

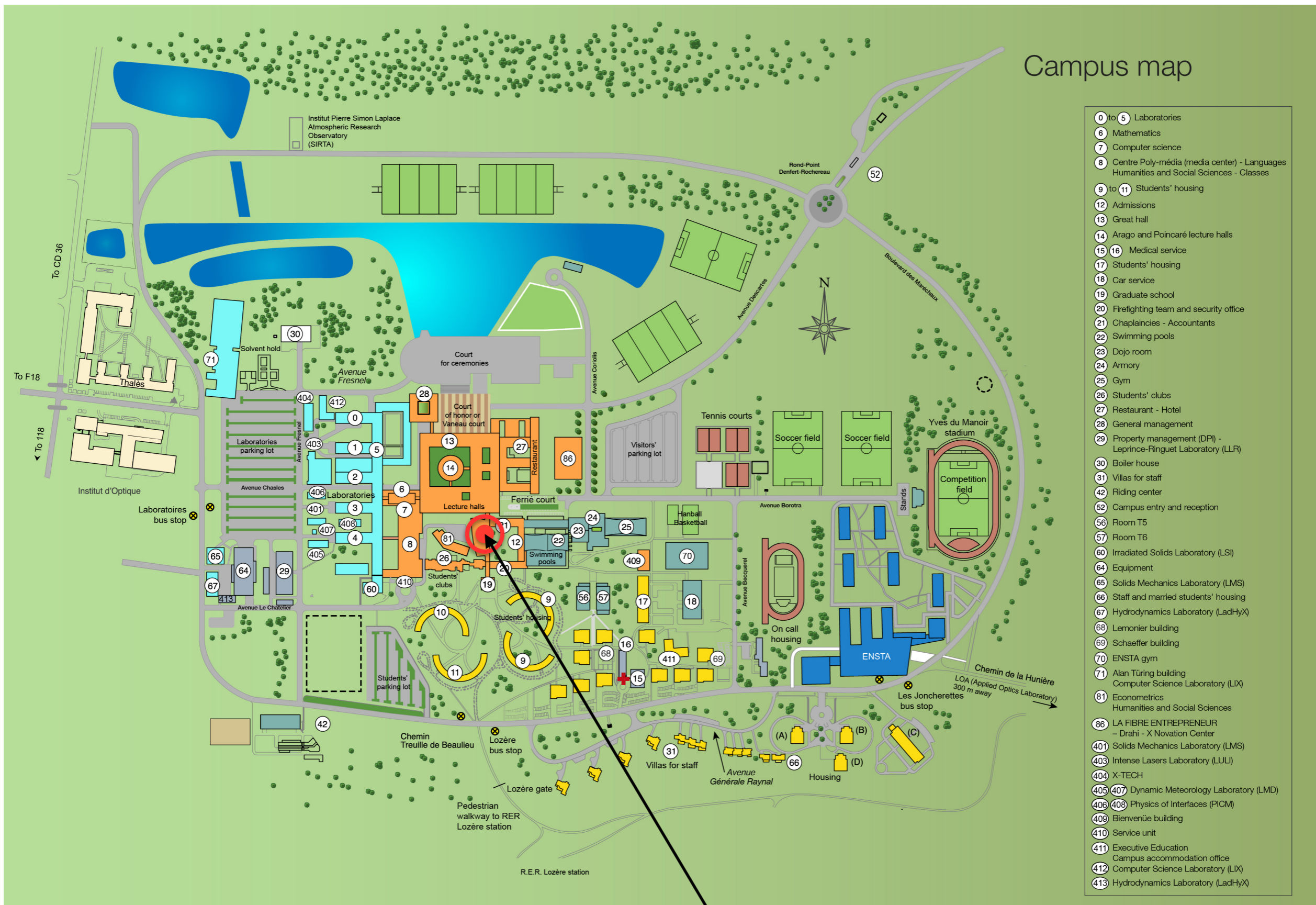
# Welcome to our workshop

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

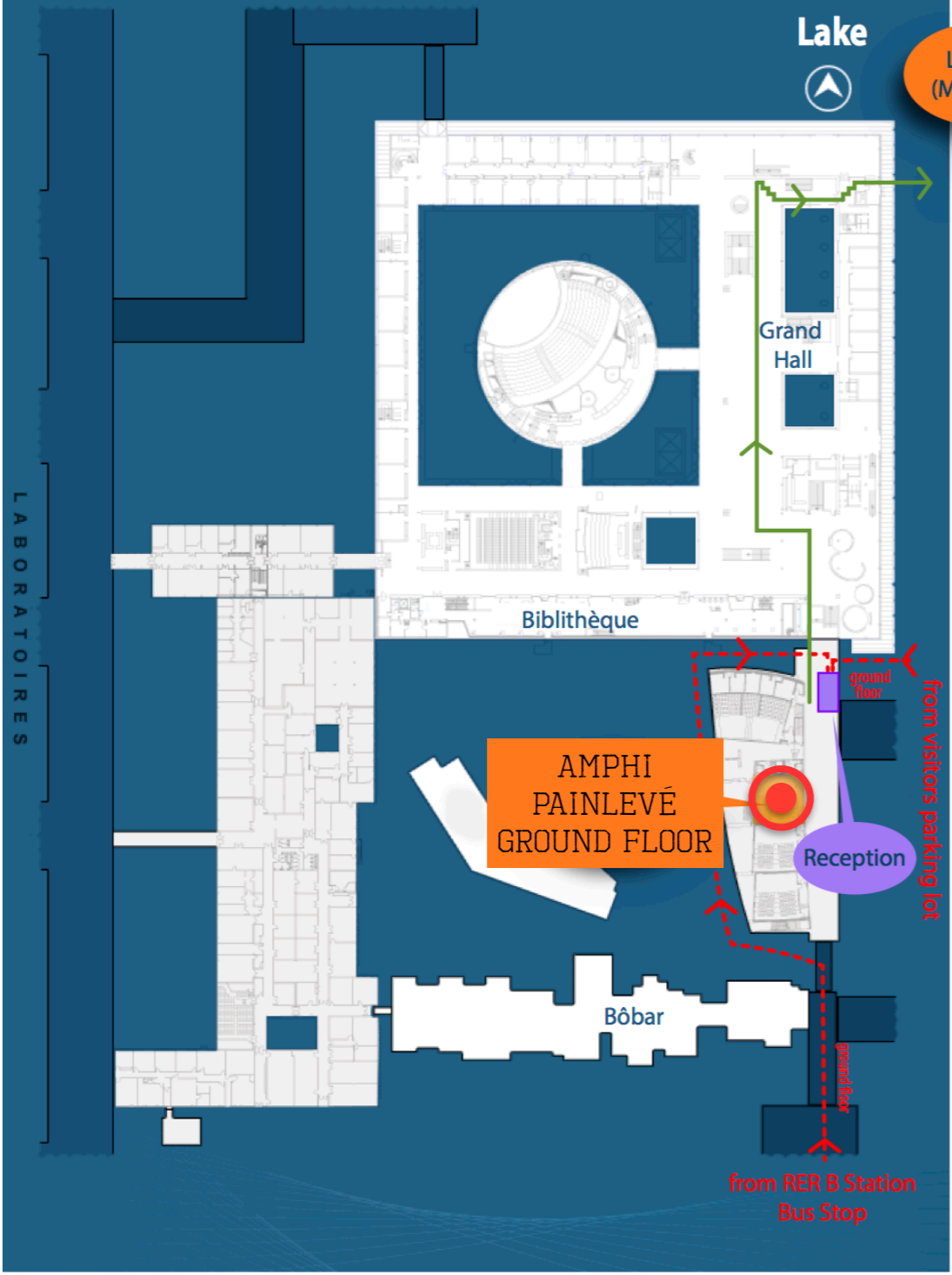
# Campus map



- 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 Turing 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 Bienvenue building
- 410 Service unit
- 411 Executive Education Campus accommodation office
- 412 Computer Science Laboratory (LIX)
- 413 Hydrodynamics Laboratory (LadHyX)

we are here

**Workshop MEV 2017**  
12 -14 avril 2017  
École polytechnique - Amphi Marie Curie



### Coffee breaks

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

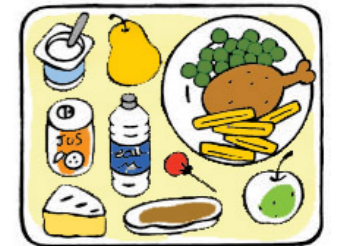


### Lunch (Thursday) - provided

- 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



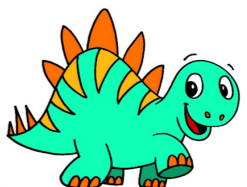
\*<https://www.polytechnique.edu/en/on-campus-dining-and-services>

