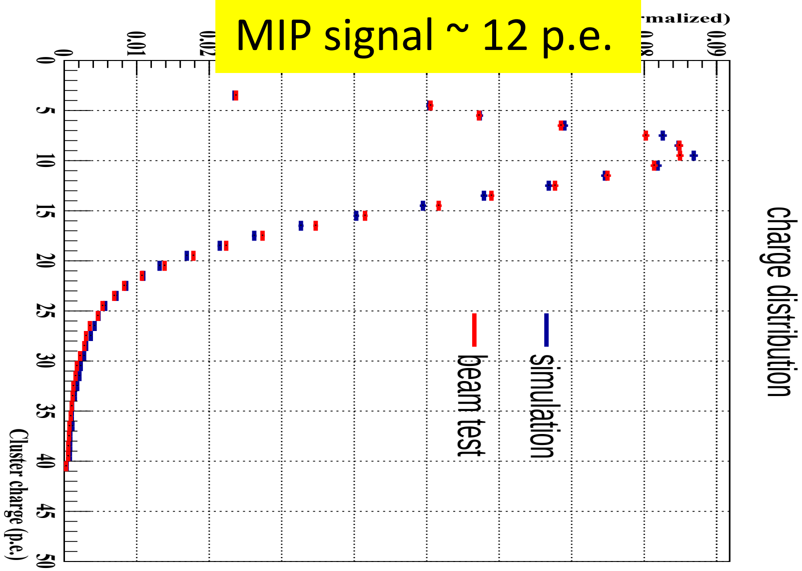


- 10µm cell-size MPPC-128 has been produced and tested

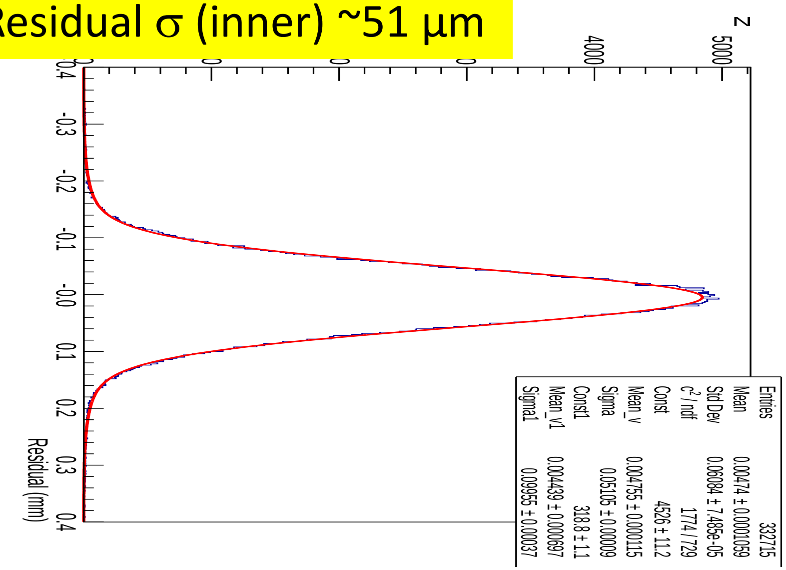
Beam test data analysis in progress …

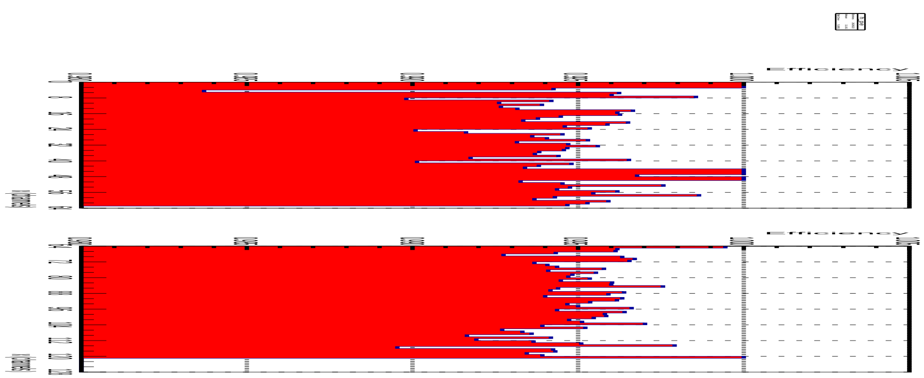
- Mat length ~ 77 cm, 10 µm MPPC, OV = 2 V, 400 GeV/c protons

MIP signal ~ 12 p.e.



