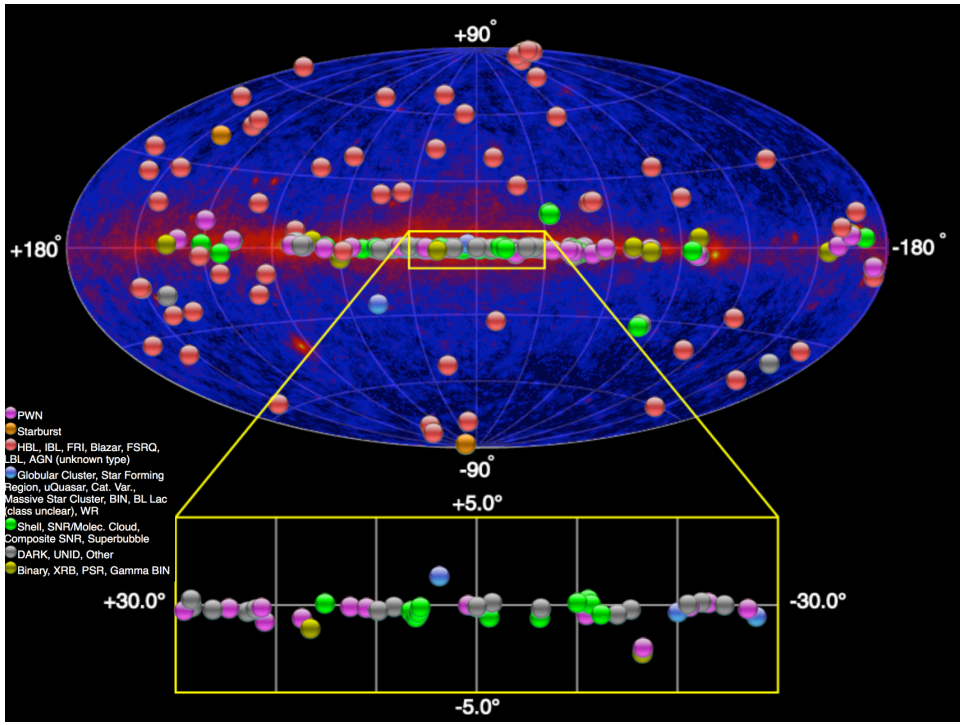
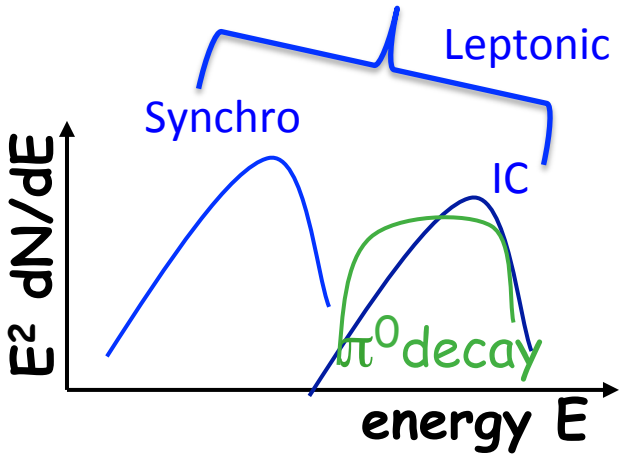
Gamma-rays: the last 10 years and what's in the next 20 (A De Angelis, INFN Pd)

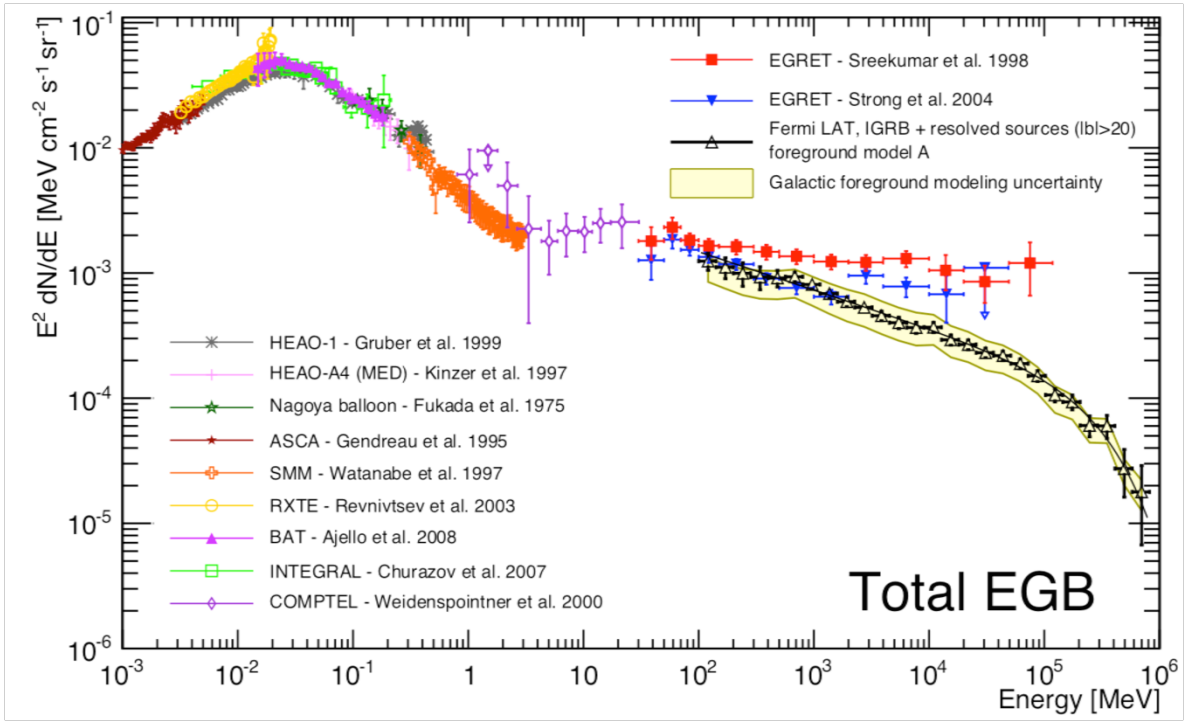
- VHE: impressive success of Cherenkov Imaging technique; will continue with CTA (balistic)
  - Fundamental physics: acceleration & CR (solved up to ~1 PeV), DM, ALPs
  - CTA knows how to improve sensitivity by a factor of 10 on the basis of present technologies with safe science and a relatively cheap price. INFN has tradition, experience, infrastructure
  - But in addition we know what was wrong with previous EAS; HAWC demonstrated we can cure it
    - New HAWC-like experiment? South, North?
  - New technologies?
- Satellite: success of Fermi (and Agile)
  - Fundamental physics: Acceleration & CR, new acc. sites, many unconfirmed hints of new particles, constraints on DM
  - But: Fermi seems still to be the successor of Fermi
  - Unless we change the scope: MeV? Calorimetry? X-rays?

