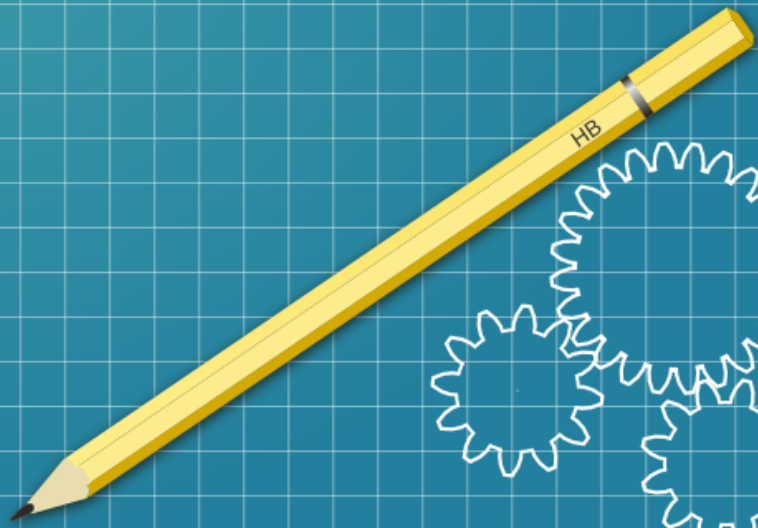
CTA+ Software/Science

A. Iuliano
CTAO NA Meeting
7 May 2024

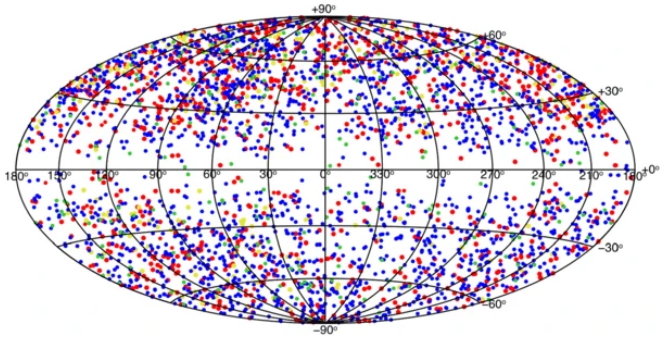


About me (and where to find me)

- Tecnologo INFN in CTA+ PNRR program from 1st September 2023
- Work office: 1Ma-01b
- Studio appoggio INFN (look for the posters!)

Search for TeV-emitting candidates in x-ray catalogs

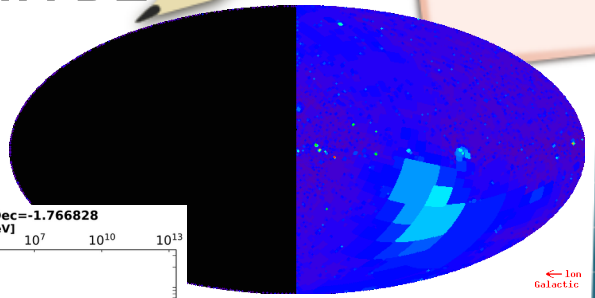
- Goal: to investigate currently available X-ray observations of known blazars
- Starting point: the Roma Multifrequency catalog of blazars,
- 5th edition: https://www.ssdc.asi.it/bzcat/: 3561 blazars
- Looking for possible sources currently undetected by Fermi
- Project within the CTAO/EGAL group
- Work with P. Da Vela, E. Prandini, S. Marchesi, D. Miceli, C. Righi, R. Zanin