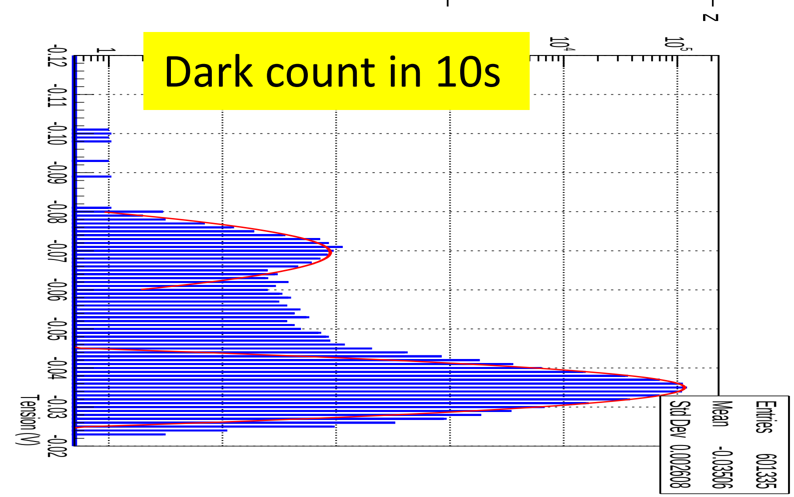
Residual σ (inner) ~51 µm





Efficiency ~99.5%

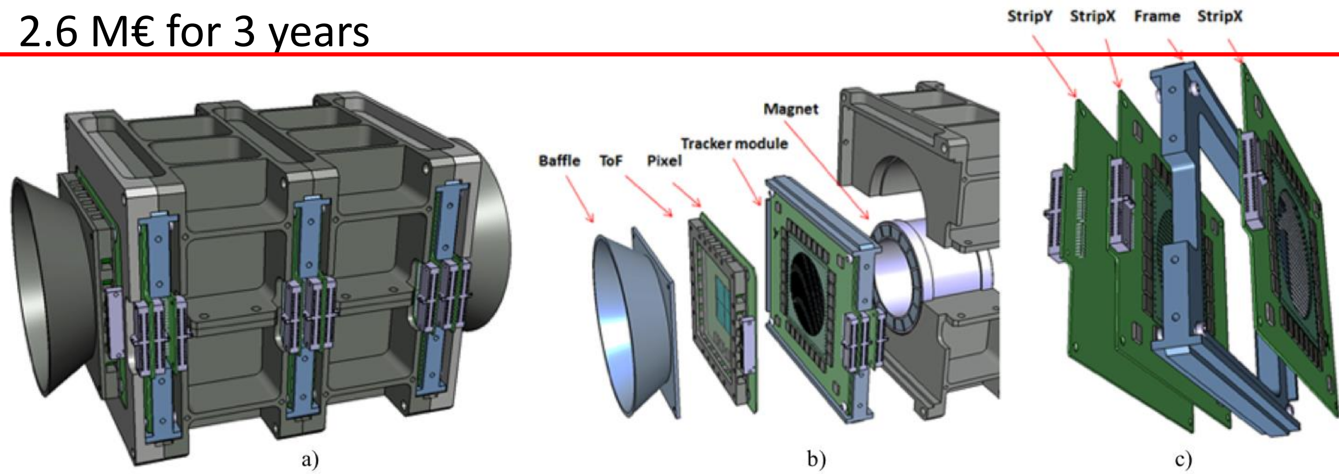
Dark count in 10s



DCR: 1p.e = 60 kcps, 2p.e = 183 cps, 3p.e = 0.6 cps

Going to Deep Space: PAN and mini.PAN

- Small magnetic spectrometer to precisely measure the flux of penetrating particles (100 MeV/n – 10 GeV/n) outside the Earth's magnetosphere
  - Never done before, has multidisciplinary applications
  - CR, DM, Solar physics, space weather, planetary, space travel …
- Project to build a demonstrator has been selected in the latest H2020 OPEN_FET call
  - UNIGE is the coordinator, with INFN Perugia and Czech Tech. U in Prague
  - 2.6 M€ for 3 years



Mini.PAN

