

Thank you for  
attending our workshop  
and for sharing your  
ideas with us

# ST3G

"steque"

A PROTOTYPE  
BALLOON DETECTOR

Self-triggering TPC telescope  
for gamma-rays



Deirdre HORAN, TPC MeV Workshop, 12.04.2017

Overview  
of project

Ground phase



ground

PROOF OF CONCEPT:  
USE TPC TO MEASURE  
POLARISATION

Balloon phase  
ST3G

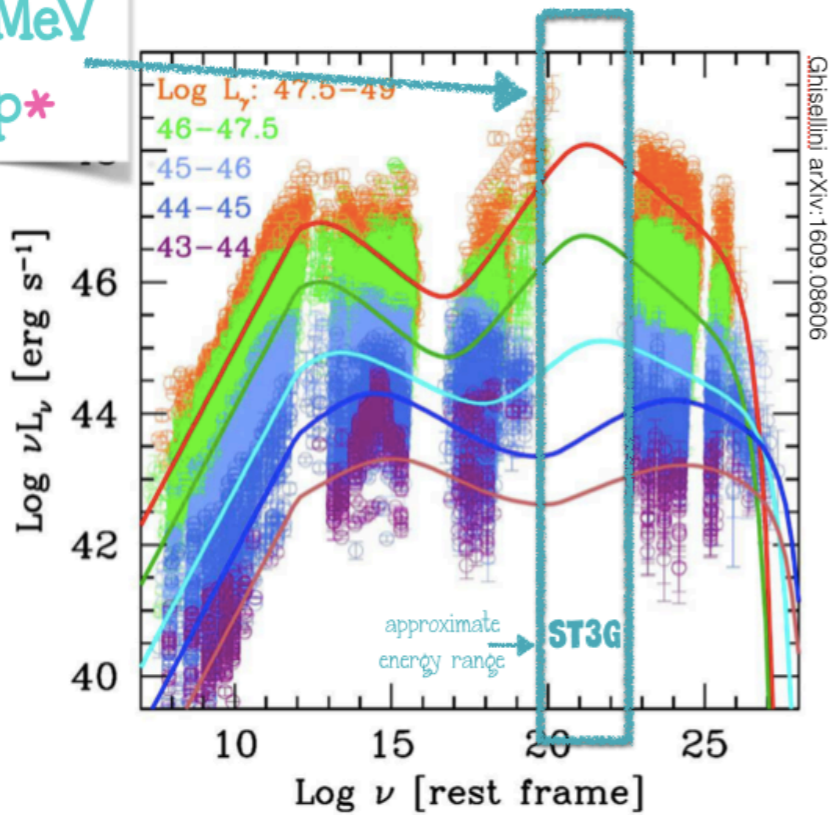
balloon

DEVELOP TRIGGER  
SYSTEM FOR TPC  
IN SPACE

Space phase

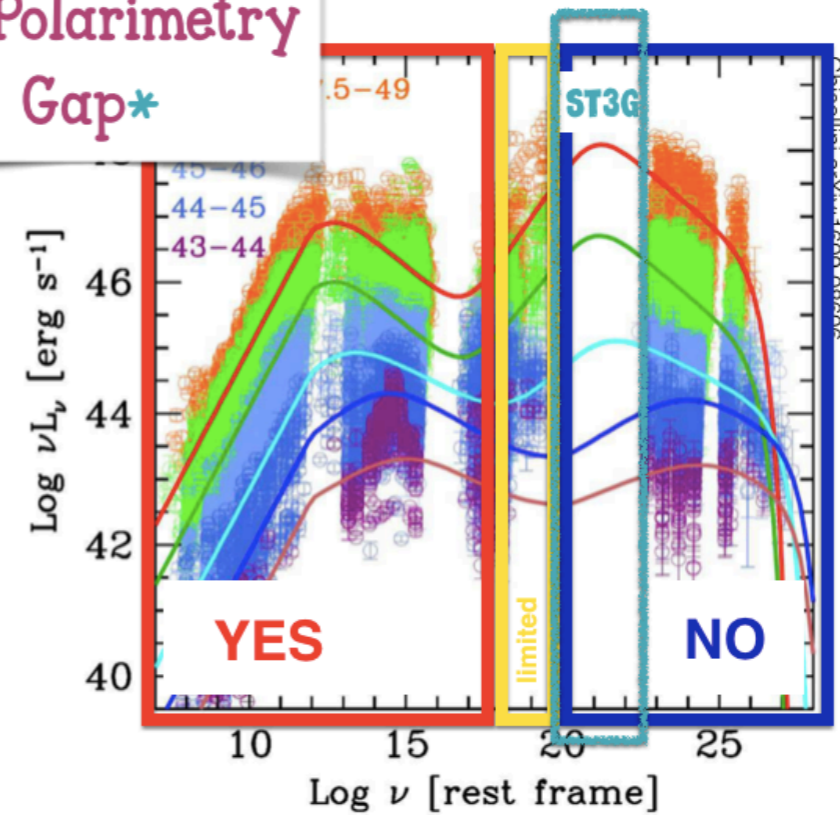
DESIGN  
INSTRUMENT FOR  
SPACE FLIGHT

## The MeV Gap\*



\* using blazars to illustrate the gap since these are broadband emitters from radio all the way up to gamma rays

## The Polarimetry Gap\*



\* using blazars to illustrate the gap since these are broadband emitters from radio all the way up to gamma rays

# Gamma-ray Astrophysics at MeV energies

MEV ENERGY  
COVERAGE

POLARIZATION



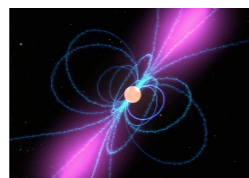
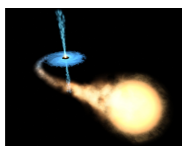
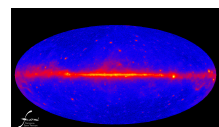
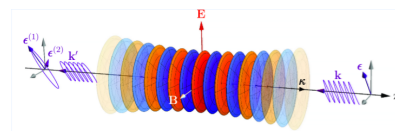
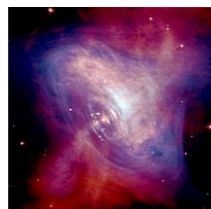
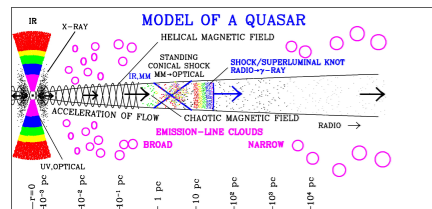
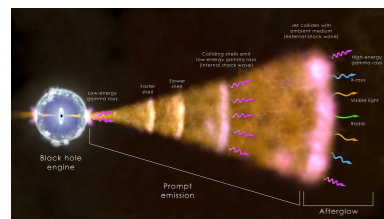
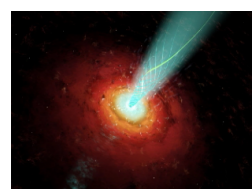
HIGH ANGULAR  
RESOLUTION