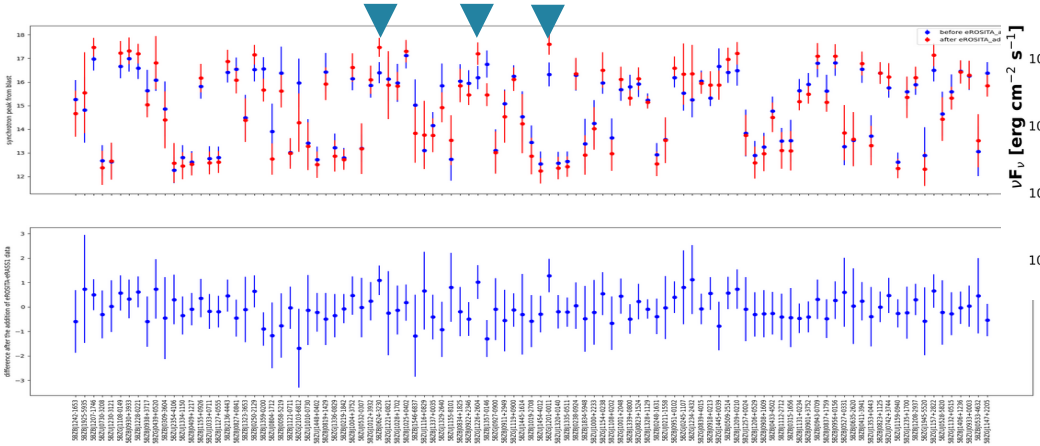


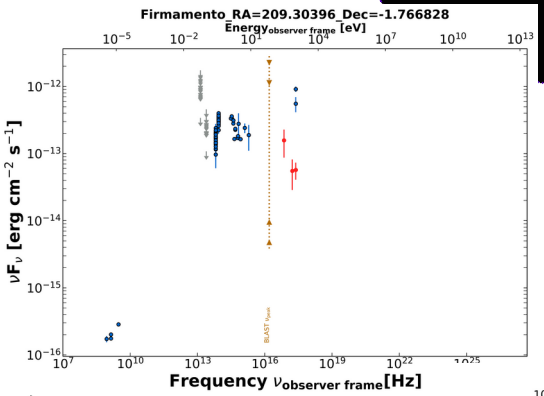
sky distribution in galactic coordinates of the blazars in the 5BZCAT catalogue,
from paper
Astrophys Space Sci 357, 75 (2015)

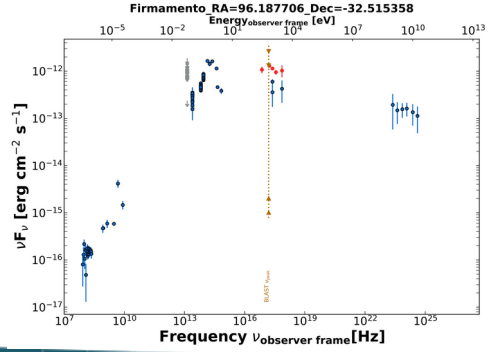
Addition of eRASS1 data to SED info

- At the end of January, released new catalog **eROSITA-DE** (20627 deg^2; eRASS1)
- https://cdsarc.cds.unistra.fr/viz-bin/cat/J/A+A/682/A34
- Studied the impact of the new large dataset in the SEDs









Outlier SEDs and variability

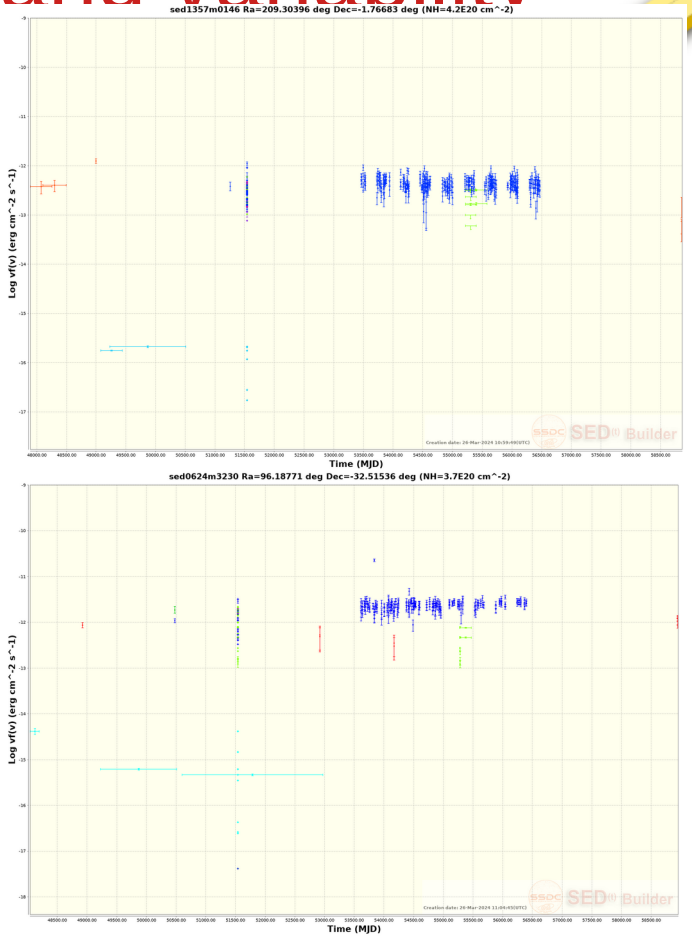
5BZBJ1357-0146

- Since eRASS1 data are more recent, different values may be explained with blazar variability in X-ray data

Colors according to energy band:
- Red: x-ray
- Blue: Optical
- Green: Infrared
- Cyan: Radio
- Violet: UV

