AGN at 1-100 MeV

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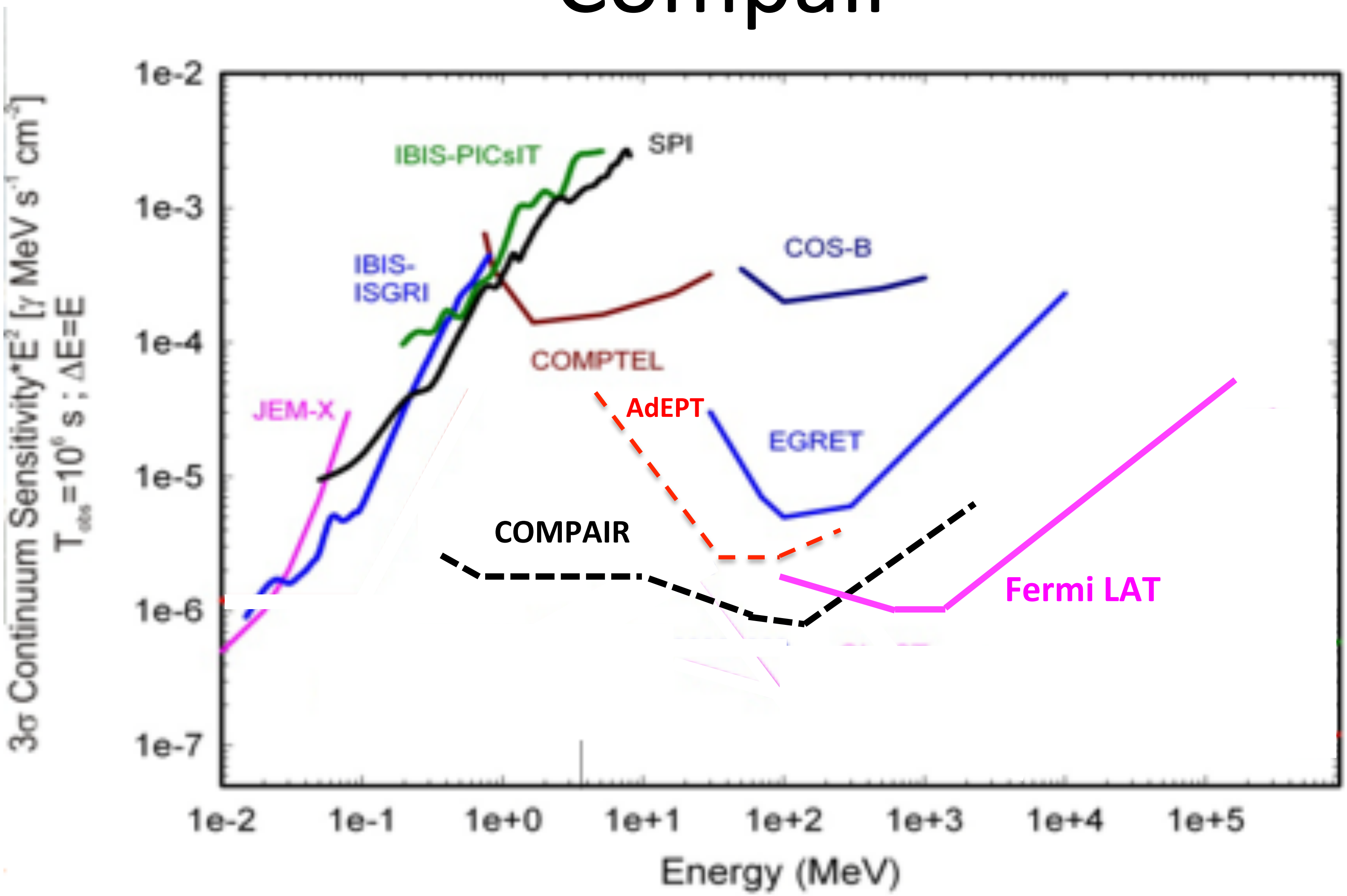
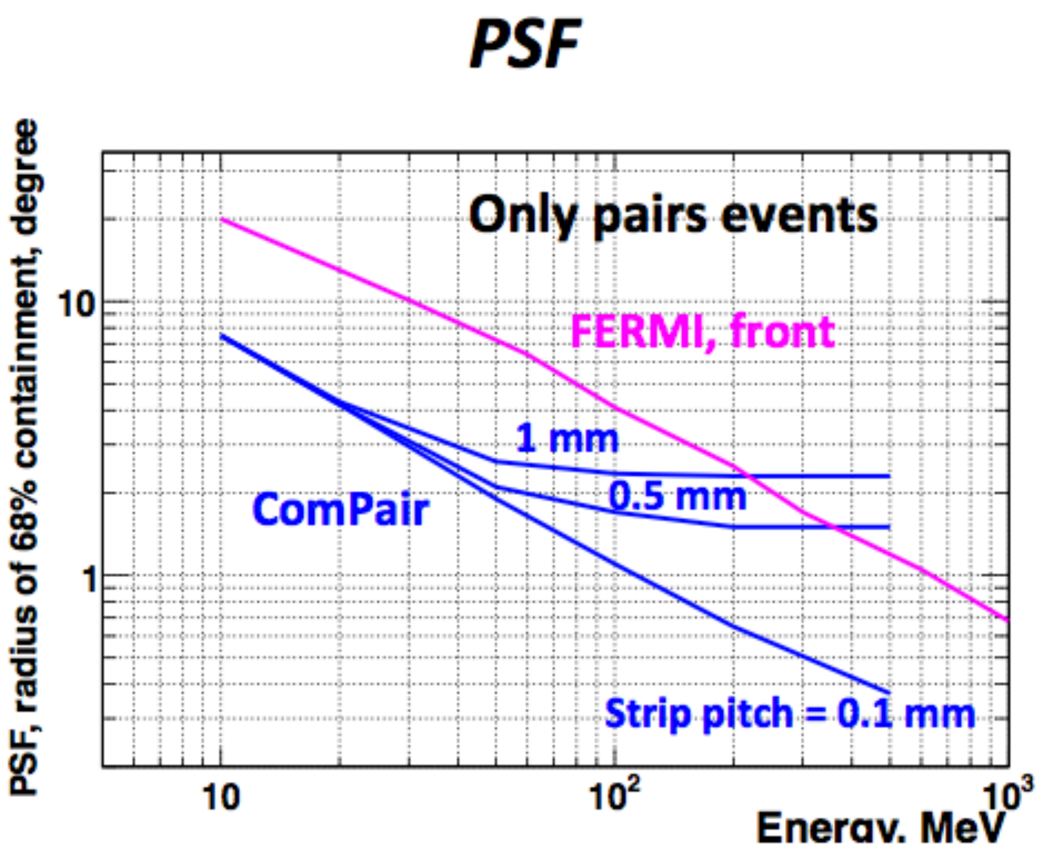
- Thanks to:
  - Roopesh Ojha
  - Greg Madejeski
  - Abe Falcone
  - Teddy Cheung
- Opinions and mistakes are mine alone

Compair



1e-2
1e-3
1e-4
1e-5
1e-6
1e-7
1e-2
1e-1
1e+0
1e+1
1e+2
1e+3
1e+4
1e+5
Energy (MeV)
3σ Continuum Sensitivity*E² [γ MeV s⁻¹ cm⁻²]
T_obs=10⁶ s ; ΔE=E
IBIS-PICsIT
SPI
IBIS-ISGRI
COS-B
COMPTEL
JEM-X
AdEPT
EGRET
COMPAIR
Fermi LAT

Compair

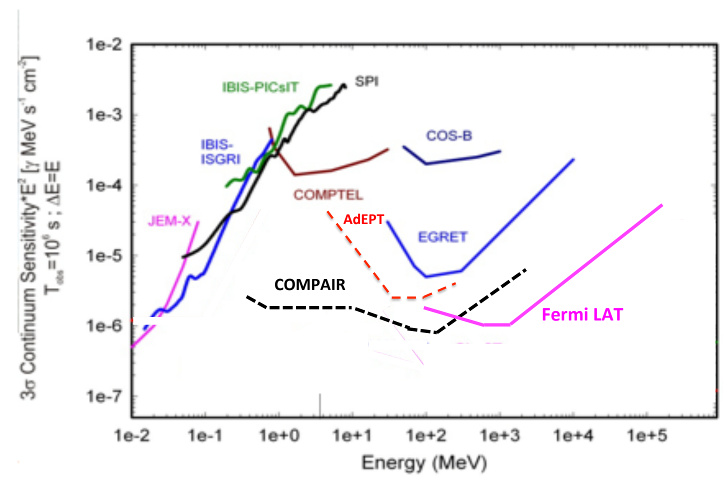


PSF:
7° at 10 MeV
1° at 100 MeV

1-100 MeV Telescope

- Assume 10^{-12} erg cm^{-2} s^{-1} in ~1 Msec (11.5 days) and flux sensitivity goes as sqrt(time)
- It will reach 10^{-13} erg cm^{-2} s^{-1} in ~3 years.
- Will it be wide field of view instrument like Fermi? Multiply timescales by 5