# ST3G



A PROTOTYPE  
BALLOON DETECTOR

Self-triggering TPC telescope  
for gamma-rays

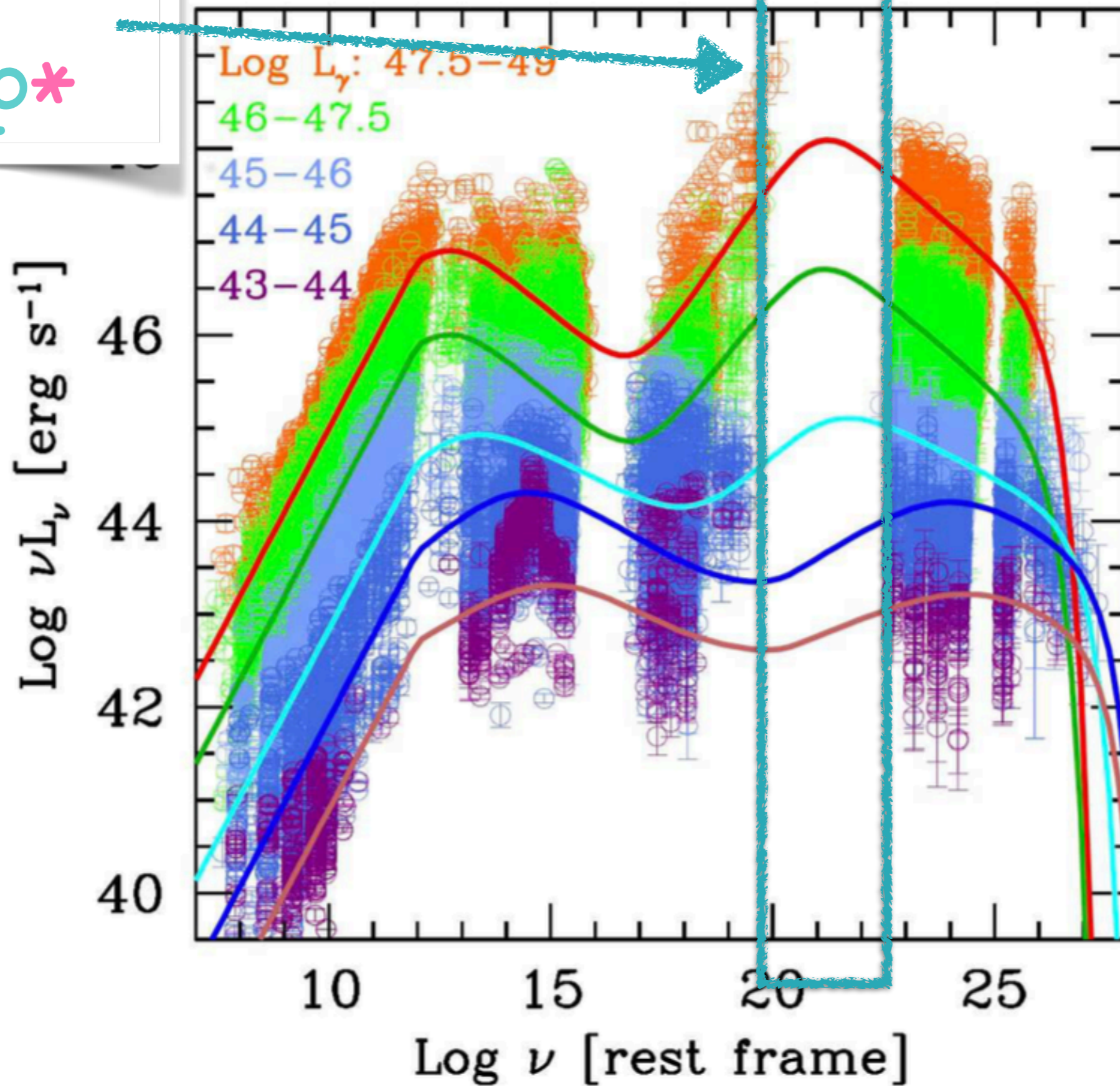


# OUTLINE

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- **SCIENTIFIC MOTIVATION**
- **BRIEF INTRODUCTION AND HISTORY**
- **ST3G - A PROTOTYPE DETECTOR**
- **OUR PLAN**