The gamma-ray spectrum



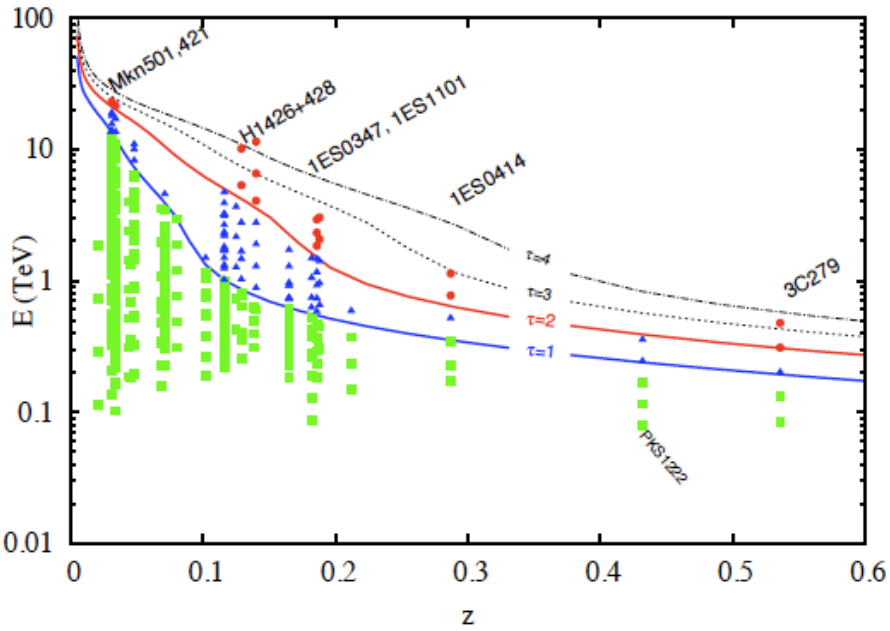
- Cutoff at PeV: leptonic mechanism? Absorption from EBL photons?
- The diffuse spectrum and the astrophysical backgrounds: limited by knowledge of the MeV region

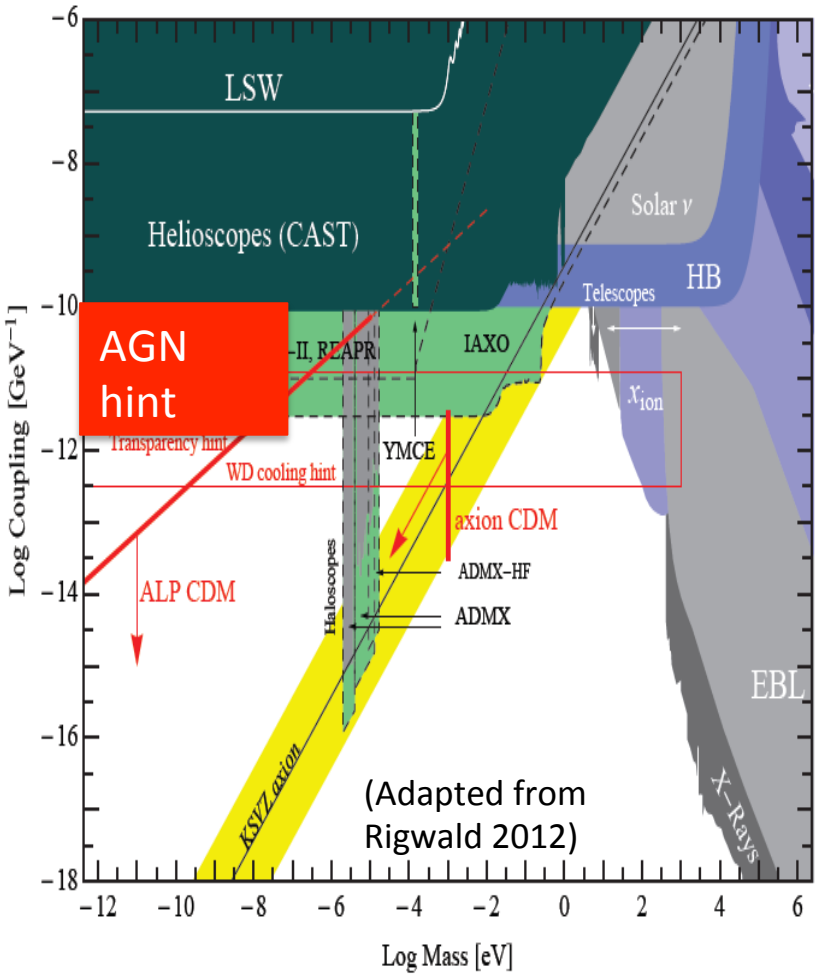




Focusing on physics items: Axion-Like particles

- The propagation of cosmological photons is marginally consistent with EBL; ALPs would make the picture coherent
- Needs more AGN at high energy (CTA, …); North is slightly better than South, but South still OK
- Overlapping with lab experiments
- But: valid for any particle with photon mixing