Compare with COMPTEL which reached ~ 10^{-10} erg cm^{-2} s^{-1}



Alex Moiseev Future Space-based Gamma-ray observations Feb 6, 2015 GSFC

COMPTEL

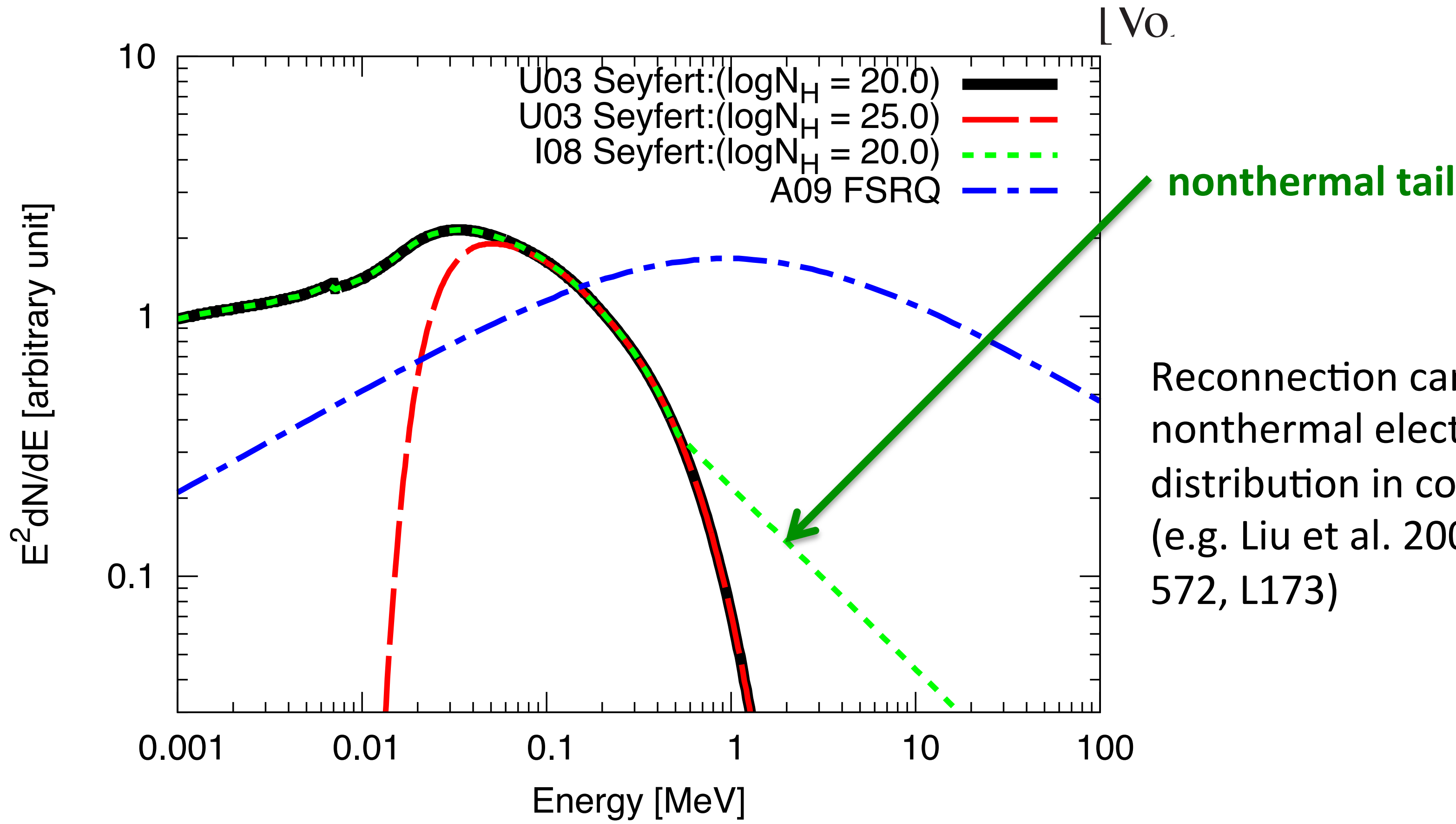
COMPTEL saw 15 AGN radio loud AGN and 0 radio quiet AGN (Collmar 2006)

Table 1. Updated list of COMPTEL AGN detections. Apart from the four new sources and Mkn 421 (Collmar et al. 1999), all others are listed in the first COMPTEL source catalog. The table lists the source name, the redshift, the AGN type, and a qualitative statement on the COMPTEL detection significance.

Source	Redshift	AGN Type	Significance
Cen A	0.0007	radio galaxy	high
Mkn 421	0.031	BL Lac object	low
3C 273	0.158	quasar	high
PKS 1222+216	0.435	quasar	medium
3C 279	0.538	quasar	high
PKS 1622-297	0.815	quasar	high
3C 454.3	0.859	quasar	high
PKS 0208-512	1.003	quasar	high
CTA 102	1.037	quasar	low
GRO J0516-609	1.09	quasar	medium
PKS 1127-145	1.187	quasar	medium
PKS 0528+134	2.06	quasar	high
PKS 0716+714	?	BL Lac object	low
0836+710	2.17	quasar	medium
PKS 1830-210	2.06	quasar	medium

Collmar (2006)

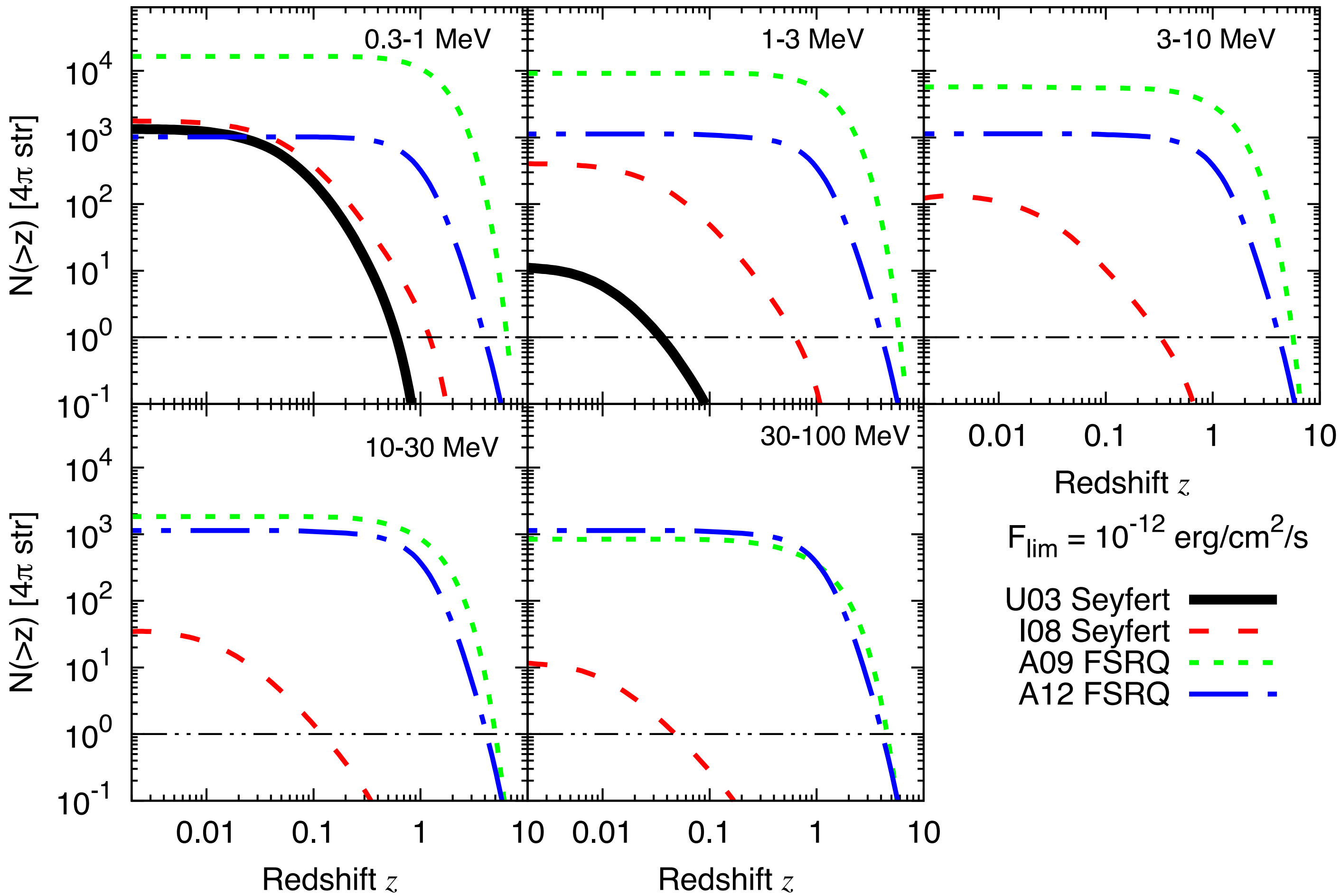
Radio Quiet AGN



Reconnection can create nonthermal electron distribution in corona (e.g. Liu et al. 2002, ApJ, 572, L173)