# Gamma-ray Astrophysics at MeV energies

MEV ENERGY  
COVERAGE

POLARIZATION

HIGH ANGULAR  
RESOLUTION



BLAZARS

PULSARS

BINARIES

COSMIC RAYS

DARK MATTER

FERMI BUBBLES

MEV BACKGROUND

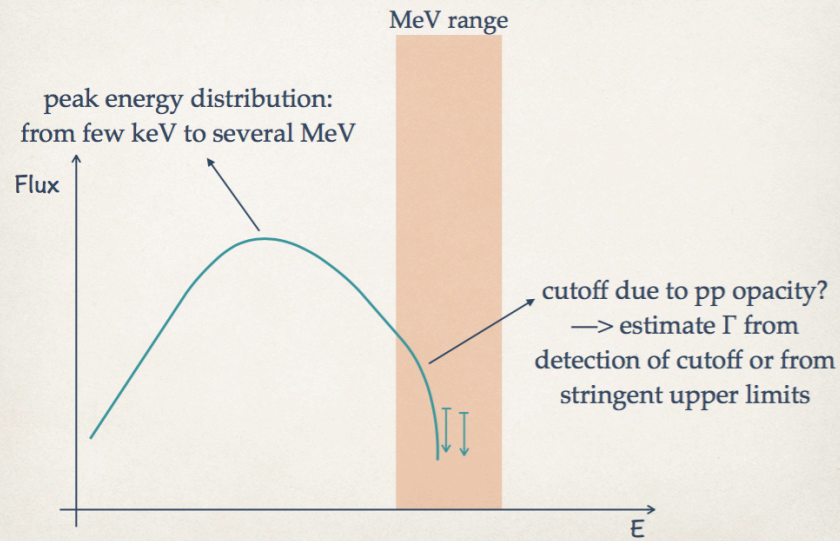
GAMMA-RAY BURSTS

LORENTZ INVARIANCE

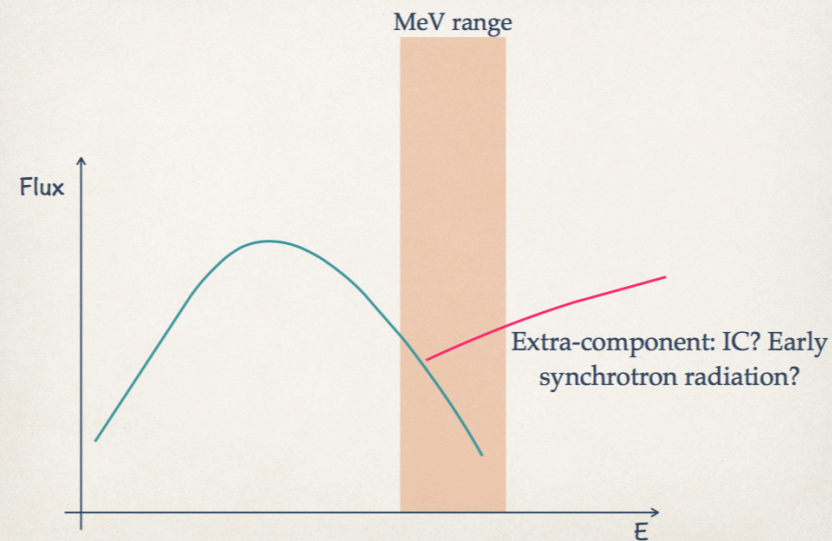
SUPERNOVA REMNANTS

# GRBS - LARA NAVA

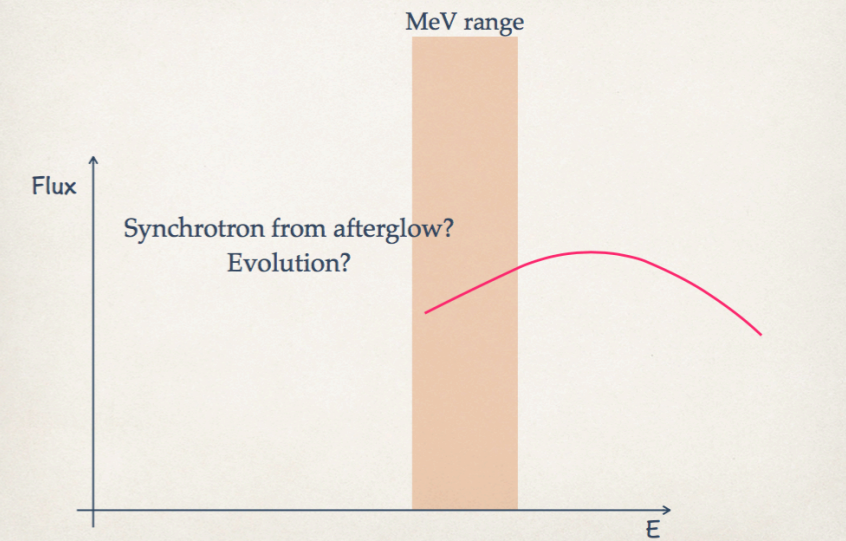
## MeV energy range: early time



## MeV energy range: intermediate times



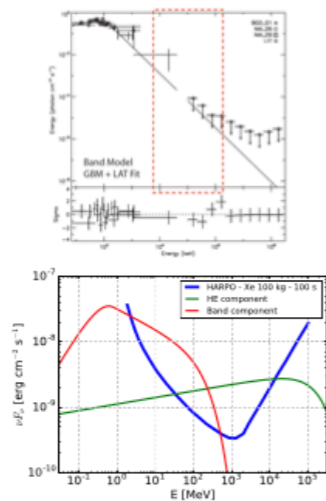
## MeV energy range: late time (>100s)



# GRBS - PÉTER VERES

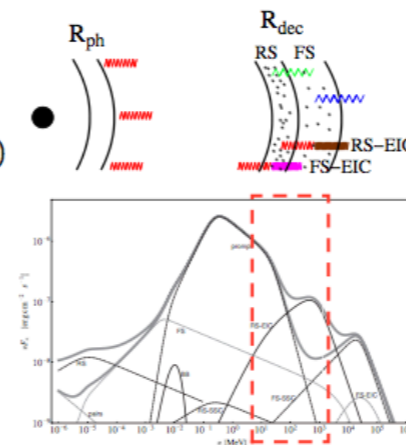
## GRBs above 10 MeV - TPC -HARPO

- Uncharted territory - emergence of the afterglow?
- Extension of Band PL - does not continue  $\gtrsim$  GeV. Spectral cutoff:
  - Pair production
  - $\Gamma m_e c^2 / (1+z) \sim 100$  MeV
- TPC-HARPO is well suited to observe this spectral regime



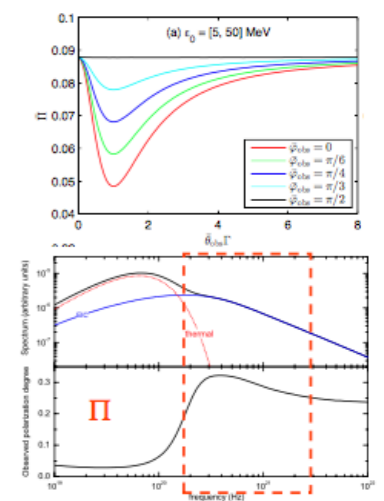
## GRBs above 10 MeV - TPC -HARPO 2.

- Emerging new component
  - Synchrotron self-Compton (SSC)
  - External inverse Compton (EIC)
  - something else?
- Transition between Band or synchrotron and power law or Compton (Veres+12)



## GRBs above 10 MeV - TPC -HARPO 3.

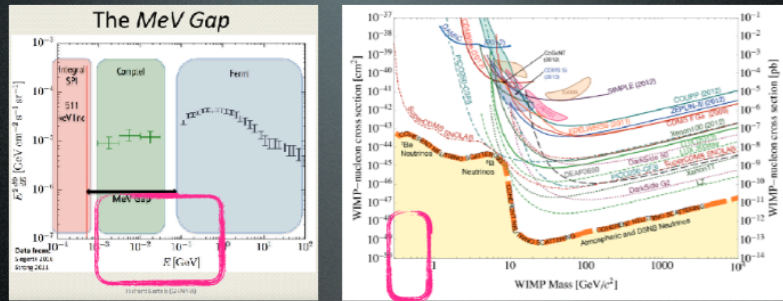
- Polarization signature
  - SSC - low  $\Pi$  - highly geometry dependent (Chang+14)
  - EIC - moderate  $\Pi$  (Fan09)
- More detailed modeling needed
  - but see talk by Böttcher for blazars
- TPC - HARPO will be able to constrain pol. for bright GRBs