Focusing on physics items: WIMPs

- Difficult for CR experiments
  - WIMPs need to be separated from astrophysical background
  - But: can answer to the question ``where''
- What is the DM? Work with no prejudice; likely that if it is in the region of large mass (ground-based), detectors in the South are better
  - LSTs in CTA South Approved
  - New projects
    - 5@5 (Aharonian+ 2000): 5 large (~20 m) detectors at 5000 m (southern hemisphere)
    - A southern HAWC (LATTES?) (Shellard+ 2014)
    - A new concept: MACHETE (meridian 50 m "static" Cherenkov) (Cortina+ 2015)
  - The problem is that all new projects are in the 20 MEUR scale
- Knowledge of astrophysical backgrounds will be needed to be able to model sources & diffuse bckg
  - MeV region, satellites

Focusing on physics items: physics near compact objects (galactic, SMBHs)

- Synergy with different messengers, larger statistics on AGN, …
- GRBs: detectability at different ranges (X, MeV, GeV, TeV), multiwavelength, …
- Planning possible discoveries is difficult

Satellites

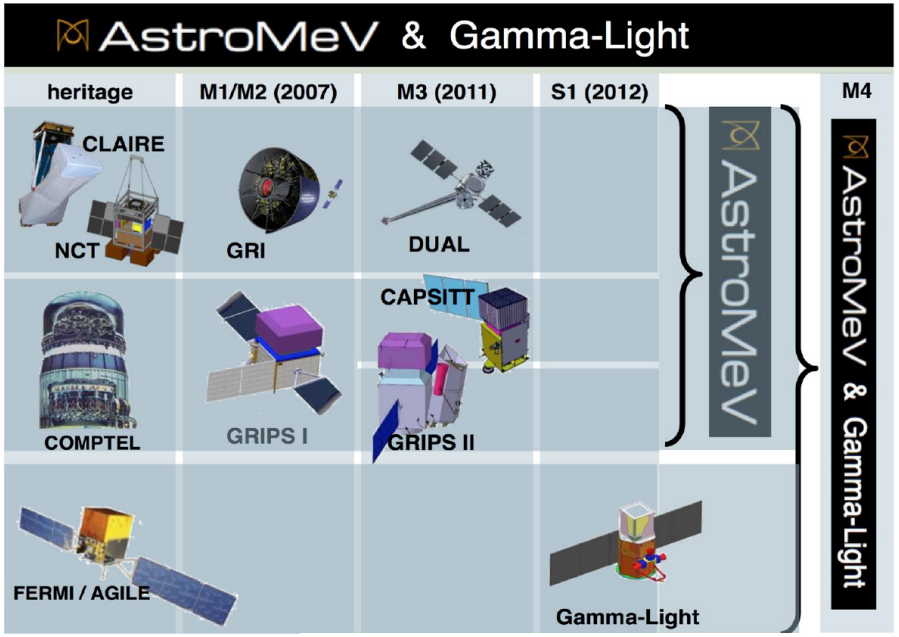
- A Fermi-like detector monitor is needed and Fermi might be its successor
  - Gamma-400 is the only possible other monitor in short time; follow the Chinese evolution
- Several projects could improve the sensitivity in the sub-GeV region
  - Gamma-400 + Si-hat, PANGU, … (> 10 MeV)
  - Astrogam, Compair, … (> 0.3 MeV)

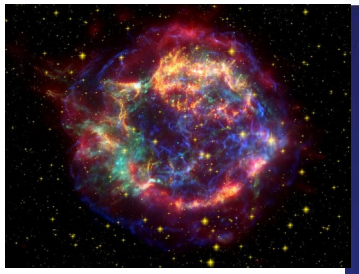
- Is the keV region of interest for INFN (LOFT)?

- The INFN participation to the satellite business would profit of directions

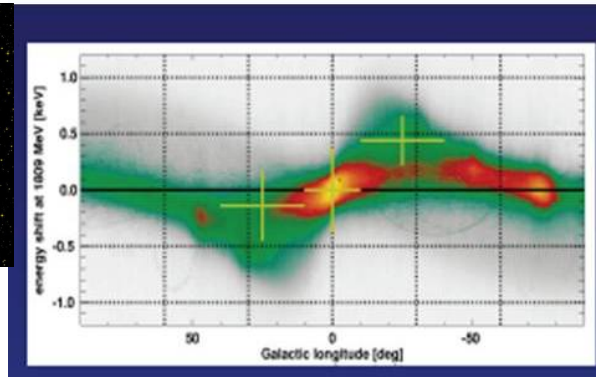
HARD X-RAY TO SOFT γ-RAY RANGE

In this range of λ, various space-borne observatories foreseen.
Gradual merging toward a synthesis ?