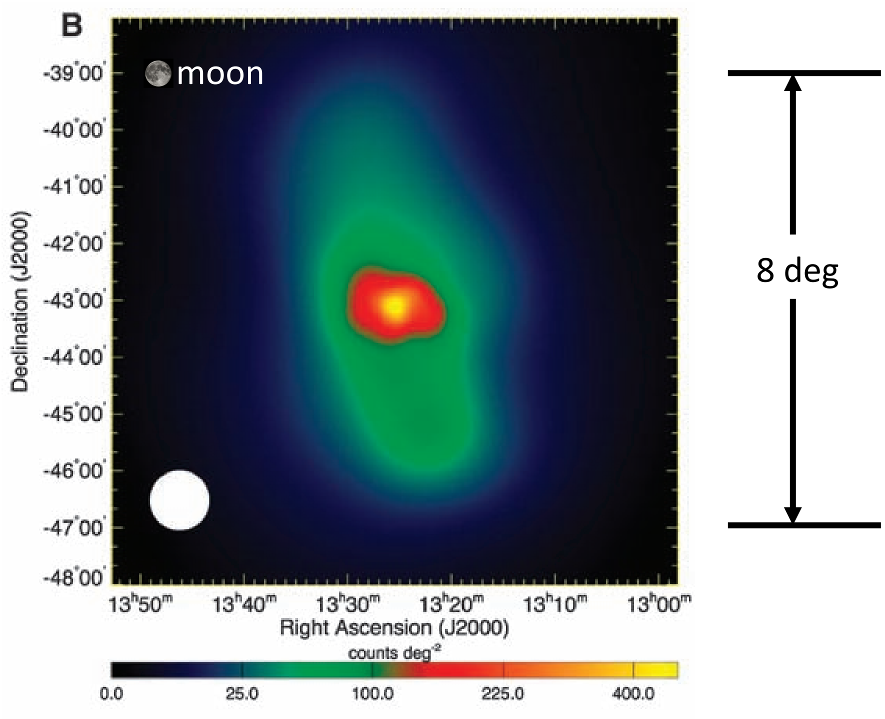
Inoue et al. (2015), PASJ, 67, 76

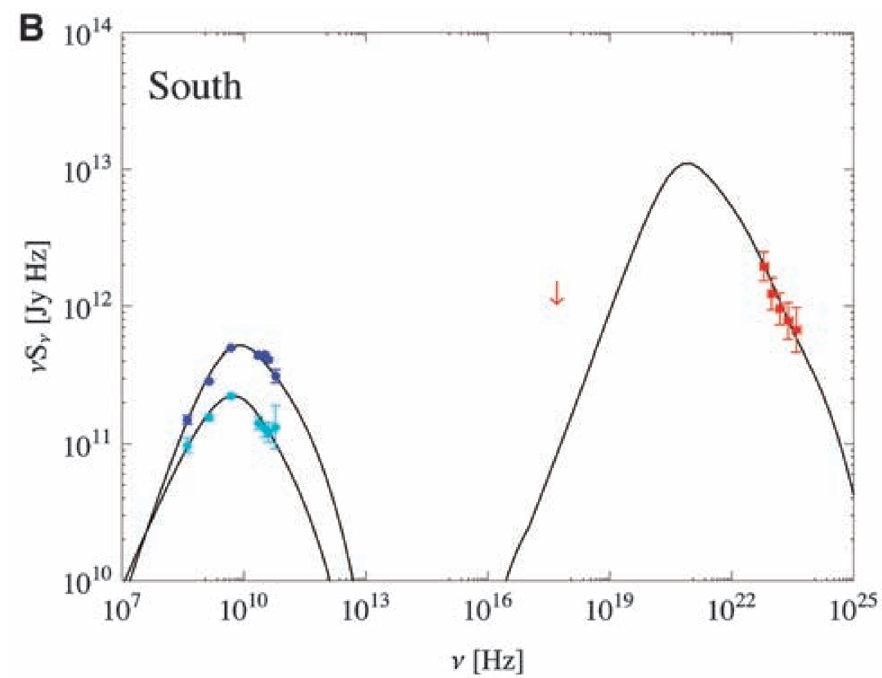
AGN population



Inoue et al. (2015), PASJ, 67, 76

Cen A Lobes





Could Compair resolve the Cen A lobes?

PSF:

7° at 10 MeV

1° at 100 MeV

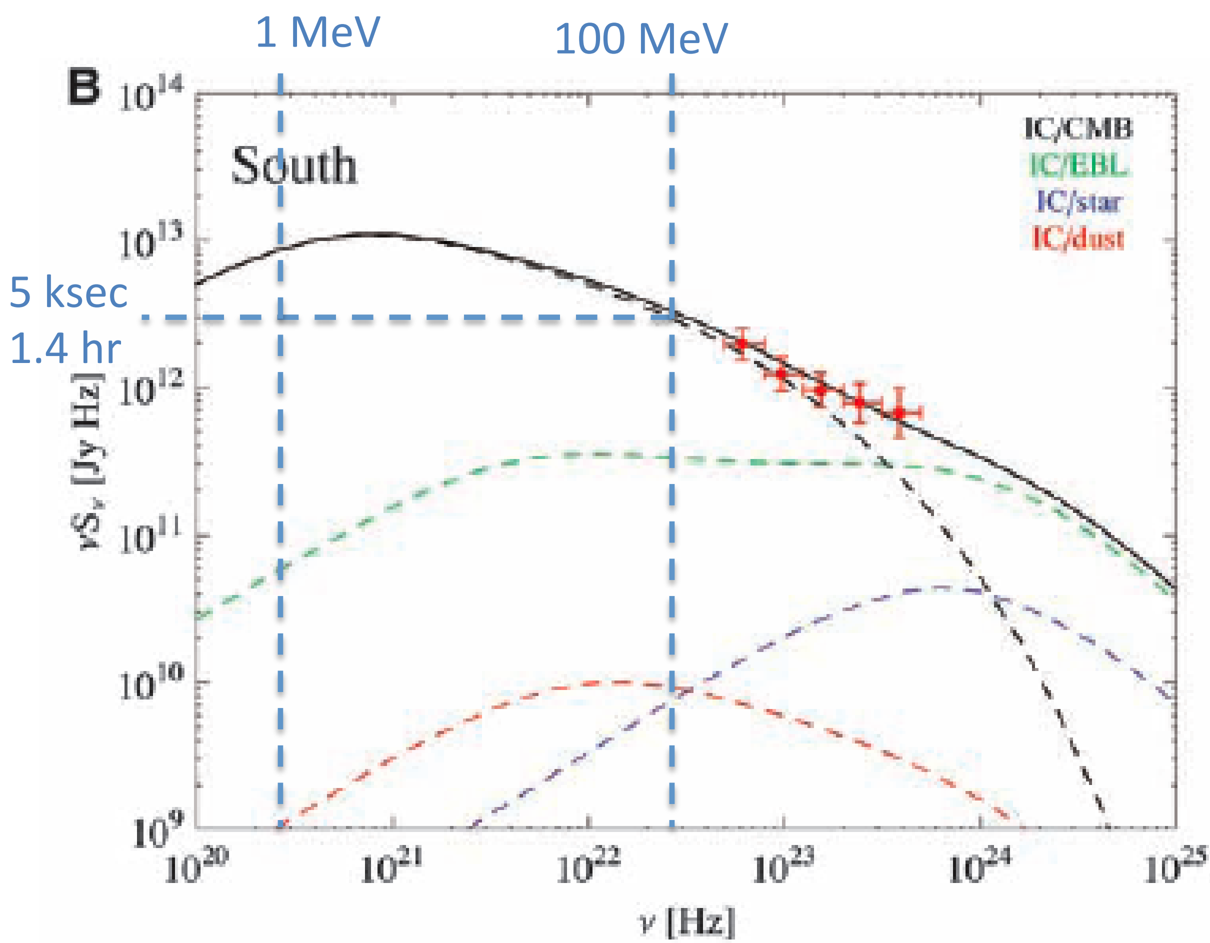
Abdo et al. (2010), Science, 328, 725

Cen A Lobes

Could be used to constrain the EBL!

