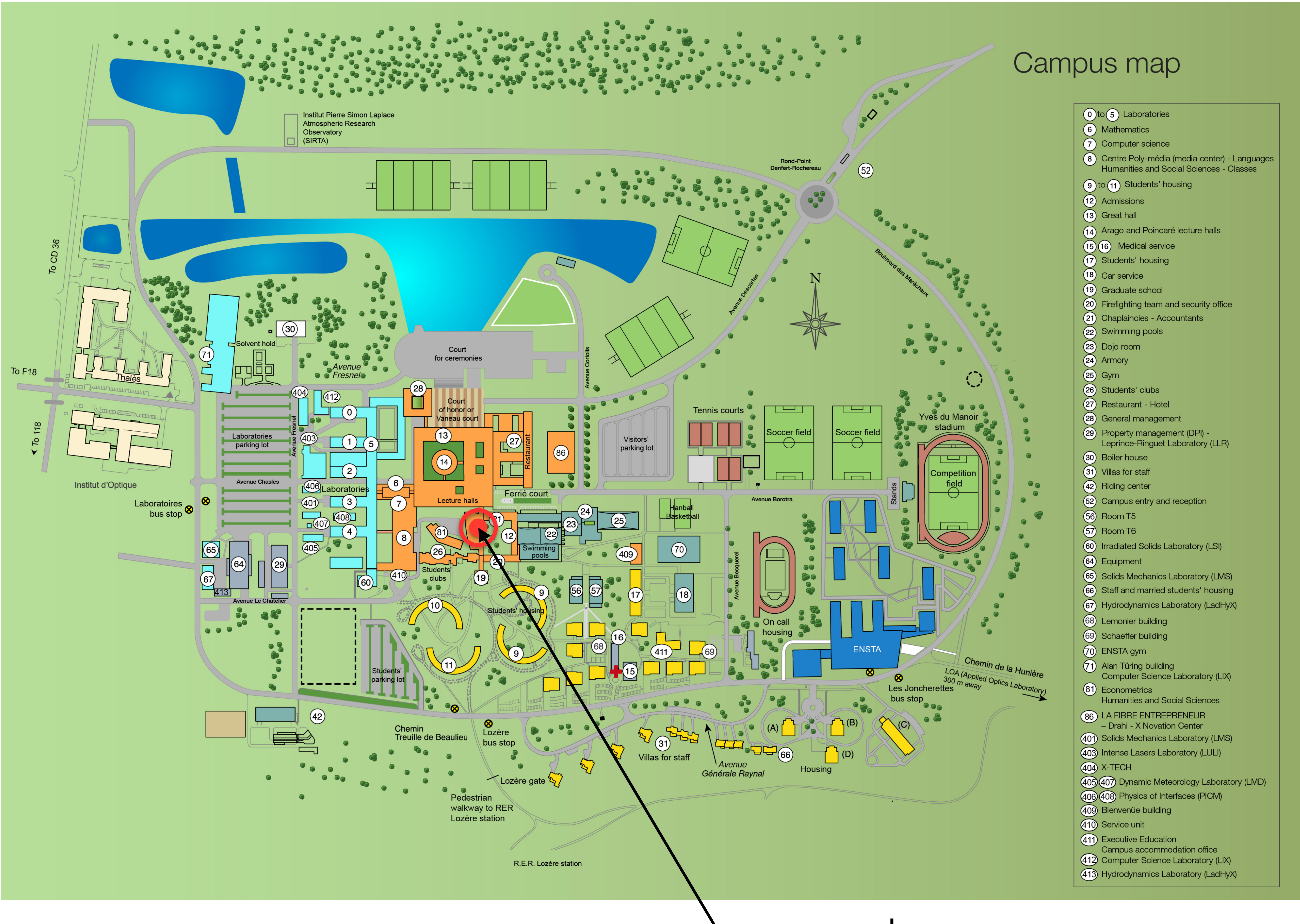
Welcome to our workshop

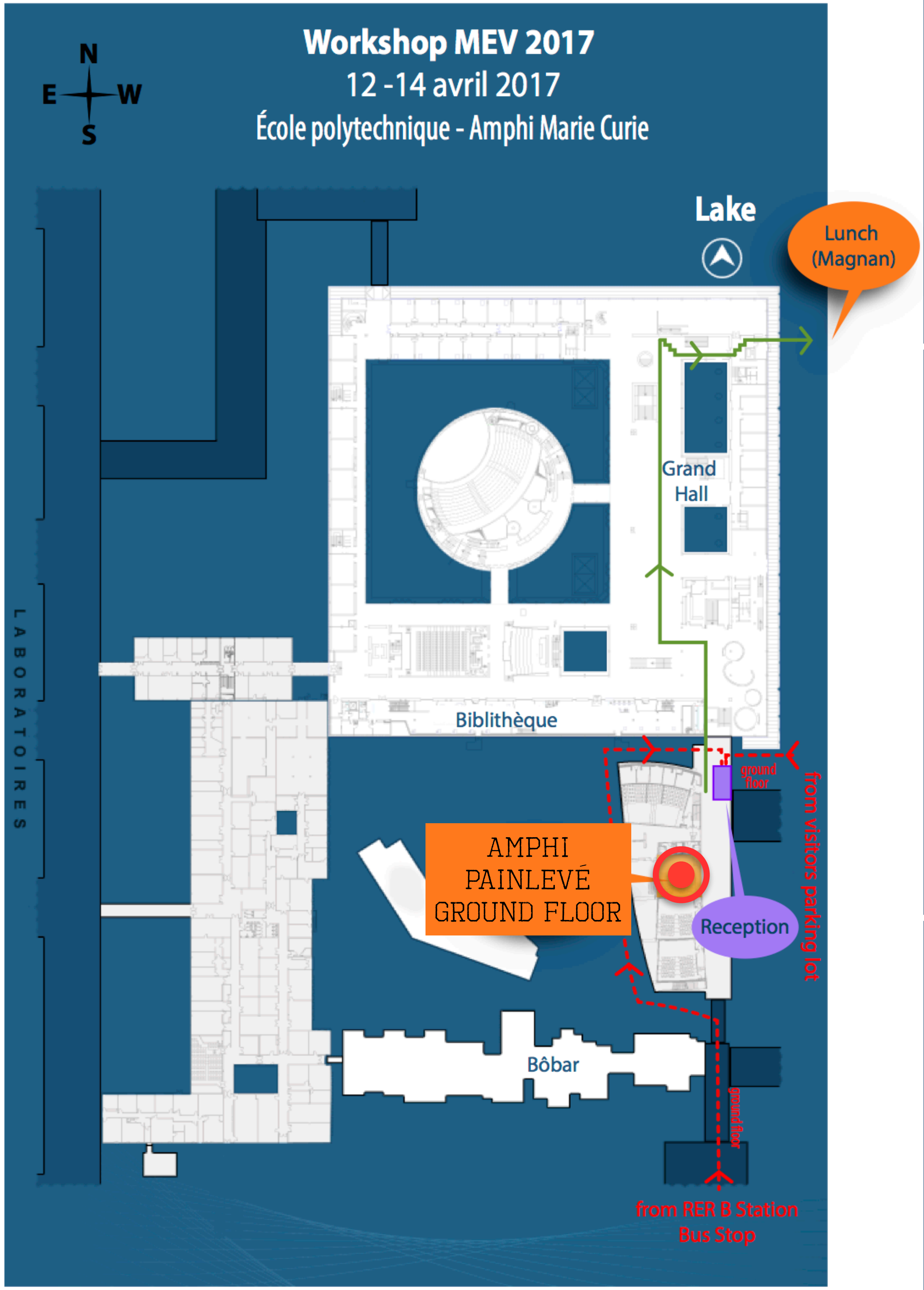
THANKS FOR TAKING THE TIME TO TRAVEL FROM NEAR AND FAR TO BE HERE WITH US

Speakers: please upload your talk to Indico

- you must be logged in to Indico to do this
- Instructions are provided on the webpage of the workshop
- if you have any difficulty, please contact one of us
  - ➡ Deirdre, Denis, Philippe or Steve


Campus map
0 to 5 Laboratories
6 Mathematics
7 Computer science
8 Centre Poly-média (media center) - Languages Humanities and Social Sciences - Classes
9 to 11 Students' housing
12 Admissions
13 Great hall
14 Arago and Poincaré lecture halls
15 16 Medical service
17 Students' housing
18 Car service
19 Graduate school
20 Firefighting team and security office
21 Chaplaincies - Accountants
22 Swimming pools
23 Dojo room
24 Armory
25 Gym
26 Students' clubs
27 Restaurant - Hotel
28 General management
29 Property management (DPI) - Leprince-Ringuet Laboratory (LLR)
30 Boiler house
31 Villas for staff
42 Riding center
52 Campus entry and reception
56 Room T5
57 Room T6
60 Irradiated Solids Laboratory (LSI)
64 Equipment
65 Solids Mechanics Laboratory (LMS)
66 Staff and married students' housing
67 Hydrodynamics Laboratory (LadHyX)
68 Lemonier building
69 Schaeffer building
70 ENSTA gym
71 Alan Türing building Computer Science Laboratory (LIX)
81 Econometrics Humanities and Social Sciences
86 LA FIBRE ENTREPRENEUR – Drahi - X Novation Center
401 Solids Mechanics Laboratory (LMS)
403 Intense Lasers Laboratory (LULI)
404 X-TECH
405 407 Dynamic Meteorology Laboratory (LMD)
406 408 Physics of Interfaces (PICM)
409 Bienvenüe building
410 Service unit
411 Executive Education Campus accommodation office
412 Computer Science Laboratory (LIX)
413 Hydrodynamics Laboratory (LadHyX)
Institut Pierre Simon Laplace Atmospheric Research Observatory (SIRTA)
Rond-Point Denfert-Rochereau
Court for ceremonies
Court of honor or Vaneau court
Lecture halls
Ferrié court
Restaurant
Visitors' parking lot
Tennis courts
Soccer field
Soccer field
Yves du Manoir stadium
Competition field
Stands
Avenue Borotra
Hanball Basketball
Swimming pools
Students' clubs
Students' housing
On call housing
ENSTA
Chemin de la Hunière
LOA (Applied Optics Laboratory) 300 m away
Les Joncherettes bus stop
Housing
Villas for staff
Avenue Générale Raynal
Lozère bus stop
Lozère gate
Pedestrian walkway to RER Lozère station
R.E.R. Lozère station
Chemin Treuille de Beaulieu
Students' parking lot
Avenue Le Chatelier
Laboratoires bus stop
Institut d'Optique
Laboratories parking lot
Avenue Chasles
Avenue Fresnel
Laboratories
Solvent hold
Thalès
To F18
To 118
To CD 36
Avenue Descartes
Boulevard des Maréchaux
Avenue Coriolis
Avenue Becquerel
N

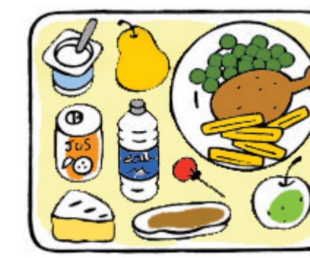
we are here



Coffee breaks

- will be set up just outside the amphi
- no food / drinks are allowed inside amphi

Lunch (Thursday) - provided



- Club Magnan
- we will walk there together

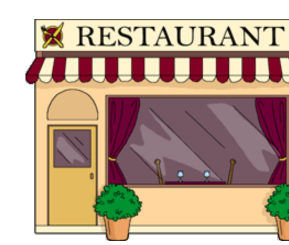
Lunch (Friday) - not provided

➡ let us know if you want to have lunch on campus

➡ 2 options:

- canteen (10€ - must buy "ticket")*
- café (various options)

Dinner



- we have not arranged a workshop dinner
- we are available to help with reservations/recommending restaurants - just come and see one of us

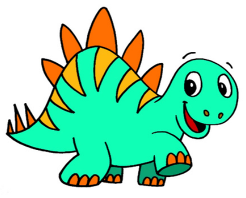
*https://www.polytechnique.edu/en/on-campus-dining-and-services

ST3G

"stègue"

A PROTOYPE BALLOON DETECTOR

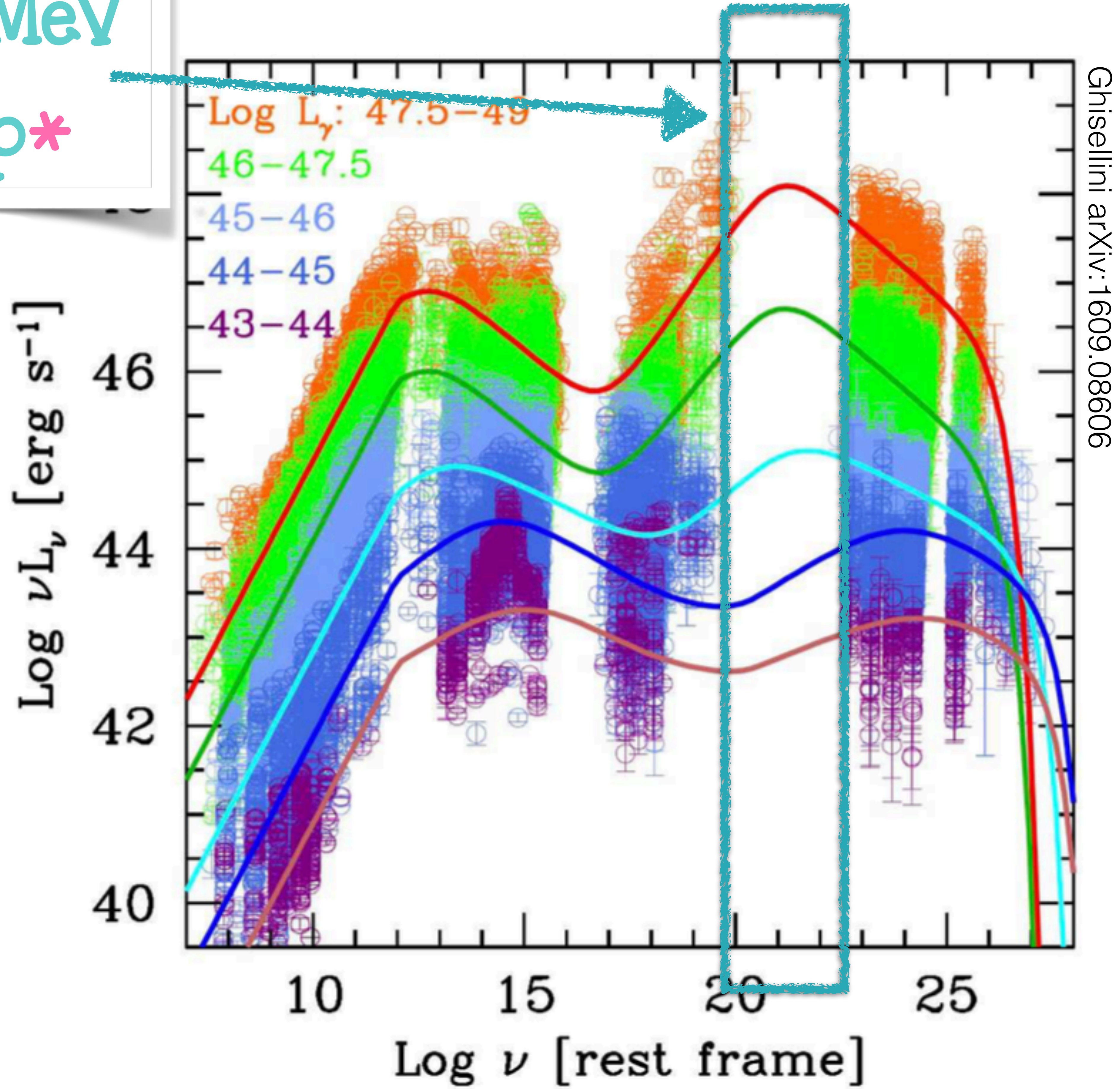
Self-triggering TPC telescope for gamma-rays



Outline

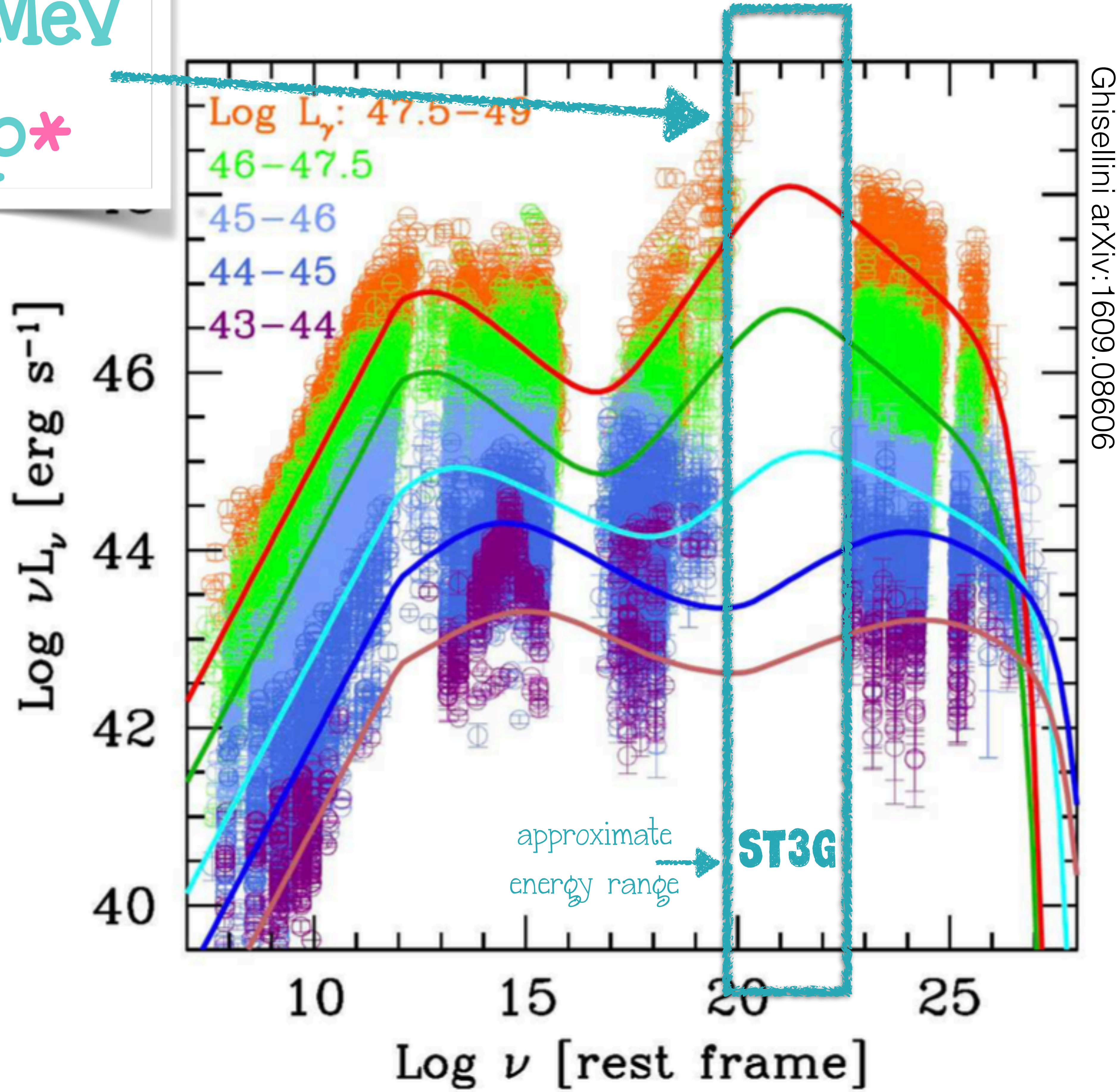
- Scientific motivation
- Brief introduction and history
- ST3G - a prototype detector
- Our plan

The MeV Gap*



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

The MeV Gap*



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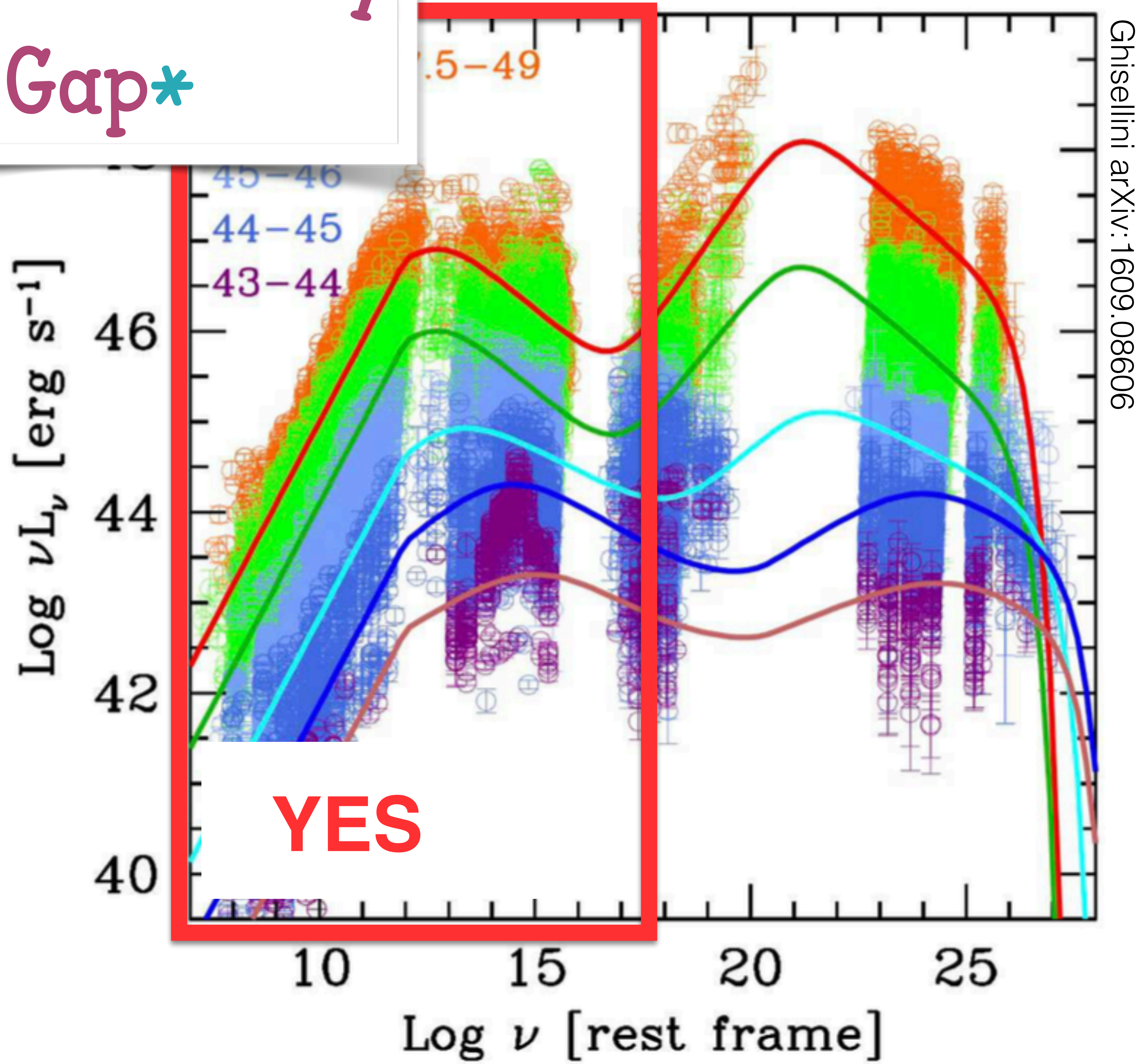
The Polarimetry Gap*