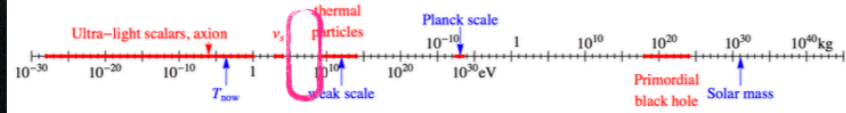
# MEV DARK MATTER - MARCO CIRELLI

## Candidates

Motivation for DM in the sub-GeV region

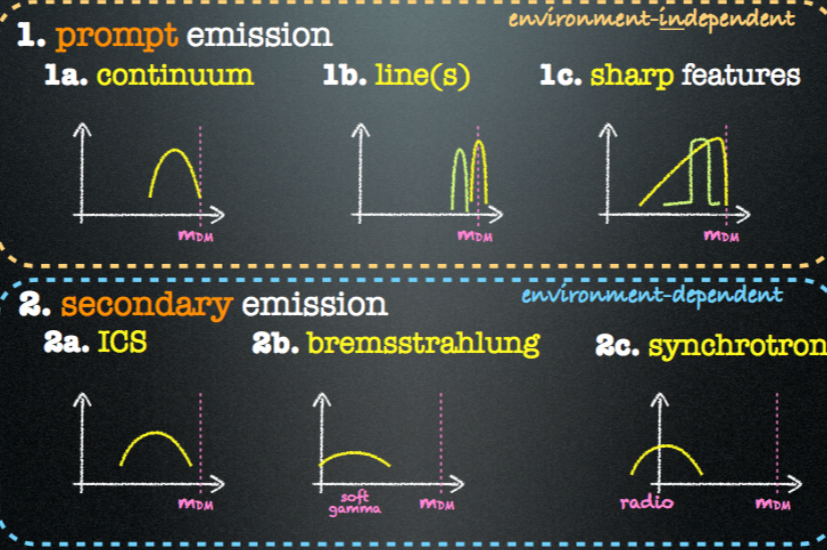


sub-GeV region

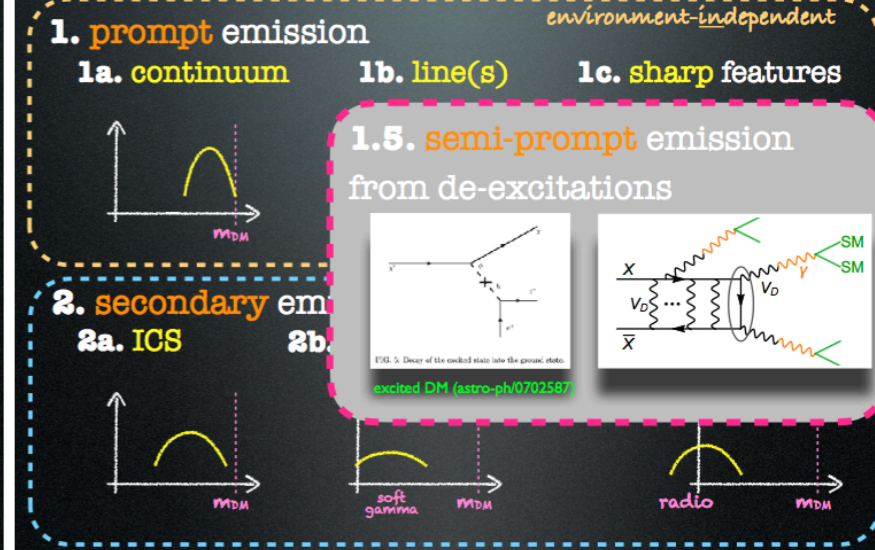


'only' 90 orders of magnitude!

## How does DM produce $\gamma$ -rays?

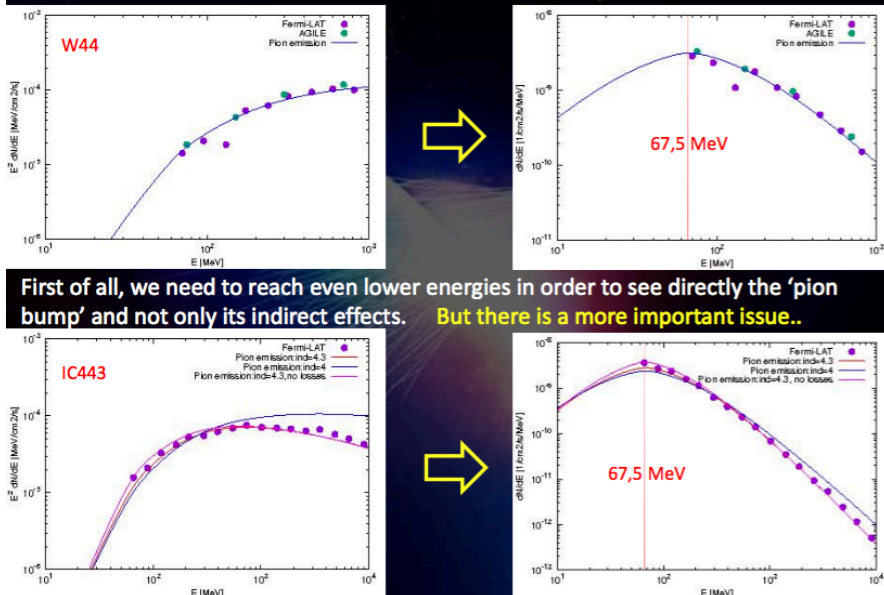


## How does DM produce $\gamma$ -rays?



# SNRs - MARTINA CARDILLO

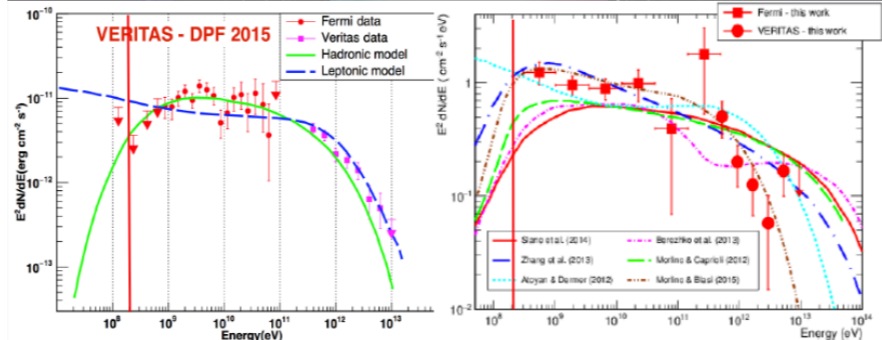
## The Pion bump Issue



First of all, we need to reach even lower energies in order to see directly the 'pion bump' and not only its indirect effects. But there is a more important issue..

## The importance of young SNRs at MeV energies

In order to have more chances to confirm the presence of freshly accelerated CRs in correspondence of the SNRs shocks, we need to detect young-fast ( $\geq 10^3$  km/s) shocks SNRs at  $E < 200$  MeV.

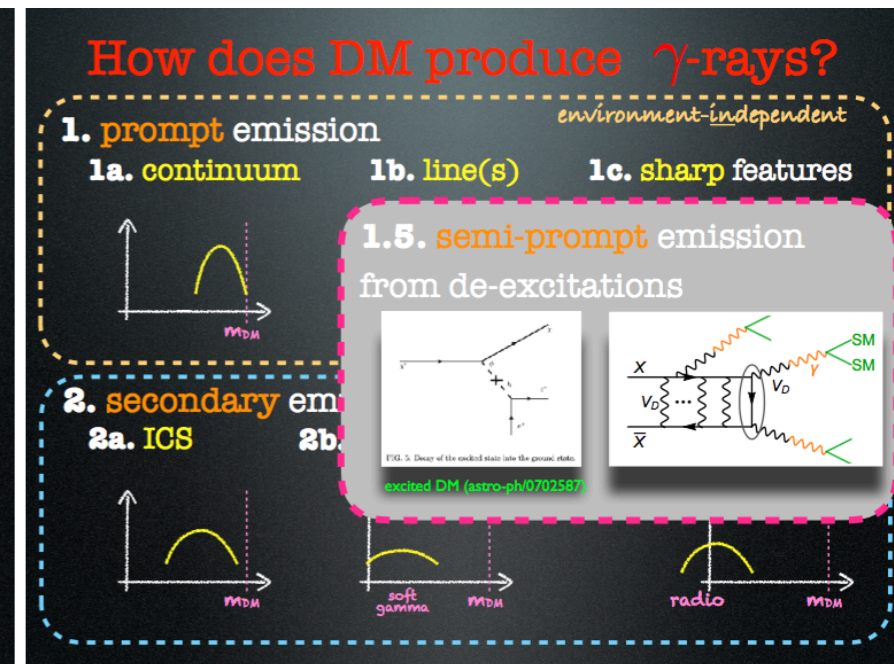
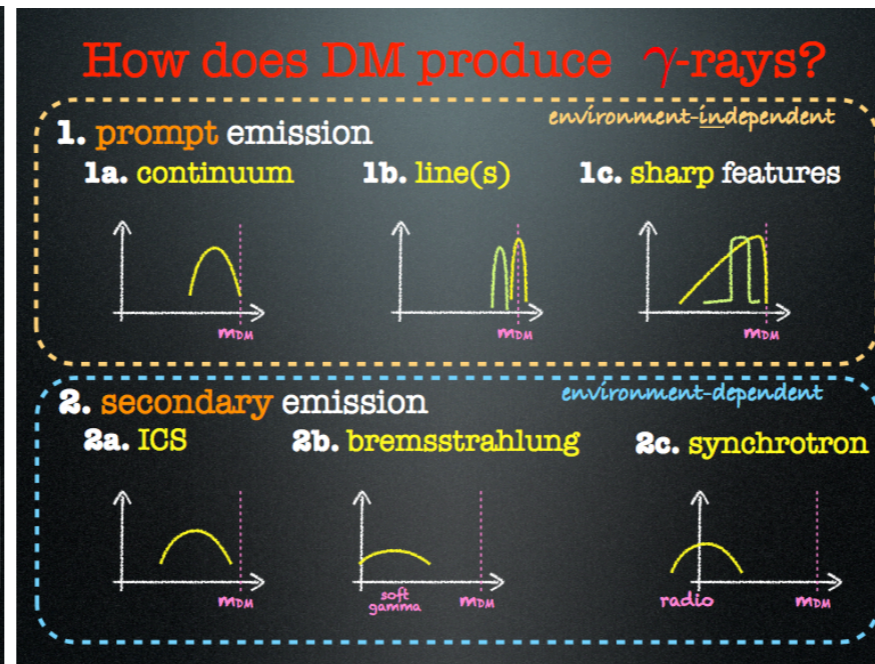
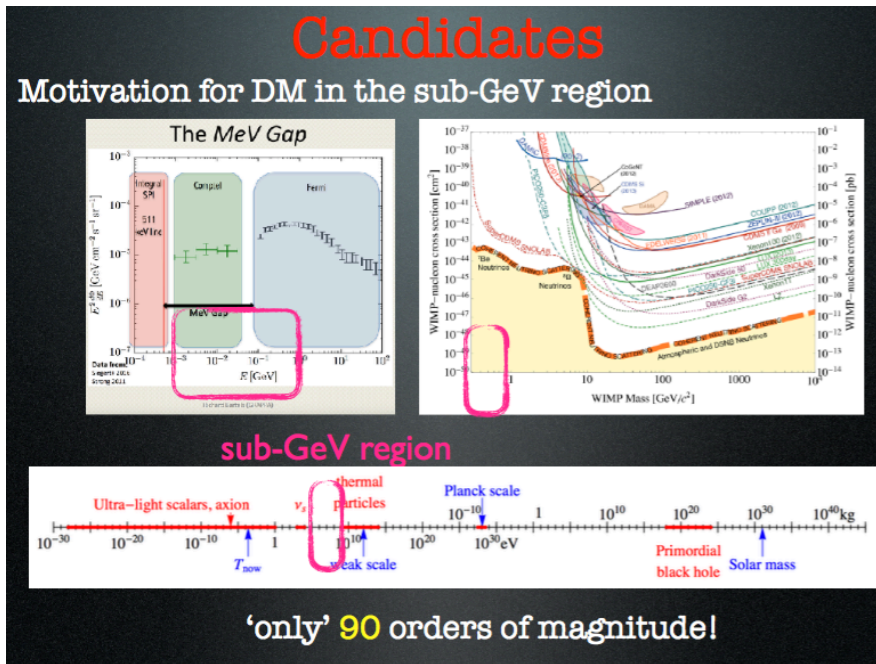