- Key technologies
  - Tracker: SSD 150 µm thick, 25 µm r.o. pitch, 2 µm resolution in bending direction, 500 µm r.o. pitch, Z measurement for non-bending direction
  - TOF for charge and direction
  - Timepix 3 for high rate solar evets

Conclusions

- As a particle physics power house, CHIPP is able to contribute strongly to astroparticle physics and more crucially, to multi-messenger astrophysics
  - Leading roles in VHE γ-ray astronomy (MAGIC, FACT, CTA)
  - Leading roles (AMS, DAMPE, HERD)
  - Leading roles AR, POLAR-2)
  - Leading roles in neutrino astronomy (IceCube)
  - Key science/instrument partner for space missions (γ-ray, X-ray, …)

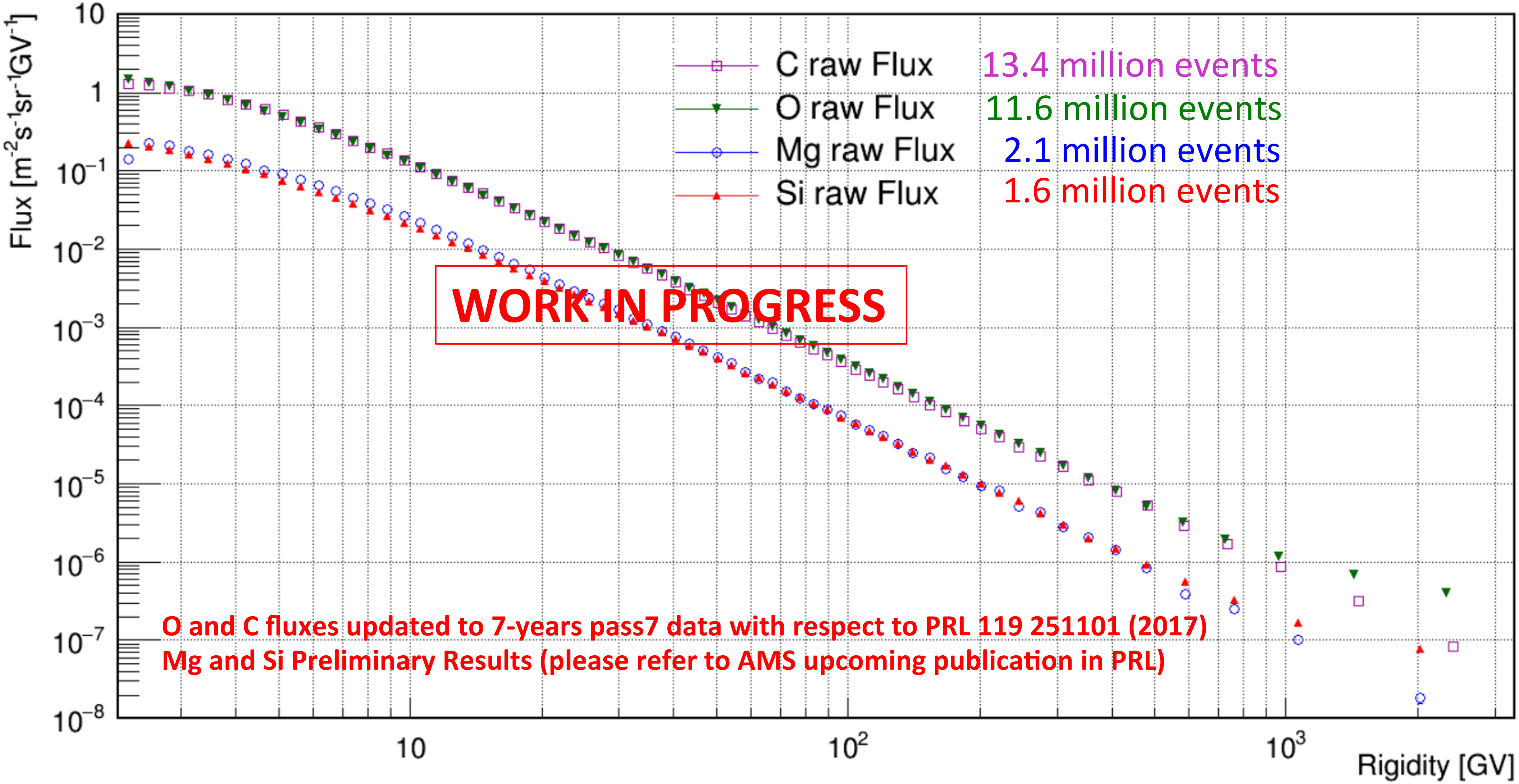
THANK YOU!