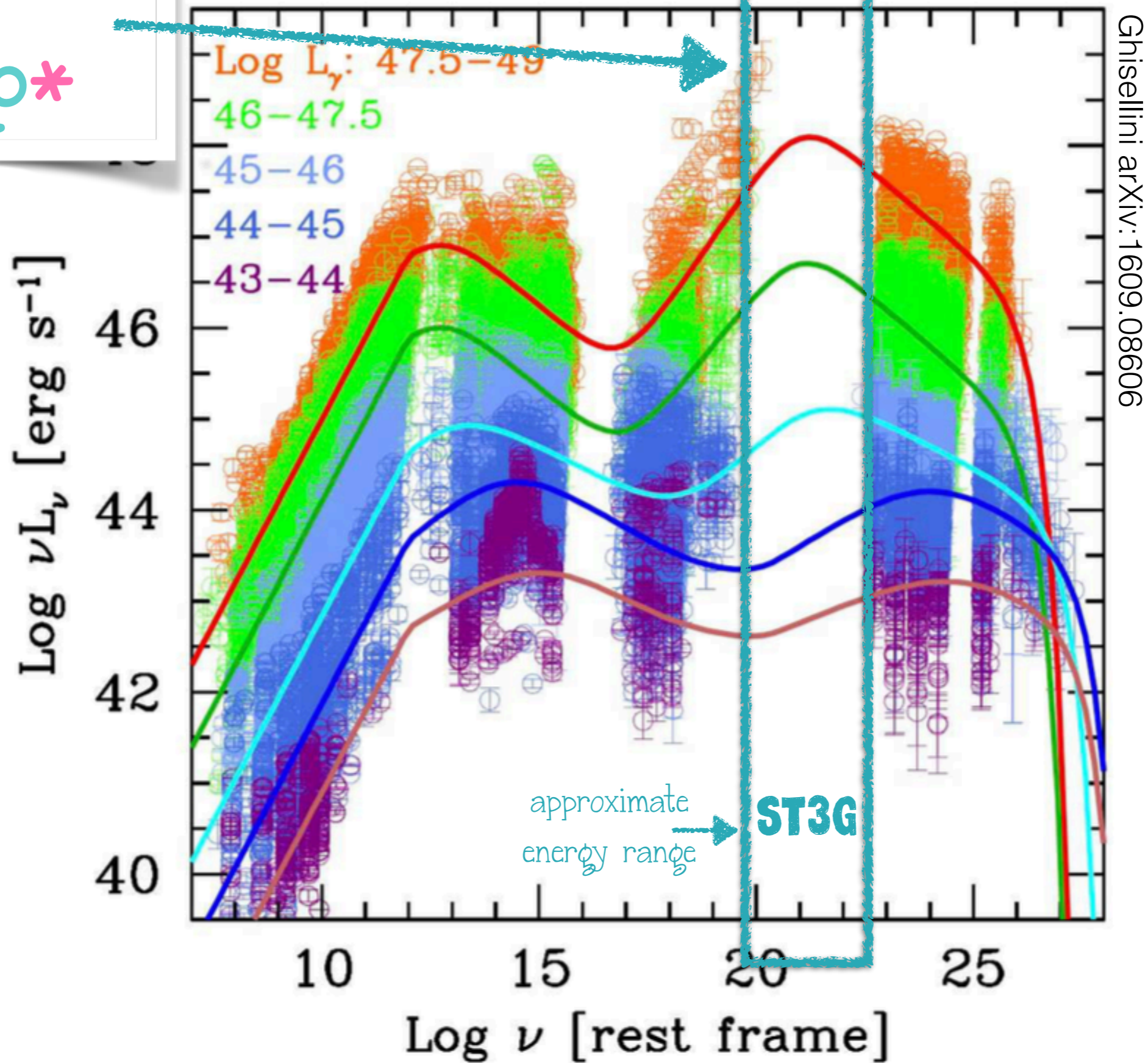
# The MeV Gap\*



Ghisellini arXiv:1609.08606

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