## Conclusions

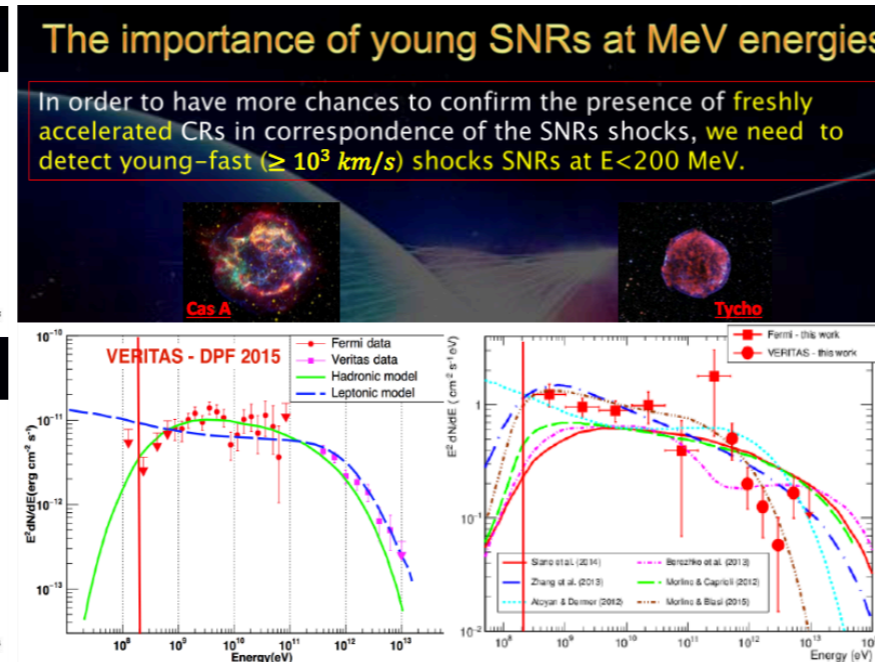
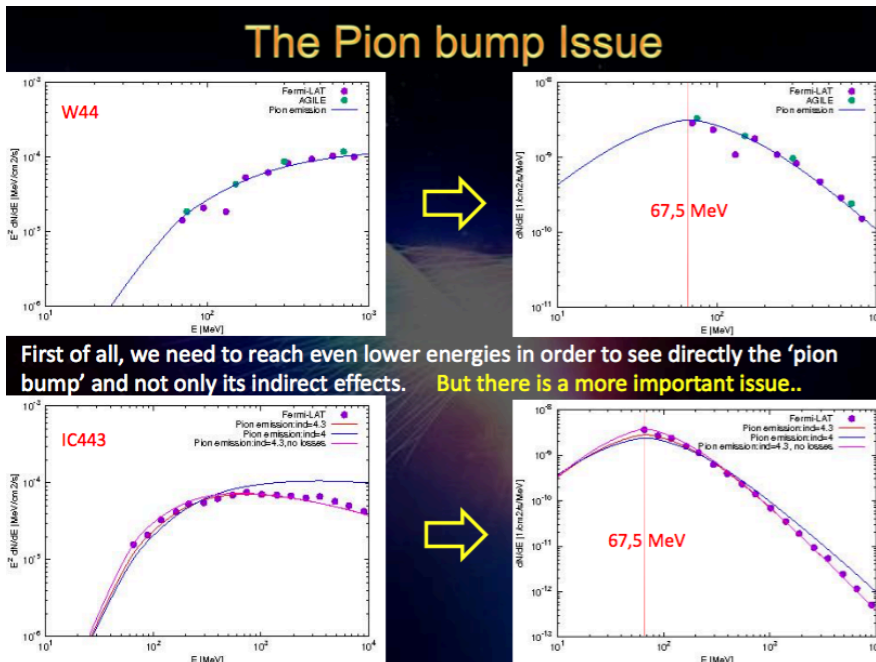
- ✦ We can have the direct proof of CR acceleration in the SNRs at very high energy (PeV  $\rightarrow$  CTA) and at lowest gamma-ray energies ( $E < 200$  MeV  $\rightarrow$  ?)
  - ✦ Despite the large amount of instruments, we had detected no PeV SNRs and only two middle-aged SNRs at  $E < 200$  MeV thanks to AGILE and Fermi-LAT  $\rightarrow$  probably reaccelerated CRs
  - ✦ We need to detect young SNRs with fast shocks at  $E < 200$  MeV in order to confirm the presence of freshly accelerated CRs
  - ✦ Acceleration (and also reacceleration) models depend from parameters like magnetic field, correlation length, density (...) that we can know thanks to other wavelengths
- We really need an instrument with improved capabilities at MeV energies in order to give the final answer to the question: how is the CR origin?**

# MEV DARK MATTER - MARCO CIRELLI

detected! Jean-Marc!



# SNRs - MARTINA CARDILLO



## Conclusions

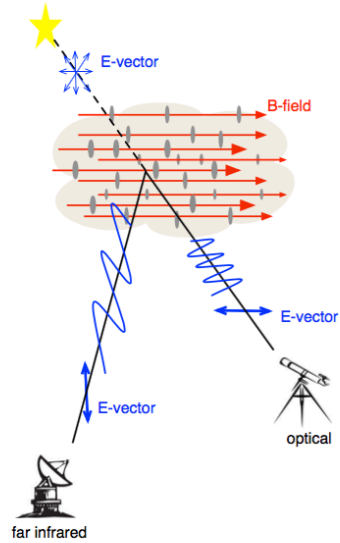
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We really need an instrument with improved capabilities at MeV energies in order to give the final answer to the question: how is the CR origin?

but Bremsstrahlung!!