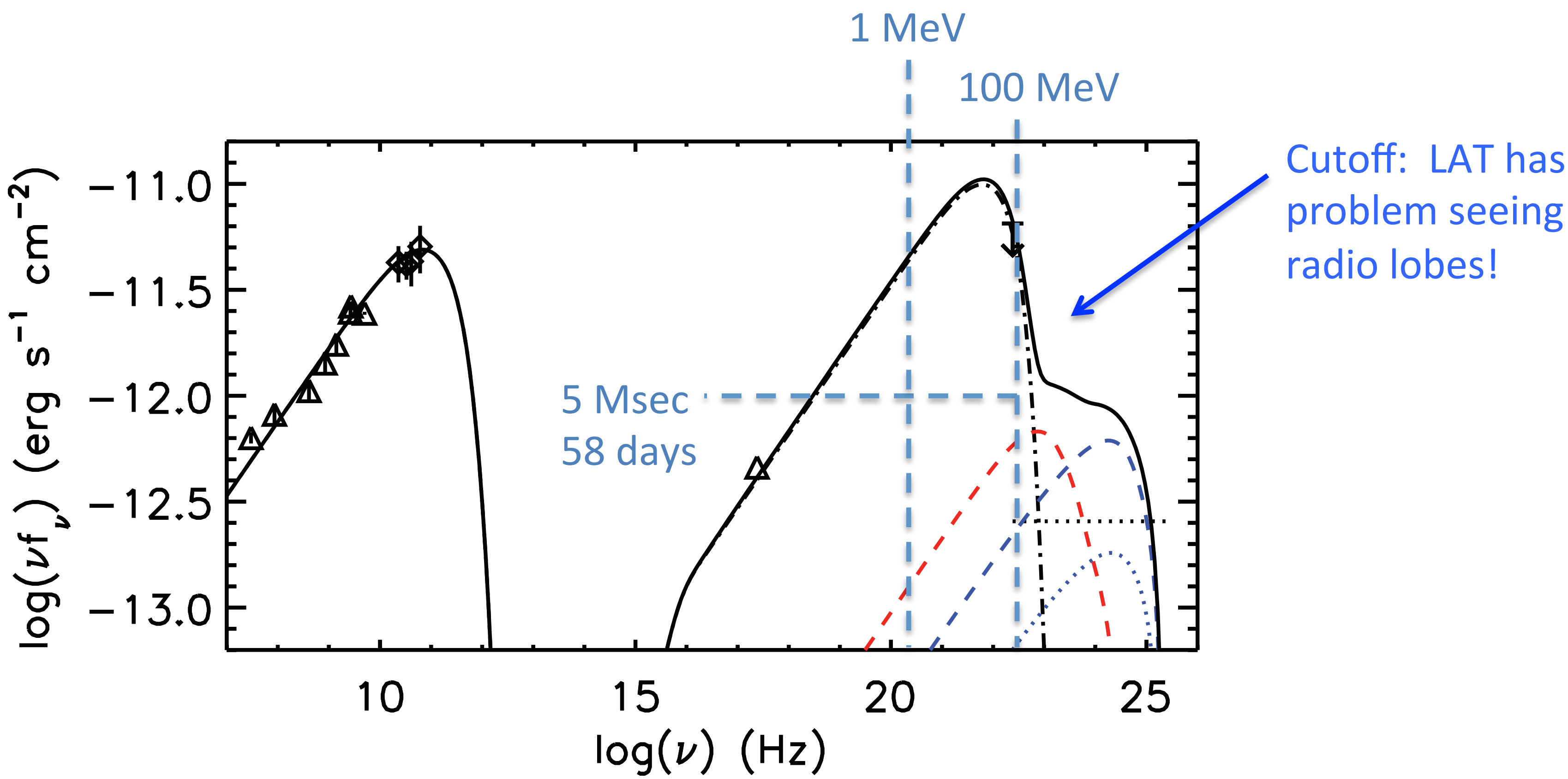
Georganopoulos et al. (2008), ApJ, 686, L5

Previous γ-ray constraints on EBL rely on opacity, but there are ways around it (UHECRs, axions, etc.). Compton scattering constraints would avoid that problem.



Abdo et al. (2010), Science, 328, 725

Radio galaxy lobes



Fornax A
Georganopoulos et al. (2008), ApJL, 686, L5

Radio galaxy lobes

TABLE 2

Spectral Fits for X-Ray Lobe Detections with Sufficient Counts

Source		Net Counts[a]	N_H[b] (cm^{-2})	Γ[c]	$S_{1\ keV}$[c] (nJy)	χ^2/dof	**Extrapolated 1-100 MeV Flux [erg cm^{-2} s^{-1}]**
3C 47N	z=0.425	197	5.87×10^{20}	1.4 ± 0.4	3.6 ± 0.7	4.9/6	10^{-11}
3C 47S		434	5.87×10^{20}	1.9 ± 0.2	10 ± 1	21/15	$3x10^{-13}$
3C 215N	z=0.411	109	3.75×10^{20}	1.4 ± 0.3	2.9 ± 0.4	1/3	10^{-11}
3C 215S		119	3.75×10^{20}	1.5 ± 0.5	2.9 ± 0.5	2.9/3	$4x10^{-12}$
3C 219N	z=0.174	188	1.51×10^{20}	2.0 ± 0.3	9 ± 1	3.6/6	10^{-13}
3C 219S		147	1.51×10^{20}	1.7 ± 0.5	7 ± 1	7/4	10^{-12}
3C 265E	z=0.811	142	1.90×10^{20}	1.9 ± 0.2	3.1 ± 0.3	1/5	$9x10^{-14}$
3C 452 (model I)[d]	z=0.081	2746	1.19×10^{21}	1.75 ± 0.09	37 ± 2	96/89	$4x10^{-12}$
3C 452 (model II)[d]		2746	1.19×10^{21}	1.5 (frozen)	23 ± 4	87/88	$3x10^{-11}$

Red: detectable in < 5 Msec

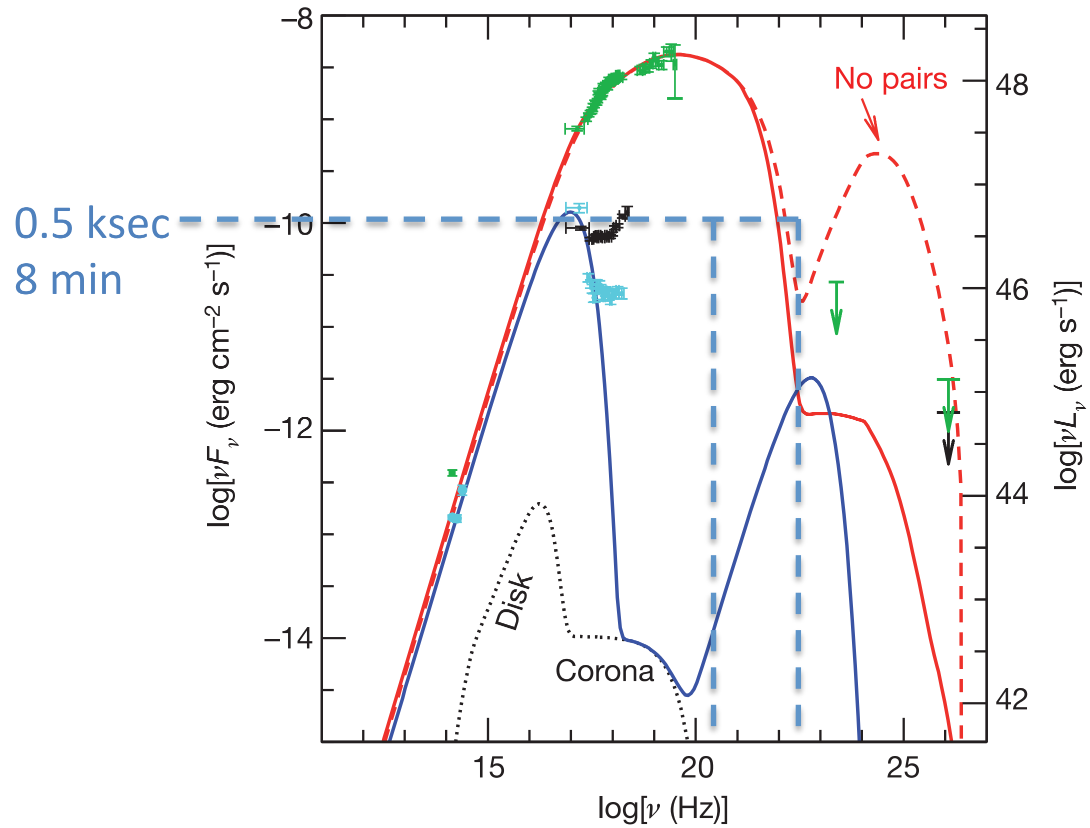
Croston et al. (2005), ApJ, 626, 733

Tidal Disruption Events

Energetics: constrained by stellar mass

Magnetic field needed to generate a jet (e.g. Kelley et al. 2014)?