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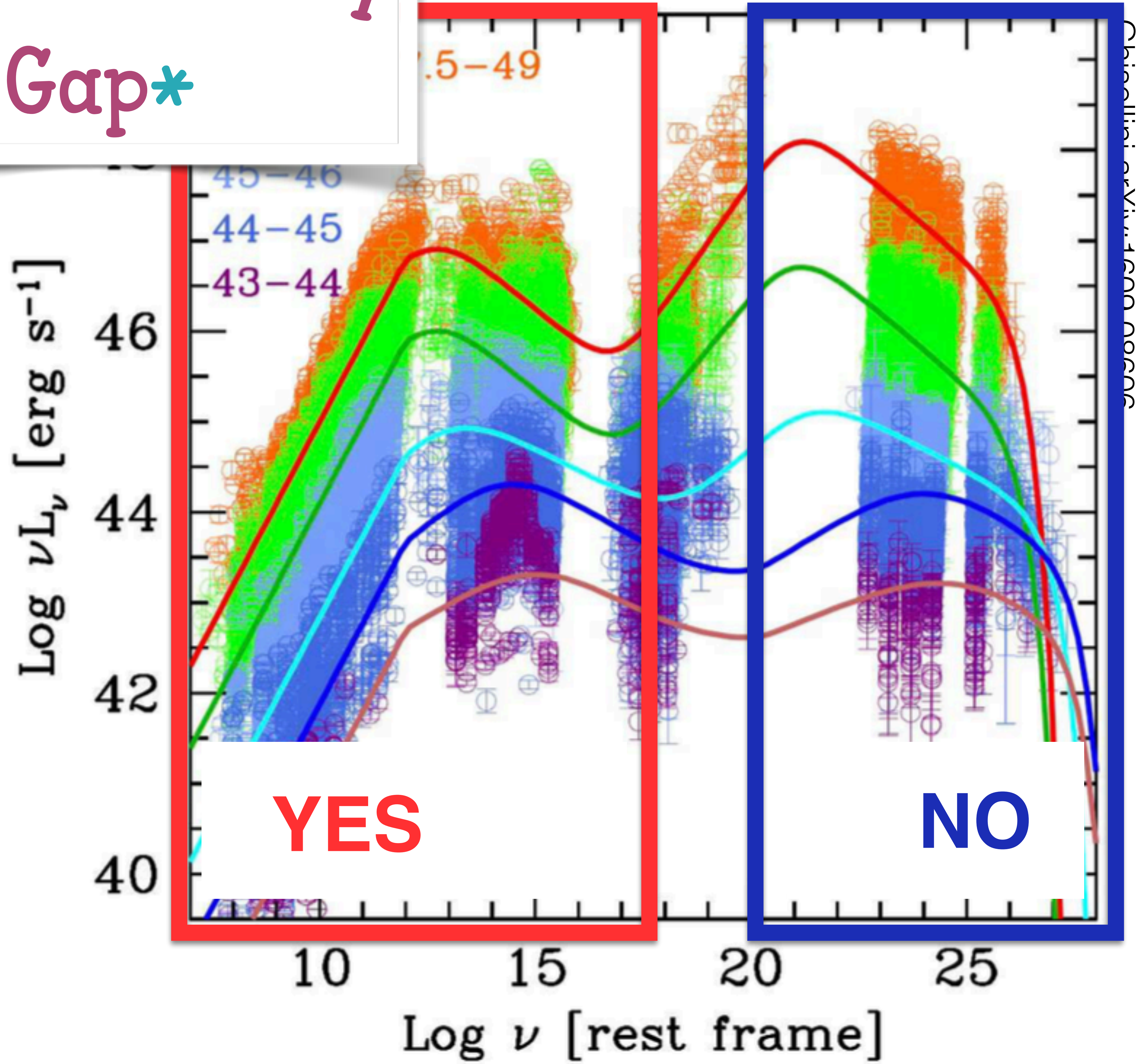
The Polarimetry Gap*



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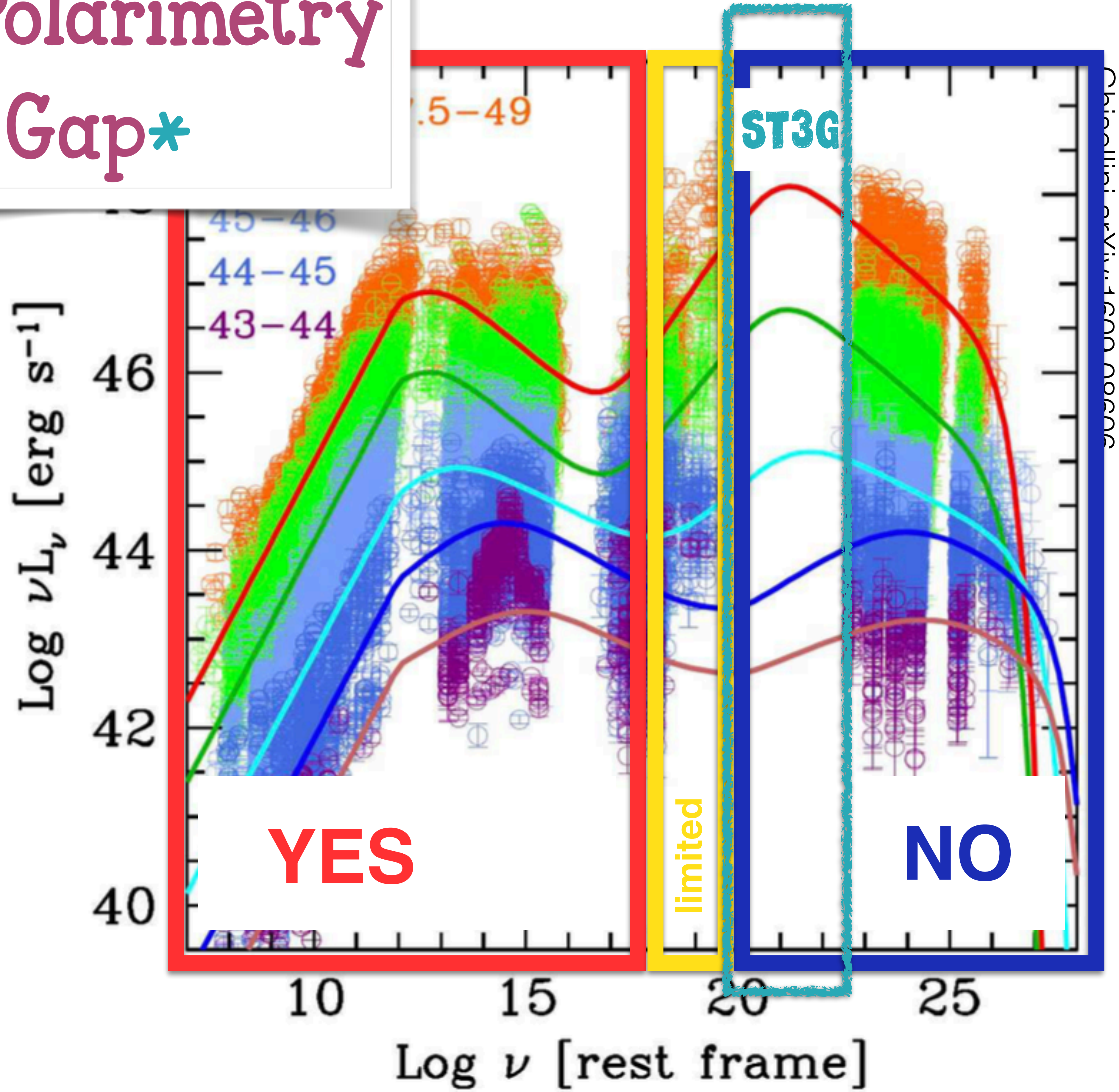
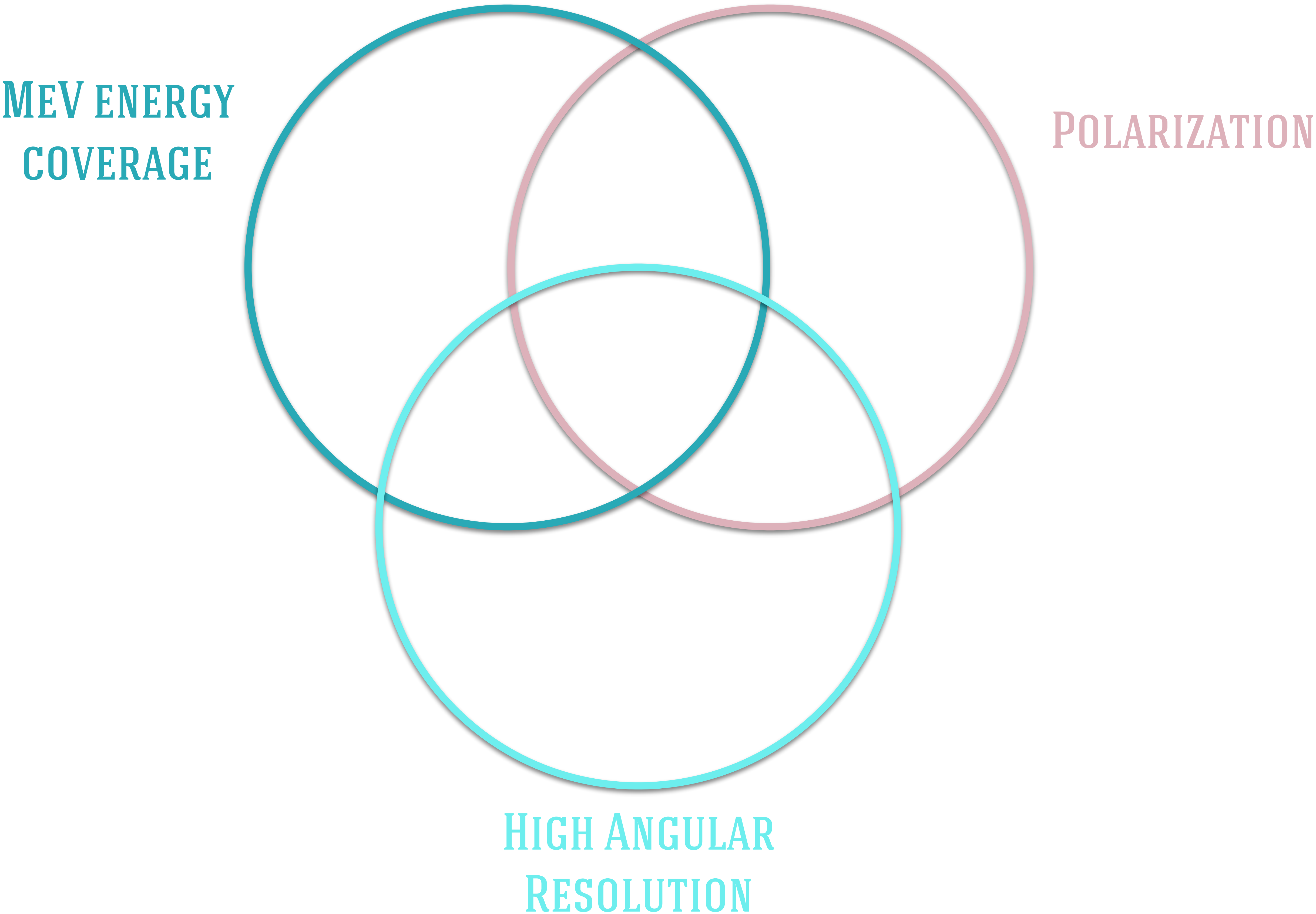
The Polarimetry Gap*

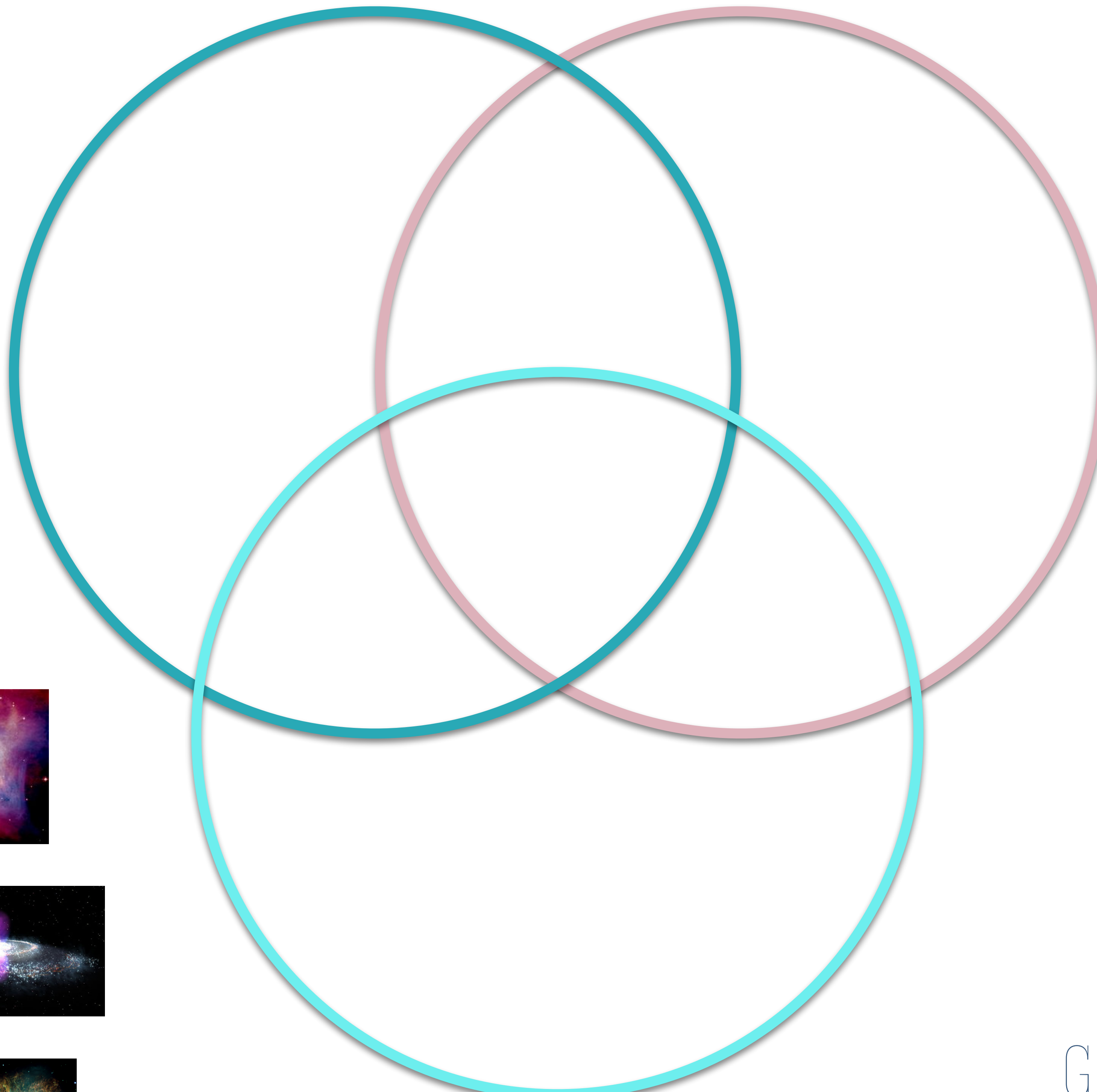


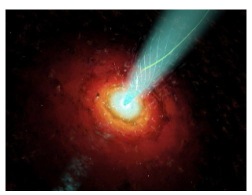
* using blazars to illustrate the gap since these are broadband emitters from radio all the way up to gamma rays

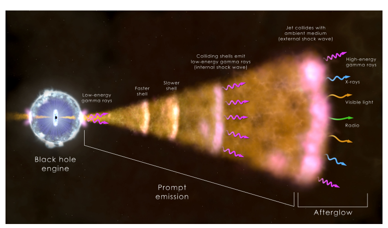
Gamma-ray Astrophysics at MeV energies

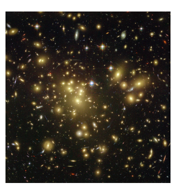


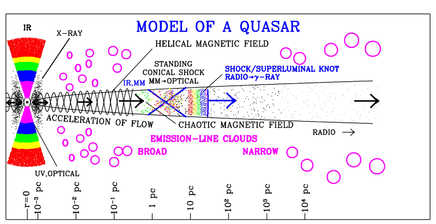
Gamma-ray Astrophysics at MeV energies

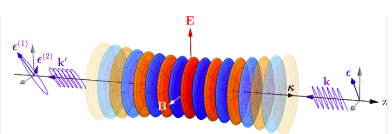


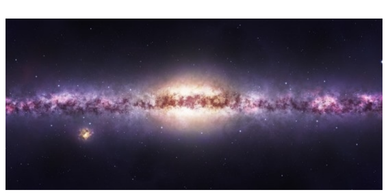


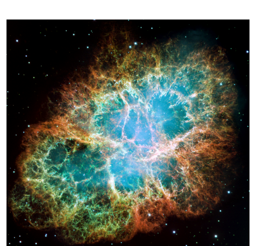


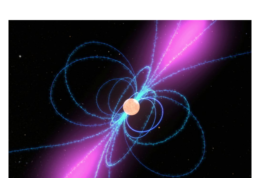


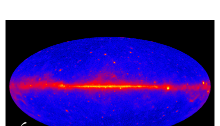


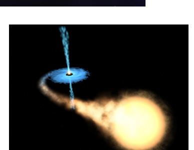










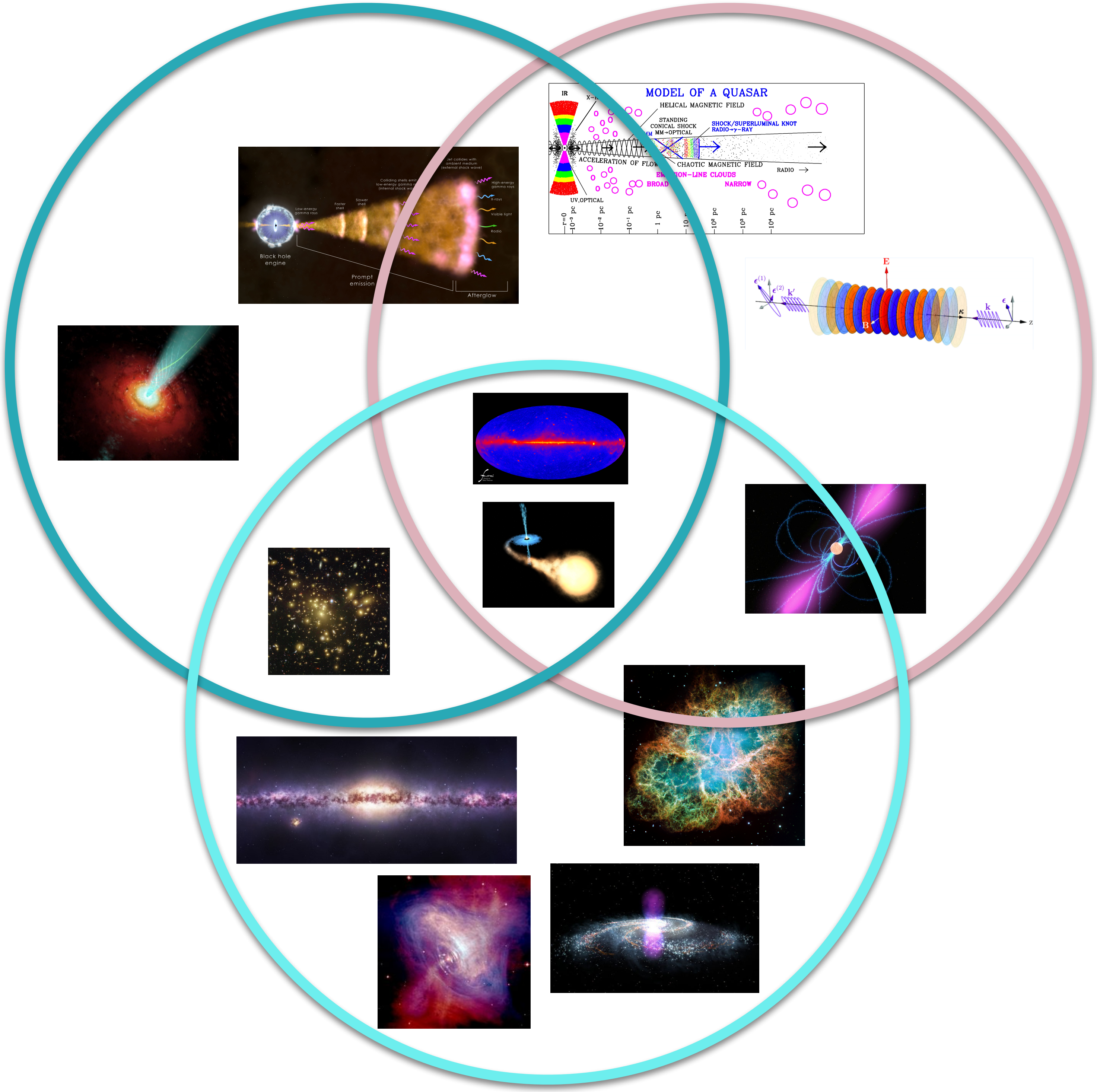


BLAZARS
PULSARS
BINARIES
COSMIC RAYS
DARK MATTER
FERMI BUBBLES
MEV BACKGROUND
GAMMA-RAY BURSTS
LORENTZ INVARIANCE
SUPERNOVA REMNANTS