SSDC(ASI) SED Builder: https://tools.ssdc.asi.it

5BZBJ0624-3230



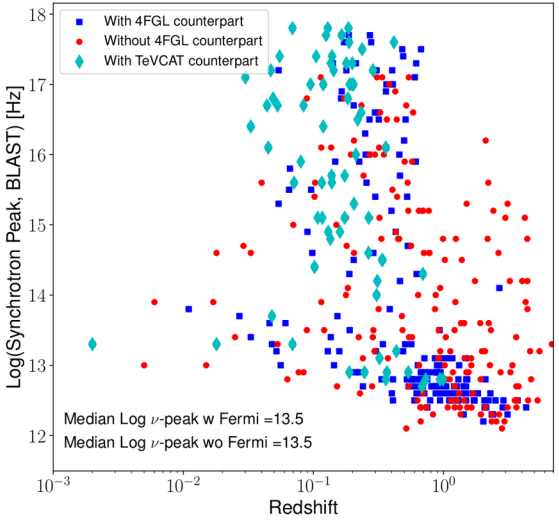
Cross-check of 5BZCat with other X-ray catalogs

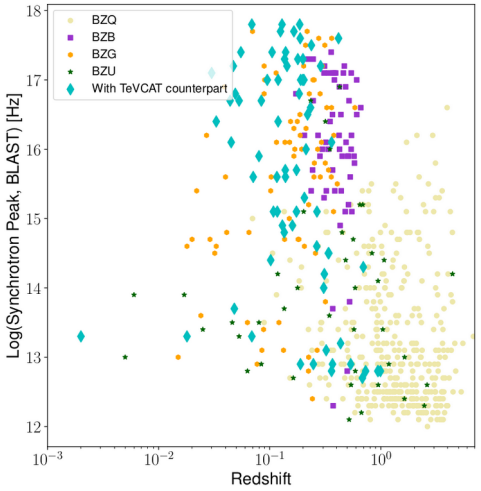
- Done by Stefano Marchesi
- Requiring angular separation of 10’’ (5’’ for Chandra’s catalog)
- TeVCAT used as a reference of TeV emitting sources

Catalog	X-ray Instrument	Area Covered deg^2	Sources	With *Fermi*-LAT	Without *Fermi*-LAT
4XMM-DR13	XMM-*Newton*	1328	313	181 (58 %)	132 (42 %)
2CSC	*Chandra*	560	218	131 (60 %)	87 (40 %)
2SXPS	*Swift-XRT*	3790	1666	1191 (71 %)	475 (29 %)
eRASS1	eROSITA	20627	1379	726 (52 %)	653 (48 %)
4XMM-DR13 or 2CSC			464	271 (58 %)	193 (42 %)
2SXPS, no 4XMM or 2CSC			1347	968 (72 %)	379 (28 %)
eRASS1 only			624	189 (30 %)	435 (70 %)
Overall			2435	1428 (59 %)	1007 (41 %)
Of which in TeVCAT			77	77 (100 %)	0 (0 %)

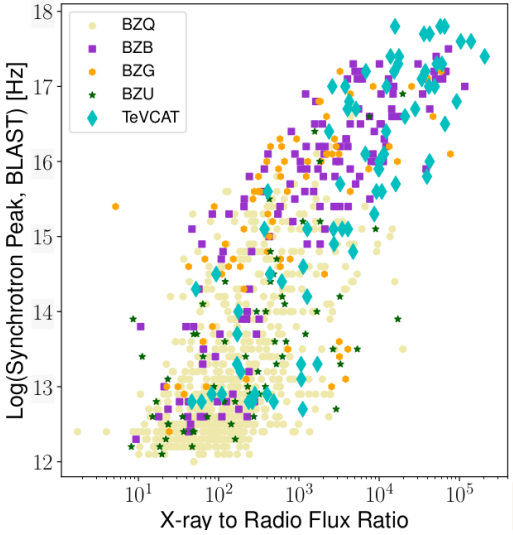
Analysis procedure

- Obtain multiwavelength Spectral Energy Distribution (SED) and estimate synchrotron peak with Firmamento
- Comparing properties of sources observed and not observed in Fermi