Compair would easily have easily have seen Swift J164449.3+1573451 .



Burrows et al. (2011), Nature, 476, 421

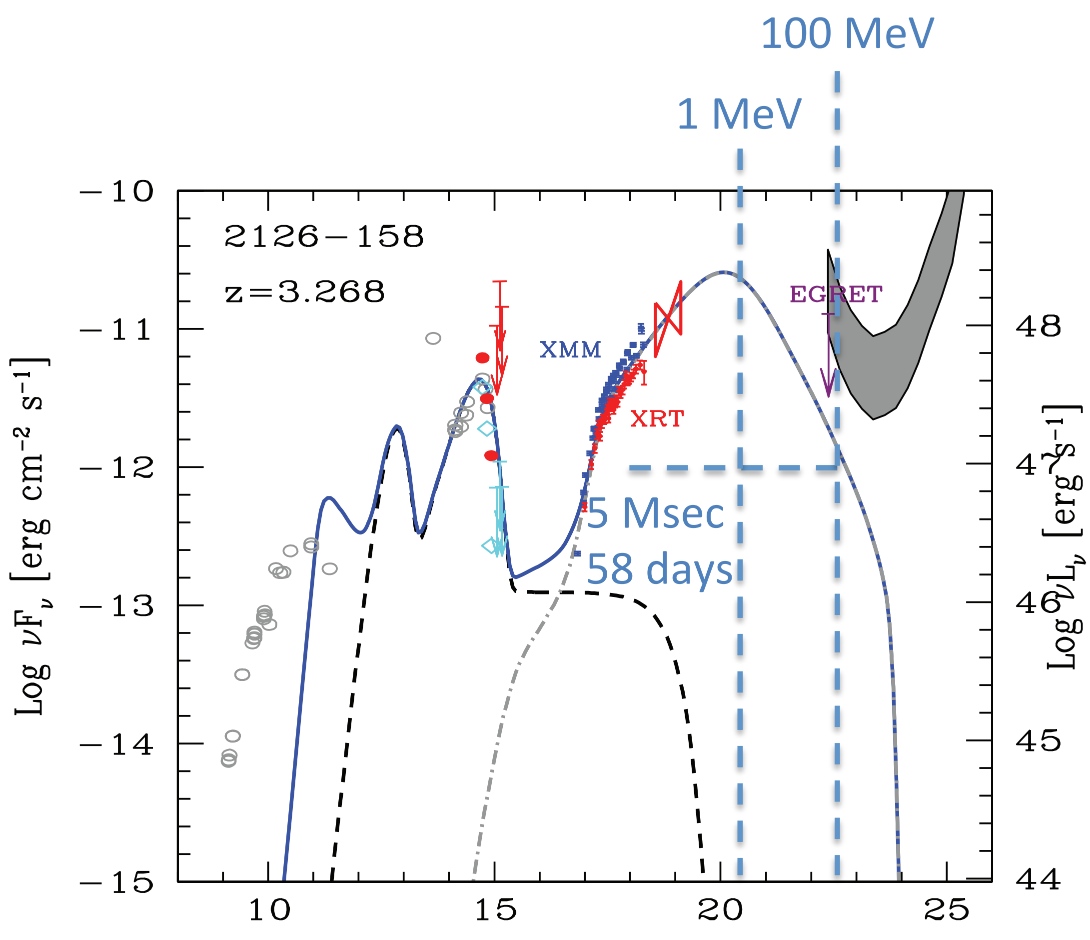
High-z AGN

Detection of high-z radio-loud quasars by Swift-BAT and Fermi-LAT indicates supermassive black hole is high at z > 4.

Since this emission is beamed, this implies a large number of mis-aligned sources at high z.

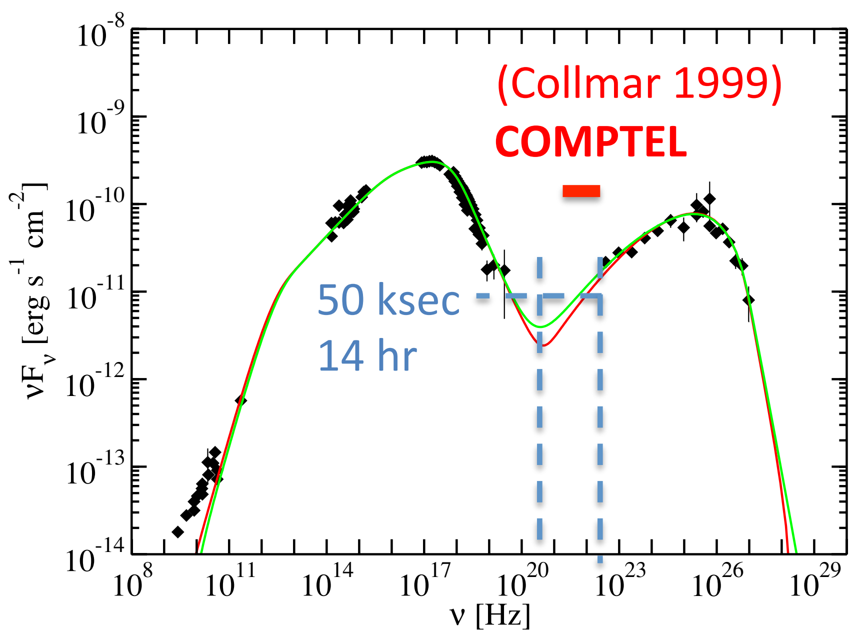
It does not seem that there would be enough time to make these high-mass BHs in the early universe (Ghisellini et al. 2013, MNRAS, 432, 2818

Exploring high-z blazars with an MeV mission may clarify this.

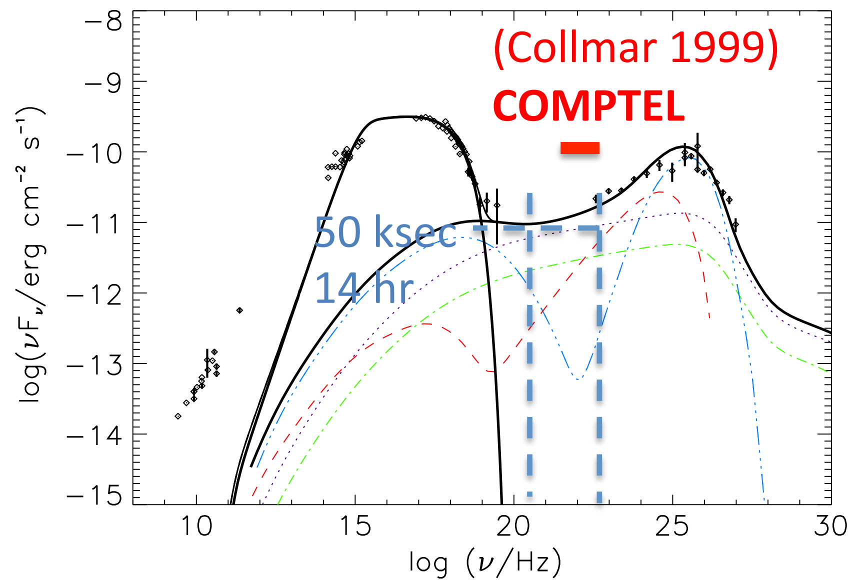


Ghisellini et al. (2010), MNRAS, 405, 387

Hadronic models for γ-ray emission



Leptonic model



Hadronic model

Hadronic models for FSRQs have mostly been ruled out for FSRQs based on energetics (Sikora et al. 2009; Zdziarski & Boettcher 2015).
What about HSP BL Lacs?