Gamma-ray Astrophysics at MeV energies

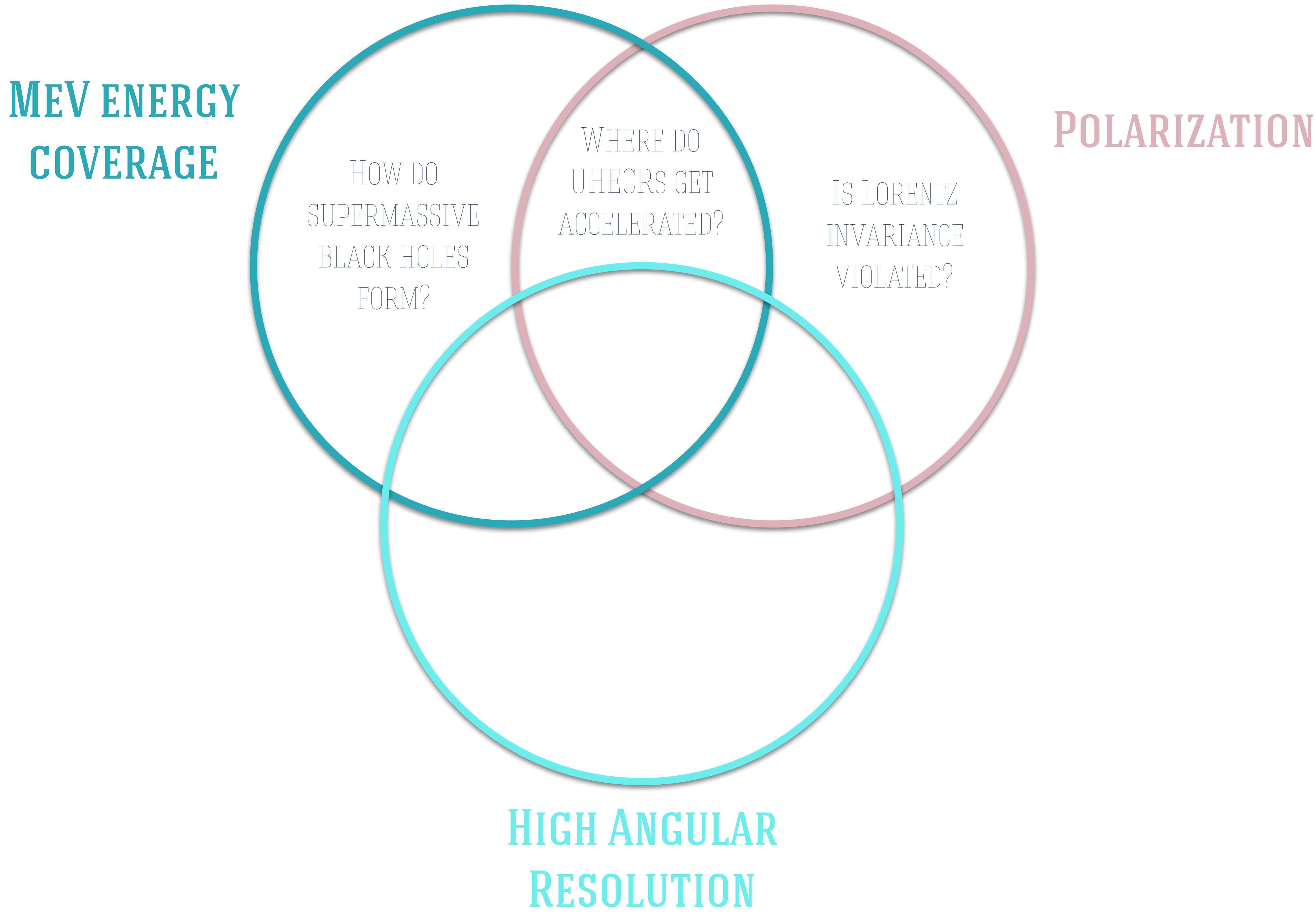
MeV energy coverage

Polarization

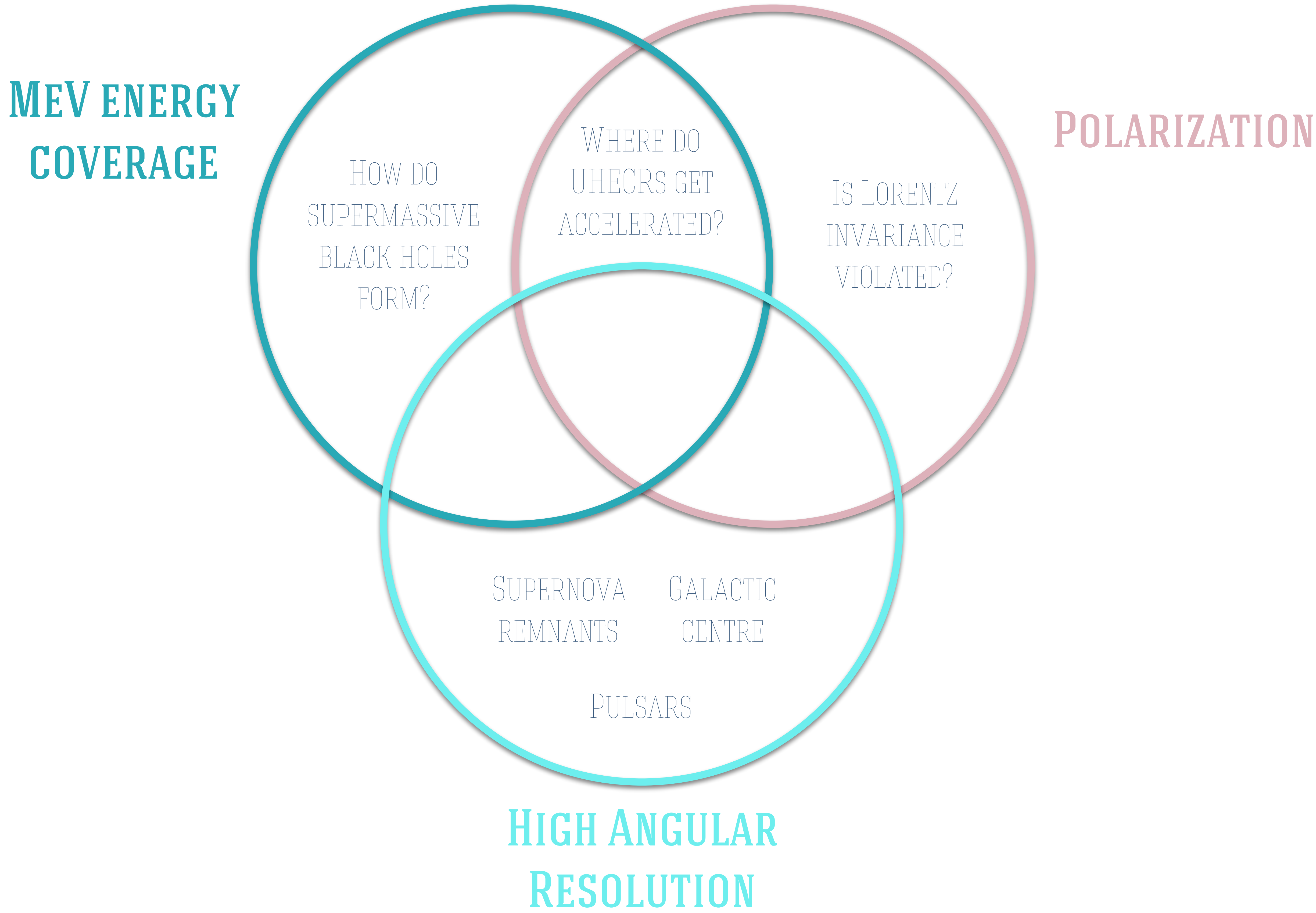


High Angular Resolution

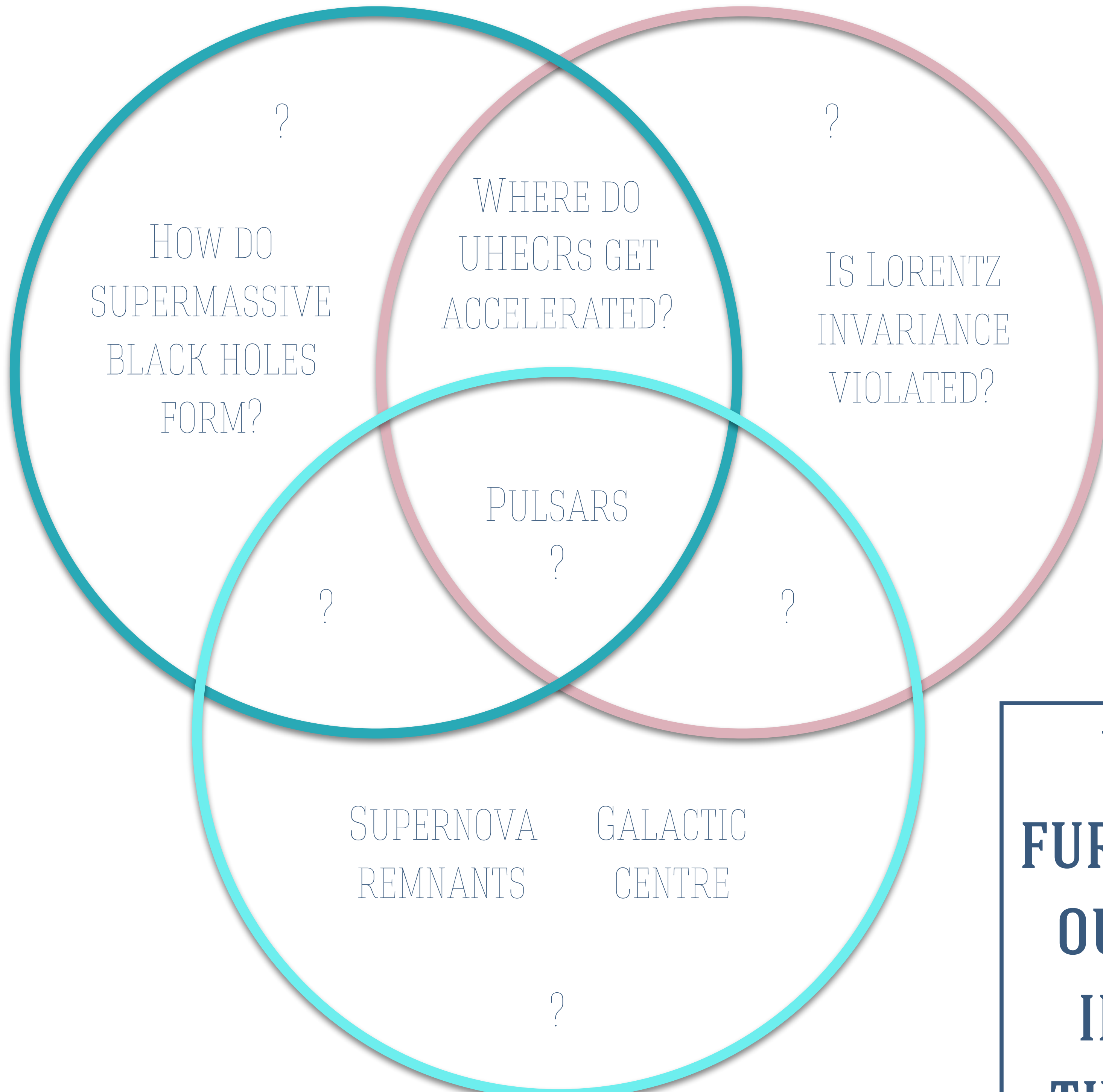
Gamma-ray Astrophysics at MeV energies



Gamma-ray Astrophysics at MeV energies



Gamma-ray Astrophysics at MeV energies



We hope to further develop our scientific ideas during this workshop ... thanks to you

Overview of project

Ground phase

HARPO

Proof of concept: use TPC to measure polarisation

Balloon phase

ST3G

Develop trigger system for TPC in space

Space phase

Design instrument for space flight

Ground phase

HARPO

2012 2013 2014 2015 2016 2017

the Hermatic ARgon POlarimeter (2012 - 2017)

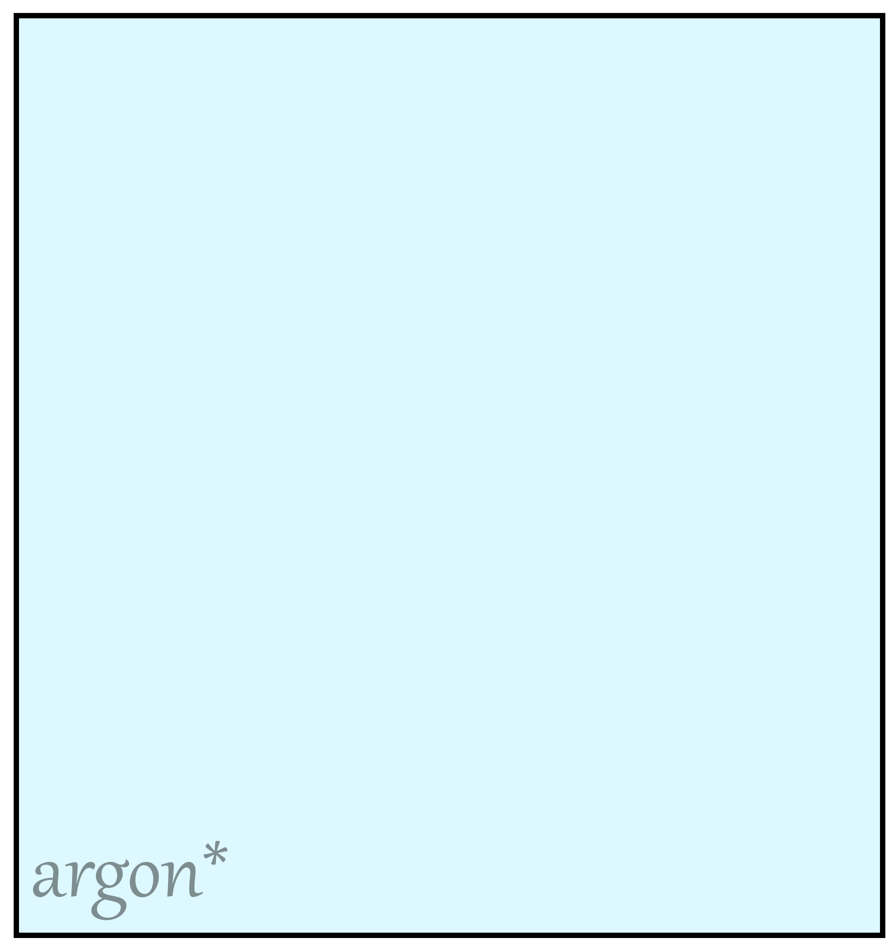
HARPO

Ground phase

2012 2013 2014 2015 2016 2017

the Hermatic ARgon POlarimeter (2012 - 2017)

TPC

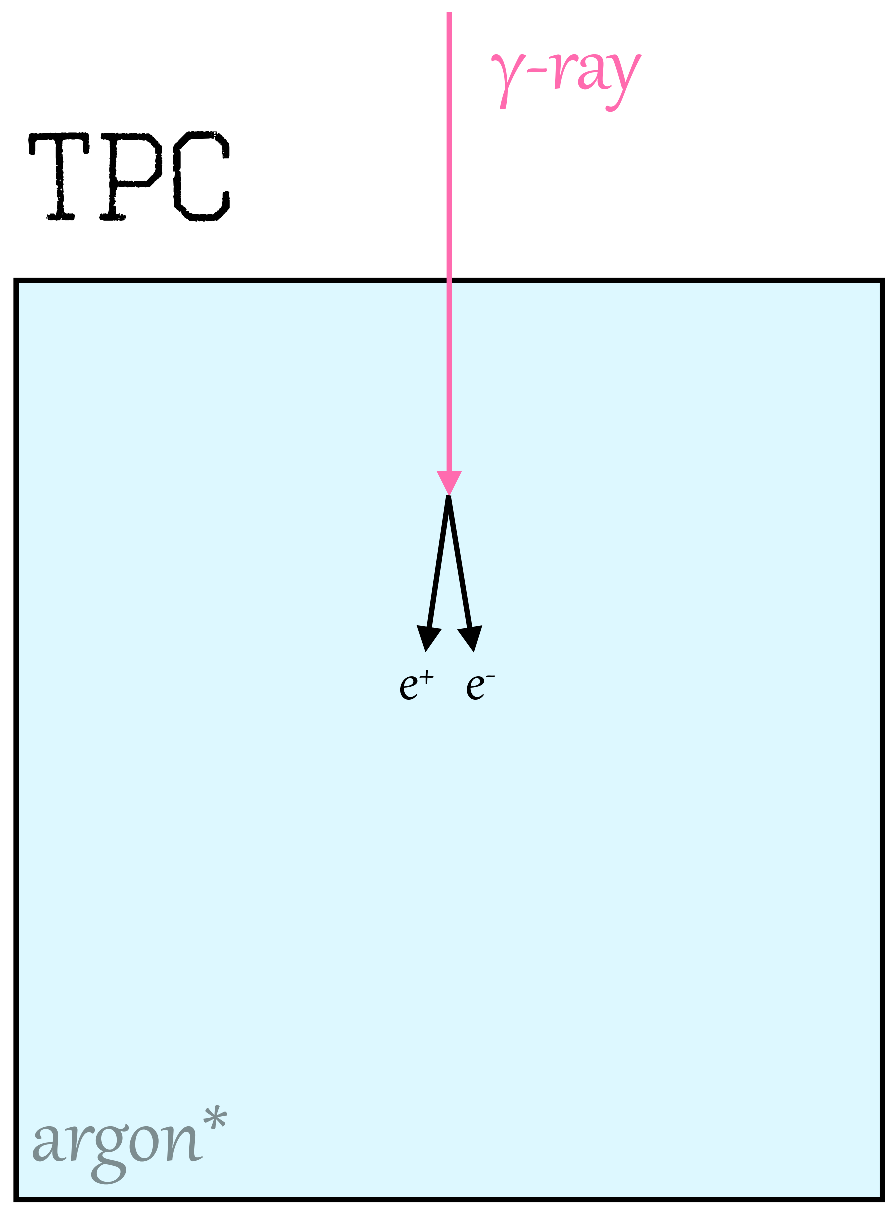


*mostly

Ground phase

2012 2013 2014 2015 2016 2017

the Hermatic ARgon POlarimeter (2012 - 2017)



- PAIR PRODUCTION
  ➡ NUCLEUS OF AR ATOM

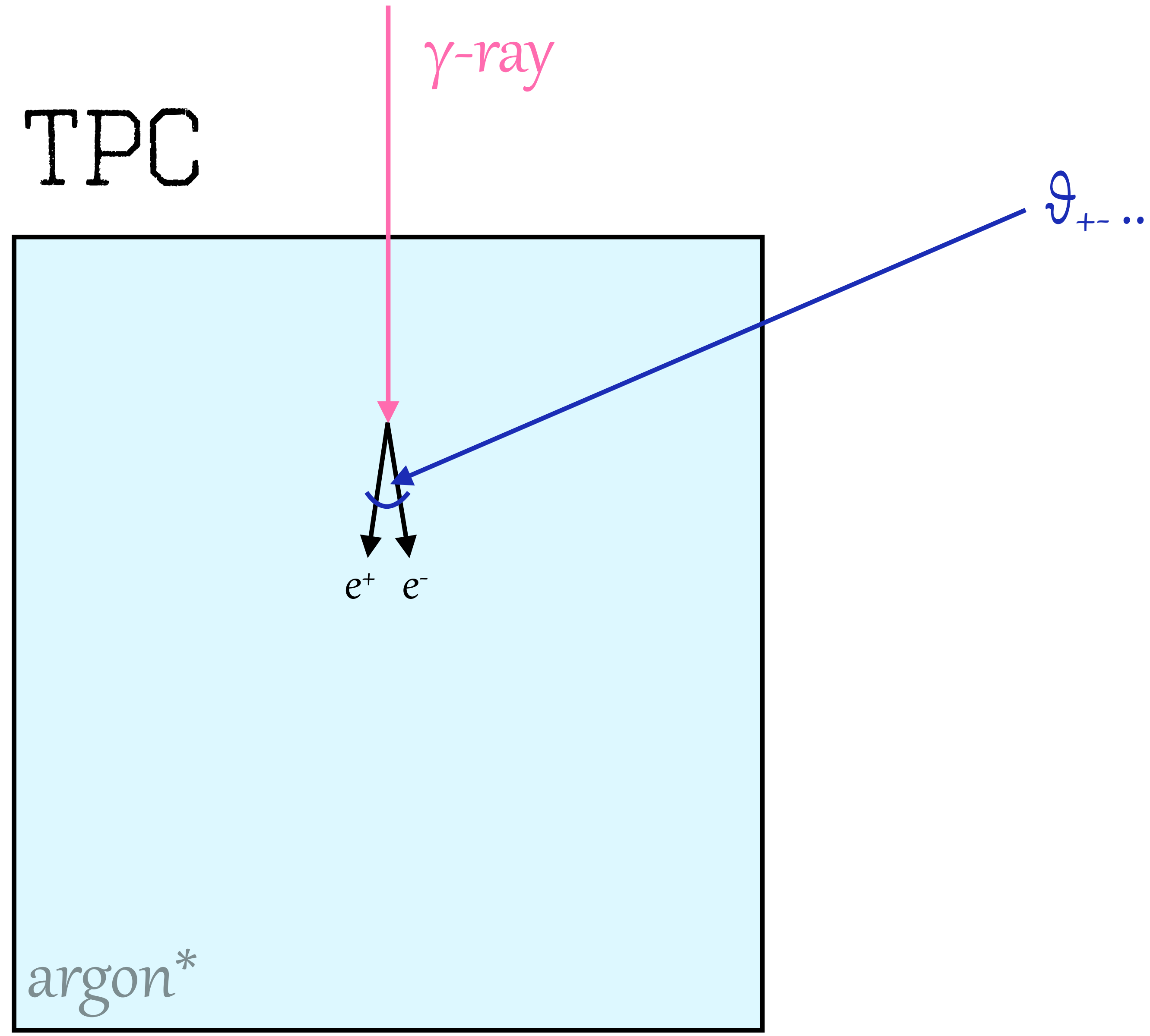
*mostly

Ground phase

2012 2013 2014 2015 2016 2017

the Hermatic ARgon POlarimeter (2012 - 2017)

- PAIR PRODUCTION
  ➡ NUCLEUS OF AR ATOM
- IONISATION
  ➡ DRIFT

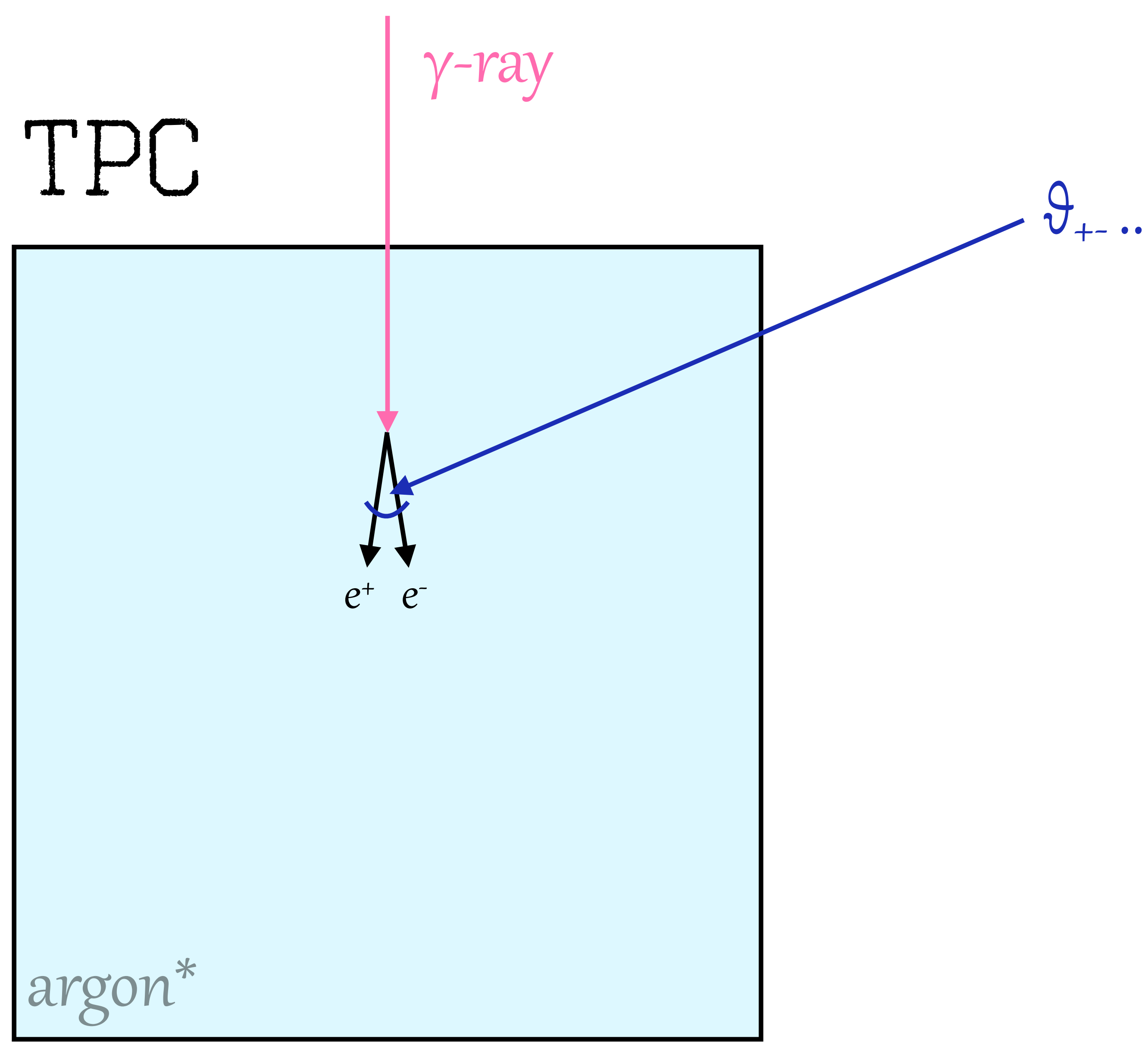


*mostly

Ground phase

2012 2013 2014 2015 2016 2017

the Hermatic ARgon POlarimeter (2012 - 2017)



- PAIR PRODUCTION
  ➡ NUCLEUS OF AR ATOM
- IONISATION
  ➡ DRIFT
- AMPLIFICATION + READ OUT

- **TPC = CONVERTOR + TRACKER**
  ➡ **100% "INSTRUMENTED"**

*mostly

Ground phase

2012 2013 2014 2015 2016 2017

the Hermatic ARgon POlarimeter (2012 - 2017)

- PAIR PRODUCTION
  ➡ NUCLEUS OF AR ATOM
- IONISATION
  ➡ DRIFT
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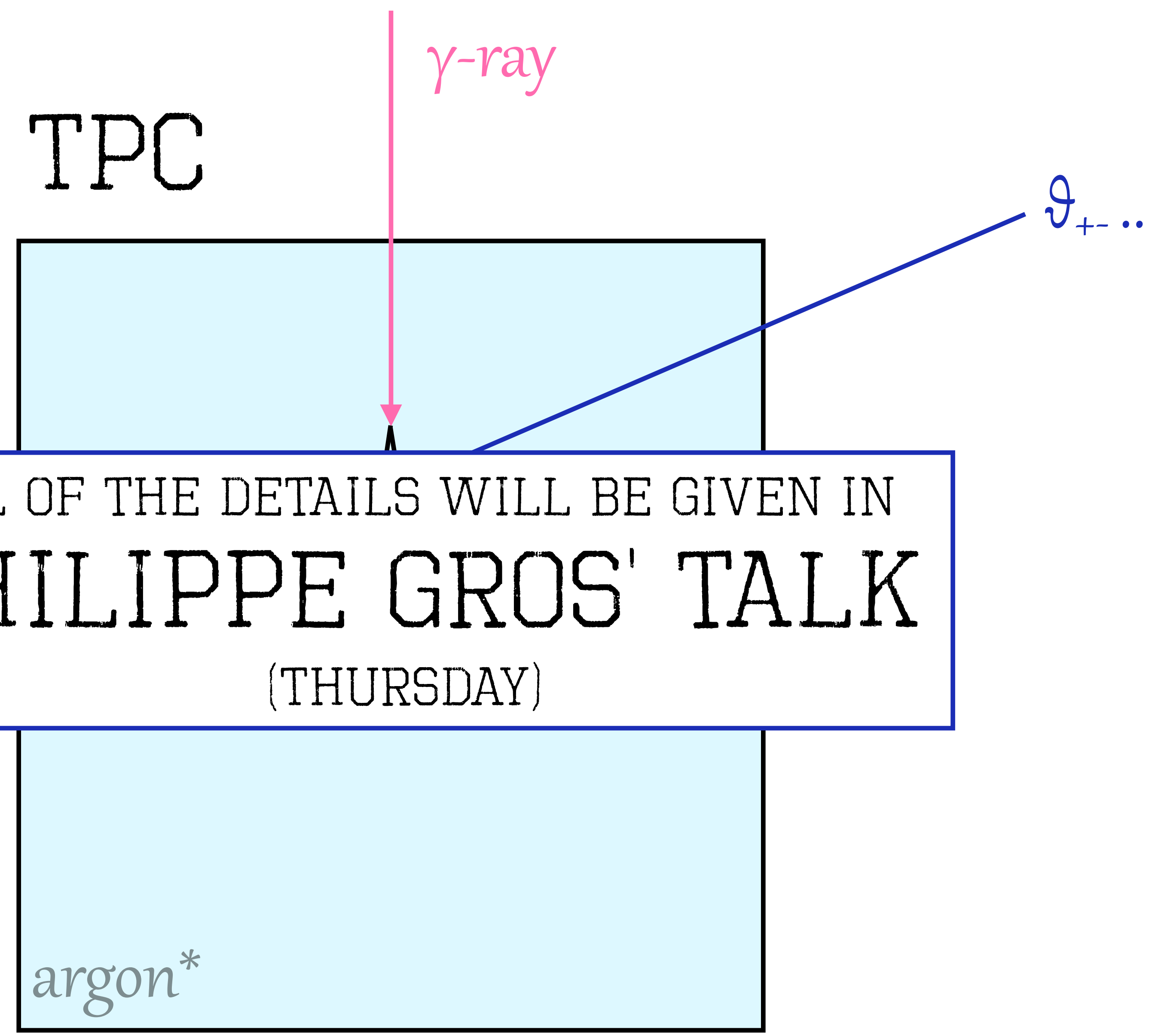