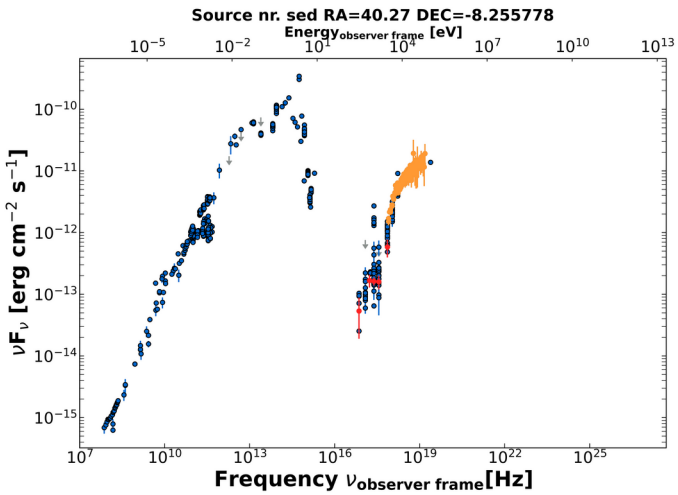


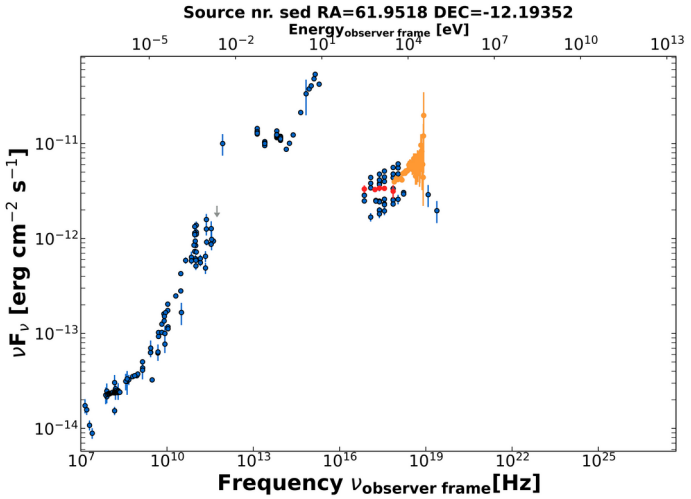
Courtesy of Stefano Marchesi



The NuBlazar catalog

- **NuBlazar** (MNRAS 514, 2022): catalog of 124 sources from NuStar measurements
- Already included in VOU-Blazars catalog lists used in our analysis
- Making an independent check of building SEDs directly from NuBlazar list
- From NuBlazar (orange) list, returned 54 sources with eRASS1 data (red)



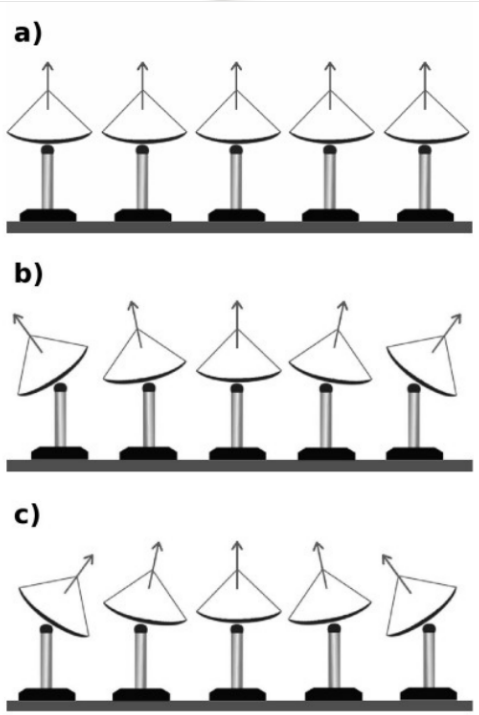


Project status

- Next steps: provide a catalog of TeV-emitting sources, assessing their detectability in CTAO
- Presentations at conferences:
  - CTAO Symposium in Bologna
  - CRIS-MAC at Trapani (in preparation)
- A paper currently in preparation to publish the results