Mrk 421
Abdo et al. (2011), ApJ, 736, 131

Polarization

ADEPT: polarization at 5-200 MeV

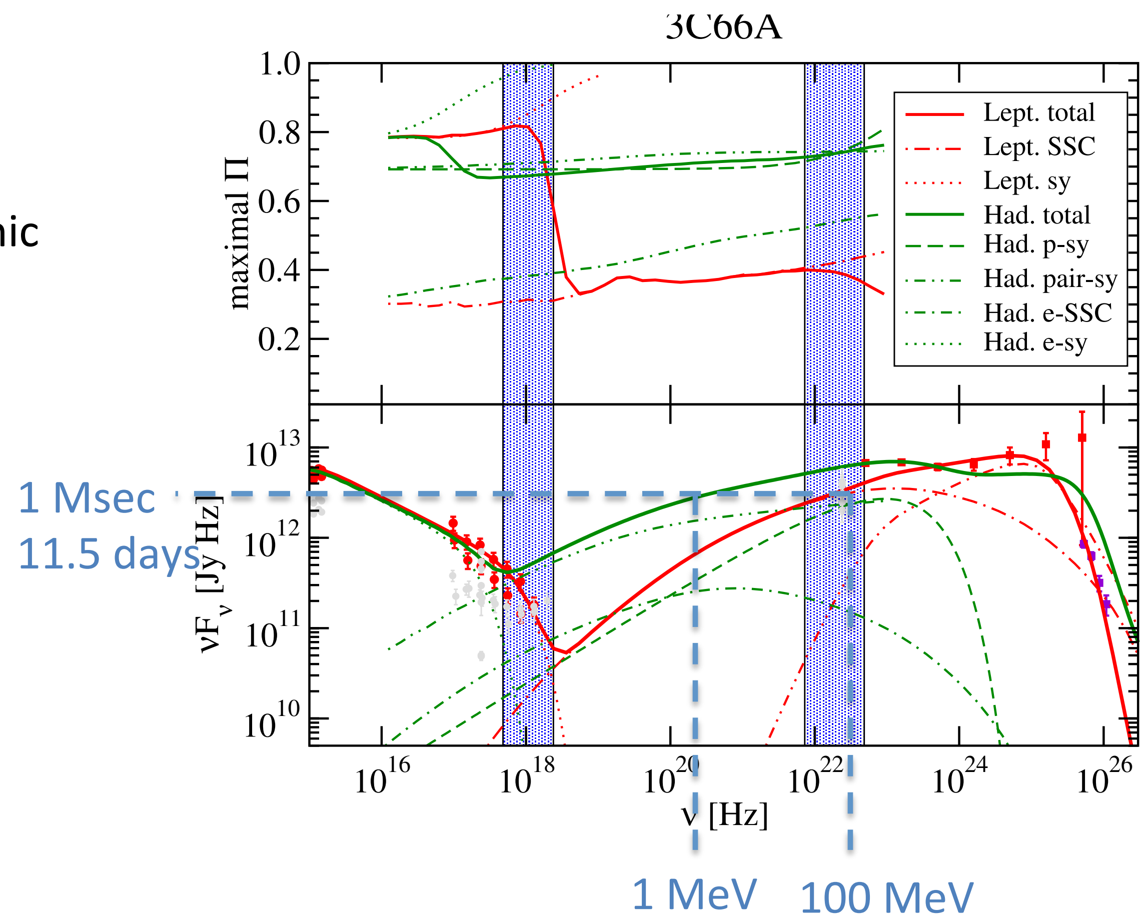
Will be able to detect 10% polarization for 10 mCrab (3×10^{-11} erg cm^{-2} s^{-1}) in 10^6 sec

Angular resolution ~0.6 deg at 70 MeV

(Hunter et al. 2014, APh, 59, 18)

Polarization

MeV energy polarization could distinguish leptonic and hadronic models (Zhang & Boettcher 2013).



Zhang & Boettcher (2013), ApJ, 774, 18

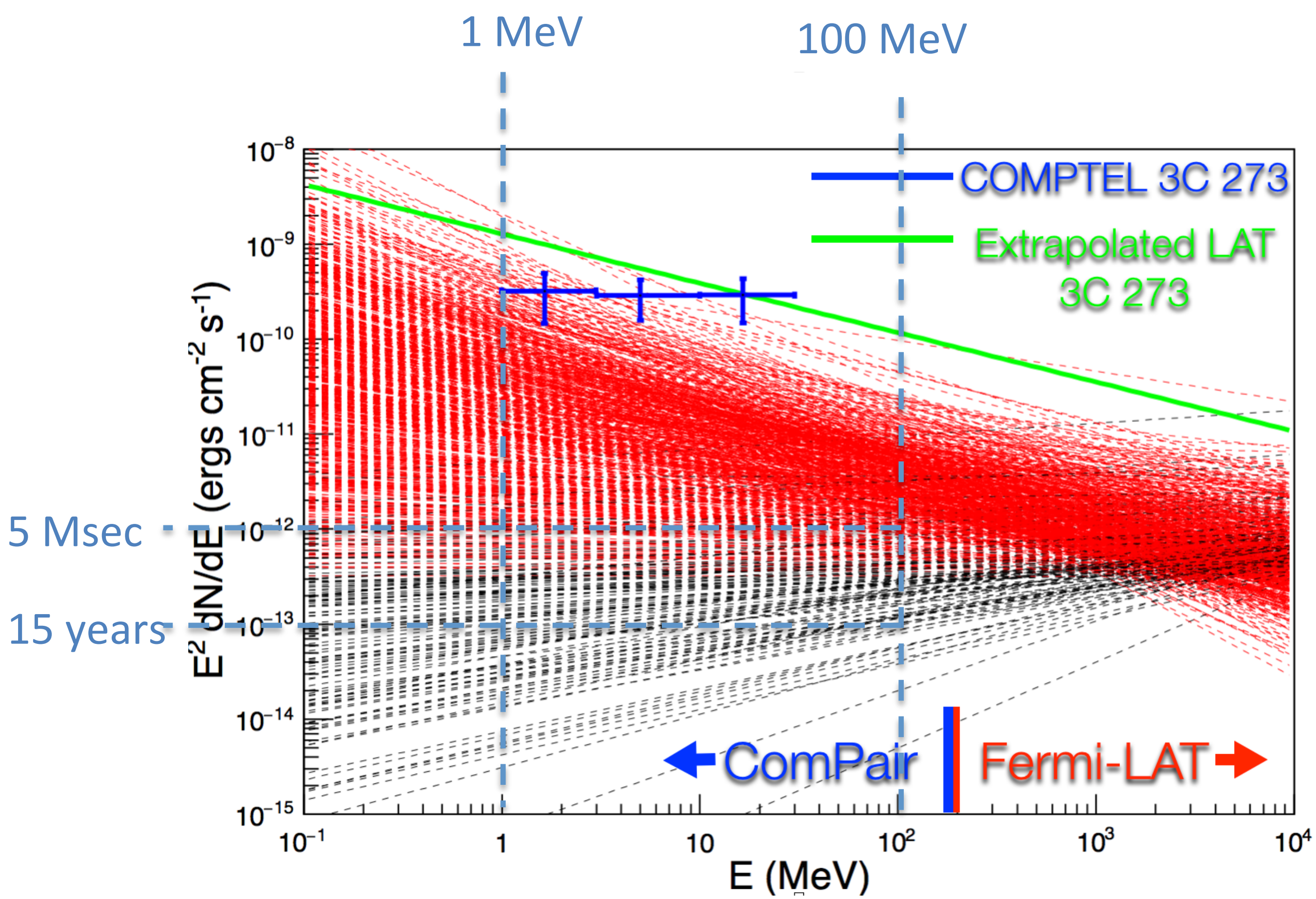
Conclusions

- An Compair type MeV instrument will see:
  - At least 1000 blazars
  - Up to 100 radio quiet AGN
  - Some radio galaxy lobes (probably more than Fermi)
  - Possibly tidal disruption events

- What do you want from an MeV instrument for AGN?
  - Good angular resolution (< 2-3 deg):
    - Avoid source confusion
    - Resolve Cen A
  - Wide field to monitor the whole sky like the LAT
  - Polarization: probably not worth it (opinion may change after Astro-H launch)

Extras

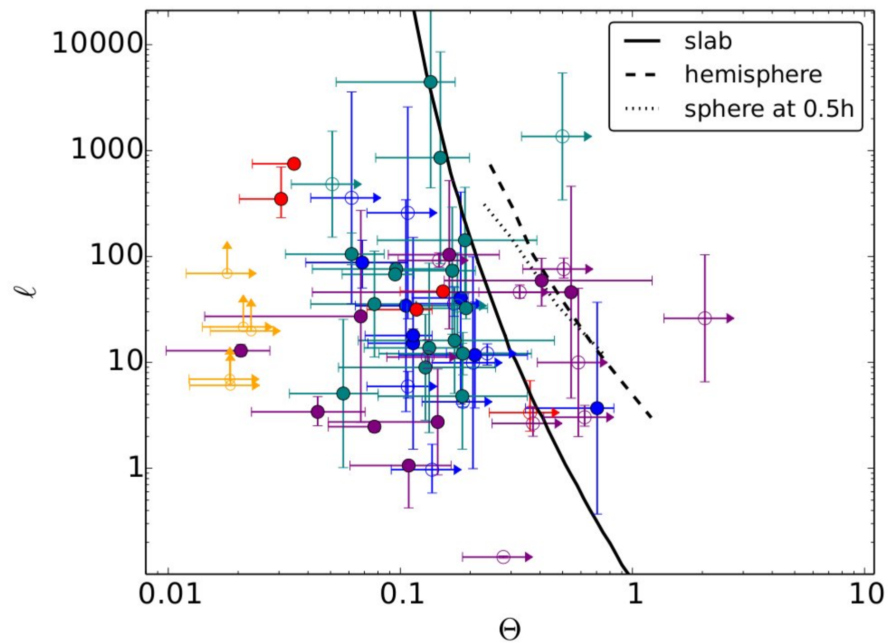
Compair


1 MeV
100 MeV
5 Msec
15 years
COMPTEL 3C 273
Extrapolated LAT
3C 273
ComPair
Fermi-LAT
E (MeV)
E^2 dN/dE (ergs cm^{-2} s^{-1})

Radio Quiet AGN

Nonthermal tail can also be created by γγ pair production in hot corona.