ALL OF THE DETAILS WILL BE GIVEN IN

PHILIPPE GROS' TALK

(THURSDAY)

- **TPC = CONVERTOR + TRACKER**
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*mostly

Ground phase

2012 2013 2014 2015 2016 2017

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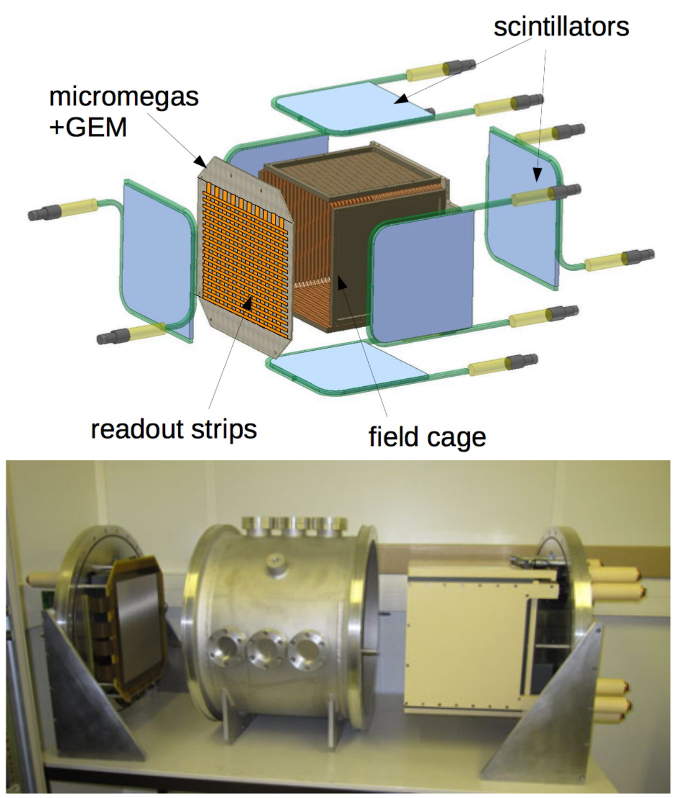

Ground phase


Nuclear Instruments and Methods in Physics Research A 729 (2013) 765–780

Contents lists available at ScienceDirect

Nuclear Instruments and Methods in Physics Research A

journal homepage: www.elsevier.com/locate/nima

Polarimetry of cosmic gamma-ray sources above e^+e^- pair creation threshold

D. Bernard *

LLR, Ecole Polytechnique, CNRS/IN2P3, 91128 Palaiseau, France

ARTICLE INFO

Article history:
Received 1 June 2013
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Keywords:
Polarimetry
Gamma rays
TPC
Pair conversion
Triplet
Event generator

ABSTRACT

We examine the potential for gamma-ray conversion to electron–positron pairs, either in the field of a nucleus or of an electron of a detector, to measure the fraction P of linear polarization of cosmic gamma sources. For this purpose we implement, validate and use an event generator based on the HELAS amplitude calculator and on the SPRING event generator.

We characterize several ways to measure P. Past proposals to increase the polarization sensitivity by the selection of a fraction of the events in a subset of the available phase space are found to be inefficient, due to the loss in statistics. The use of an optimal variable that includes the full 5D probability density function is found to improve the precision of the measurement of P of a factor of approximately 2.

We then study the dilution of the asymmetry that parametrize the degradation of the precision due to experimental effects such as multiple scattering. In a detector made with a succession of converter slabs and tracker foils, the dependence of the dilution is found to be different from that predicted assuming a given (the most probable) value of the pair opening angle. The limitations of a slab detector are avoided by the use of an active target, in which conversion and tracking are performed by the same device, in which case the dilution of the measurement of P is found to be manageable. Based on a realistic sizing of the detector, and for an effective exposure of 1 year, we estimate the precision for a Crab-like source on the full energy range to be approximately 1.4%.


Nuclear Instruments and Methods in Physics Research A 701 (2013) 225–230

Contents lists available at SciVerse ScienceDirect

Nuclear Instruments and Methods in Physics Research A

journal homepage: www.elsevier.com/locate/nima

TPC in γ-ray astronomy above pair-creation threshold

D. Bernard *

LLR, Ecole Polytechnique, CNRS/IN2P3, 91128 Palaiseau, France

ARTICLE INFO

Article history:
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Keywords:
γ rays
Telescope
TPC
Pair production
Angular resolution
Sensitivity

ABSTRACT

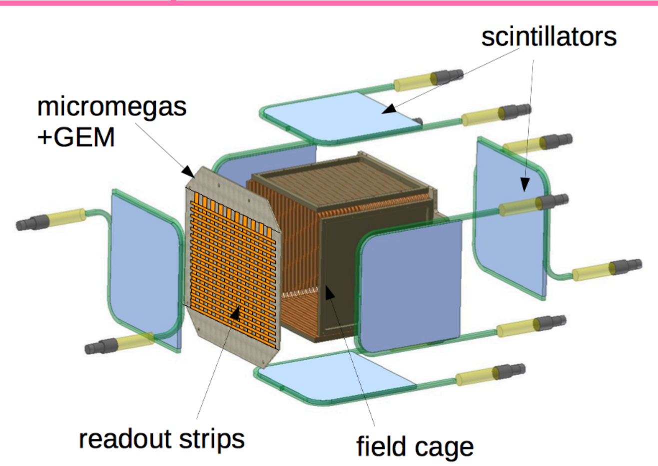
We examine the performance of a TPC as a γ-ray telescope above the pair-creation threshold. The contributions to the photon angular resolution are studied and their dependence on energy is obtained. The effective area per detector unit mass for such a thin detector is the conversion mass attenuation coefficient. The differential sensitivity for the detection of a point-like source is then derived. Finally, the measurement of track momentum from deflections due to multiple scattering is optimized.

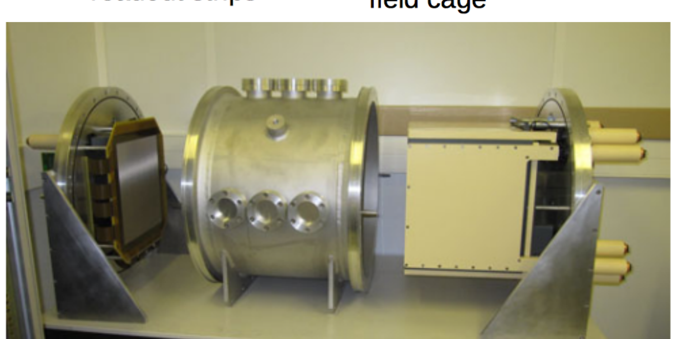
These analytical results are exemplified numerically for a few sets of detector parameters. TPCs show an impressive improvement in sensitivity with respect to existing pair-creation-based telescopes in the [MeV–GeV] energy range, even with the modest detector parameters of this study. In addition, gas TPCs allow an improvement in angular resolution of about one order of magnitude.

HARPO

2012 2013 2014 2015 2016 2017

the Hermatic ARgon POlarimeter (2012 - 2017)





Ground phase


Nuclear Instruments and Methods in Physics Research A

Polarimetry of cosmic gamma-ray sources above e^+e^- pair creation threshold

D. Bernard


Nuclear Instruments and Methods in Physics Research A

TPC in γ-ray astronomy above pair-creation threshold

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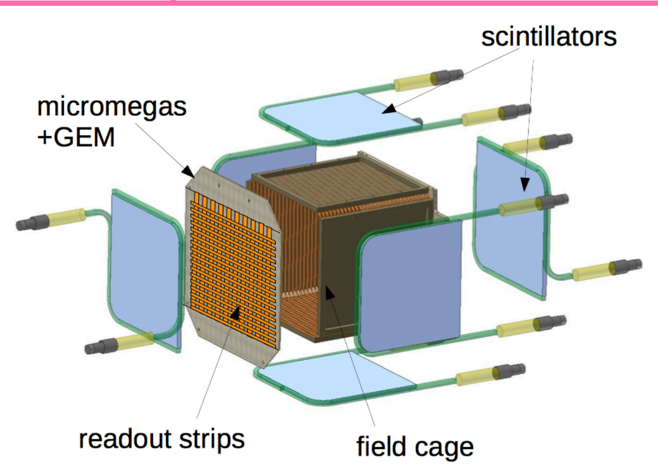

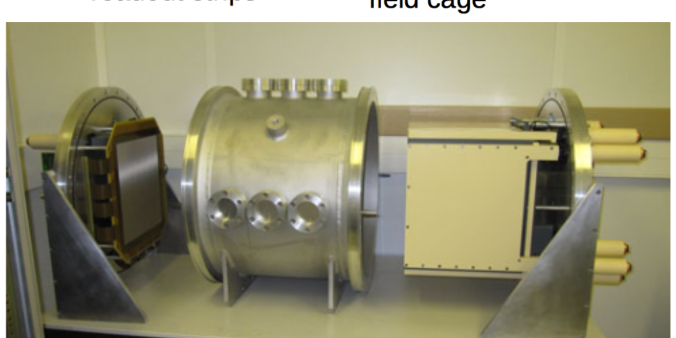

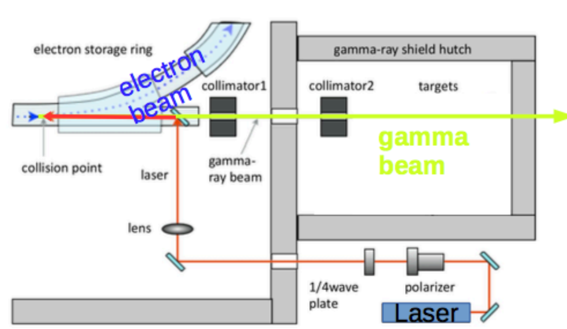

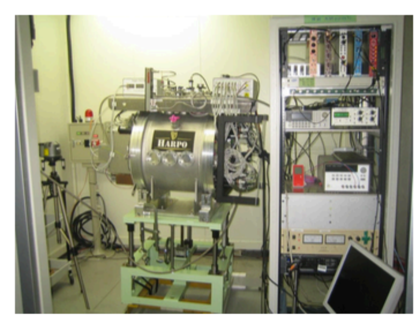

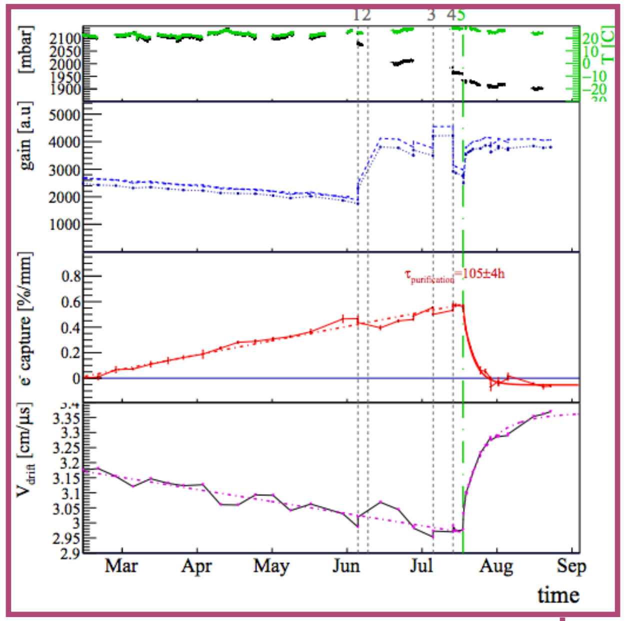

Ground phase

HARPO

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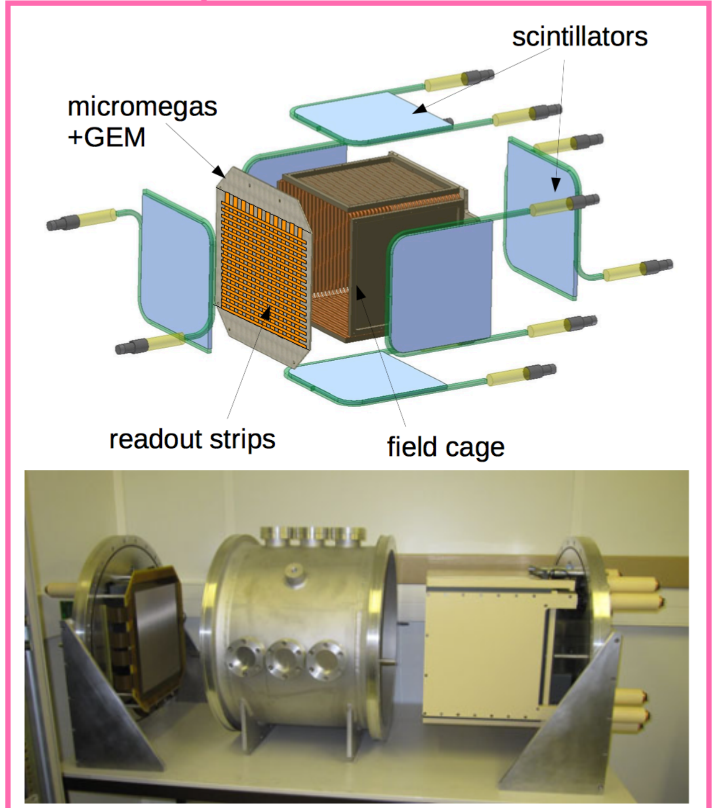
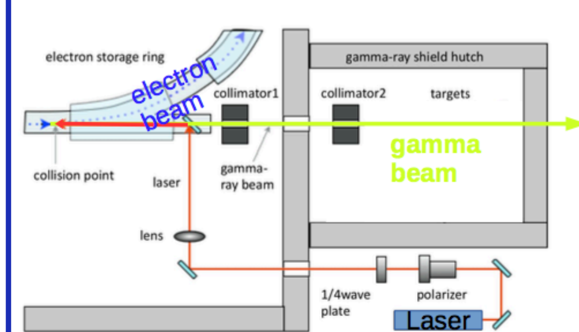
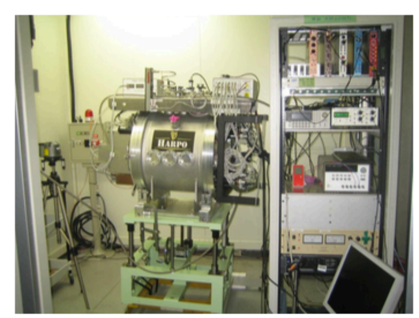
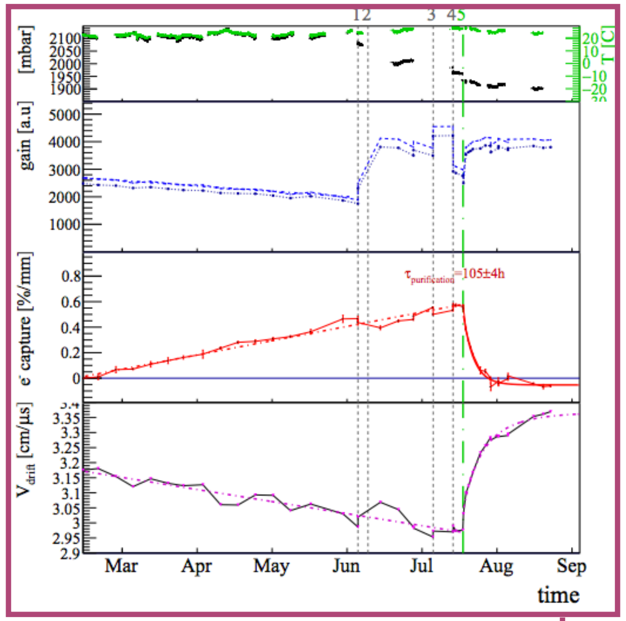
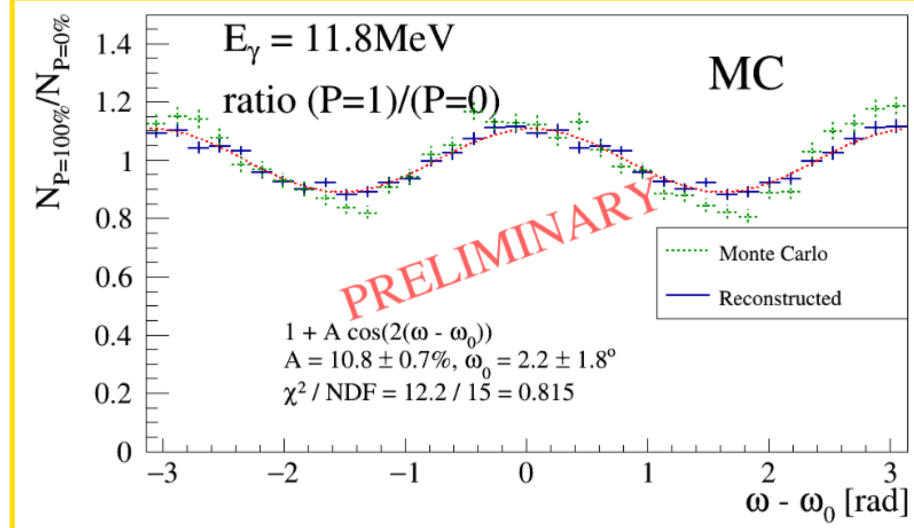






Ground phase





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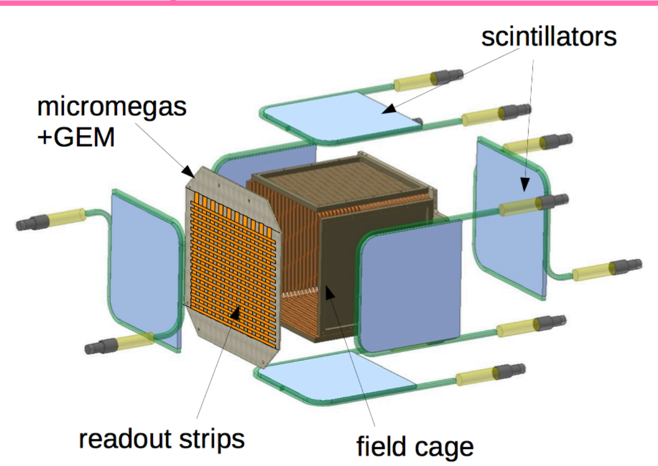
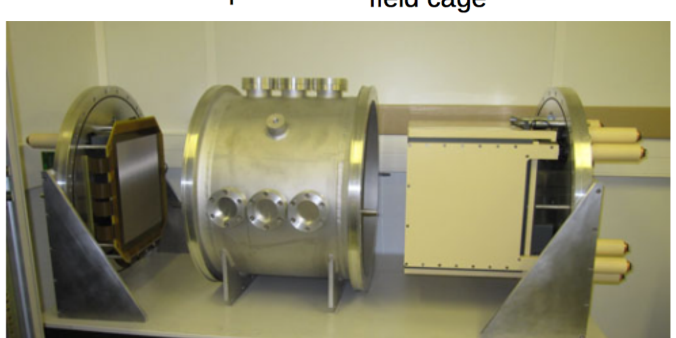
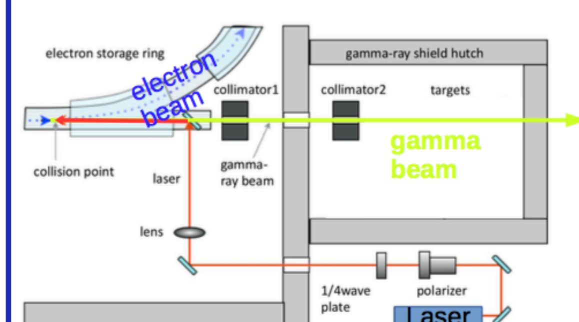
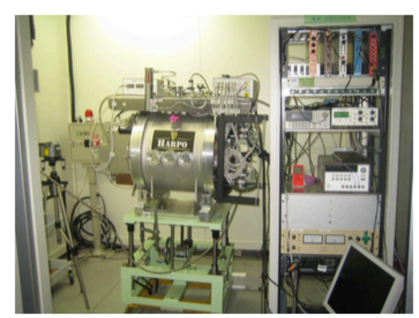
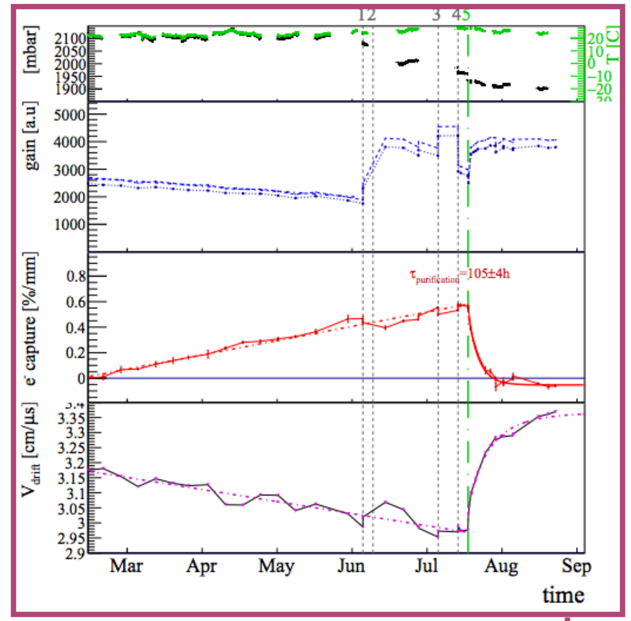