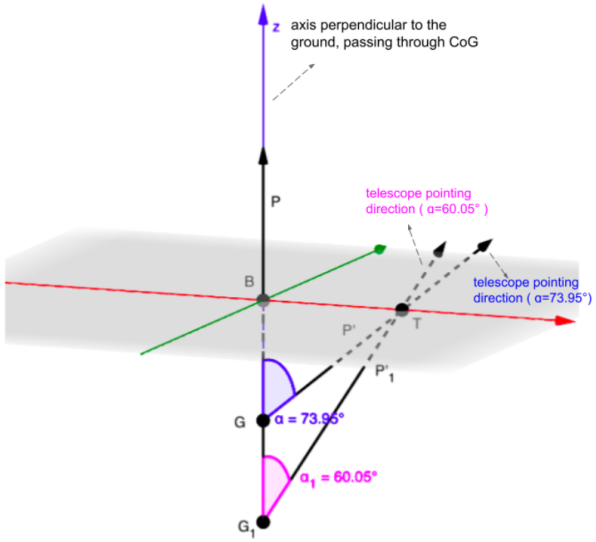
Divergent Pointing

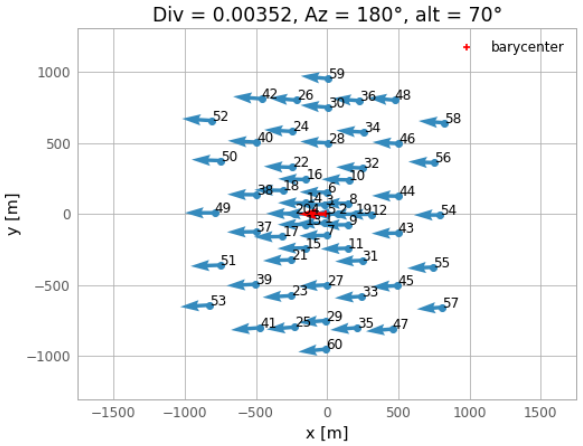
- An innovative strategy, profiting of the large number of telescopes in CTAO
- Telescopes bent into **outward** direction by an angle increasing with the distance from array Center of Gravity. Large Field of View at the cost of reconstruction capabilities
- Trade-off between performance and acceptance, according to source and aims



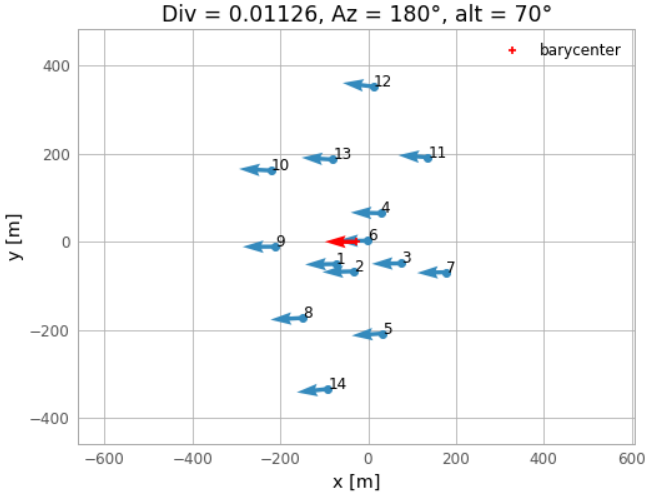
CTAO and Divergent Pointing

- CTAO Divergent Pointing project started by F. Longo's group
- Work with D. Ambrosino, C. Aramo, I. Burelli, T. Di Girolamo, N. Jahanvi, F. Longo, H. Luciani
- Current goal: design optimal pointing for the new array configurations





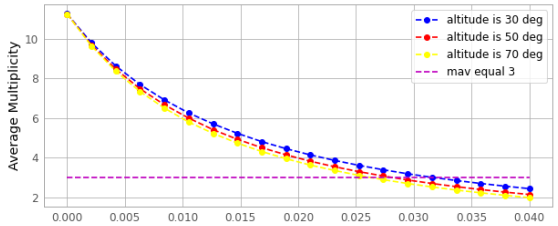
CTAO-South Alpha

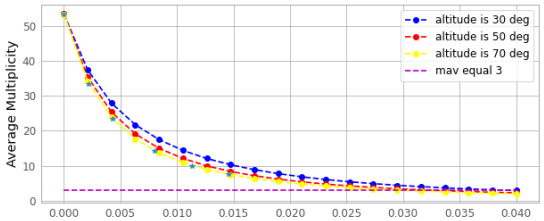


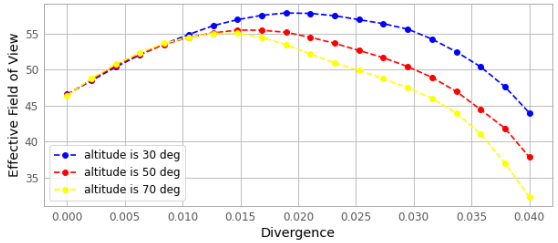
CTAO-North Alpha

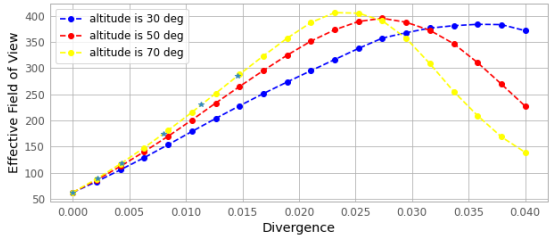
Geometrical performance

- Stand-alone python code divtel (https://github.com/cta-observatory/divtel)
- Provides pointing of telescopes in arrays (possibly sub-arrays)
- Purely geometrical performance assessment:









Summary of divtel performance study

- Computed configurations for two particular conditions:
  - 2xFOV: doubles the effective hyper Field of View
  - 3m: average multiplicity equal to 3