# The MeV Gap\*

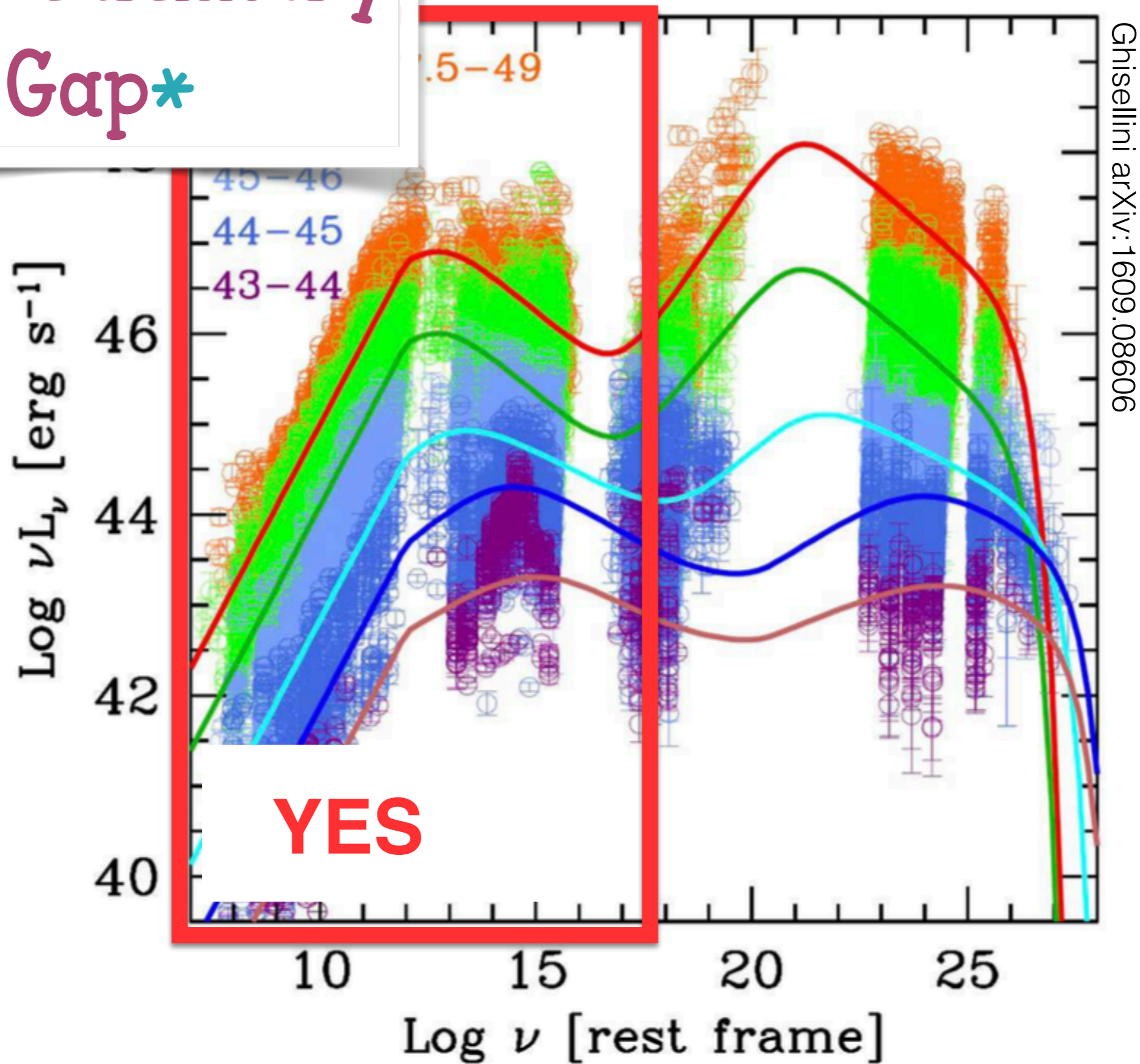


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# The Polarimetry Gap\*