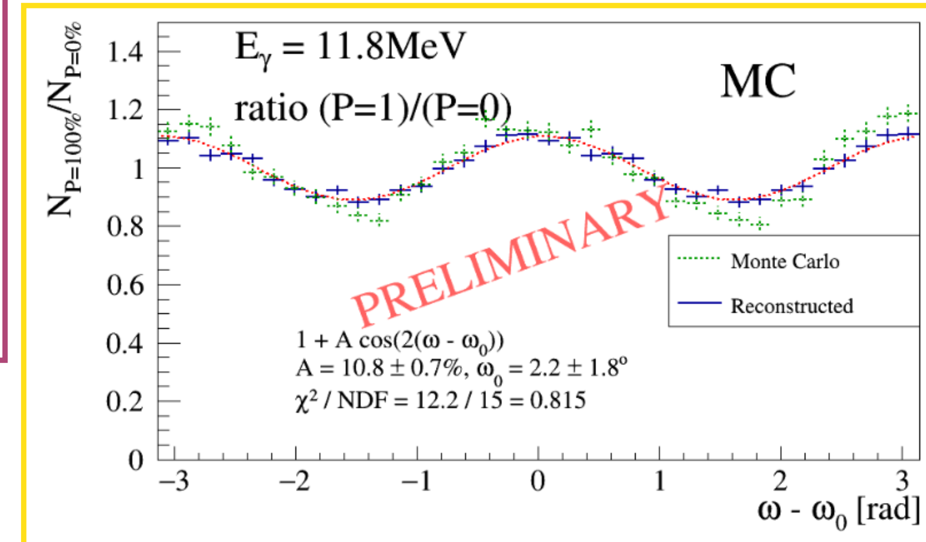








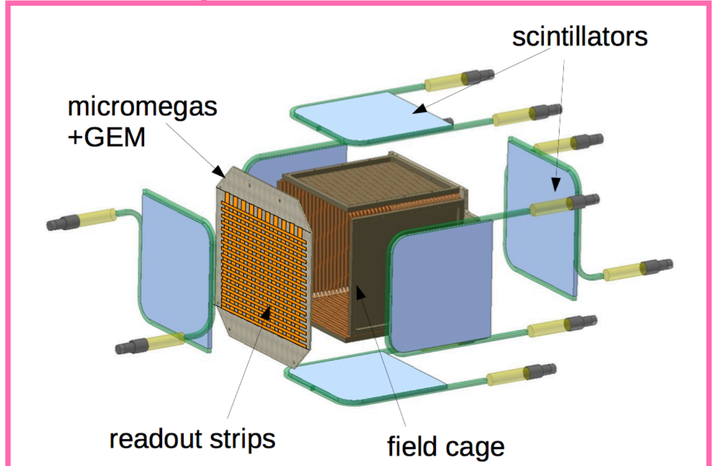
Ground phase

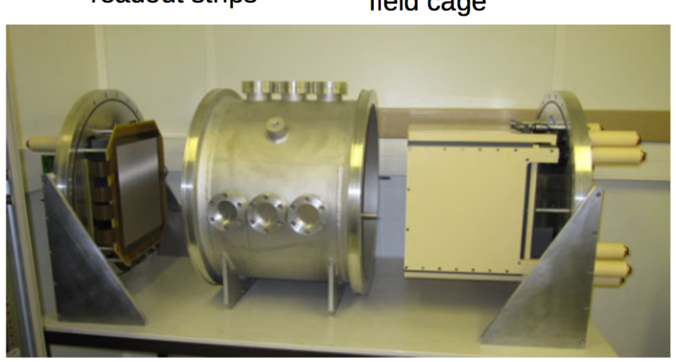


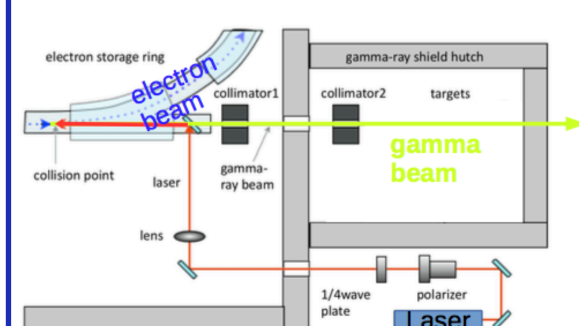
HARPO

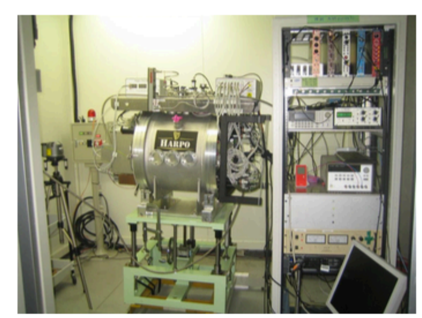
2012 2013 2014 2015 2016 2017

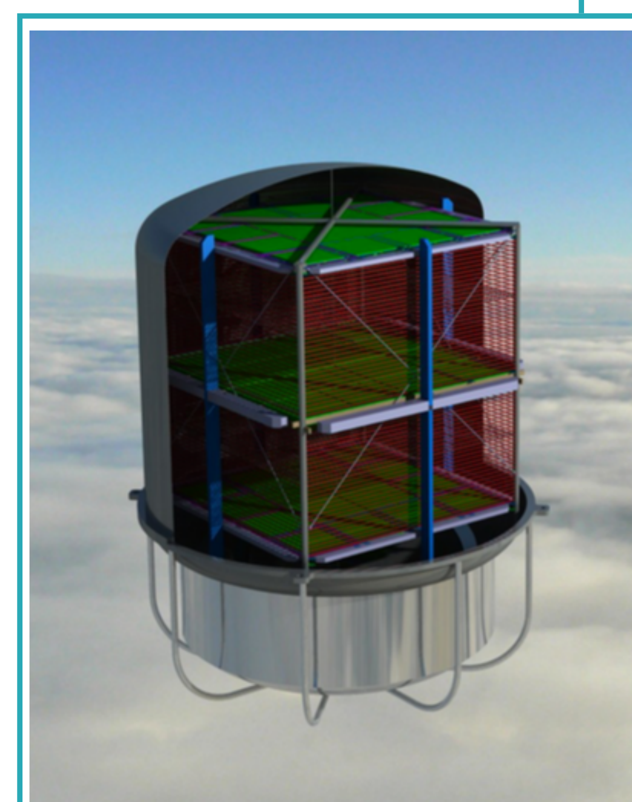
the Hermatic ARgon POlarimeter (2012 - 2017)

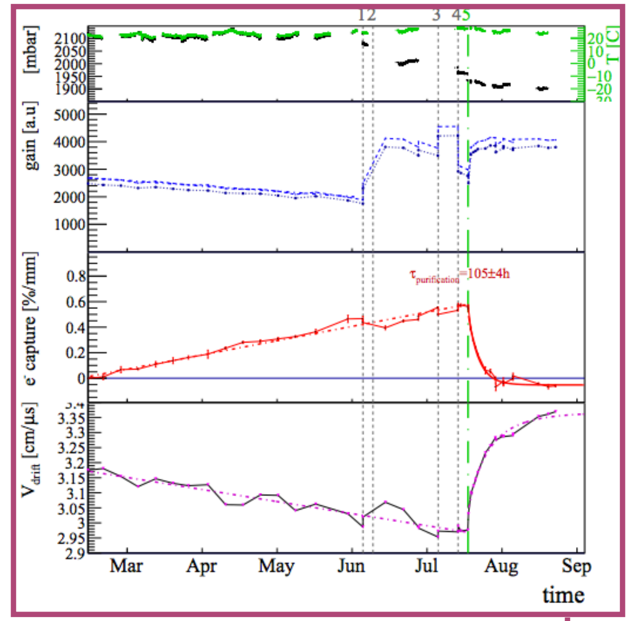












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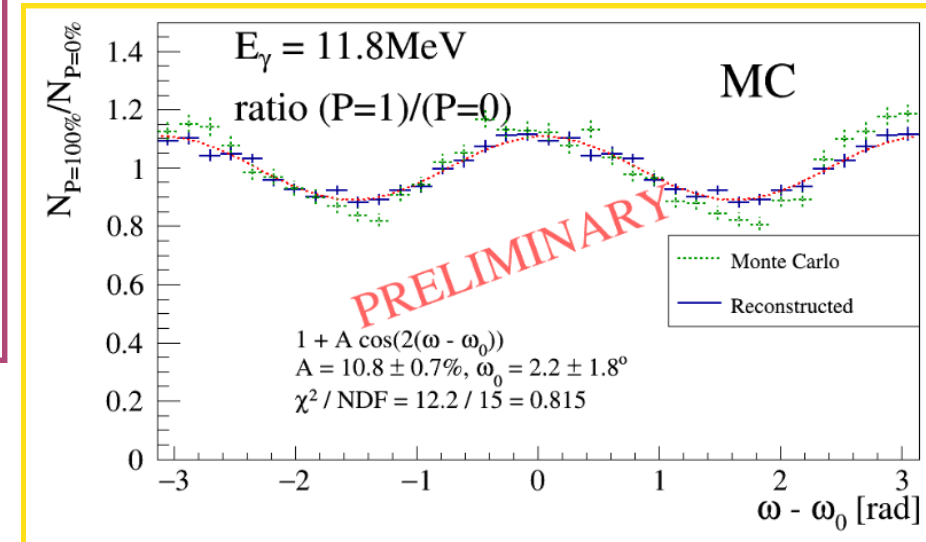

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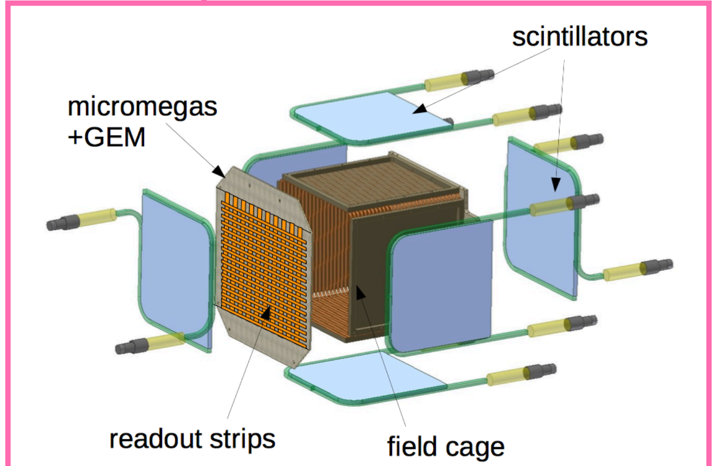

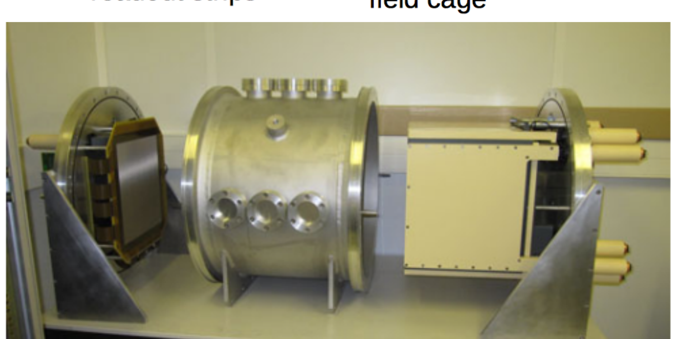

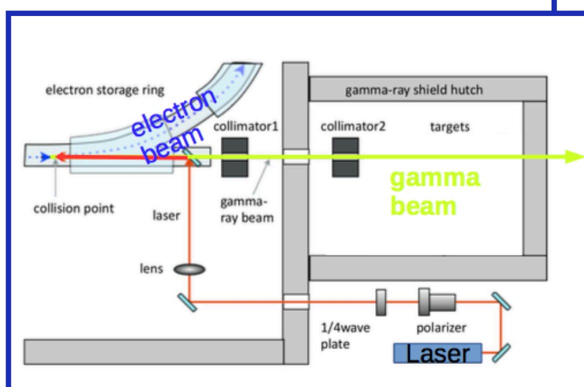

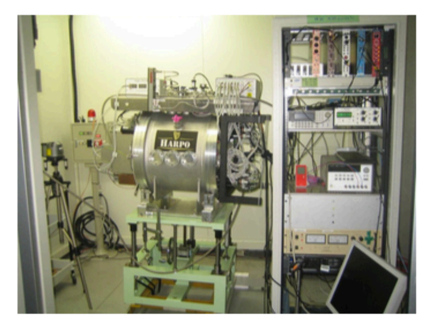

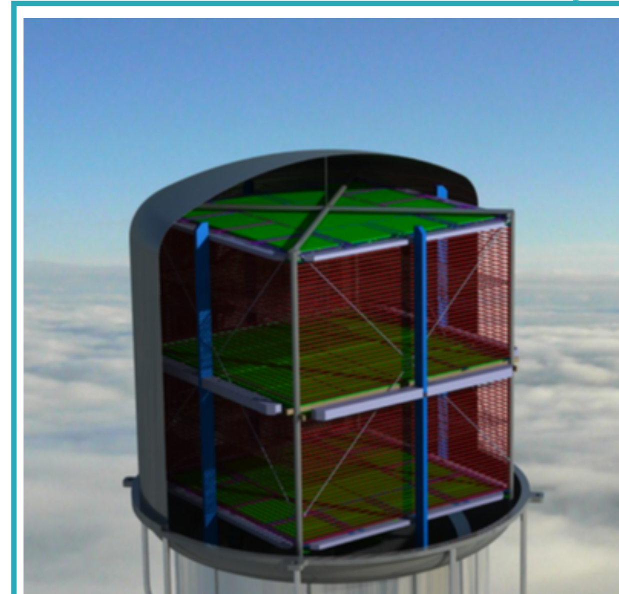

Balloon phase

Overview of project

Ground phase

HARPO

ground

Proof of concept: use TPC to measure polarisation

Balloon phase

ST3G

Develop trigger system for TPC in space

Space phase

Design instrument for space flight

Overview of project

Ground phase

HARPO

ground

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Balloon phase

ST3G

balloon

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ST3G

DEVELOP TRIGGER SYSTEM FOR TPC IN SPACE

- develop scientific case
  - balloon flight
  - eventual space-based instrument
- perform simulations to develop trigger
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  - test in lab
- build instrument for balloon flight
  - run trigger in "real" space environment
  - can we self-trigger a TPC efficiently?

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ST3G

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WE WOULD LIKE TO BUILD A LARGER TEAM OF SCIENTISTS AND ENGINEERS FOR THIS BALLOON PHASE

Balloon phase

ST3G

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ST3G

Key Characteristics

- Energy: a few MeV - GeV
- Polarisation capabilities
- High angular resolution

ST3G

Key Characteristics

- Energy: a few MeV - GeV*
- Polarisation capabilities*
- High angular resolution*

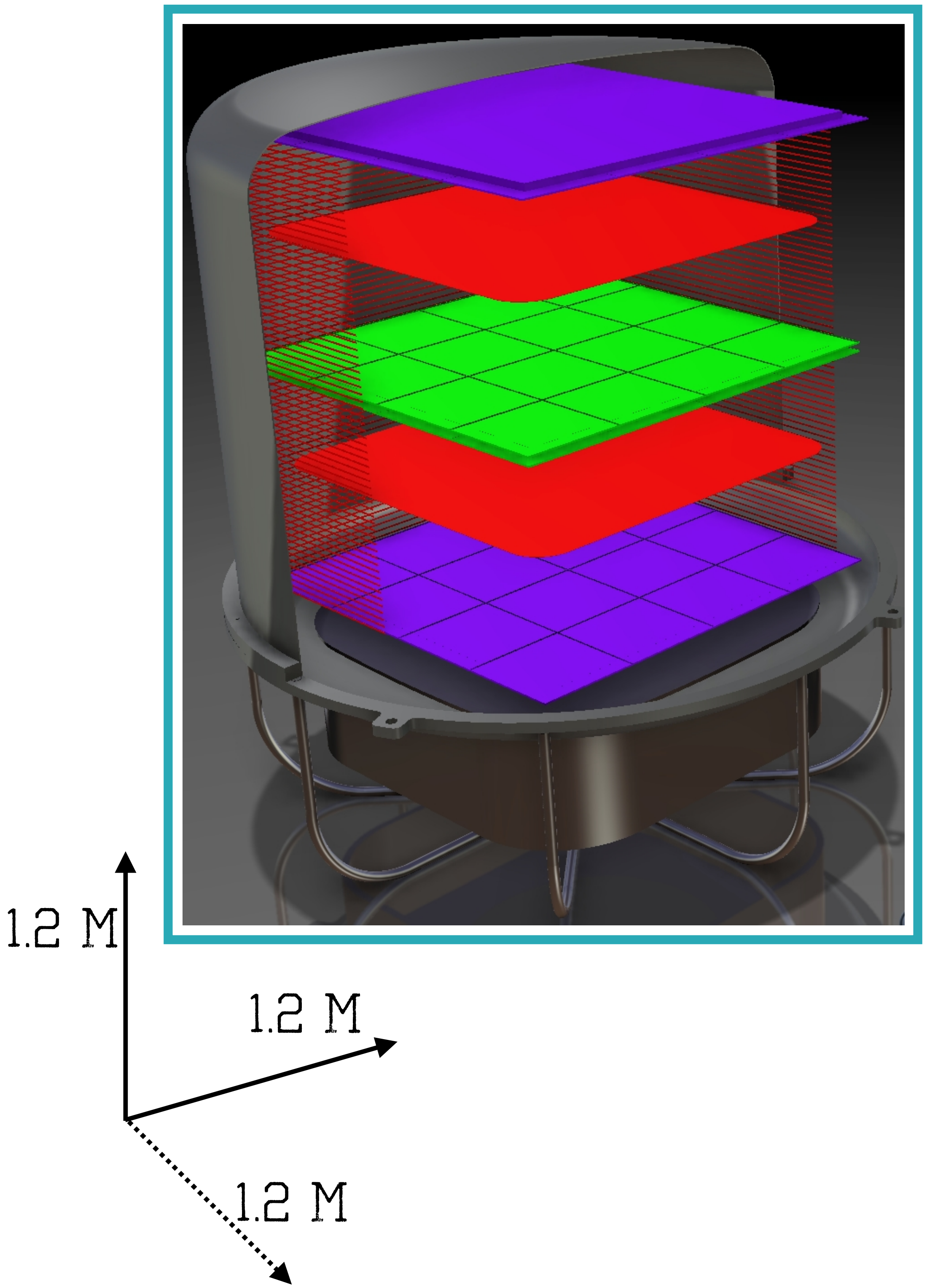
*We will only have limited capabilities during a balloon flight

ST3G

Key Characteristics of ultimate instrument

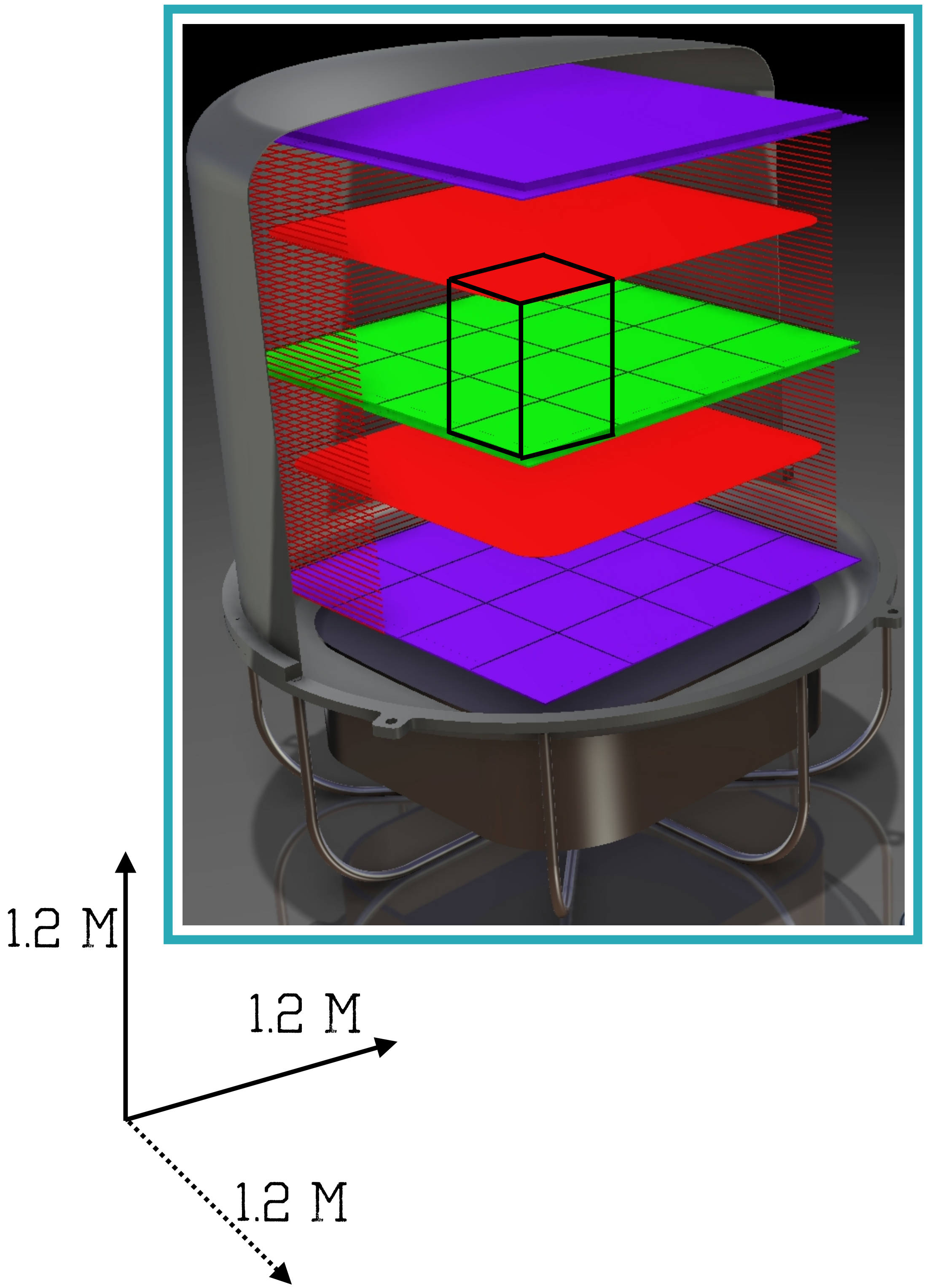
- Energy: a few MeV - GeV
  - GRBs - peak of emission
  - MeV blazars
  - MeV dark matter
- Polarisation capabilities
  - source geometry
  - distinguish between emission models
  - Lorentz invariance searches
- High angular resolution
  - Galactic centre
  - Supernova observations
  - Radio galaxies

ST3G



- 64 modules :
  - 1 module = HARPO
- 32 TPCs :
  - 2 modules with a common cathode
- 2 bar Argon gas
- Readout chip ASTRE

ST3G



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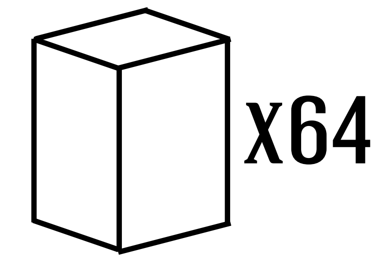
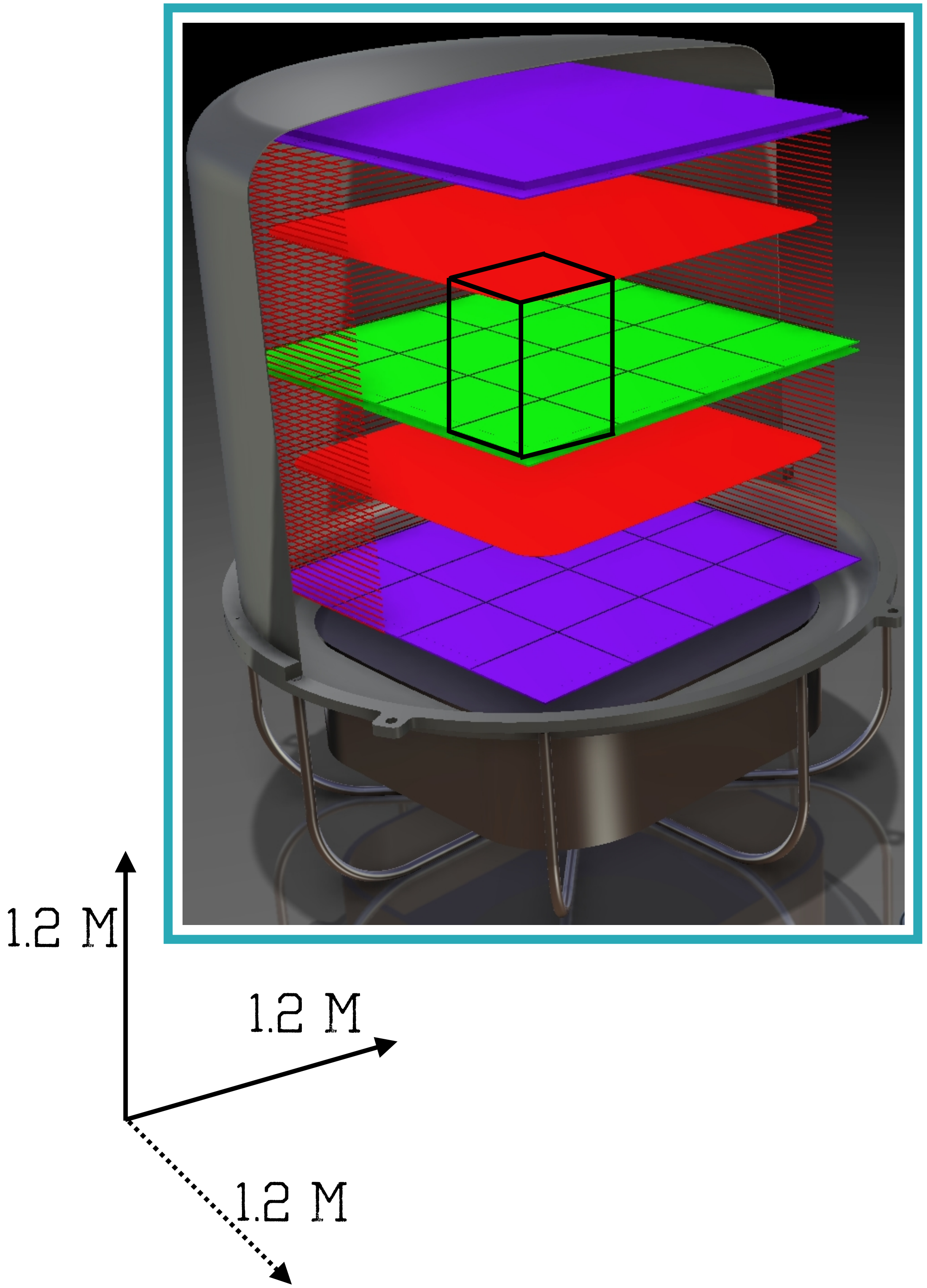