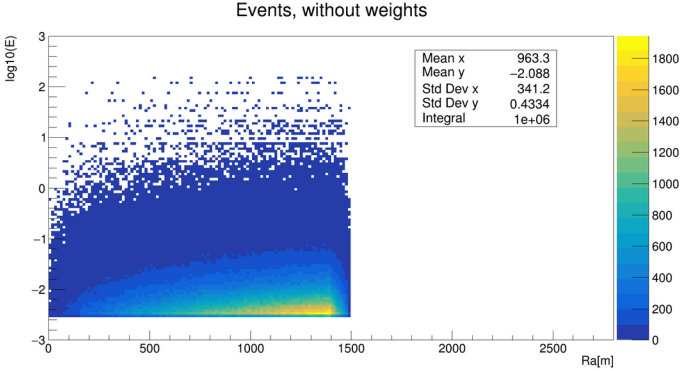
Config	divtel	hFOV	hFOV_eff	m_{ave}
South-3m	0.02955	1108.8	354.9	3.0
South-2xFoV	0.00352	124.9	107.1	26.6
North-3m	0.02631	174.4	49.3	3.0
North-2xFoV	0.01126	93.5	54.8	5.6

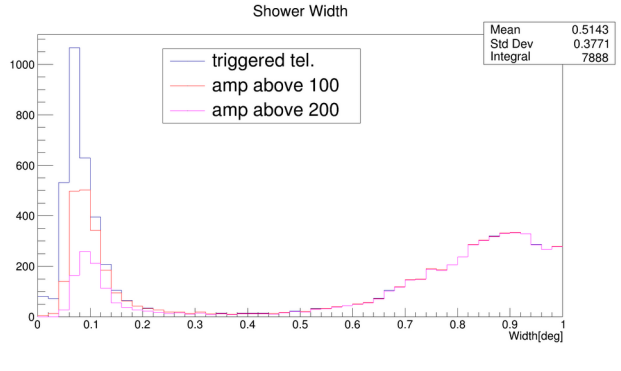
Monte Carlo production

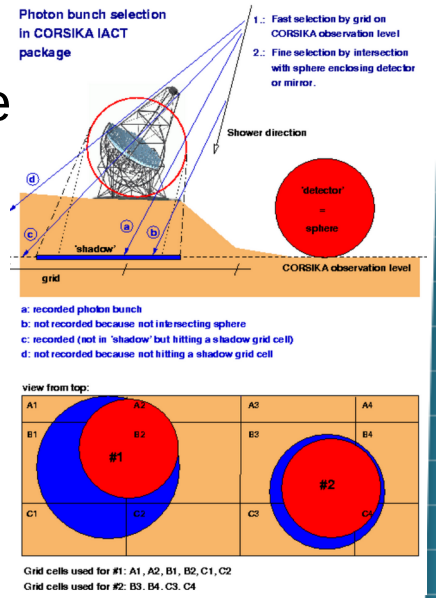
- Performance evaluation requires full Monte Carlo simulation
- Tests can be performed on the on-site container (as for LST data analysis)
- For us in Naples, ssh tunnel via our pc-cta server
- Actual simulations performed by the CTAO MC team (n.b. a few months required) and available in the GRID

CORSIKA and simtel_array

- CORSIKA: simulation of shower development in the air
  - Currently Fortran-based, a new C++ version under development with GPU support (CORSIKA 8)
- simtel_array: C++ library for response of the telescope array
  - Usually simulated along with CORSIKA, in our case done afterwards to include different divergence configurations





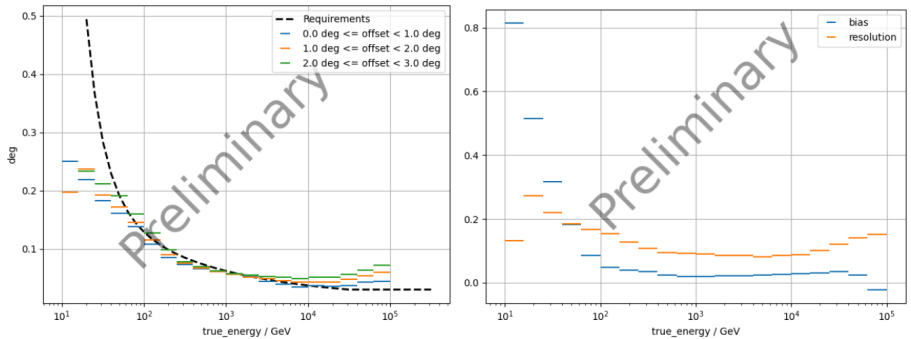


Test simulation of 10^5 ɣ

From simtel_array website

Analysis and IRF production

- After simulation, analysis can be performed with ctapipe
- Data level and procedure (DL0→DL3), same as parallel pointing simulations
- Finally, pyirf used for production of IRFs
- Again, small simulations can be used to test procedure, but actual IRFs need large statistics and Grid production