# PASIPHAE - KOSTAS TASSIS

## Optopolarimetry of Starlight



Dust absorption – induced polarization of starlight:

*Common origin* with polarized dust emission

*Unique handle* on 3-d structure of foreground dust & B-field

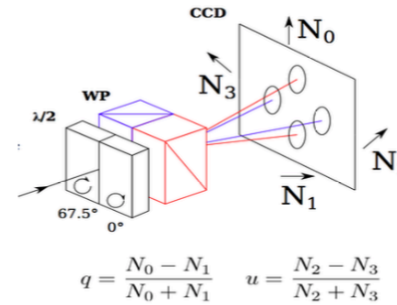
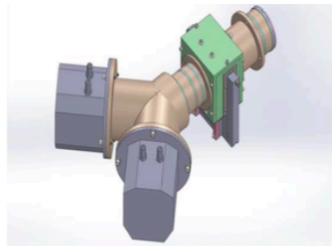
20

## PASIPHAE's WALOPs: Innovative Design

For each point source:

- Split light in 4 linear polarization states differing by 22.5° .
- Project each state in a different CCD
- Combine to obtain Stokes Parameters

- Technology successfully tested with RoboPol, expanded to wide FoV



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## Survey Mode

PASIPHAE will identify high optical polarization point sources

Previously Unknown High Energy Systems

Candidate Optical Counterparts For *Fermi* Unidentified Sources

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# HIGH-ENERGY POLARISATION - NACHI CHAKRABORTY

CHAKRABORTY, PAVLIDOU & FIELDS, APJ (2015), 798, 15

THE ASTROPHYSICAL JOURNAL, 798:16 (12pp), 2015 January 1

CHAKRABORTY, PAVLIDOU, & FIELDS

**Table 2**  
Input Parameters for 3C 279 are Detailed in Section 5.4.2

Polarimeter ID $j$	Polarimeter Energy Range $\Delta E_{\text{pol}}(j)$ (keV)	Energy Range of Observed Flux $\Delta E_{\text{obs}}(j)$ (keV)	Observed Energy Flux of Blazar $F_{E, \Delta E_{\text{obs}}, \text{blazar}}(j)$ ( $\times 10^{-12}$ erg cm $^{-2}$ s $^{-1}$ )	Scaled Energy Flux of Blazar $F_{E, \Delta E_{\text{pol}}, \text{blazar}}(j)$ ( $\times 10^{-12}$ erg cm $^{-2}$ s $^{-1}$ )	Photon Index of Blazar $\Gamma_{\text{blazar}}(j)$	Electron Index of Blazar $p(j)$	Seed Polariz. Degree $\Pi_{\text{init}}$ (%)
1,2	25–80	17–60	12.40	13.07	1.6	2.2	20.0
3,4	2–10	2–10	10.00	10.00	1.56	2.12	20.0
5,6	50–195	14–195	34.3	22.7	1.49	1.98	20.0

**Notes.** We list the energy fluxes in the observed energy ranges and the scaled energy fluxes appropriate for the polarimeter energy range,  $\Delta E_{\text{pol}}(j) = E_{\text{pol, min}}(j) - E_{\text{pol, max}}(j)$ , using the spectral index,  $\Gamma$ , of 3C 279 in the observed energy range,  $E_{\text{obs, min}}(j) - E_{\text{obs, max}}(j)$ . In the final column, we also list the seed polarization degree value (temporal average). For ASTRO-H and GAP, we scale fluxes to a BAT energy range of 50–195.

**Table 3**  
Input Parameters for PKS 1510-089 are Detailed in Section 5.4.2, as in Table 2 for 3C 279

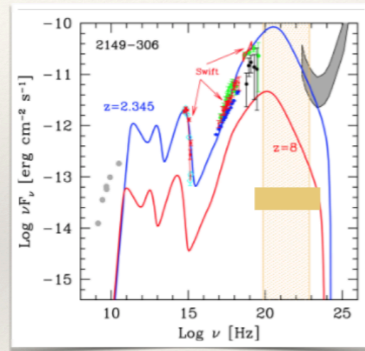
Polarimeter ID $j$	Polarimeter Energy Range $\Delta E_{\text{pol}}(j)$ (keV)	Energy Range of Observed Flux $\Delta E_{\text{obs}}(j)$ (keV)	Observed Energy Flux of Blazar $F_{E, \Delta E_{\text{obs}}, \text{blazar}}(j)$ ( $\times 10^{-12}$ erg cm $^{-2}$ s $^{-1}$ )	Scaled Energy Flux of Blazar $F_{E, \Delta E_{\text{pol}}, \text{blazar}}(j)$ ( $\times 10^{-12}$ erg cm $^{-2}$ s $^{-1}$ )	Photon Index of Blazar $\Gamma_{\text{blazar}}(j)$	Electron Index of Blazar $p(j)$	Seed Polariz. Degree $\Pi_{\text{init}}$ (%)
1,2	25–80	10–50	38.2	45.7	1.23	1.46	15.0
3,4	2–10	2–10	6.09	6.09	1.38	1.76	15.0
5,6	50–195	14–195	70.0	36.4	1.38	1.76	15.0



# MEV BLAZARS - MARCO AJELLO

## MeV Blazars

- Among most powerful persistent objects in the Universe
- Large jet power, easily larger than accretion luminosity
  - BH spin may be important
- Host massive black holes, near 1 billion solar masses (or more)
- They are detected up to very high redshift (Ajello et al. 2009)



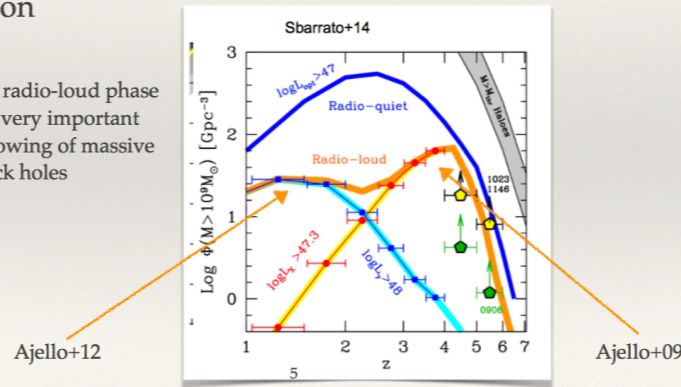
*This population is not well understood, yet very important*

4

## Evolution of MeV blazars

- Evolution of MeV blazars is stronger than any other source class: i.e. their maximum density may be very early on

Clear that the radio-loud phase may play a very important role in the growing of massive black holes

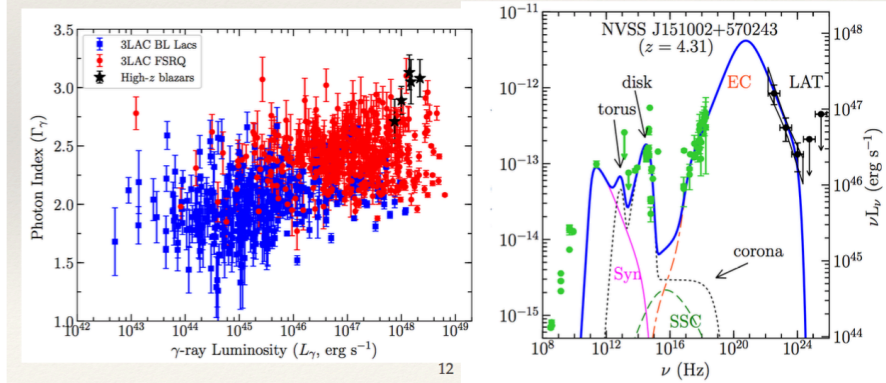


Ajello+12

Ajello+09

## Recent Detections

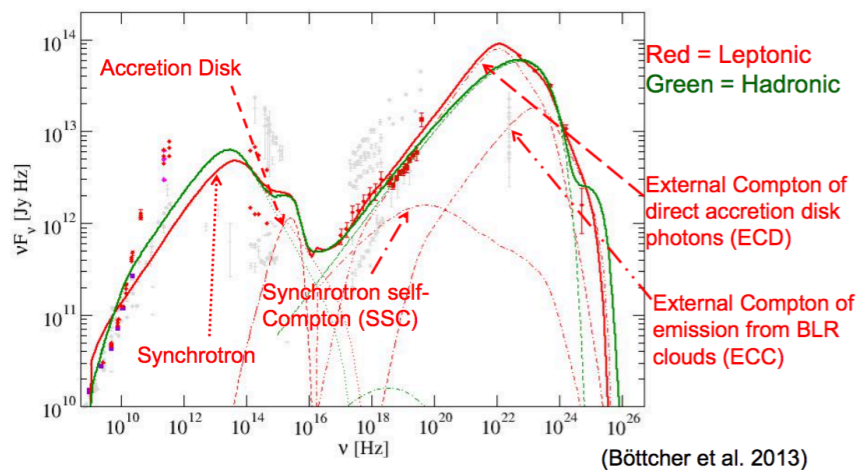
- Improved low-energy response (with P8) allowed Fermi-LAT to detect 5  $z > 3.1$  blazars (Ackermann+17)



# BLAZARS - MARKUS BÖTTCHER

## Leptonic and Hadronic Model Fits to Blazar SEDs

3C454.3

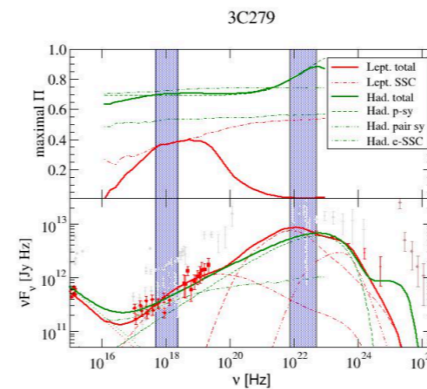


(Böttcher et al. 2013)

## Observational Strategy

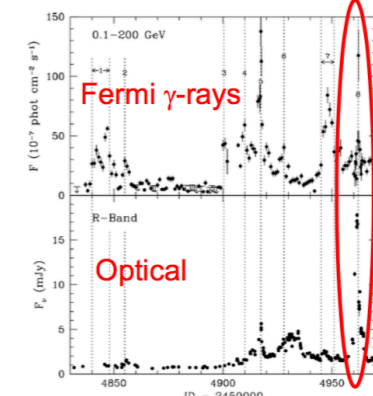
- Results shown here are **upper limits** (perfectly ordered magnetic field perpendicular to line of sight)
- Scale results to actual B-field configuration from known synchrotron polarization (e.g., optical for FSRQs/LBLs) => Expect 10 - 20 % X-ray and  $\gamma$ -ray polarization in hadronic models!
- X-ray and  $\gamma$ -ray polarization values substantially below synchrotron polarization will favor leptonic models, measurable  $\gamma$ -ray polarization clearly favors hadronic models!