ST3G



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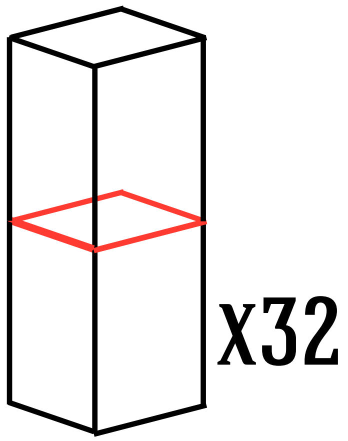

ST3G

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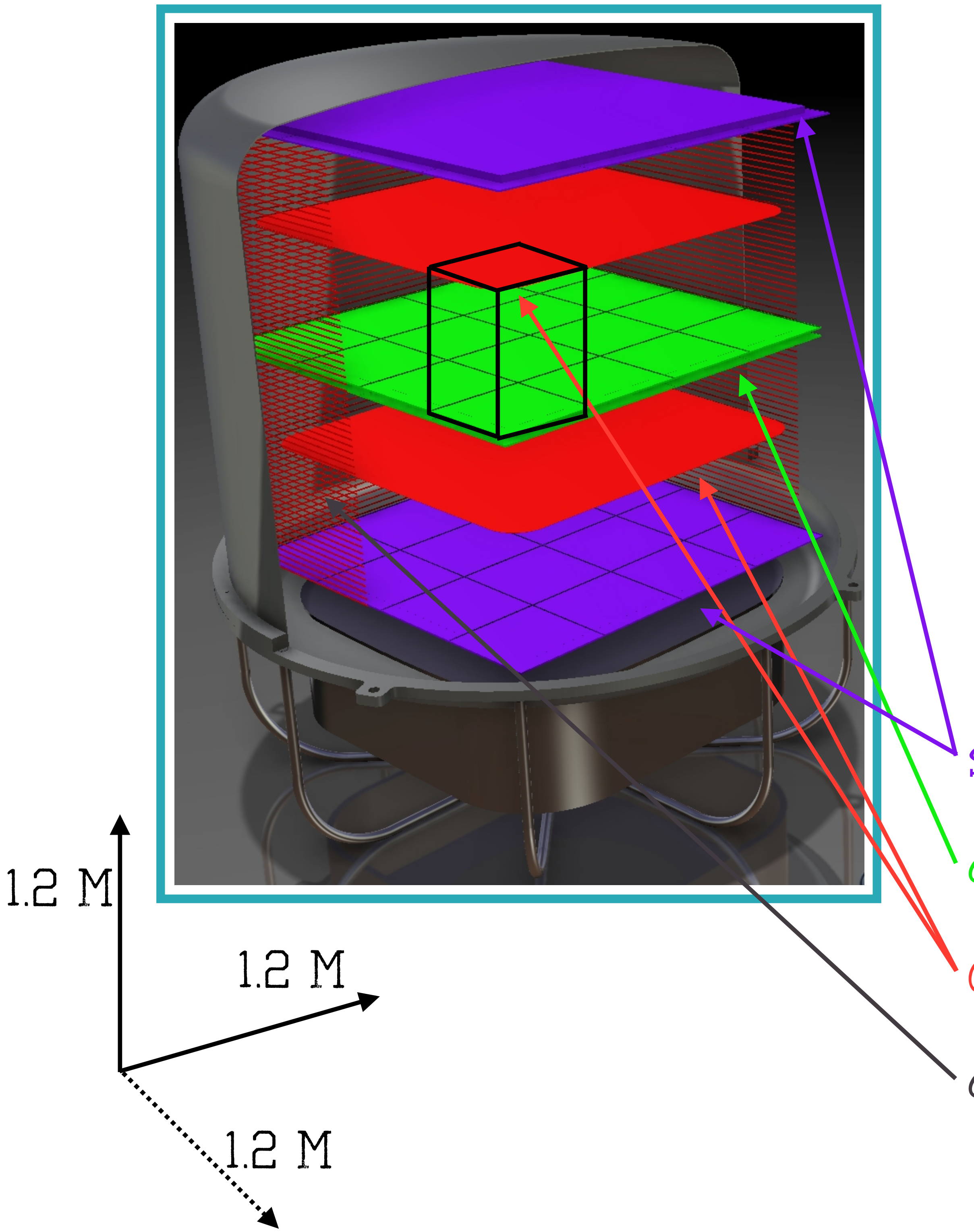

ST3G

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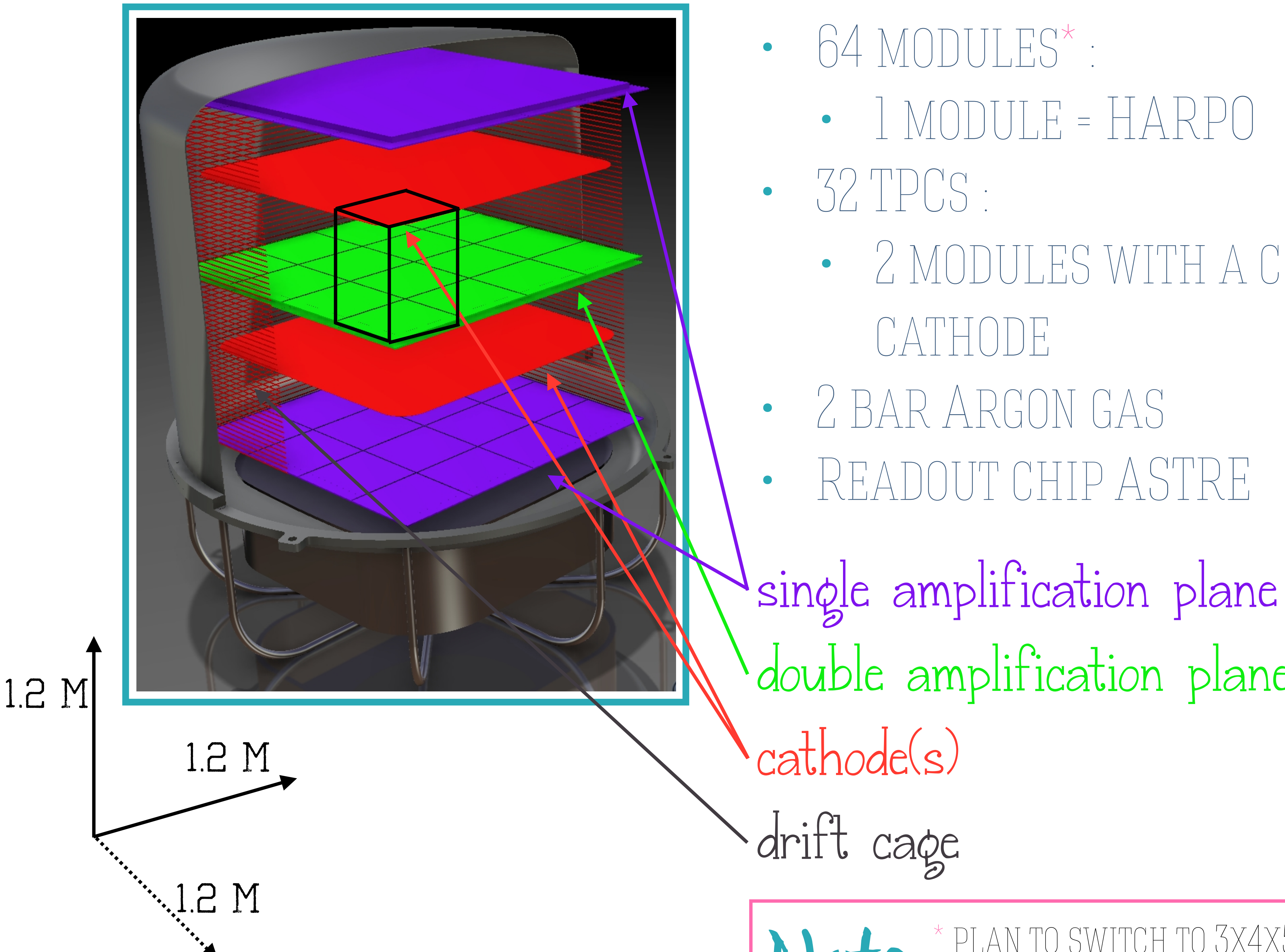
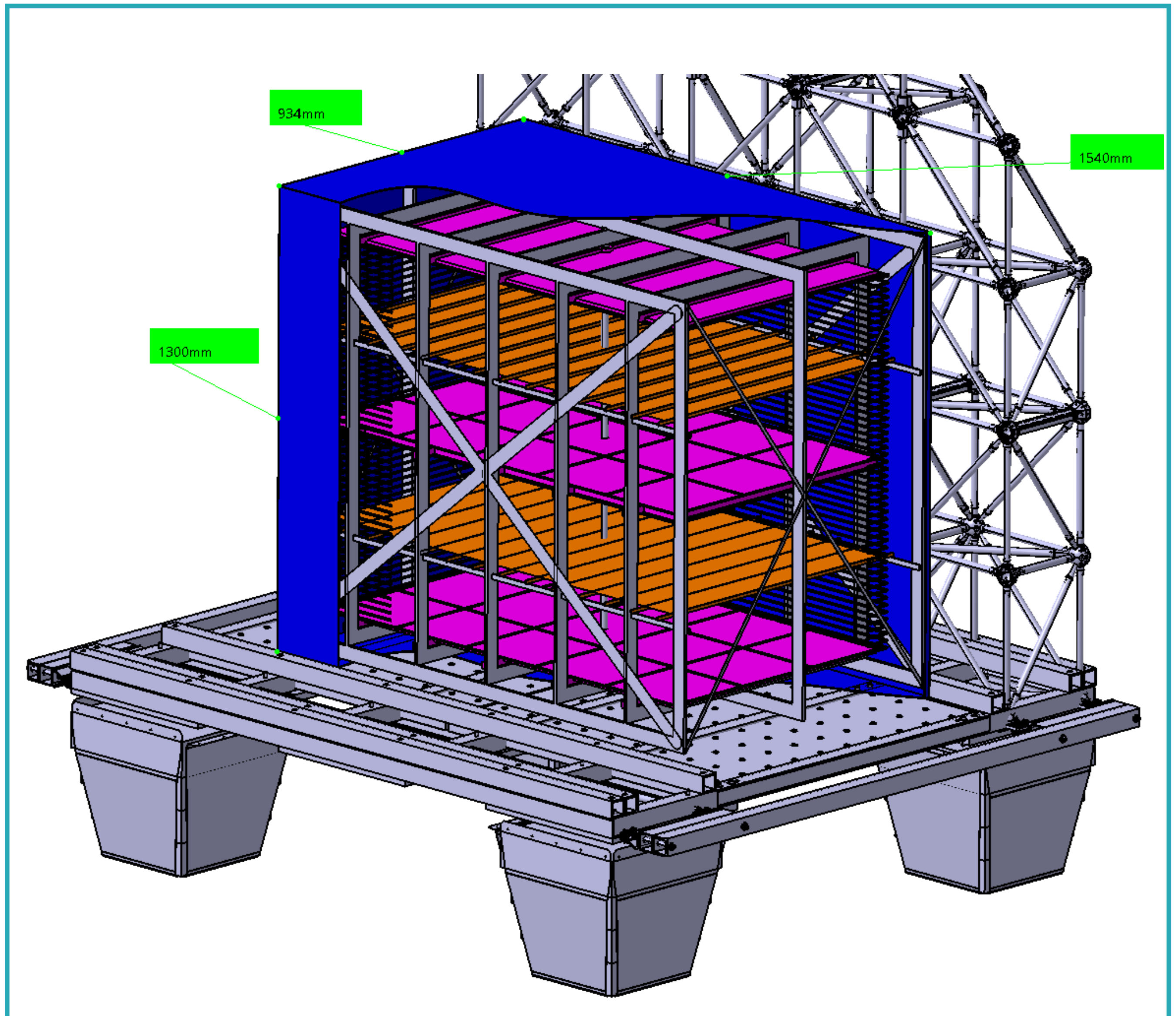
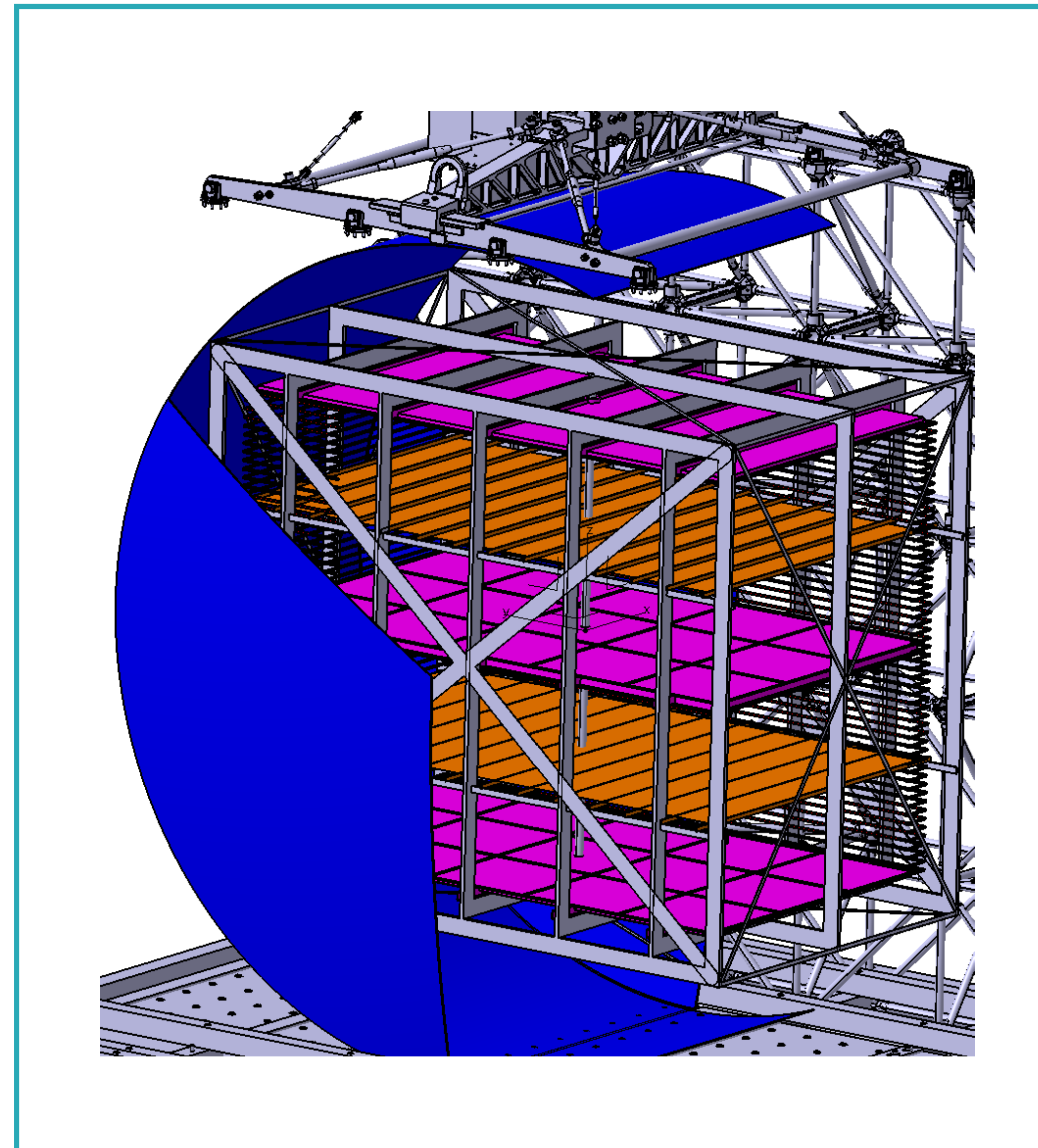


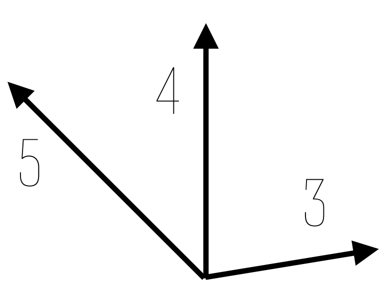
Note: * PLAN TO SWITCH TO 3X4X5 (60 MODULES) DUE TO THE PLATFORM THAT CNES PROPOSE (CARMEN)

ST3G





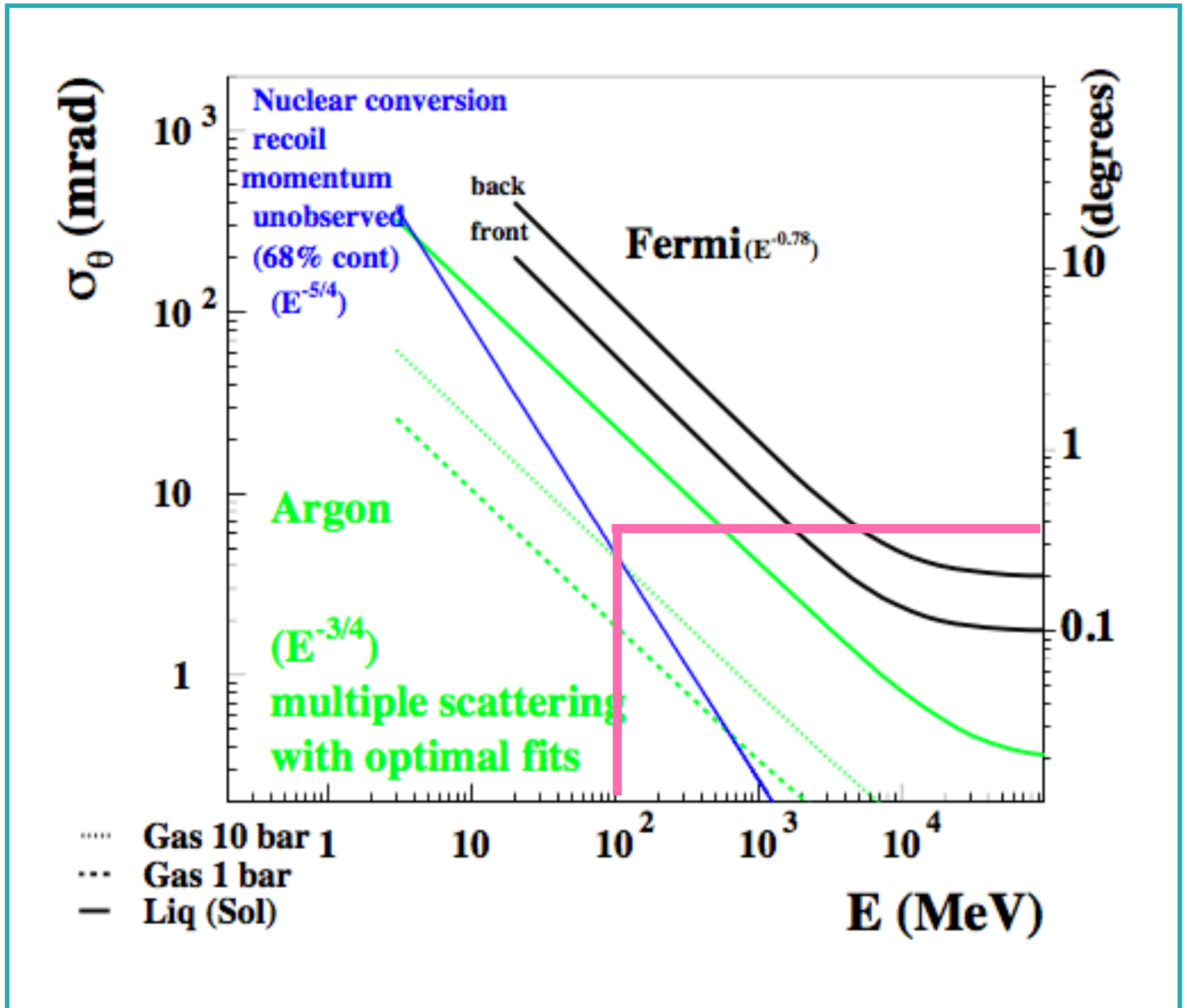
Credit: Mikaël Frotin



Note: * Plan to switch to 3x4x5 (60 modules) due to the platform that CNES propose (CARMEN)