^{44}Ti



^{26}Al

Old-style good physics (GP), plus considerable options of new physics (NP). **GP:**

i) Nuclear lines from radioactive isotopes (^{26}Al, 1.8 MeV; ^{7}Be (0.47MeV); ^{44}Ti (up to 1.157 MeV...). → Mapping of SNe (Ti) vs diffuse (Al) nucleosynthesis.

ii) e^+e^- annihilation (0.5 MeV)

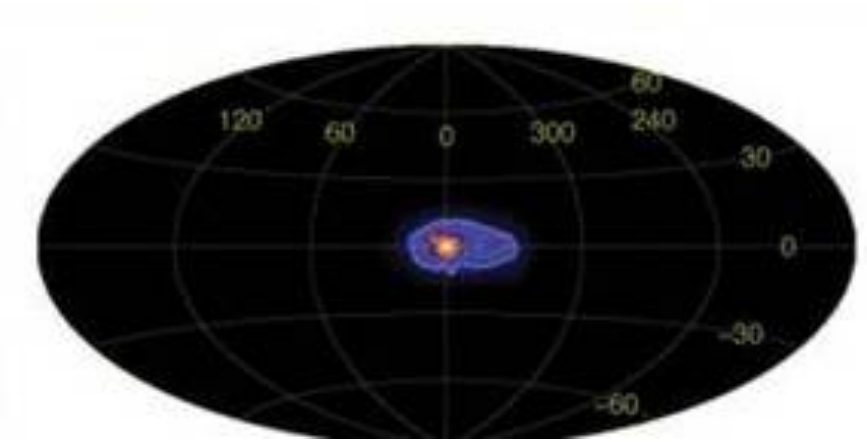
Isotope	Mean Lifetime	Decay Chain	γ -Ray Energy (keV)
^{7}Be	77 d	$^{7}Be \rightarrow {}^{7}Li^*$	478
^{56}Ni	111 d	$^{56}Ni \rightarrow {}^{56}Co^* \rightarrow {}^{56}Fe^* + e^+$	158, 812; 847, 1238
^{57}Ni	390 d	$^{57}Co \rightarrow {}^{57}Fe^*$	122
^{22}Na	3.8 y	$^{22}Na \rightarrow {}^{22}Ne^* + e^+$	1275
^{44}Ti	85 y	$^{44}Ti \rightarrow {}^{44}Sc^* \rightarrow {}^{44}Ca^* + e^+$	78, 68; 1157
^{26}Al	1.04 10^6y	$^{26}Al \rightarrow {}^{26}Mg^* + e^+$	1809
^{60}Fe	3.8 10^6y	$^{60}Fe \rightarrow {}^{60}Co^* \rightarrow {}^{60}Ni^*$	59, 1173, 1332
e^+	.... 10^5y	$e^+ + e^- \rightarrow Ps \rightarrow \gamma\gamma$..	511, <511

NP:

Emission from Galactic Center

i) Info from the lop-sided distribution of DM?

ii) Or simply distribution of X-ray binaries? Other sources?



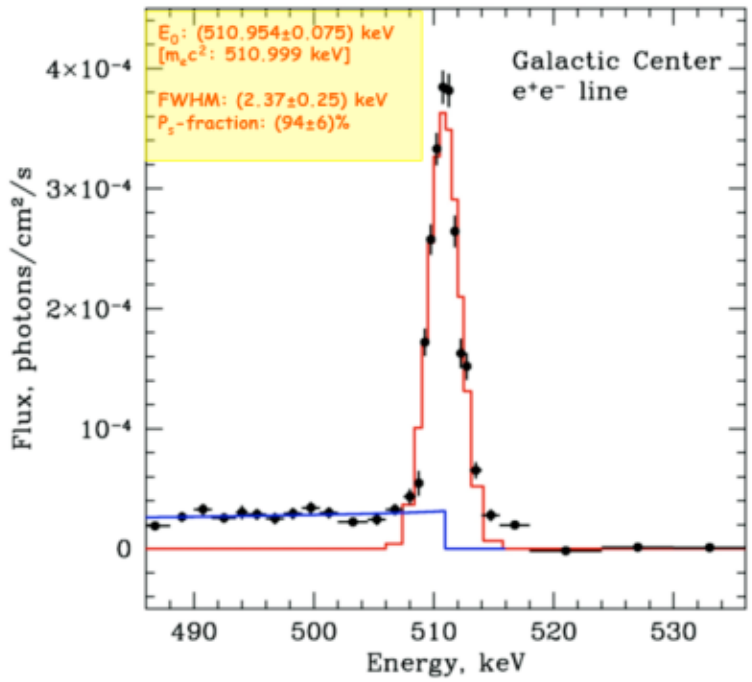
- This (0.1-100MeV) is in any case a region with few data & worth exploring
- Here we see transition from "quasi" thermal (Compton) radiation & non-termal phenomena)

-Important for light DM searches (and in general DM background), nucleosynthesis, Cosmic Rays at the border of solar radiation, GRB, ...

Range in energy can be covered by:

-Si tracker (higher energies, E > 10 MeV)

-(Si tracker+) Calorimeter (lower energies, E = 0.3 - 10 MeV)