It has been proposed that pairs can regulate temperature in corona (Fabian et al. 2015). Potentially testable with MeV observations of nonthermal tail.



Fabian et al. (2015), MNRAS, 451, 4375

Hadronic models for γ-ray emission

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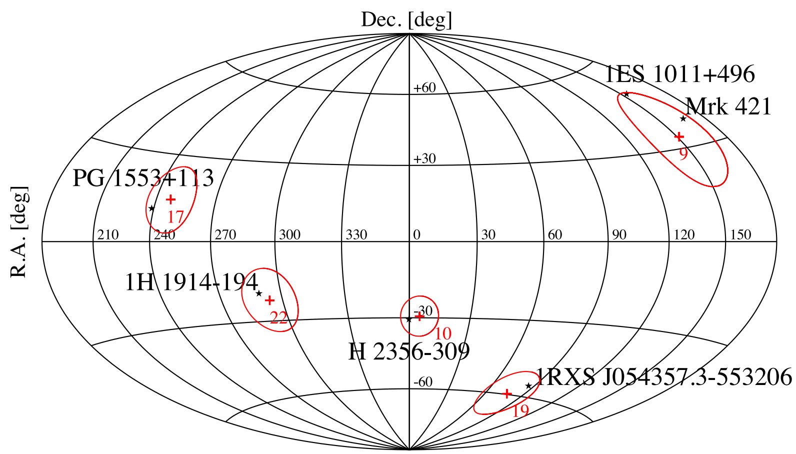
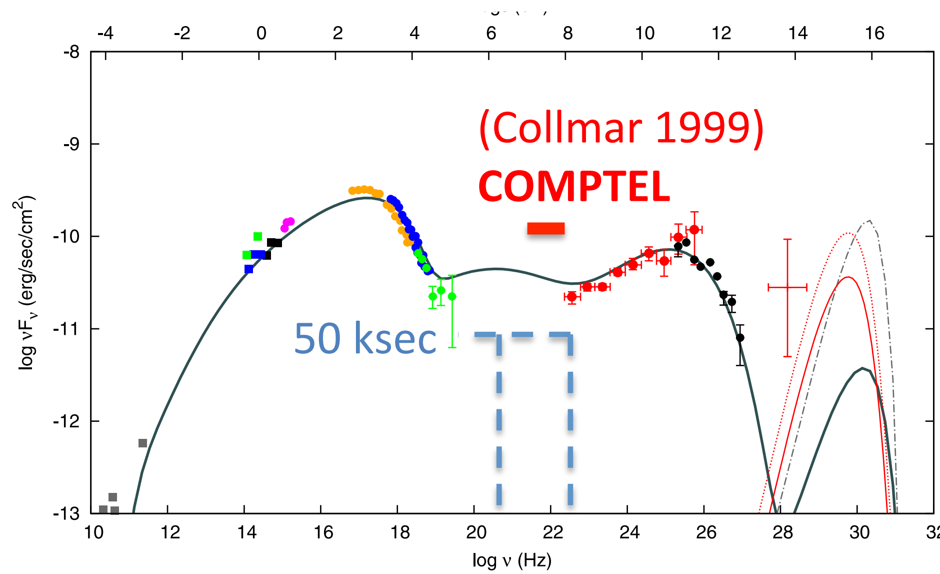
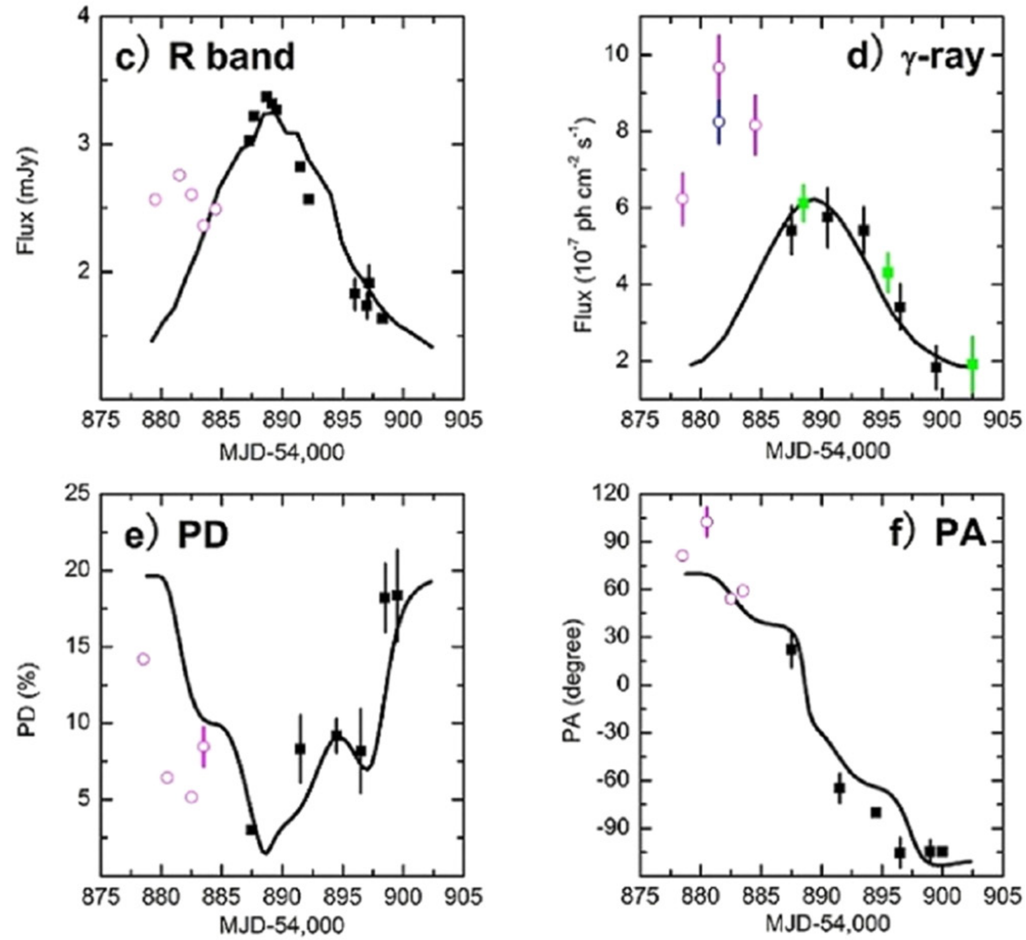