ST3G

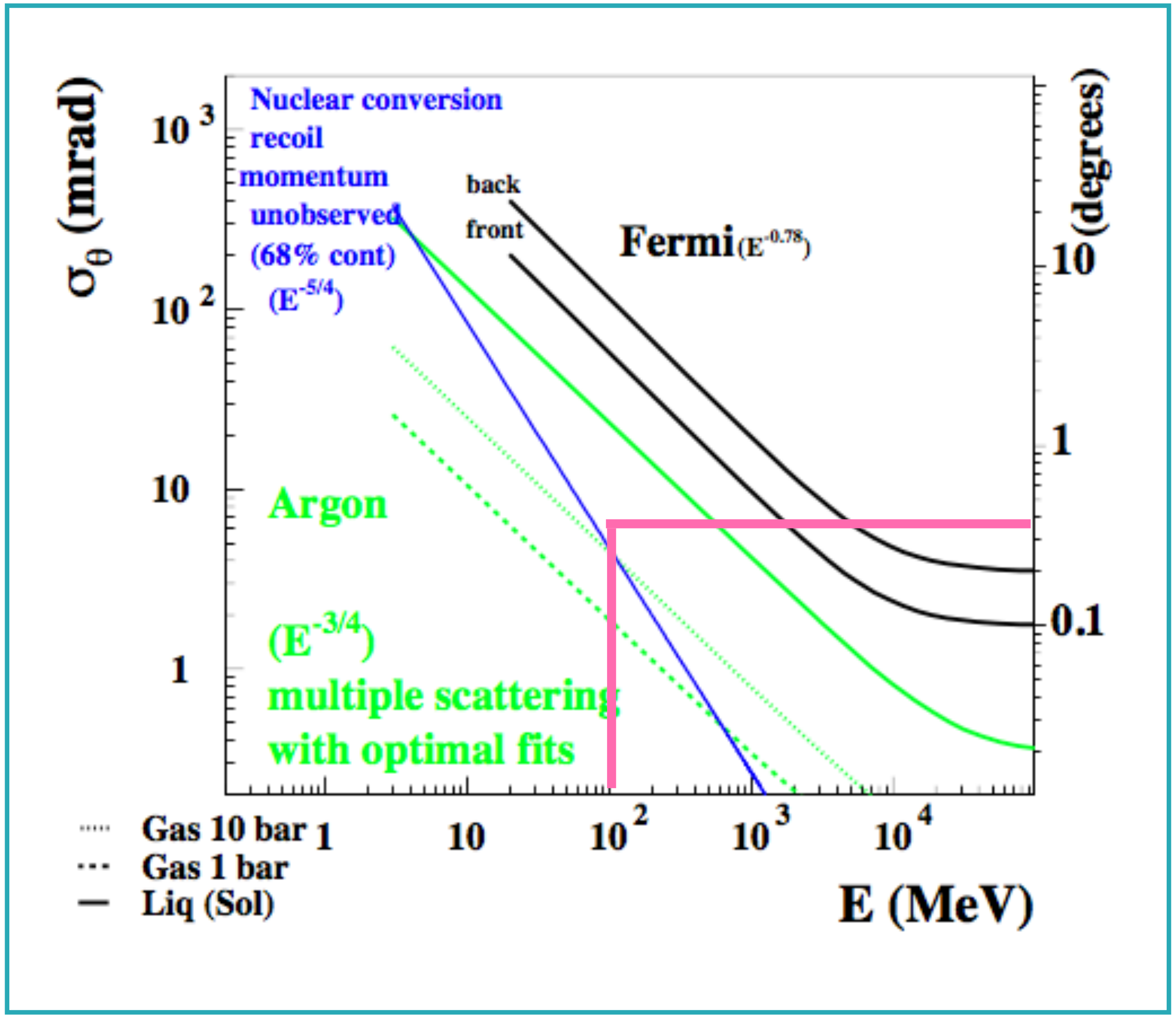
Angular Resolution



From document circulated by Denis

ST3G

Angular Resolution

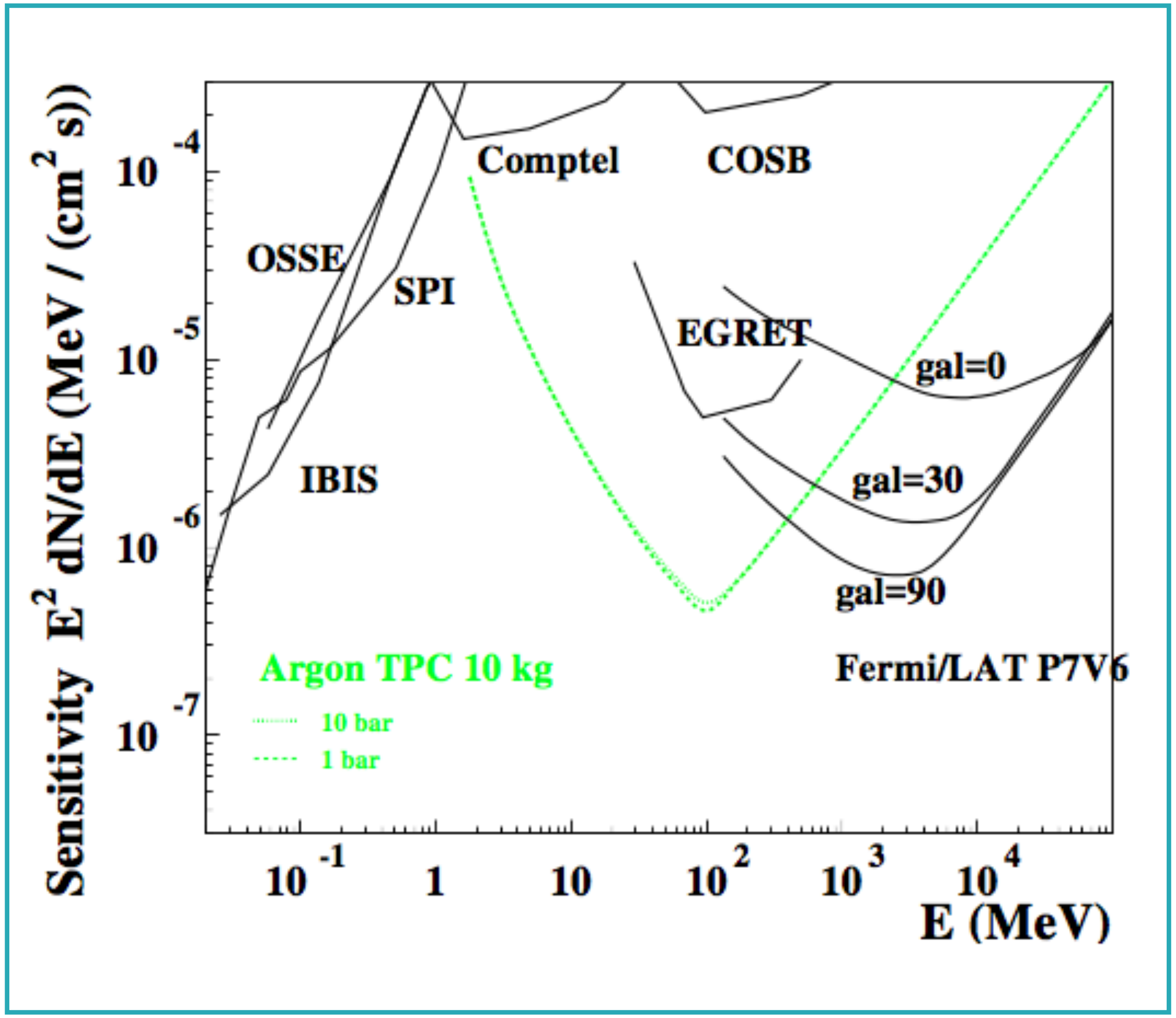


From document circulated by Denis

See Denis Bernard's talk

ST3G

Sensitivity

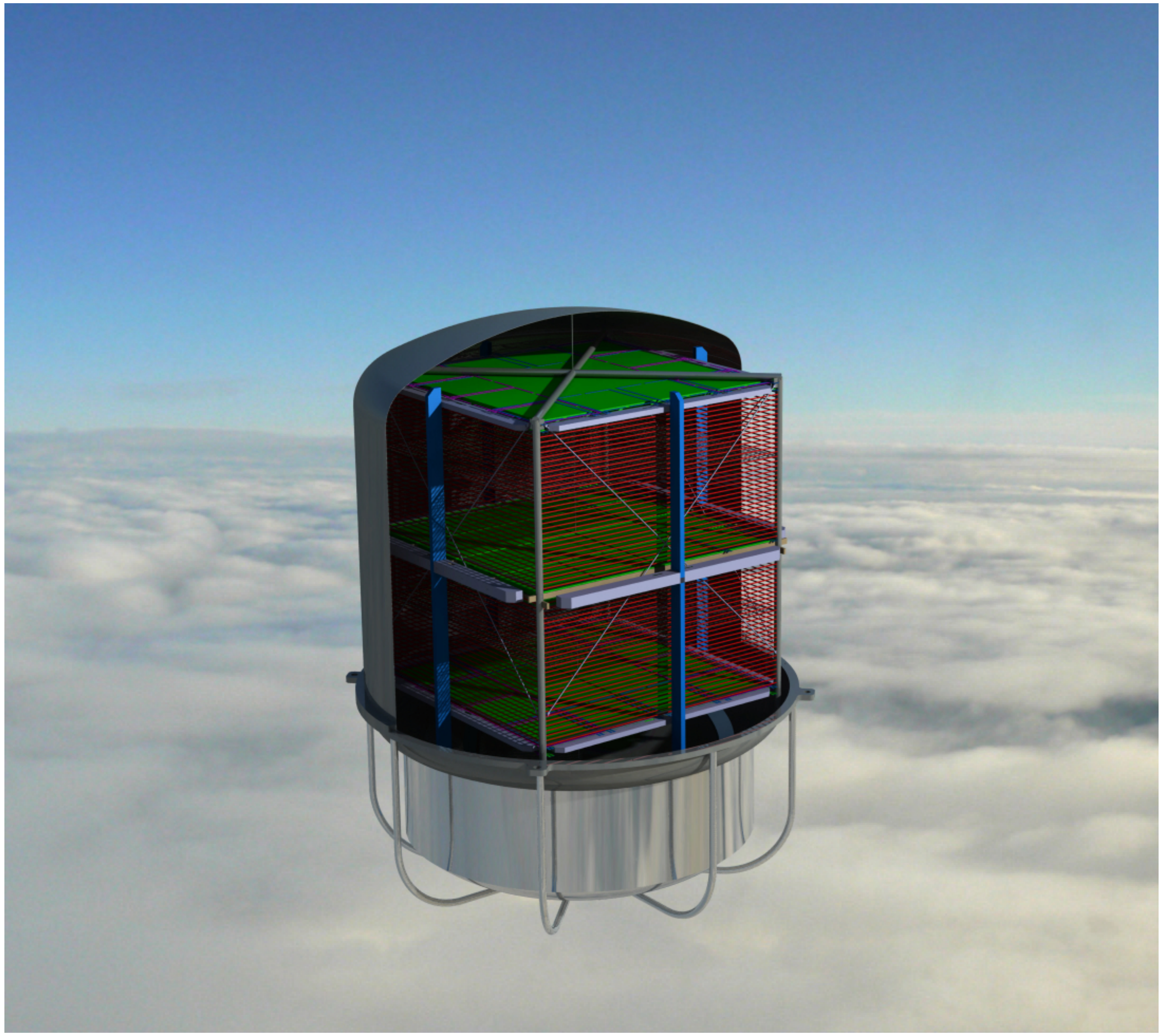


5 sigma
3 years
10 photons
90 deg from gal. plane
4 energy bins per decade

from document circulated by Denis

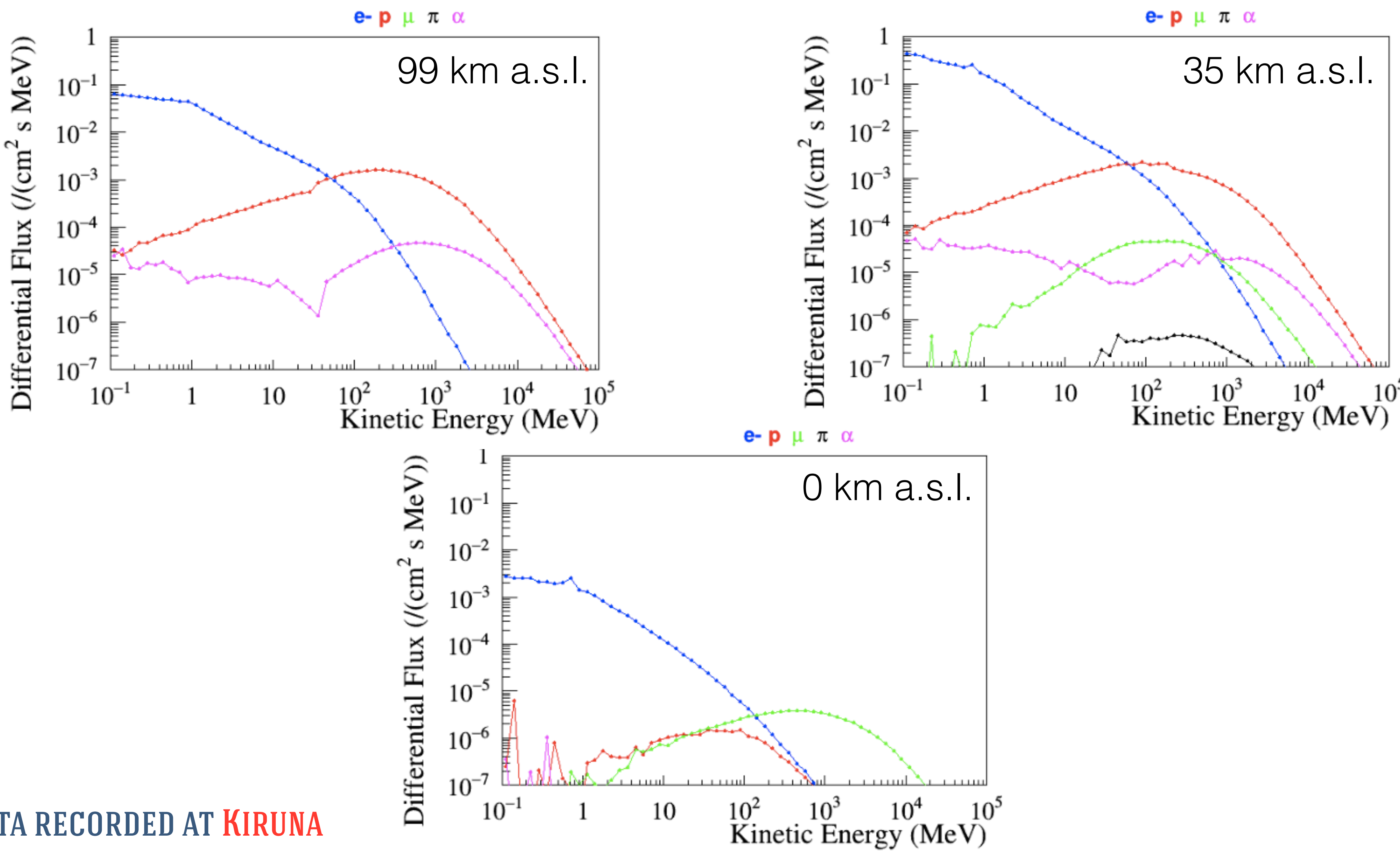
ST3G

Key challenge:



➡ Self triggering ... in real time ... in space

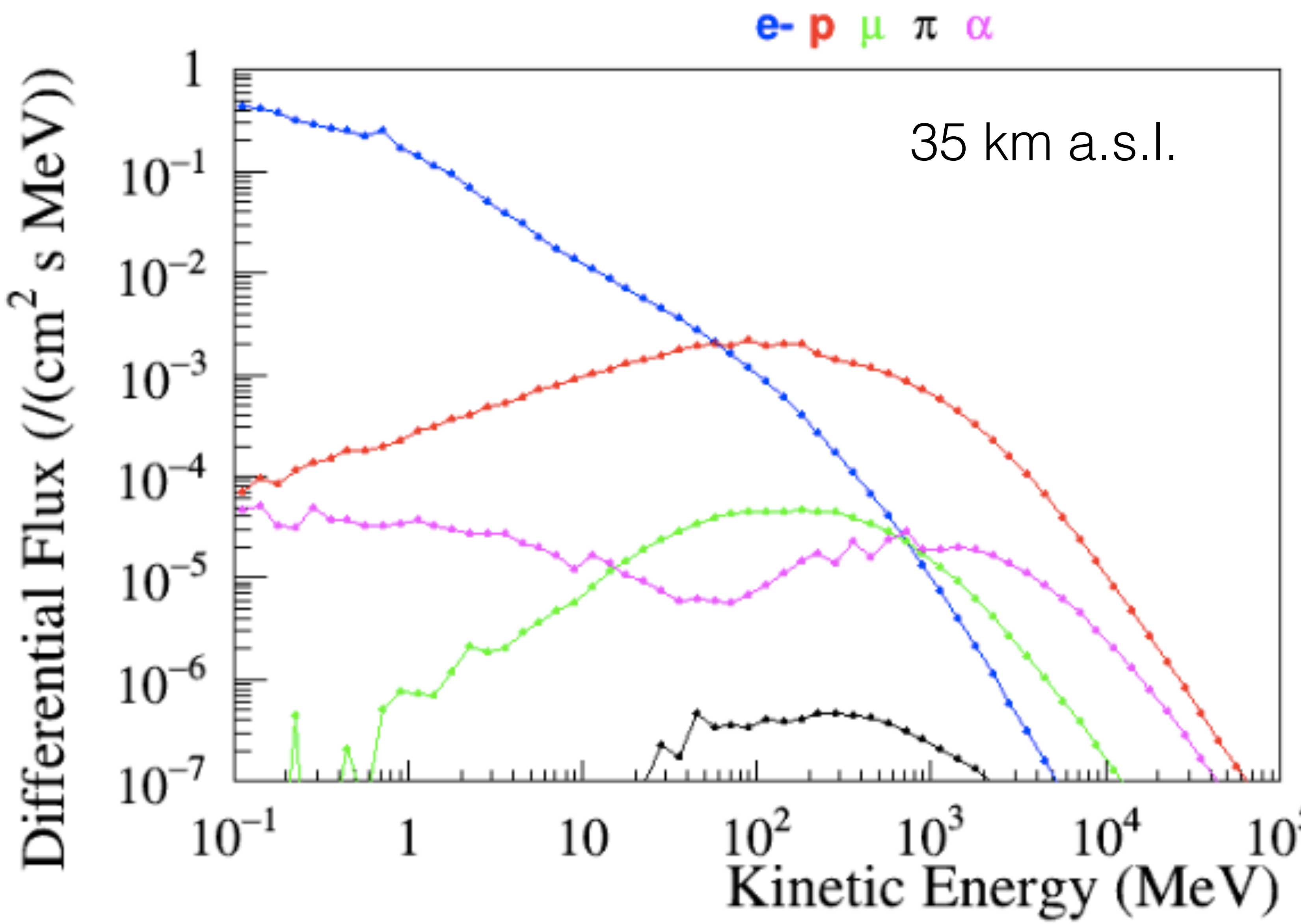
ST3G



Data recorded at Kiruna (Northern Sweden) 20.01.1996 (Quotid Atmospheric Radiation Model (QARM))

a.s.l. = above sea level

ST3G



Data recorded at Kiruna
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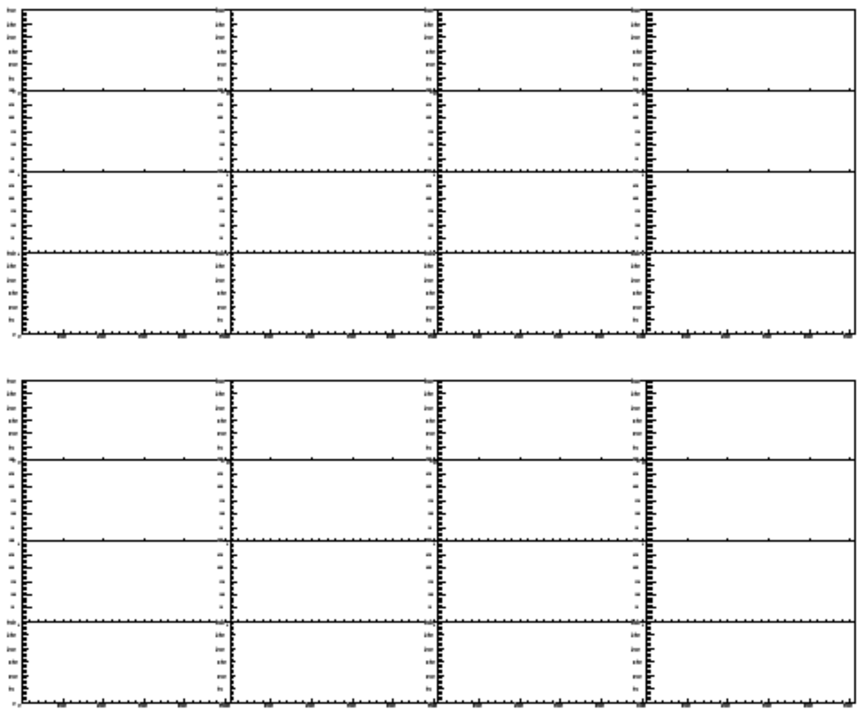
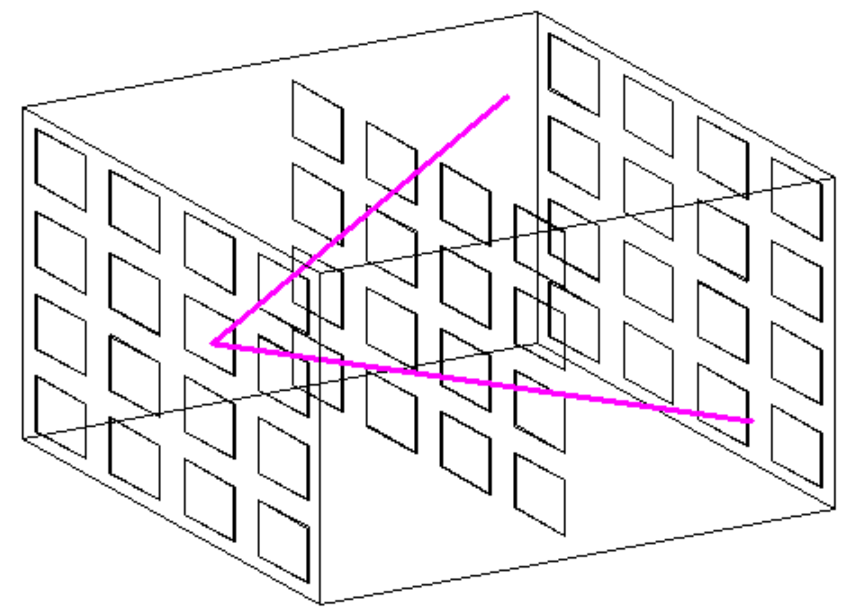
ST3G

Simulation of event in ST3G

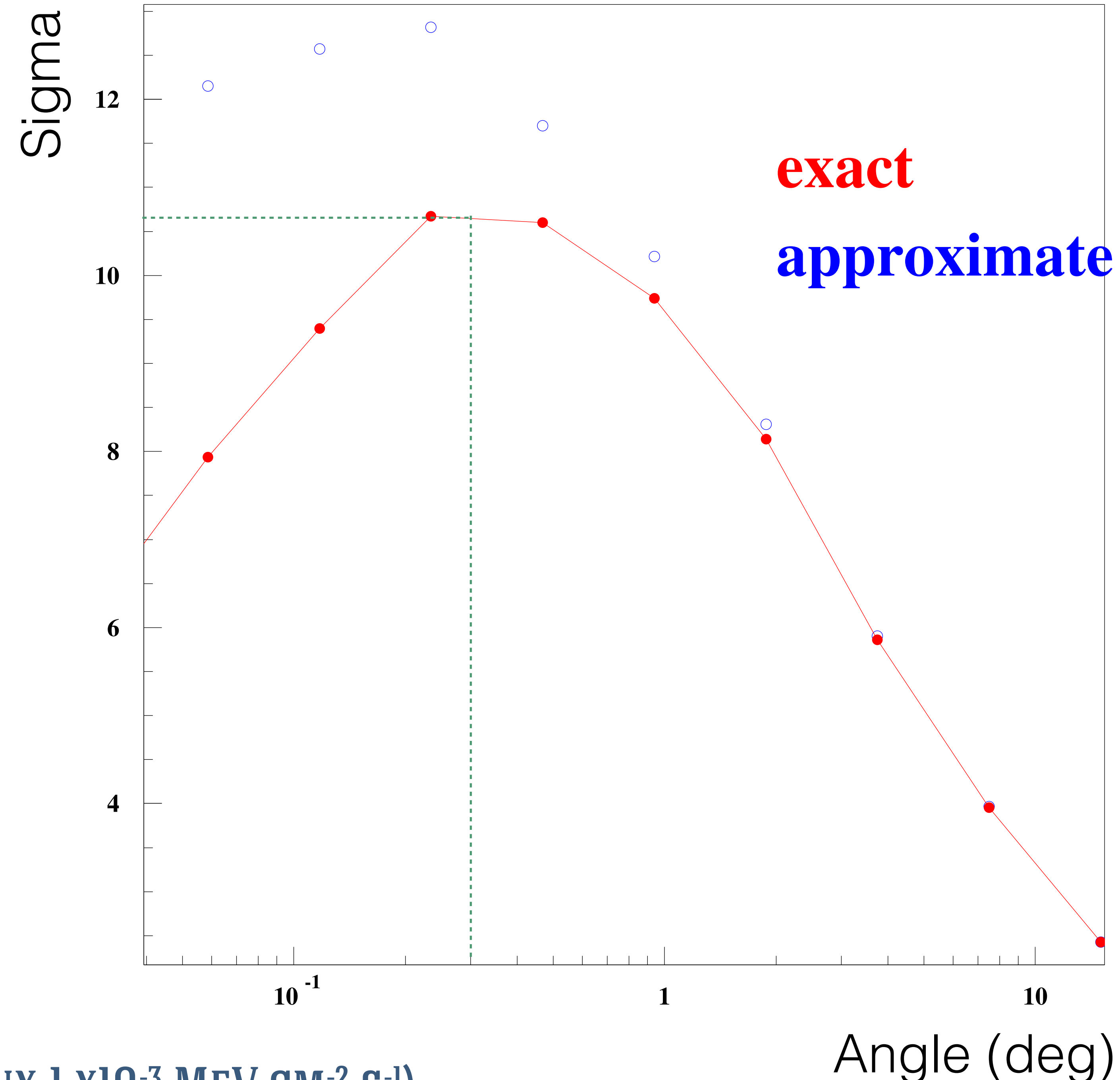




Credit: Philippe GROS

ST3G

Simulation of the Crab Nebula



FROM DOCUMENT CIRCULATED BY DENIS

- Crab (index: 2; flux:1 x10^{-3} MeV cm^{-2} s^{-1})
- 1 week effective exposure with ST3G @35 km (Kirune)
- 10.5 sigma for angular cut of 0.3 deg

ST3G

- We want to fly ST3G on a balloon to:
  - Calibrate the instrument with actual cosmic data
  - Understand the background
  - Run the trigger in its real environment

➡ Measure the combined sensitivity of the trigger/detector system

ST3G

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CNES Appel d'offre 2017: deadline - 21 April

ST3G

CNES Appel d'offre 2017: deadline - 21 April

- We plan to submit a proposal to construct the demonstrator of ST3G
- We will not request a balloon flight at this point

ST3G

CNES Appel d'offre 2017: deadline - 21 April

- We plan to submit a proposal to construct the demonstrator of ST3G
- We will not request a balloon flight at this point

Thanks for your attention

ST3G

CNES Appel d'offre 2017: deadline - 21 April

- We plan to submit a proposal to construct the demonstrator of ST3G
- We will not request a balloon flight at this point

Thanks for your attention

and collaboration we hope!