Some messages

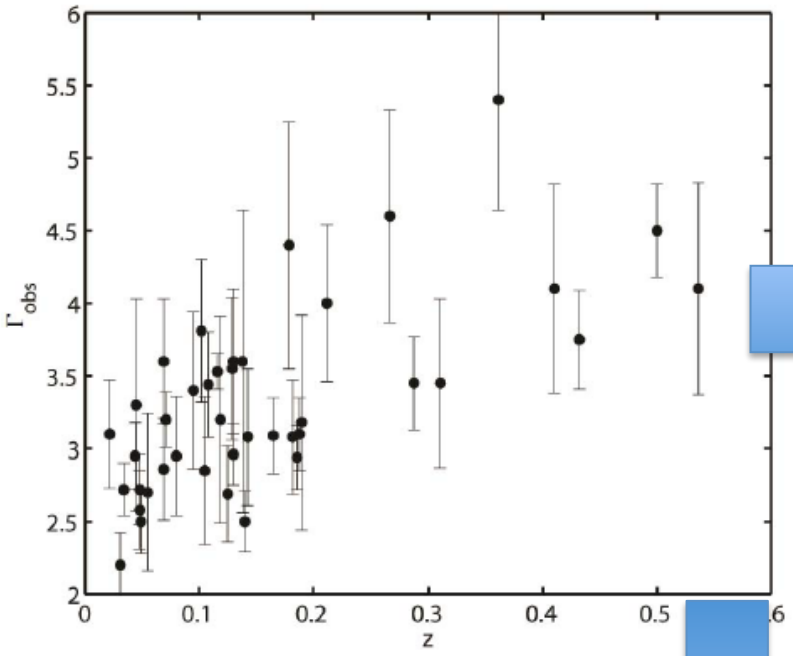
- Now
  - Prepare for CTA
  - Keep Fermi in space as long as possible
  - Make some exploration on new technologies (satellite, ground)
  - Follow the debate on MeV instruments, *maybe in an organized way*

- In 2025, there could be HAWC, CTA, a GeV satellite (?), one or more MeV satellites, and (?) one or two new EAS?
  - And in any case (V)HE gammas will be needed for multimessenger astrophysics

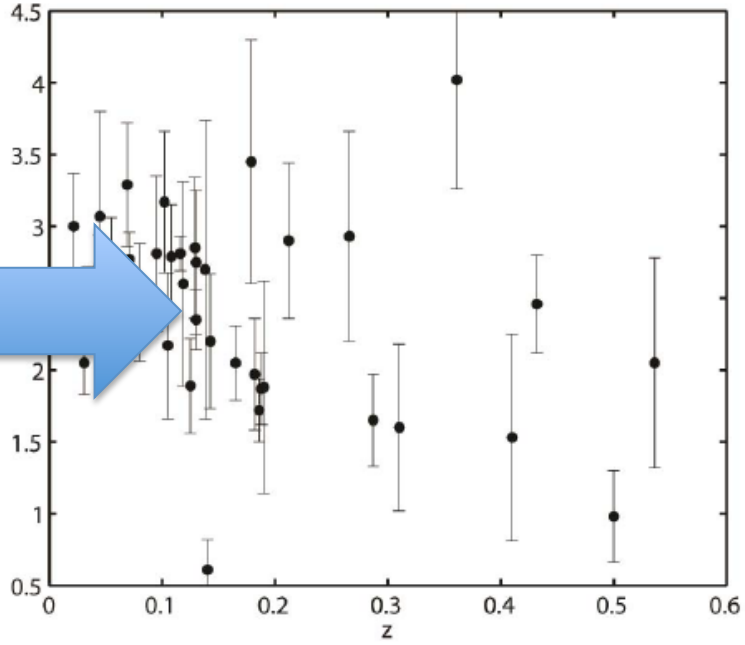
Post scriptum: an important thing missing

- A world infrastructure for discussing multimessenger astroparticle physics
  - What is CERN for accelerator physics
  - Could it be a CERN division?
  - Could it be in Italy? (What next has been/can be a seed)