(Zhang & Böttcher, 2013)

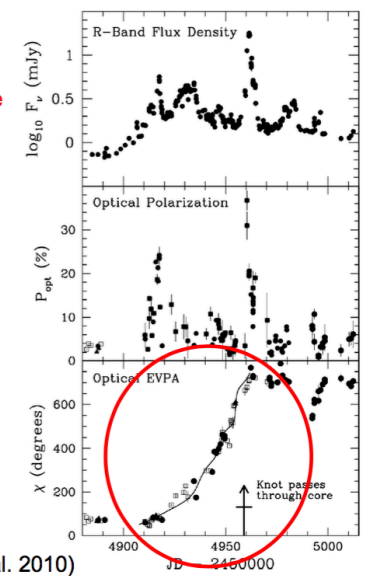


## Polarization Angle Swings

- Optical +  $\gamma$ -ray variability of LSP blazars often correlated
- Sometimes  $O/\gamma$  flares correlated with **increase in optical polarization and multiple rotations of the polarization angle (PA)**

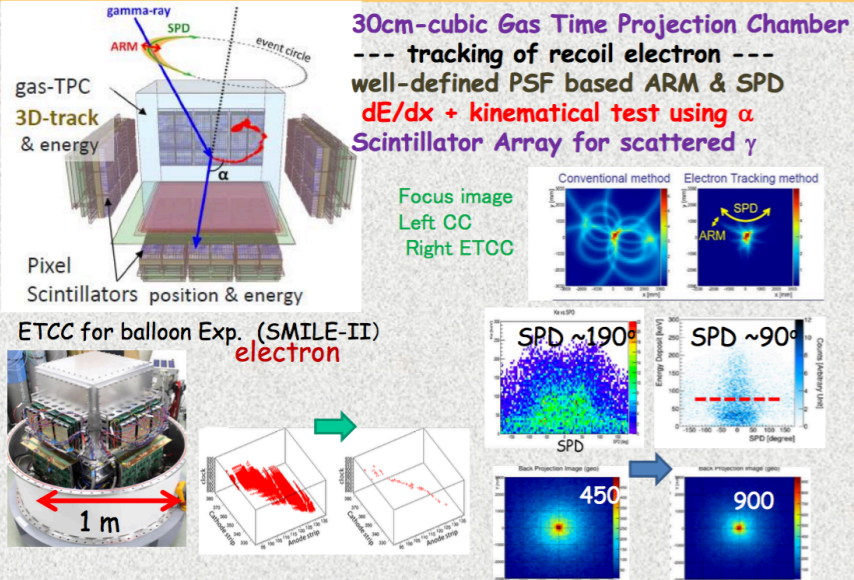


PKS 1510-089 (Marscher et al. 2010)



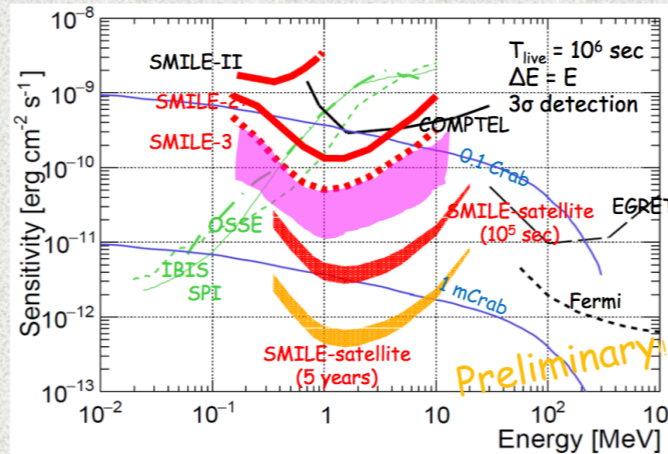
# ELECTRON TRACKING CAMERA - TORU TANIMORI

## Electron Tracking Compton Camera



## Expected Sensitivity based on well-defined PSF

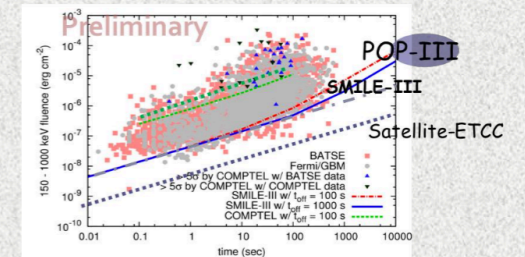
Sensitivities area are calculated from effective area and PSF determined by ARM and SPD



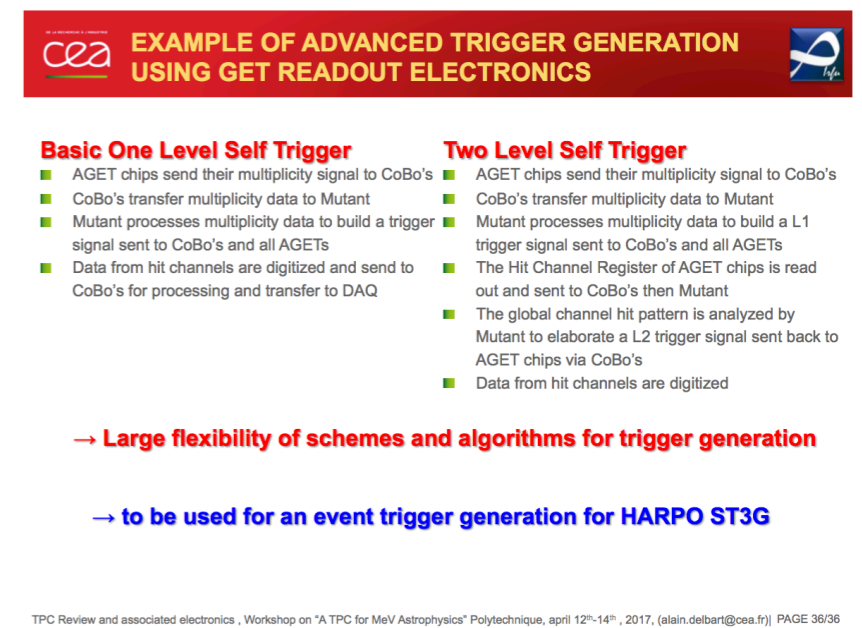
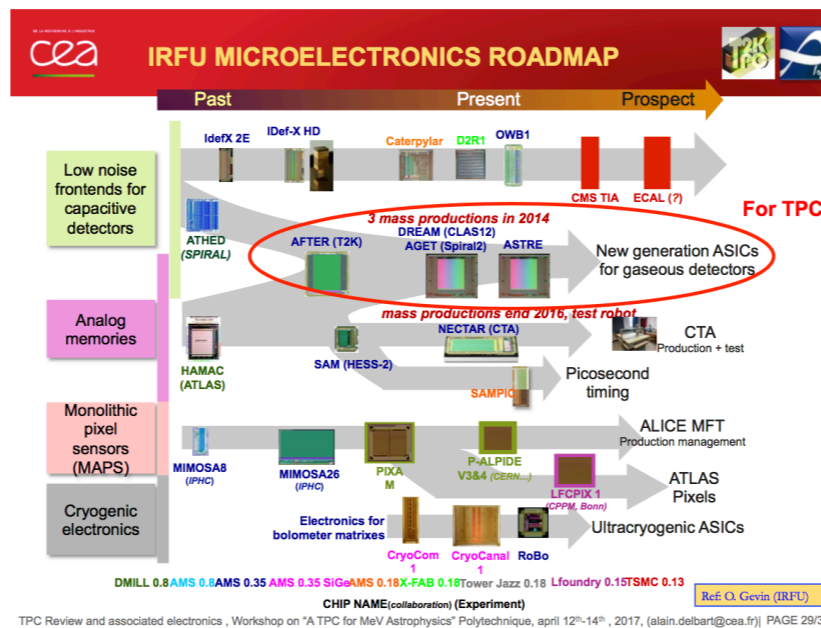
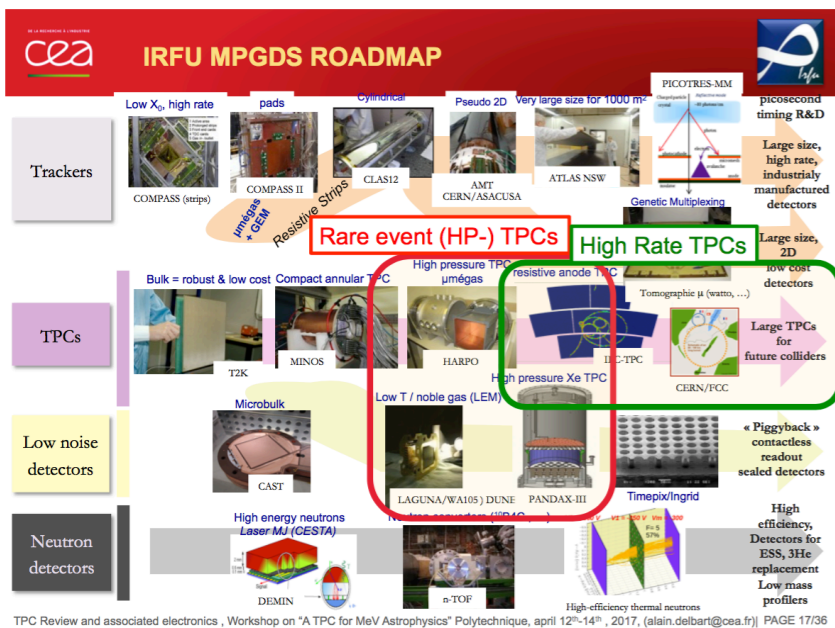
SMILE-Satellite 50cm-cubic ETCC x 4 modules  
 Effective Area ~200cm<sup>2</sup>@1MeV and PSF 1-2°