References

HTTPS://WWW.UNIVERSETODAY.COM/30594/BLAZARS/
HTTPS://WWW.BU.EDU/BLAZARS/RESEARCH.HTML
HTTPS://FUTURISM.COM/PULSARS-WHAT-ARE-THEY-WHY-DO-THEY-SPIN-SO-FAST-2/
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HTTPS://SITES.GOOGLE.COM/SITE/VISALACROSSTHEGALAXY/THE-GALACTIC-CENTRE
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HTTPS://EN.WIKIPEDIA.ORG/WIKI/SUPERNOVA_REMNANT
HTTPS://WWW.NASA.GOV/MISSION_PAGES/GLAST/NEWS/GAMMA-RAY-DRAGONS.HTML
HTTP://EARTHSKY.ORG/SPACE/MIND-BOGGLING-FERMI-BUBBLES-PROBED-VIA-QUASAR-LIGHT

Backup slides

Is Lorentz Invariance violated?

Lorentz invariance is the fundamental symmetry of Einstein's theory of relativity

i.e. the laws of physics remain the same for all observers that are moving with respect to each other at uniform velocity

- Lorentz invariance has been tested to a great level of detail but there exist grand unified theories (e.g. the Standard-Model Extension) where gravity is combined with the three other fundamental forces which allow for the breaking of Lorentz symmetry at the Planck scale
  - i.e. at very high energies - unattainable experimentally (1.22×10^{19}GeV)

- But minute deviations from Lorentz invariance might still be present at much lower energies
  - these deviations can accumulate over large distances
  - this makes **astrophysical measurements** the most sensitive tests of Lorentz symmetry

Is Lorentz Invariance violated?

In the photon sector violations of Lorentz symmetry include **vacuum dispersion** and **vacuum birefringence**

Vacuum dispersion

- if the speed of light in a vacuum is energy (frequency)-dependant
- photons of different energies emitted from a high-z source will arrive on earth at different times
- Fermi LAT observations of, e.g., distant GRBs has placed limits on this effect

$$\delta t \propto \delta v L$$

sensitivity depends on **L**

Vacuum birefringence

- when the rotation symmetry of the vacuum is broken, light still has two polarisation components but they travel at different speeds
- as a result, the net polarisation of the light changes as it propagates
- change in polarisation depends on the energy (frequency) of the light

$$\delta \phi \propto \omega \delta v L$$

sensitivity gain of **1/ω** compared to time-of-flight measurements

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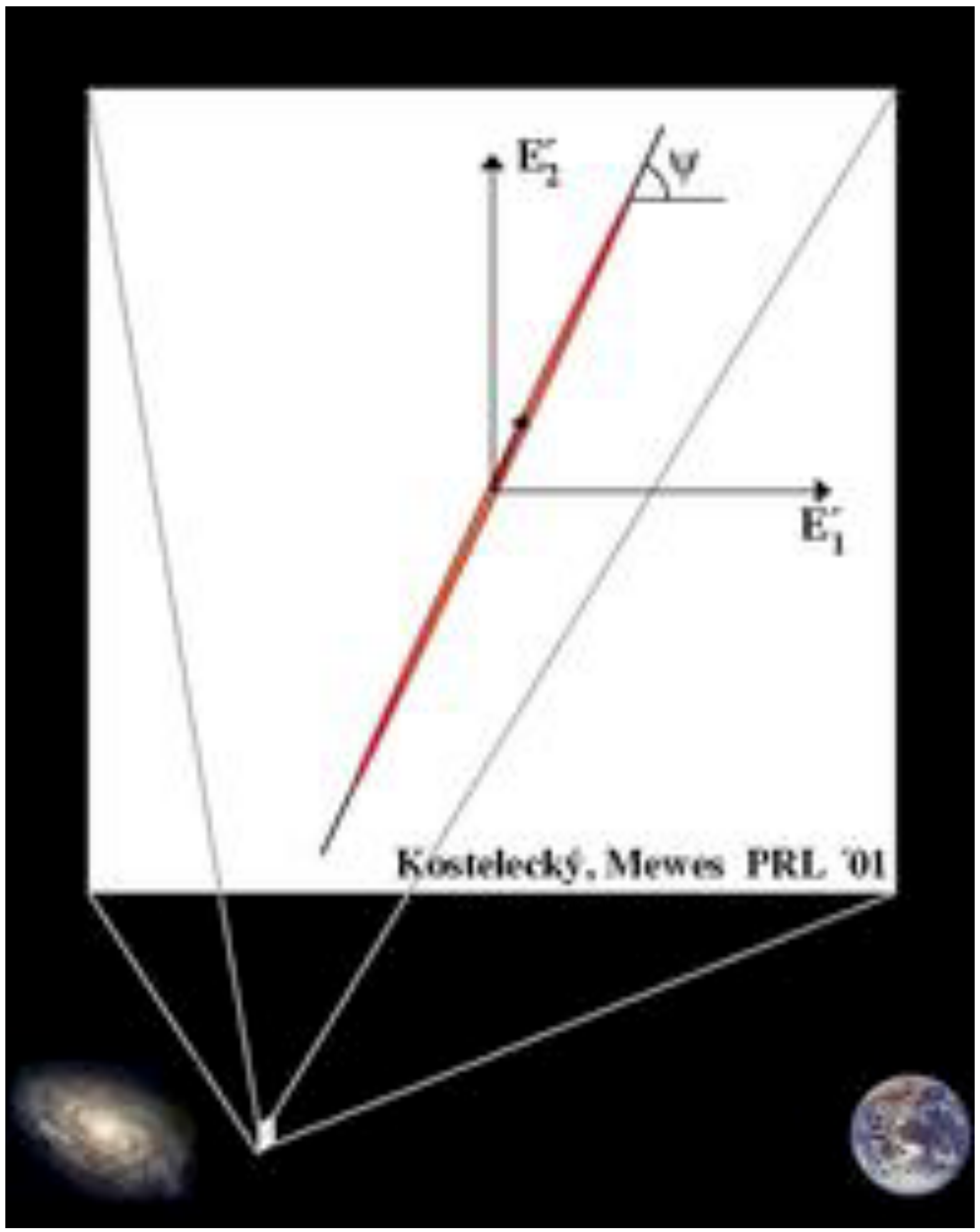
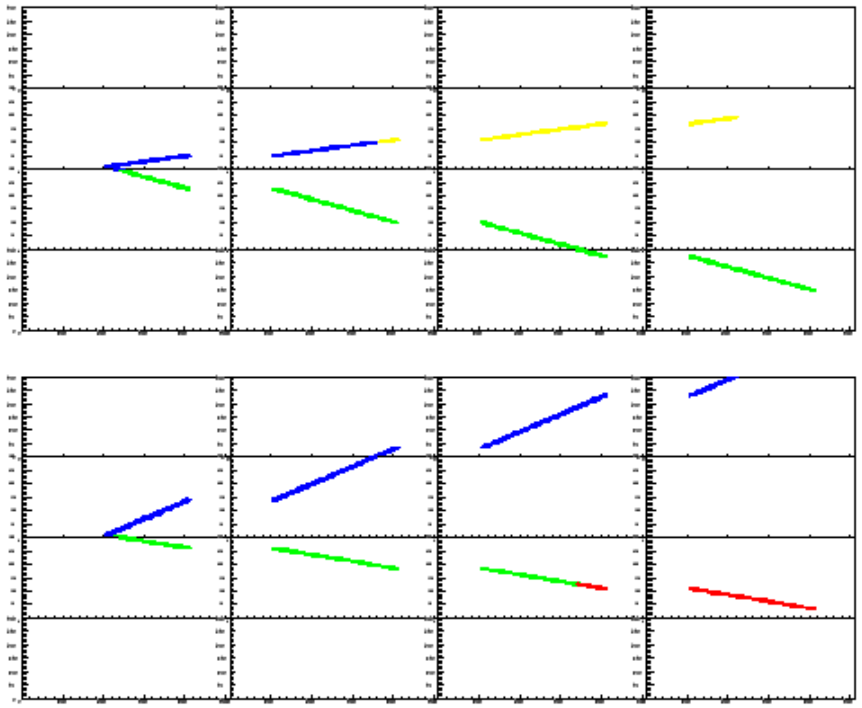


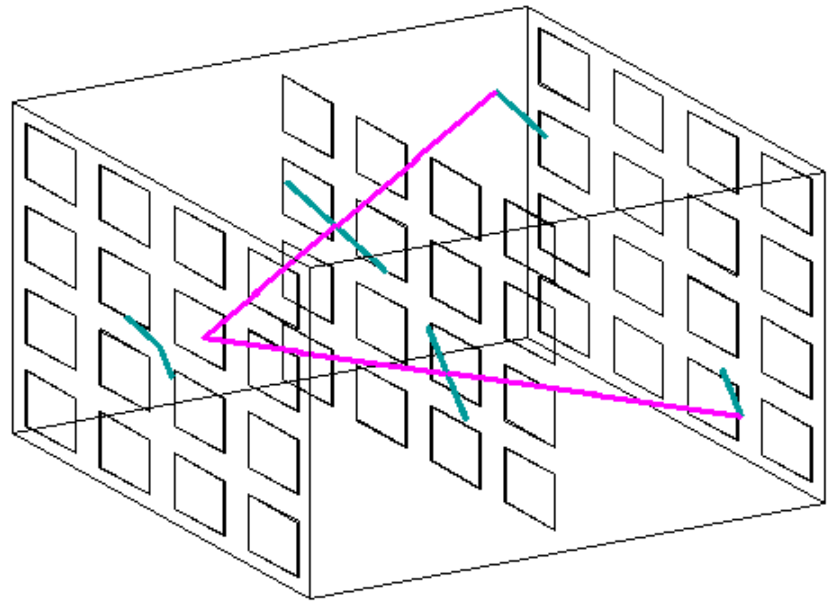
http://www.physics.indiana.edu/~kostelec/mov.html#4

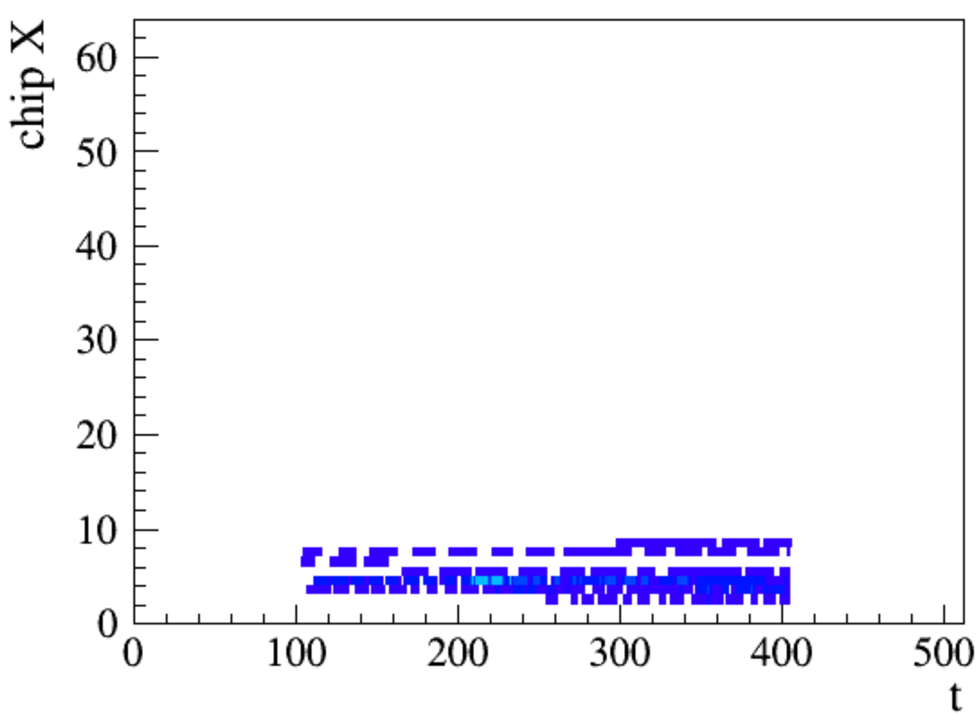
Vacuum birefringence

- light is shown propagating from a distant galaxy to the Earth
- the instantaneous electric-field vector in a plane transverse to direction of motion is shown as a black arrow
- the polarisation of the light is determined by 2 quantities:
  - the orientation of the ellipse (ω)
  - its shape (E1 and E2)
- the breaking of rotation symmetry causes the polarisation and hence the orientation and shape of the ellipse to change as the light travels through space

ST3G



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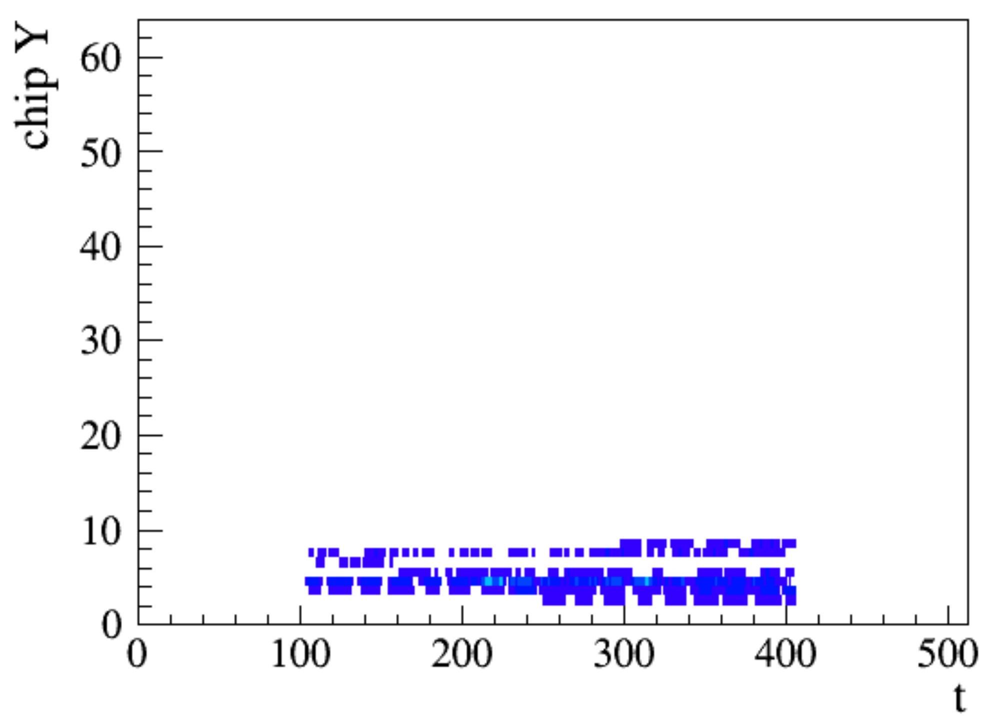
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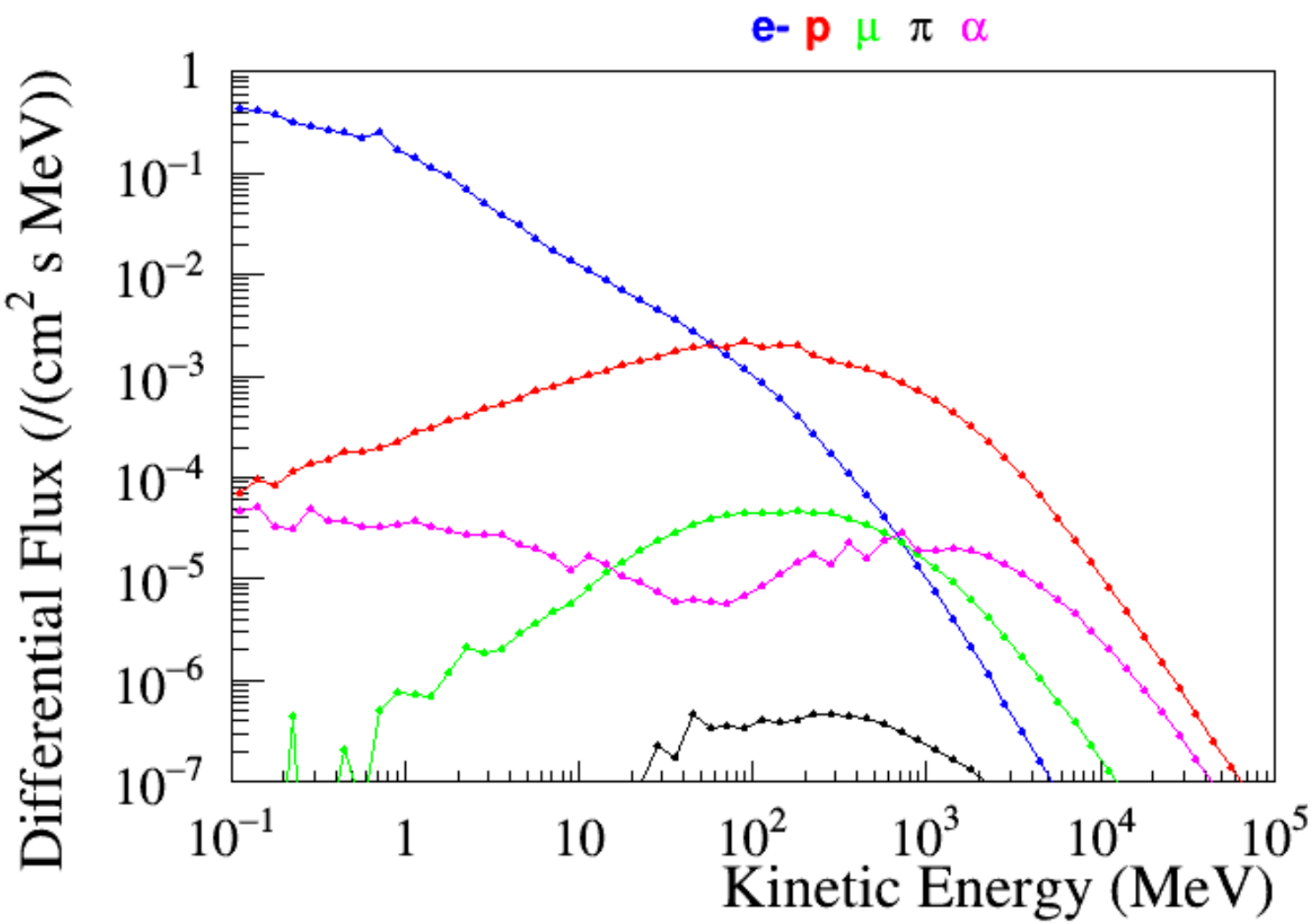
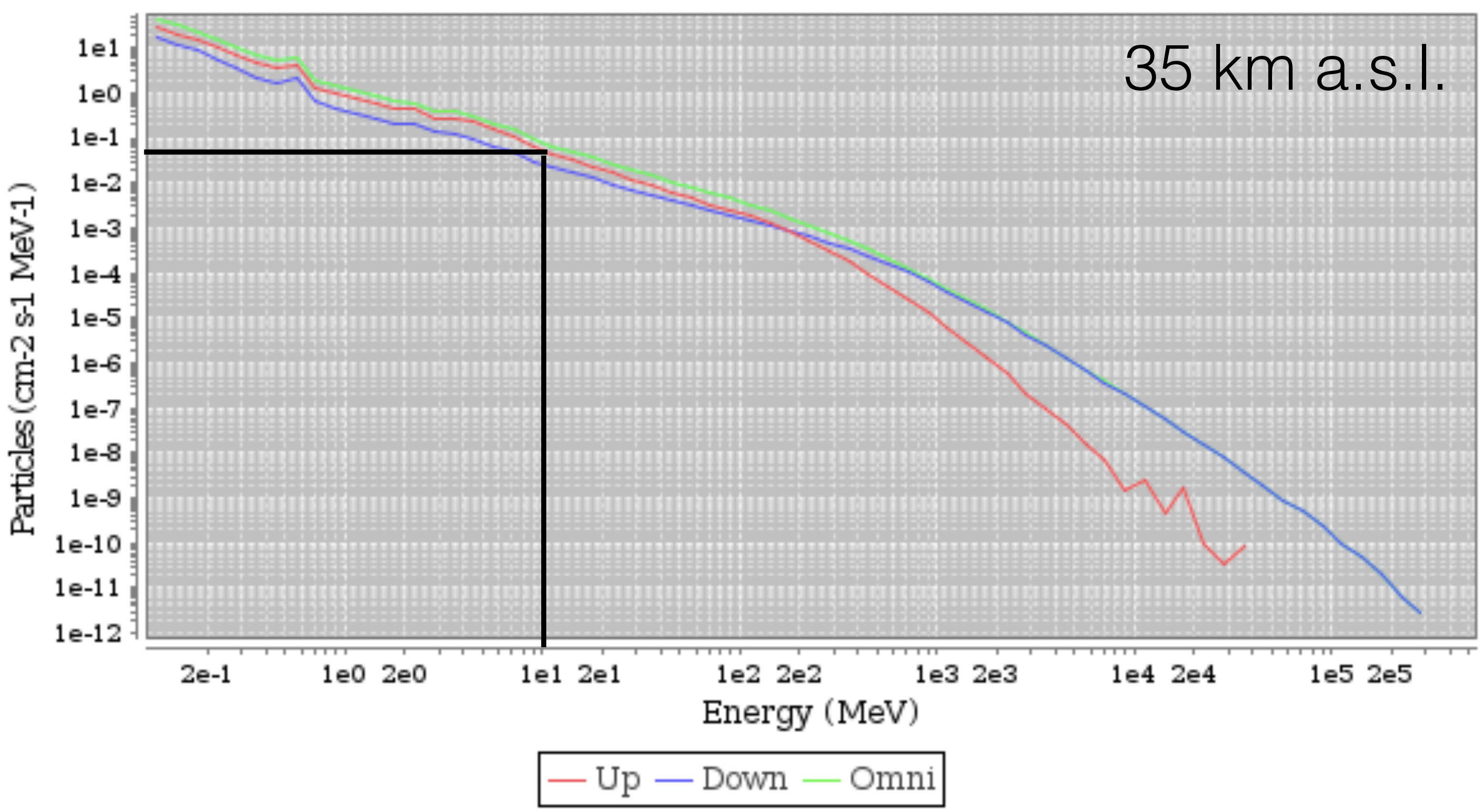
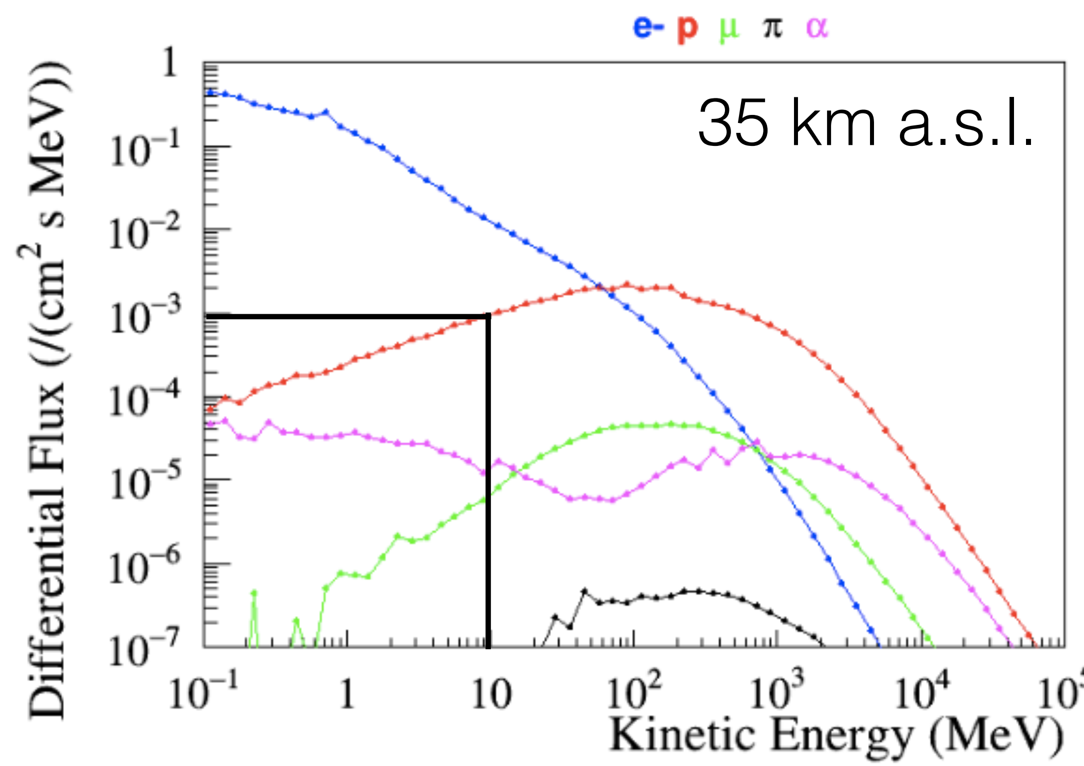
ST3G



Key challenge: self-triggering ... in real time ... in space

ST3G





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