- Same for underground experiments (**next talk**)
- The important CH contributions are rewarded by many groundbreaking results in the past few years, and have ensured privileged access to future important experiments, with excellent long term perspectives
- Particle detection technology in space, same as in medical science, opens up new venues of science interest, technology development and cross-disciplinary collaboration
- It is important to strengthen the third pillar to provide the necessary extra leg (diversity) to keep CHIPP standing tall and stable!

Backup

Measurement of Primary Cosmic-Ray Nuclei fluxes

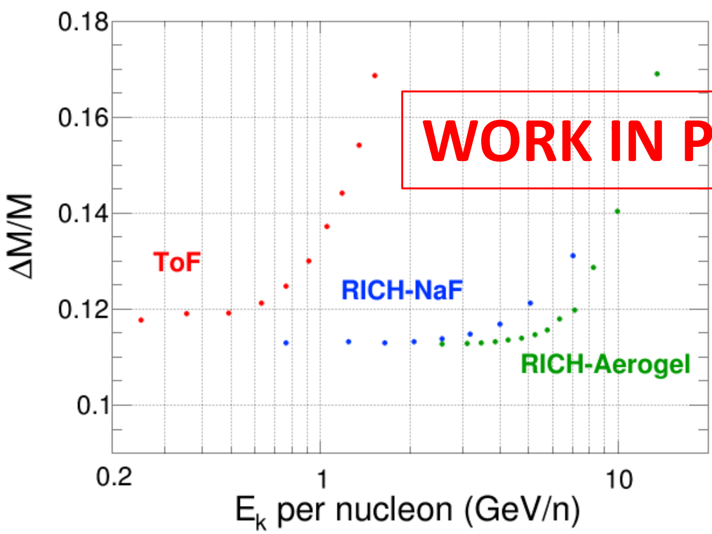
PhD theses works of
Yao Chen (Oxygen and Silicon)
and Zhen Liu (Carbon and Magnesium)



Beryllium Isotopic Composition

Jiahui Wei PhD thesis work

- The measurement of radioactive isotope to stable isotope ratio $^{10}Be/^{9}Be$ provides information to understand the propagation of cosmic rays.
- The beryllium isotopic ratio is measured by fitting to the mass spectra in kinetic energy per nucleon intervals.
- The mass is calculated with rigidity measured by the tracker and velocity measured by the Time-of-Flight and RICH detectors.
- The mass templates are built from Monte Carlo, and are validated by a data sample selected with geomagnetic cutoff where only one isotope exists.



WORK IN PROGRESS