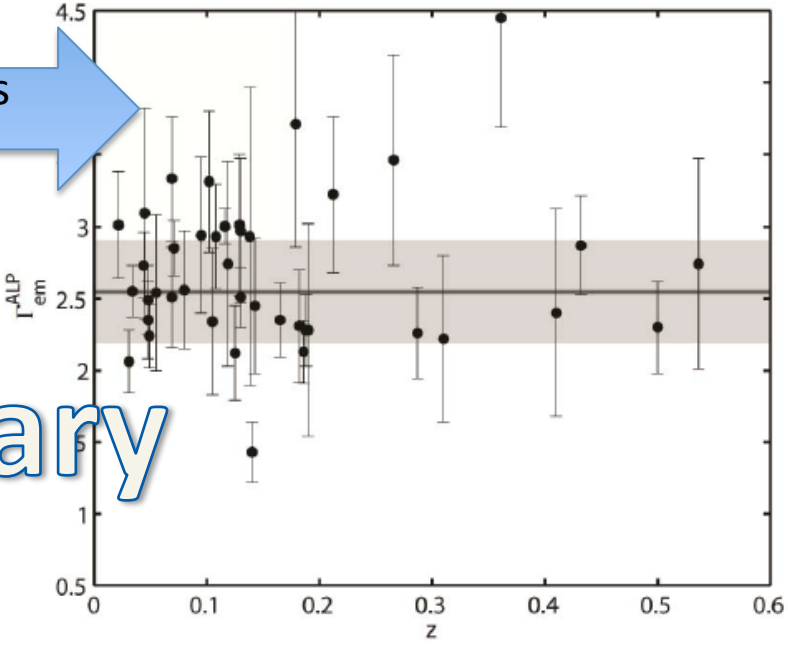
BACKUP



EBL



EBL+axions



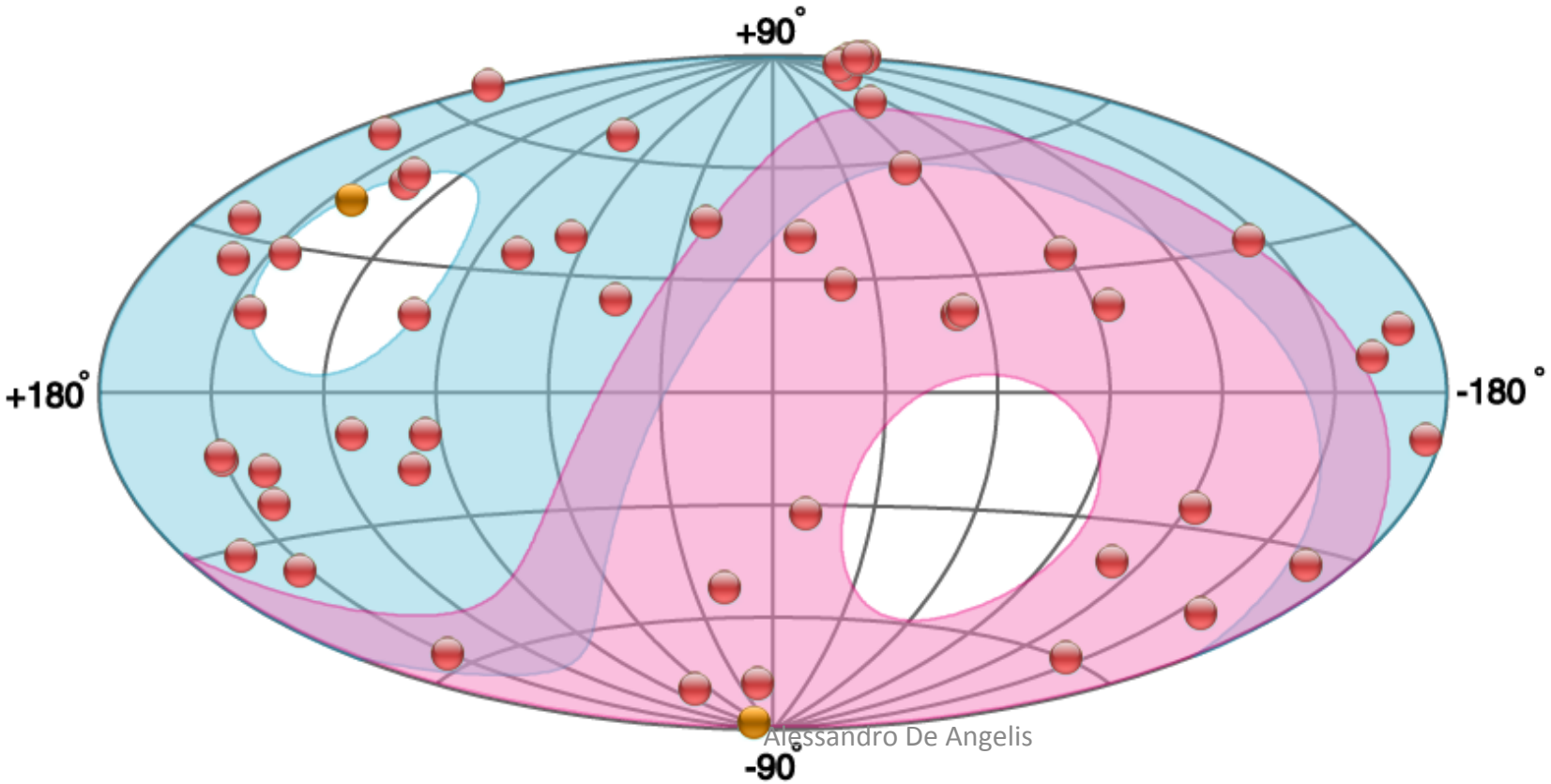
Potential of LST: improve statistics at large z