## Summary

- ◆ ETCC provides **Imaging Spectroscopic Observation for the first time**, and hence reveals the reliable way to reach to sub mCrab sensitivity.
- ◆ Also ETCC provides a ability of imaging polarimetry. another my presentation in the evening.
- ◆ SMILE-II+ will be launched at Alice Spring Australia in Apr. 2018 to observe 511keV from Galactic center



# TPCs - ALAIN DELBART

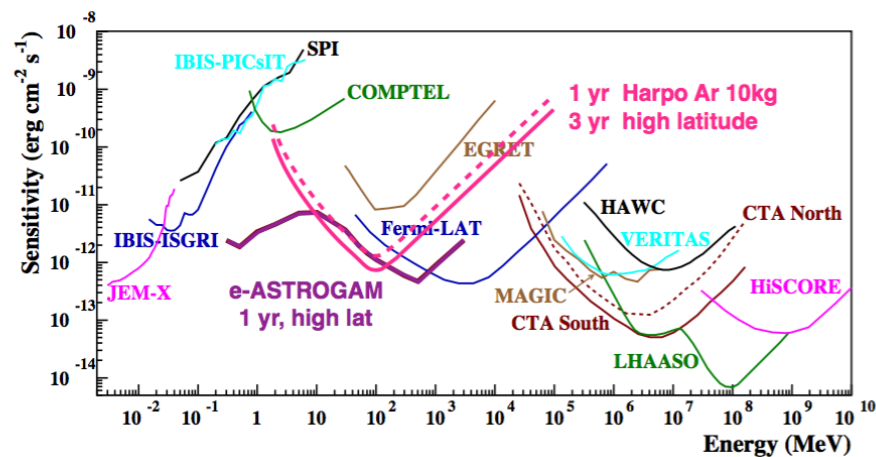


# PULSARS

ISABELLE GRENIER (+ ALICE HARDING)

## prospects for MeV pulsars in a nutshell

- uncover the population of energetic MeV pulsars
- shed light on acceleration & pair cascades near the polar caps
- diagnostics of
  - the radiation processes at MeV & GeV energies
  - the pulsed radiation pattern (caustic crossing)
  - magnetic reconnection in the wind



# BINARIES - BENOÎT CERUTTI

## Conclusions

- Gamma-ray binaries are **bright and variable MeV sources**.
- MeV emission probes the **high-end** of the particle energy spectrum. Constraints on extreme particle acceleration mechanism?
- Origin of the **MeV flux** is still not understood.
- **Connection** between MeV and >100 MeV is not clear. Two **different components** are needed.
- Great opportunity to **probe pulsar and pulsar wind physics**.

# PULSAR TIMING - DAVID SMITH

## Conclusions

- Recording accurate event times and instrument positions isn't as easy as you may think.
- Many major missions goofed.
- Studying gamma polarization as a function of pulsar rotational phase requires forethought and testing.

# GALACTIC DIFFUSE- JEAN-MARC CASANDJIAN

## Conclusions

Lot's of astrophysics can be done at low energy gamma-ray

We did learn a lot about ISM and CRs with Fermi.

MeV will give us access to the electrons and positions density in the local and outer Galaxy and clouds.

It should be possible to model the diffuse emission for point-source extraction.

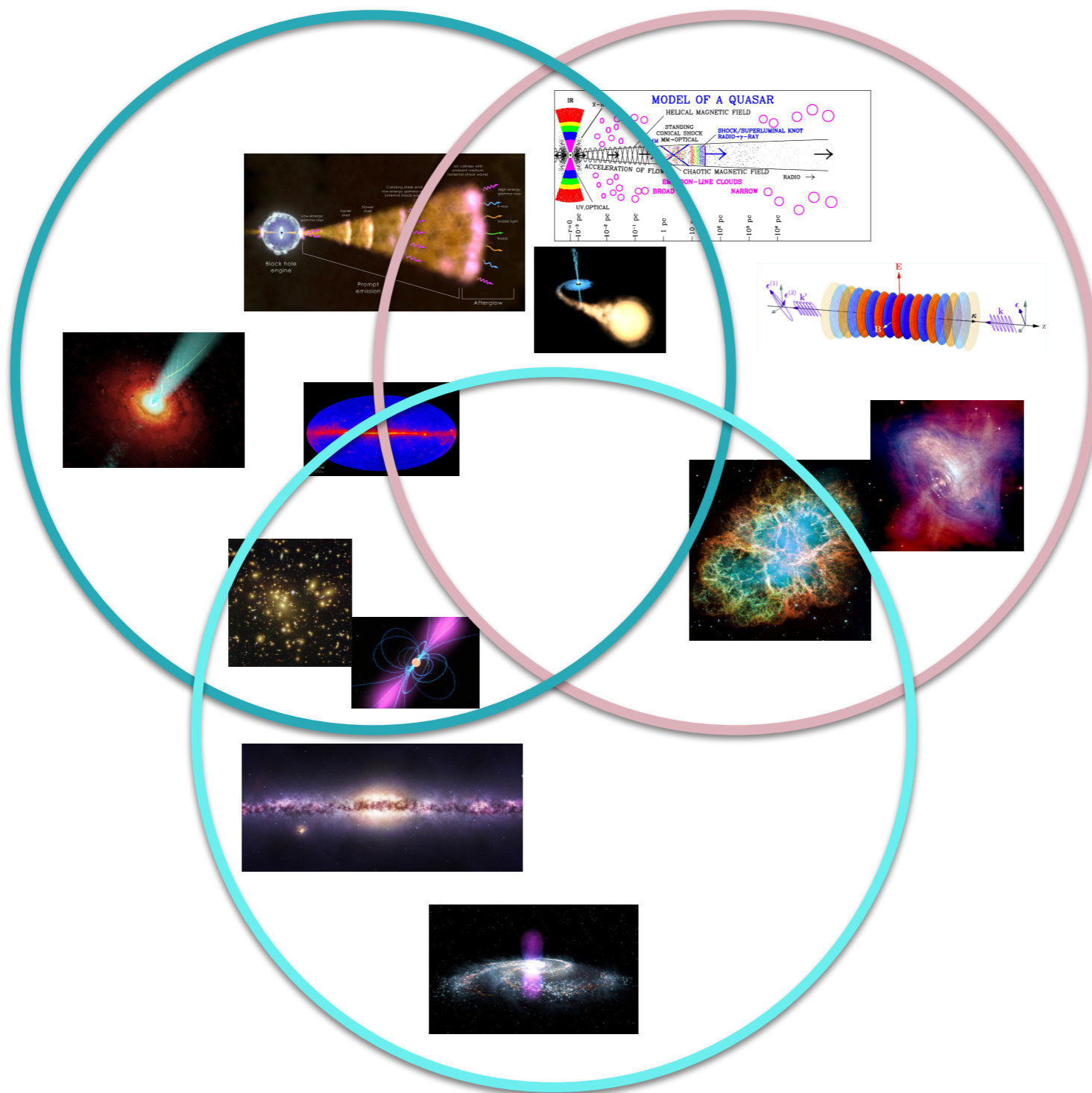
IC has a smooth spatial structure, it is difficult to model, it should be ok for point sources but a problematic background for extended sources.