Southern array performance, Presented at ICRC 2023 by A. Donini
arXiv:2309.14106

Project Status

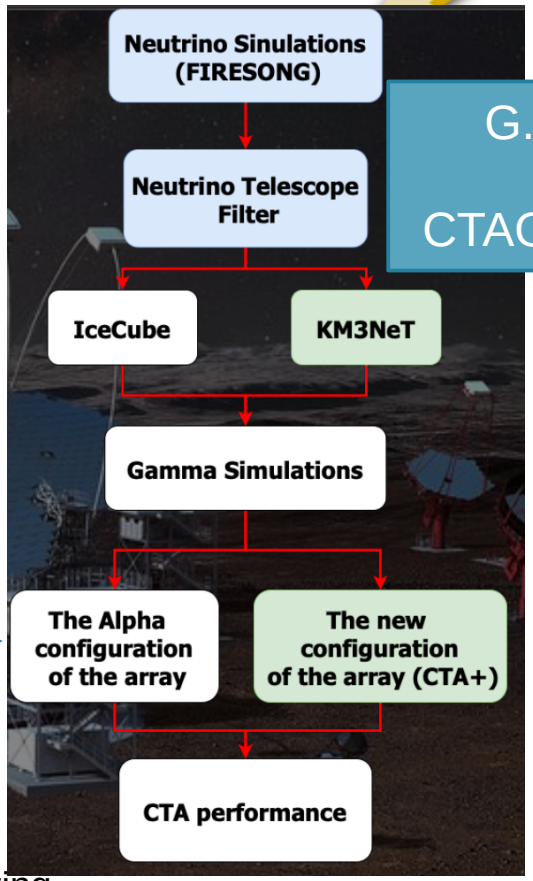
- Performance of multiple divergence configurations available for Southern array, to be assessed for the Northern array
- Irene recently completed her PhD at Udine
- Working towards a technical paper about divergence pointing configuration and performance
- Need to establish pointing configurations for specific user cases
- Possible convergence configuration for SSTs, subarray performance

Possible topics for personal study

- Maintenance and development of divtel repository (Irene now mostly busy in MAGIC activities)
- Gamma-ray counterpart for neutrino source alerts (NtoOs):
  - FIRESONG software repository for neutrino source simulations:

    https://github.com/icecube/FIRESONG/
  - Assess Divergent Pointing performance

Divergent Pointing



G.M.Cicciari
Talk at
CTAO symposium

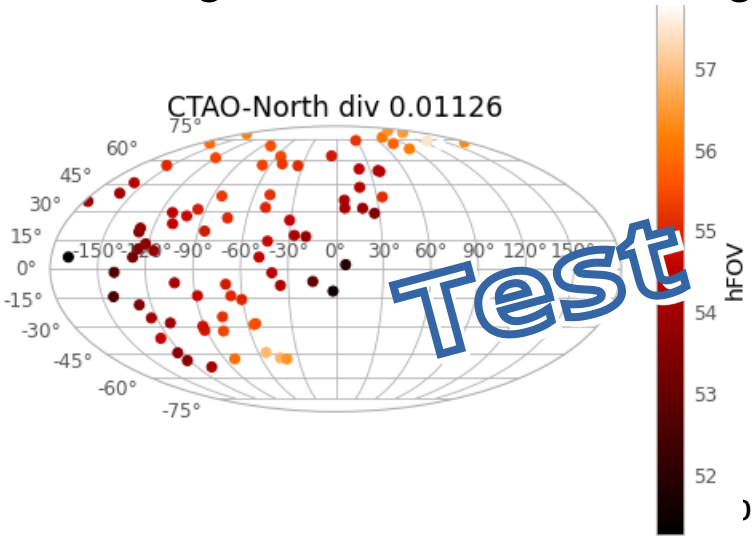
Divergent pointing to neutrino sources

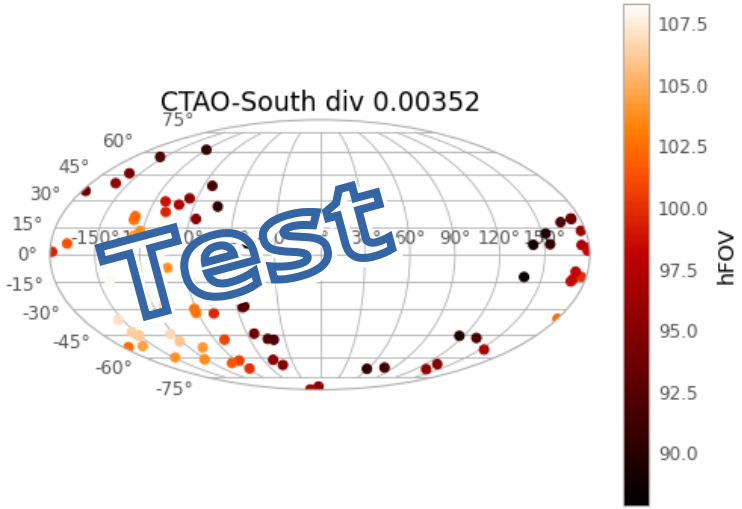
- FIRESONG provides source position, along with flux conversion to gamma:

$$E_\gamma J_\gamma(E_\gamma) \simeq e^{-\frac{d}{\lambda_{\gamma\gamma}}} \frac{2}{K} \frac{1}{3} \sum_{\nu_\alpha} E_\nu J_{\nu_\alpha}(E_\nu)$$

M.Ahlers, K. Murase
Phys. Rev. D 90, 023010

- Pointing CTAO with divtel for geometrical performances





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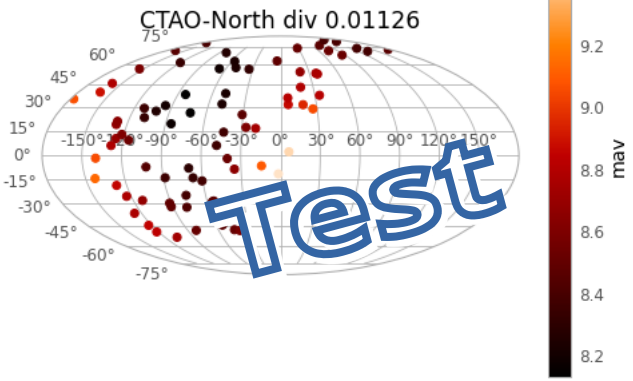
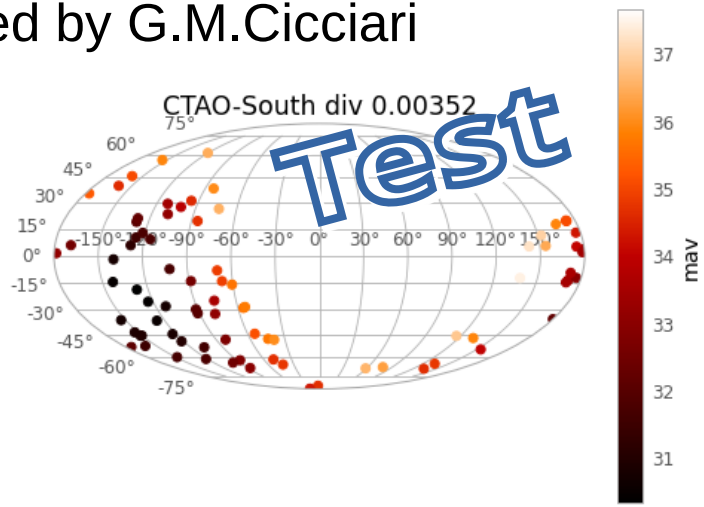
M.Ahlers, K. Murase
Phys. Rev. D 90, 023010

- 174 sources with z≤ 1.0 and flux ≥ 10^{-12} erg cm^{-2} s^-1
- Can be done with same sources selected by G.M.Cicciari





Other planned activities

- Poster presentation at CRIS-MAC conference in Trapani:
  - Cosmic rays course for high school teachers held at L’Aquila in December 2023
- Teaching assistance at CTAO Summer School in Bertinoro:
  - Hands-on session in Proposal Preparation for LST
- High school teachers course at Padova in September
- Shift at LST-1 as my LST duty (23 September – 14 October)


Thanks


Introduction
• Goal: to investigate currently available X-ray observations of known blazars, with a complete and unbiased approach
• Starting point: the Roma Multifrequency catalog of blazars, 5th edition: https://www.ssdc.asi.it/bzcat/
3561 blazars, selected on the basis of their rádio emissions
• Four classes, according to multiwavelength properties:
5BZB, 5BZG, 5BZQ, 5BZU (colors as in sky distribution dots)
• Dividing the set of blazars in two groups, according to the presence or not of a counterpart in the Fermi-LAT 4FGL-DR4 catalog
https://fermi.gsfc.nasa.gov/ssc/data/access/lat/14yr_catalog/
sky distribution in galactic coordinates of the blazars in the 5BZCAT catalogue, from paper Astrophys Space Sci 357, 75 (2015)
Iuliano - VHE Blazars
Missione 4 • Istruzione e Ricerca
CTAOSymposium