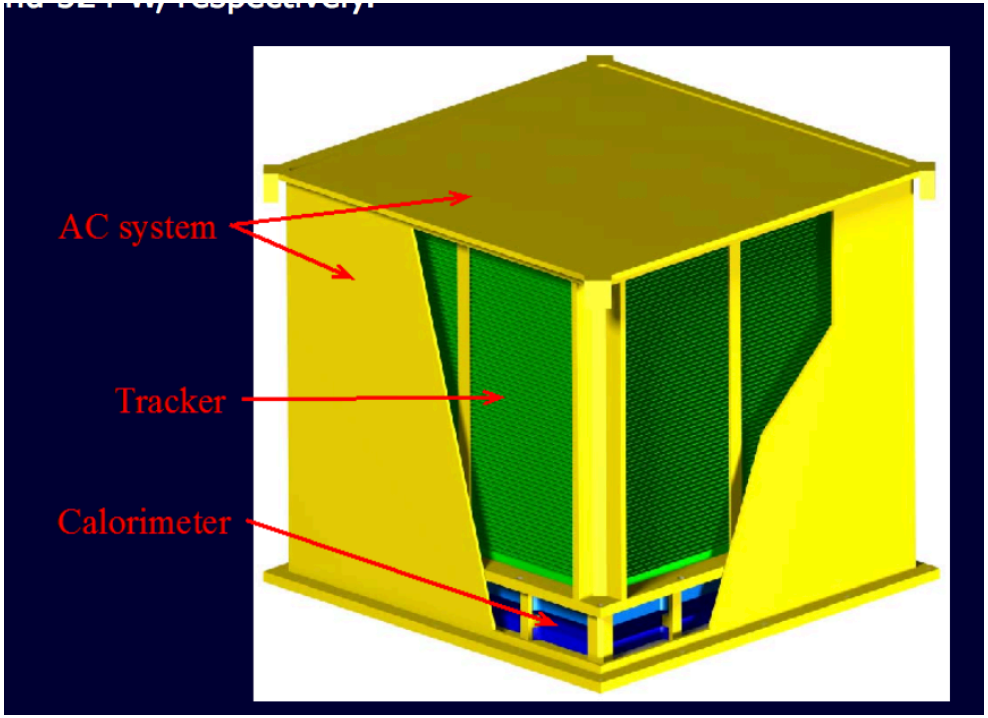
Preliminary

Galanti, Roncadelli, Bignami, AdA
arXiv:1503.04436

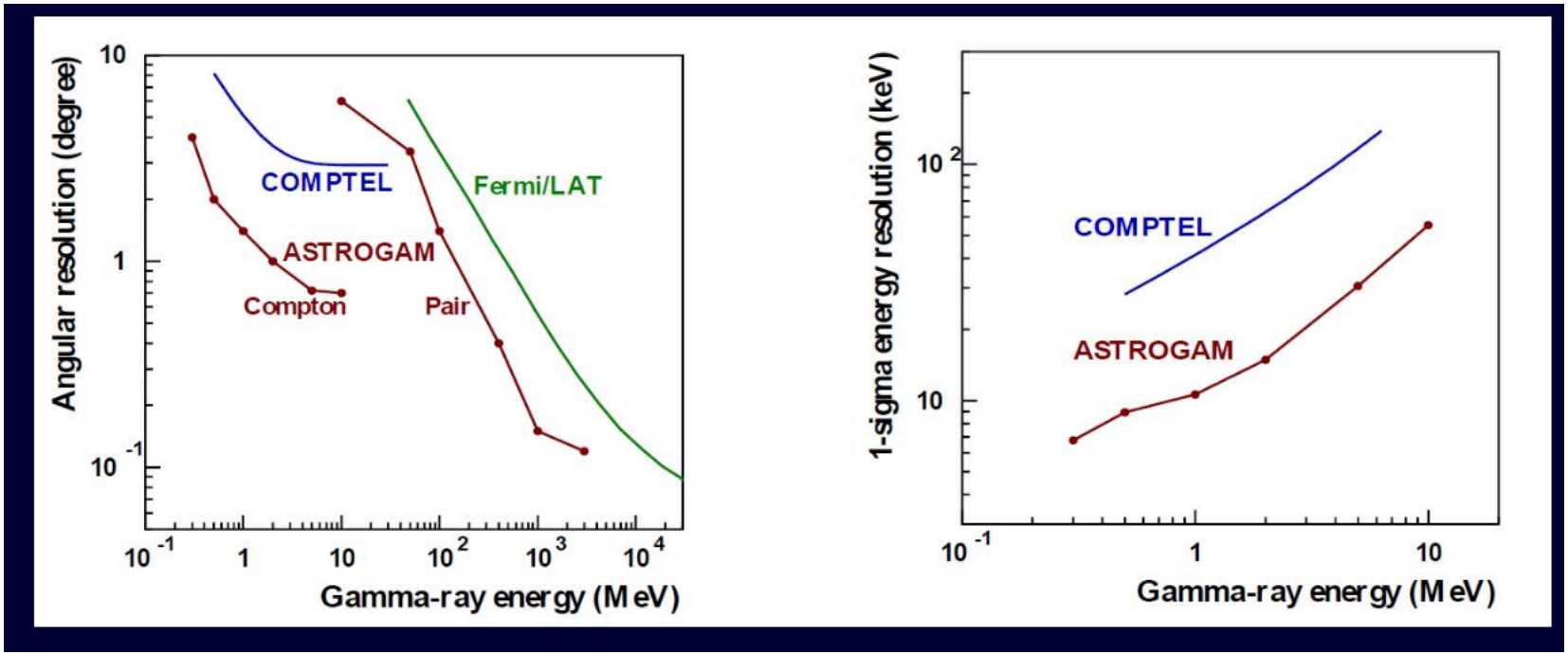
Extragalactic Sources

S3 0218+35	02 21 05.5	+35 56 14	Blazar	2014.07	z = 0.944
3C 279	12 56 11.1	-05 47 22	FSRQ	2008.06	z = 0.5362
PG 1553+113	15 55 44.7	+11 11 41	HBL	2006.03	z = 0.5
1ES 0647+250	06 50 46.5	+25 03 00	HBL	2011.09	z = 0.45
4C +21.35	12 24 54.4	+21 22 46	FSRQ	2010.06	z = 0.432
3C 66A	02 22 41.6	+43 02 35.5	IBL	1998.03	z = 0.41
PKS 1510-089	15 12 52.2	-09 06 21.6	FSRQ	2010.03	z = 0.361
PKS 0447-439	04 49 28.2	-43 50 12	HBL	2009.12	z = 0.343
1ES 0502+675	05 07 56.2	+67 37 24	HBL	2009.11	z = 0.341
S5 0716+714	07 21 53.4	+71 20 36	IBL	2008.04	z = 0.31
1ES 0414+009	04 16 52.96	+01 05 20.4	HBL	2009.11	z = 0.287
PKS 0301-243	03 03 23.49	-24 07 35.86	HBL	2012.07	z = 0.2657
MS 1221.8+2452	12 24 24.2	+24 36 24	HBL	2013.05	z = 0.218
1ES 1011+496	10 15 04.1	+49 26 01	HBL	2007.09	z = 0.212
RBS 0723	08 47 12.9	+11 33 50	HBL	2014.01	z = 0.198
RBS 0413	03 19 47	+18 45 42	HBL	2009.10	z = 0.19
1ES 0347-121	03 49 23.0	-11 58 38	HBL	2007.08	z = 0.188
1ES 1101-232	11 03 36.5	-23 29 45	HBL	2006.04	z = 0.186
1ES 1218+304	12 21 26.3	+30 11 29	HBL	2006.05	z = 0.182
RX J0648.7+1516	06 48 45.6	+15 16 12	HBL	2010.03	z = 0.179
H 2356-309	23 59 09.42	-30 37 22.7	HBL	2006.04	z = 0.165