From Fermi we know a good PSF helps a lot to study the interstellar emission.

# Gamma-ray Astrophysics at MeV energies

MEV ENERGY  
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POLARIZATION



HIGH ANGULAR  
RESOLUTION

# ST3G - what next?

CNES APPEL D'OFFRE 2017: DEADLINE - 21 APRIL

- WE WILL SUBMIT A PROPOSAL TO CONSTRUCT DEMONSTRATOR OF ST3G
- WE WILL NOT REQUEST A BALLOON FLIGHT AT THIS POINT

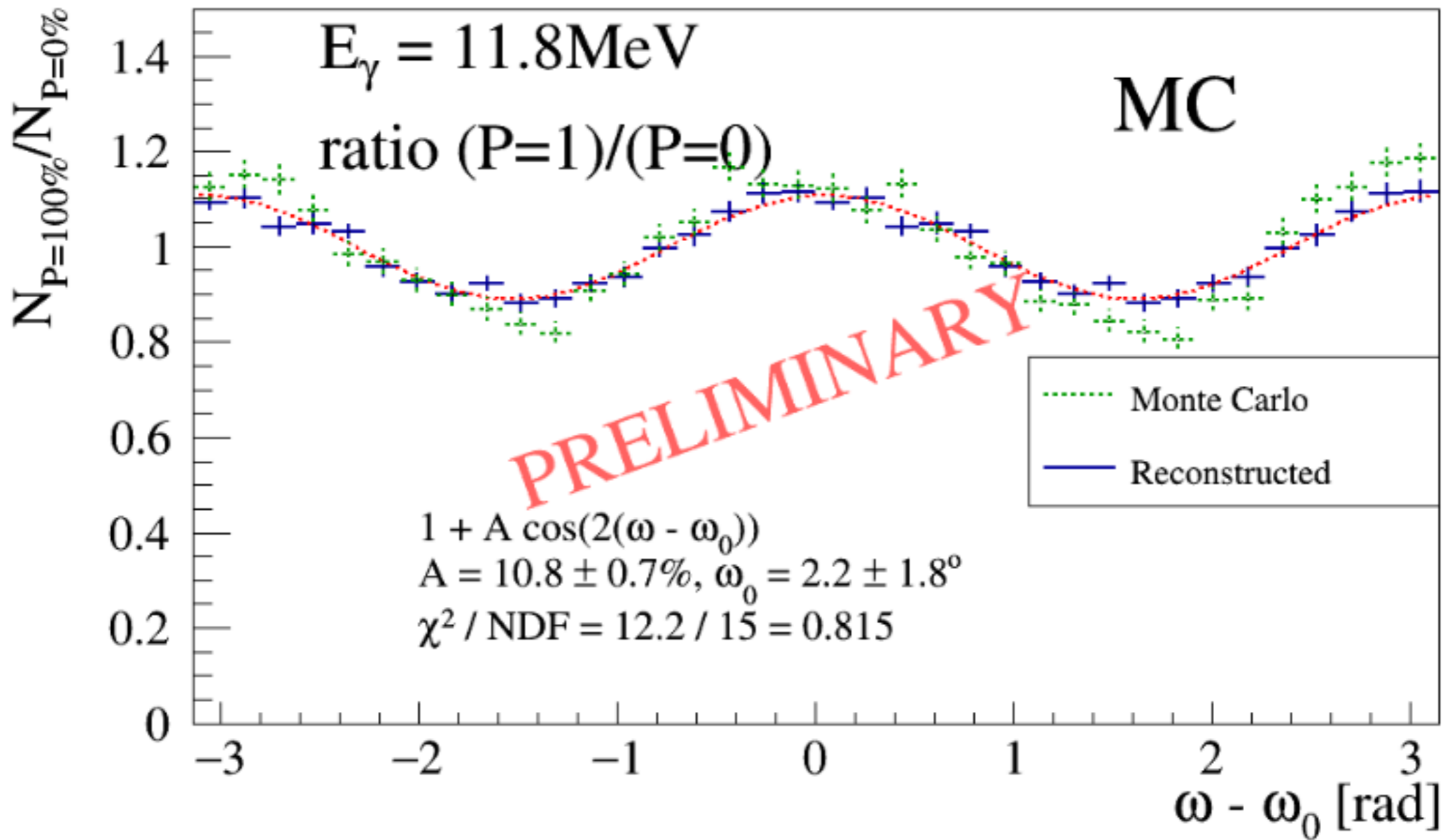
P210 POST-DOC CALL: DEADLINE - 18 APRIL

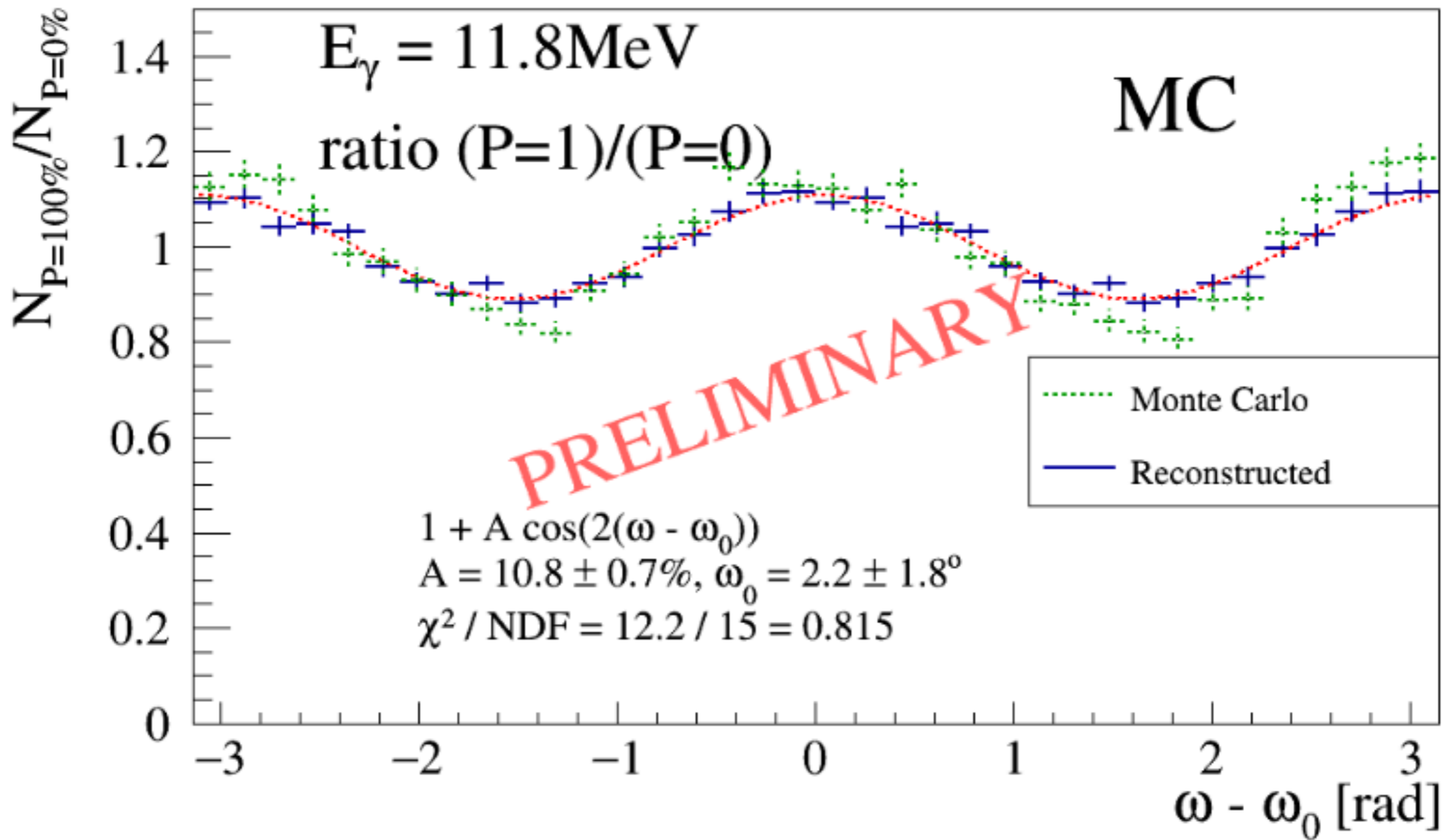
*i.e. next Tuesday!*

- JOINT POST-DOC WITH ANOTHER P210 LAB - 2 YEARS

EN SUITE ...

- ANR?
- ERC?
- ???





HARPO TOUR