Petropoulou et al. (2015), MNRAS, 448, 2412

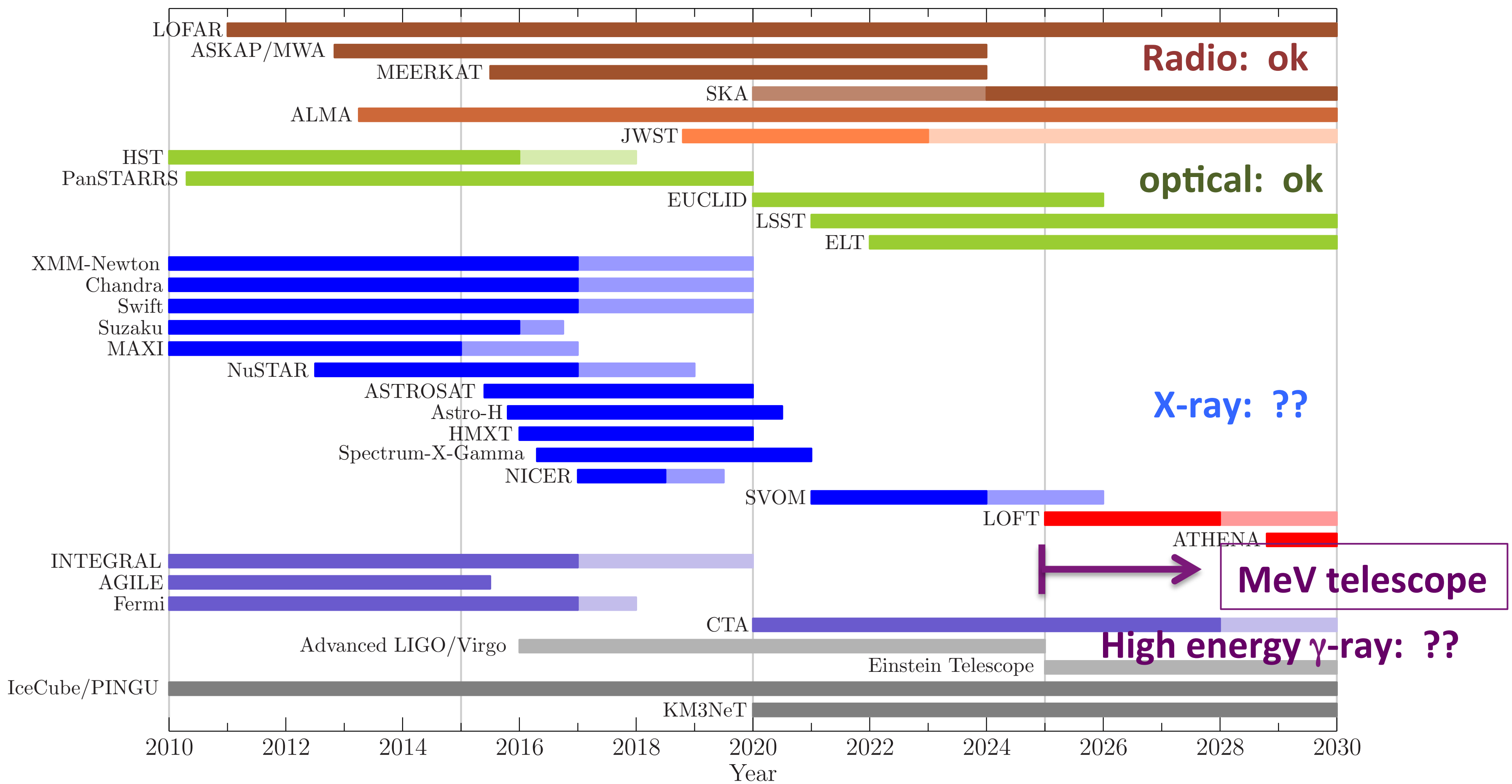
Polarization

MeV polarization on day timescales could probe jet magnetic field structures (Zhang & Boettcher 2014; Zhang et al. 2015) but this seems unlikely to be possible.

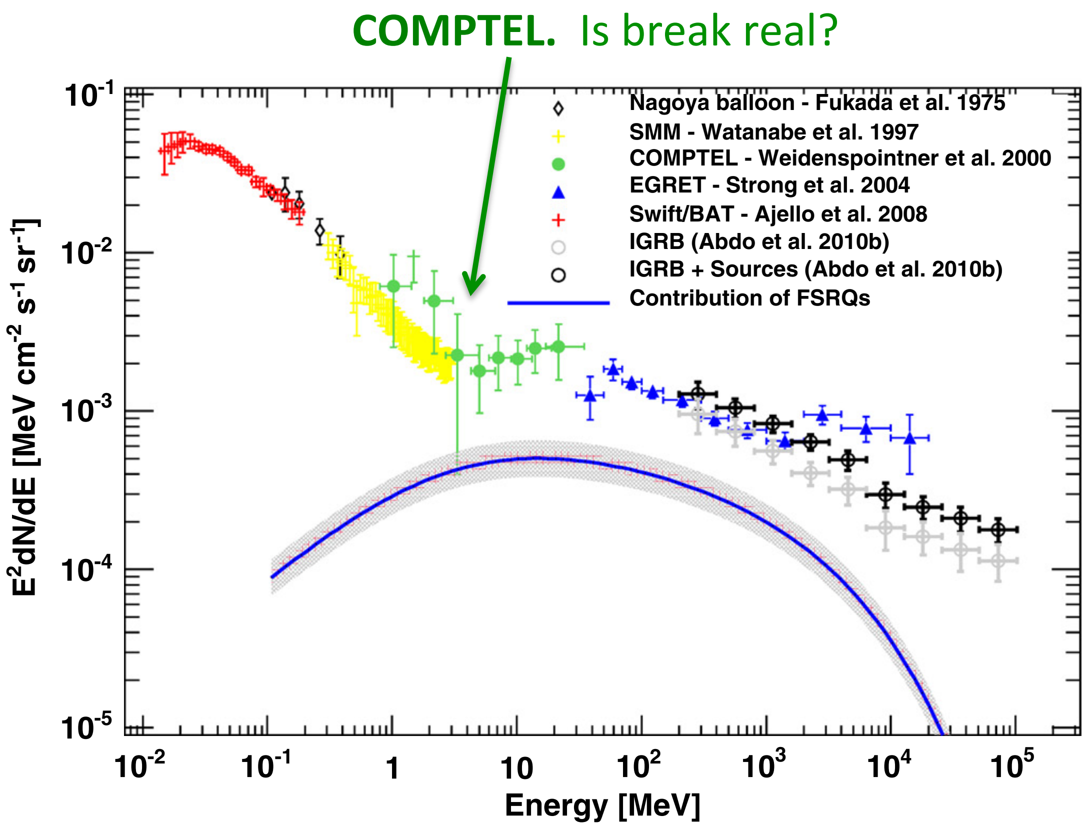


3C 279; Zhang et al. (2015), ApJ, 804, 58

Multi-Wavelength



MeV background



Ajello et al. (2012), ApJ, 751, 108

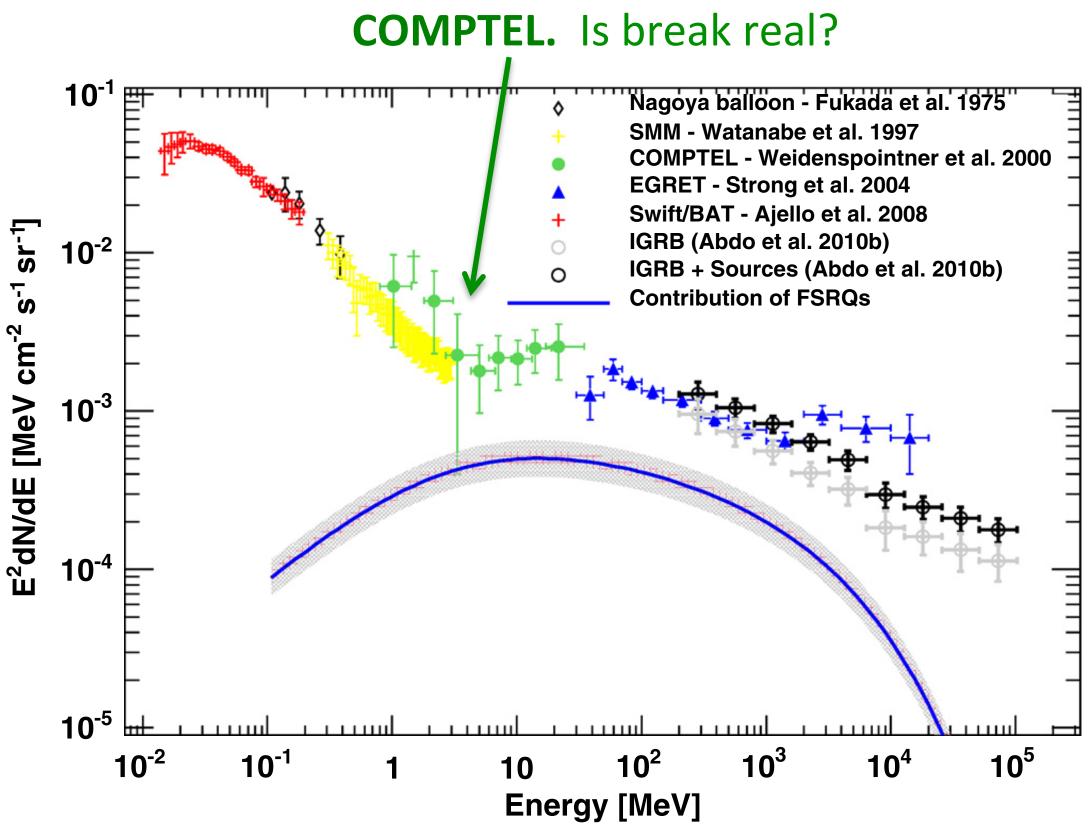
Type Ia supernovae?
About 10% (e.g., Strigari et al., 2005; Horiuchi & Beacom, 2010; Ruiz-Lapuente et al., 2015)

Radio galaxies?
About 10% (Massaro & Ajello 2011, Inoue 2011)

Star-forming galaxies?
<~ 10% (Lacki et al. 2014)

Dark matter?

MeV background



Ajello et al. (2012), ApJ, 751, 108

Extrapolating from BAT: FSRQs make up entire MeV background.

Extrapolating from LAT: FSRQs make up 30% of MeV background.

Only a small fraction of the MeV background will be resolved.

Inoue et al. (2015), PASJ, 67, 76