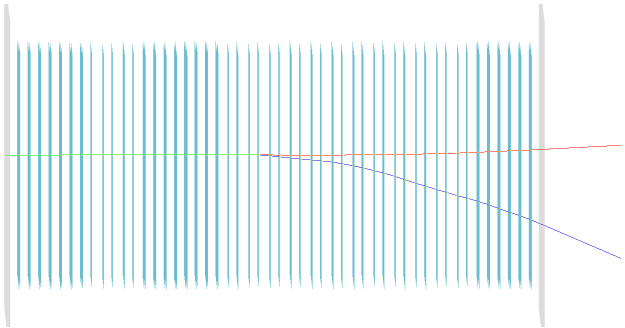


ASTROGAM (COMPTON + PAIR)

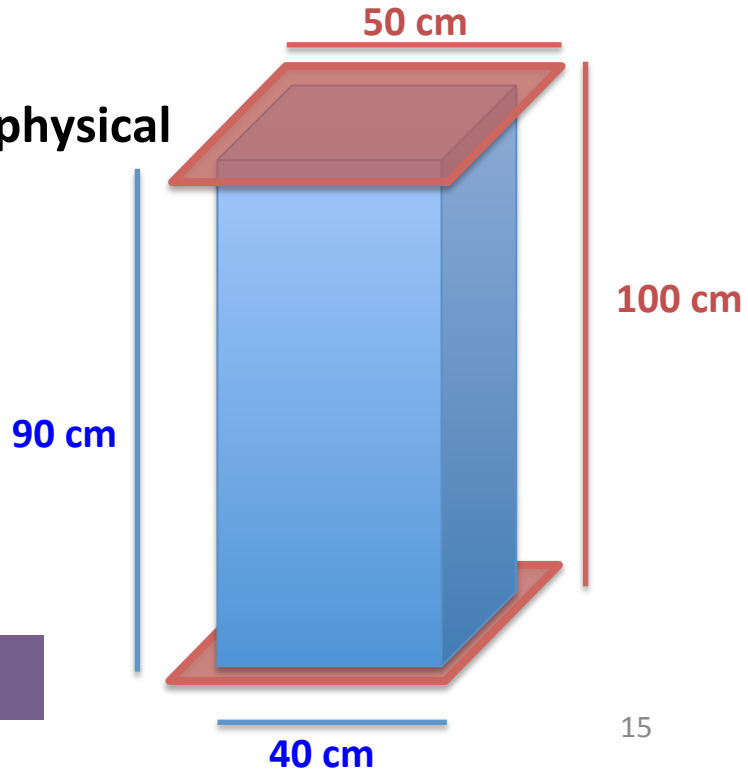


PANGU Detector Concept

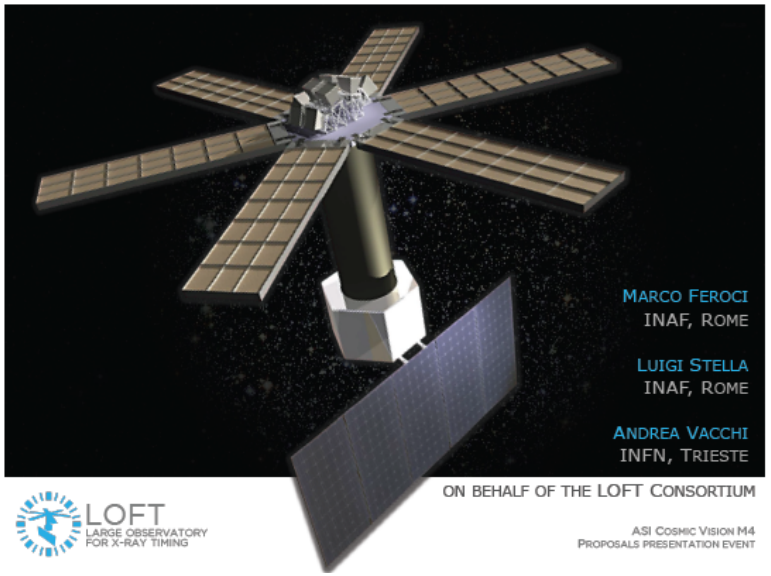
- **Conceptually very simple:**
  - **Silicon TracKer (STK) + AntiCoincidence Detector (ACD)**
  - **Push the "thinness" to the limit for best PSF!**
    - **Silicon single-sided detector (SSSD) of 150 µm thick**
  - **No calorimeter because of weight limitation**
  - **Energy measurement rely on Multiple Coulomb Scattering (MCS)**
    - **Need good angular resolution:**
      - **Small pitch: 100/50 µm readout/physical**
      - **Long lever arm**



Symmetric : can observe from both ends



LOFT



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ON BEHALF OF THE LOFT CONSORTIUM

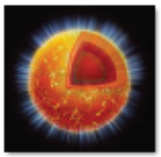
LOFT
LARGE OBSERVATORY FOR X-RAY TIMING

ASI COSMIC VISION M4
PROPOSALS PRESENTATION EVENT

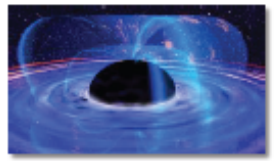
LOFT SCIENCE

LOFT ADDRESSES THE COSMIC VISION THEME
"Matter Under Extreme Conditions"

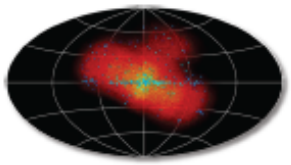
Probe the state of matter at supra nuclear densities in Neutron Stars ("**Dense Matter**")



Probe gravity theory in the very strong field environment of Black Holes ("**Strong Gravity**")



Probe physics of hundreds of galactic and bright extragalactic cosmic sources ("**Observatory Science**")



MACHETE

DE/E ~ 15%-20%