Gap\*



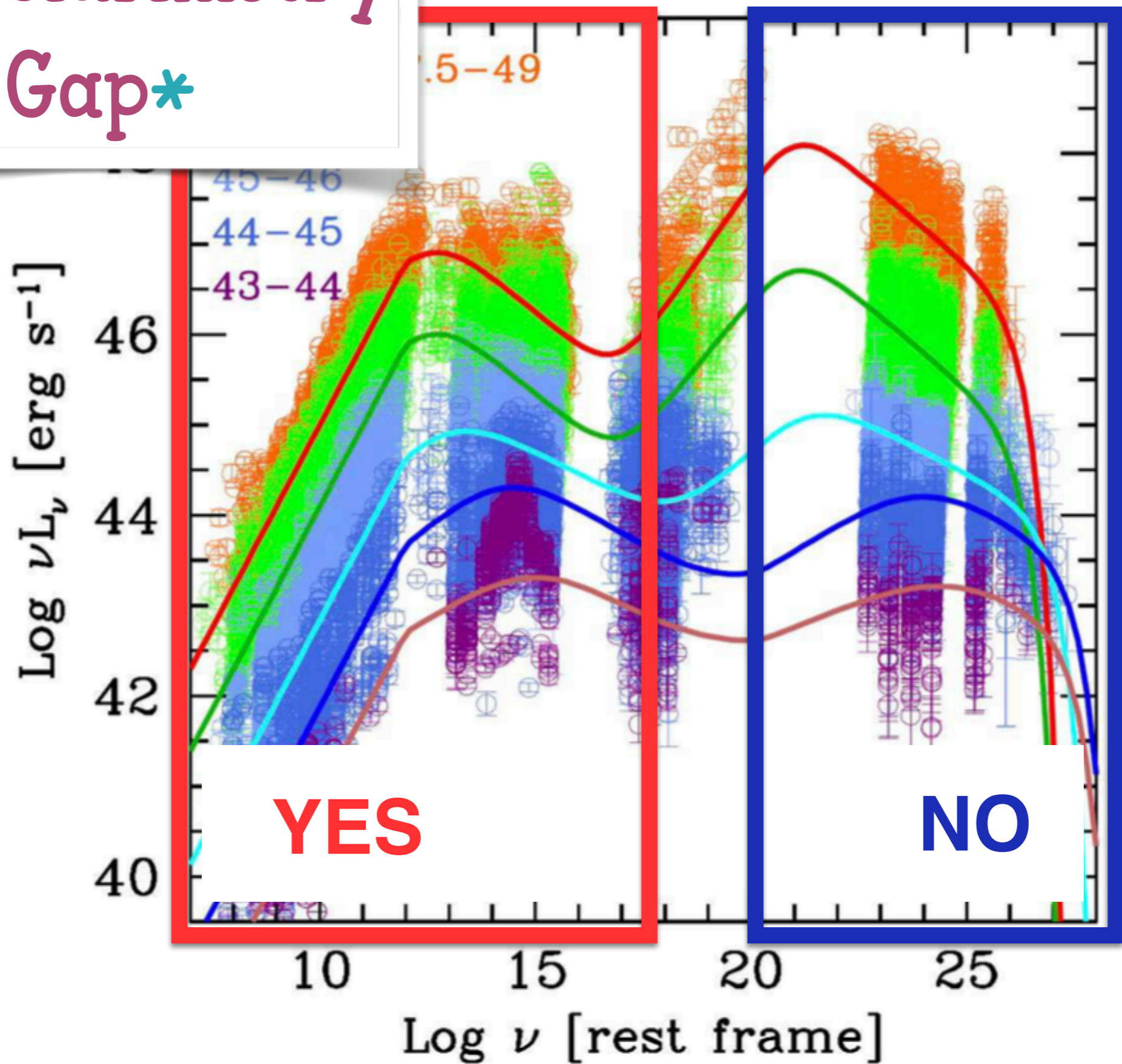
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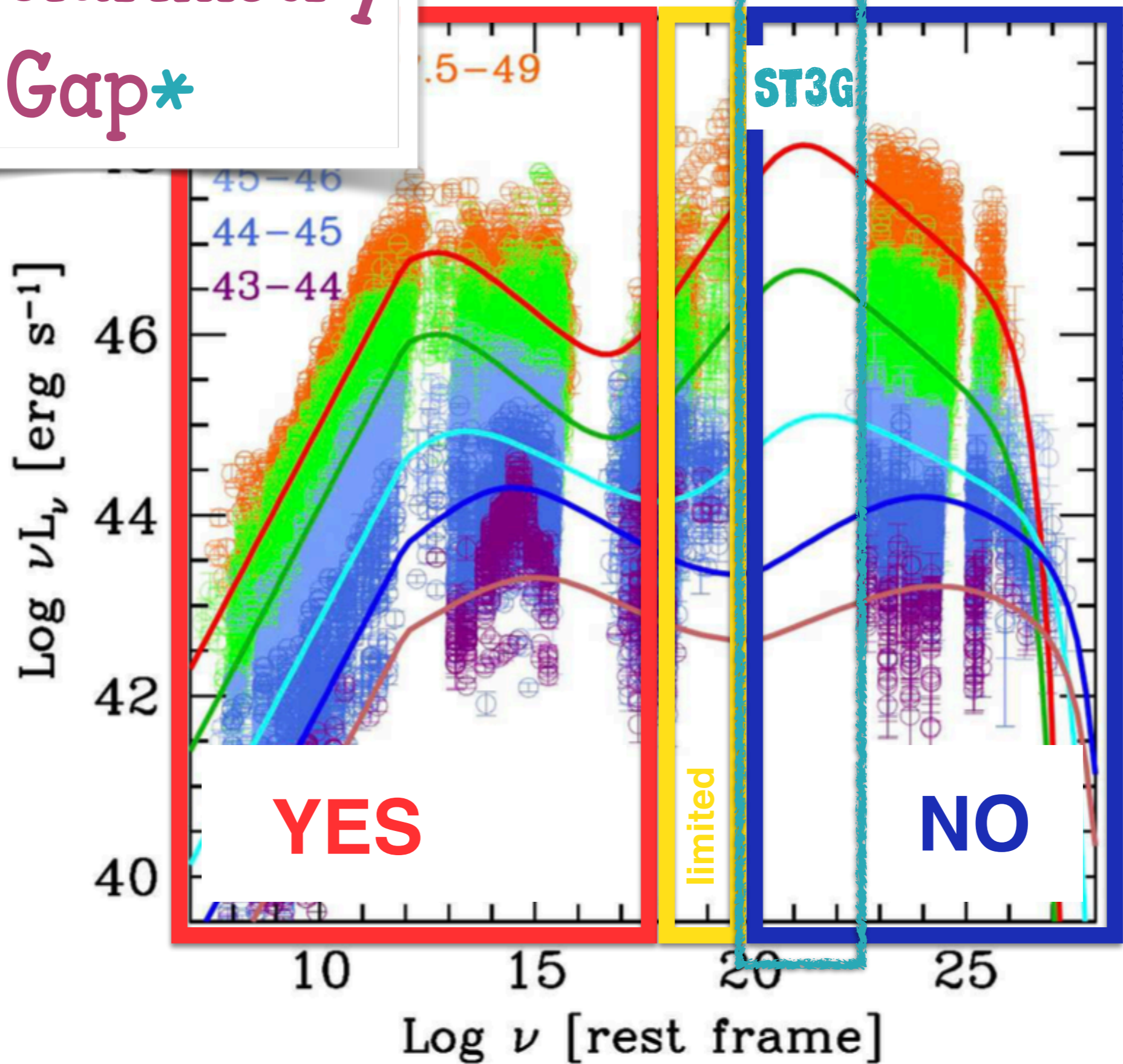
Gap\*



Christina Yu, 1500 00608

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

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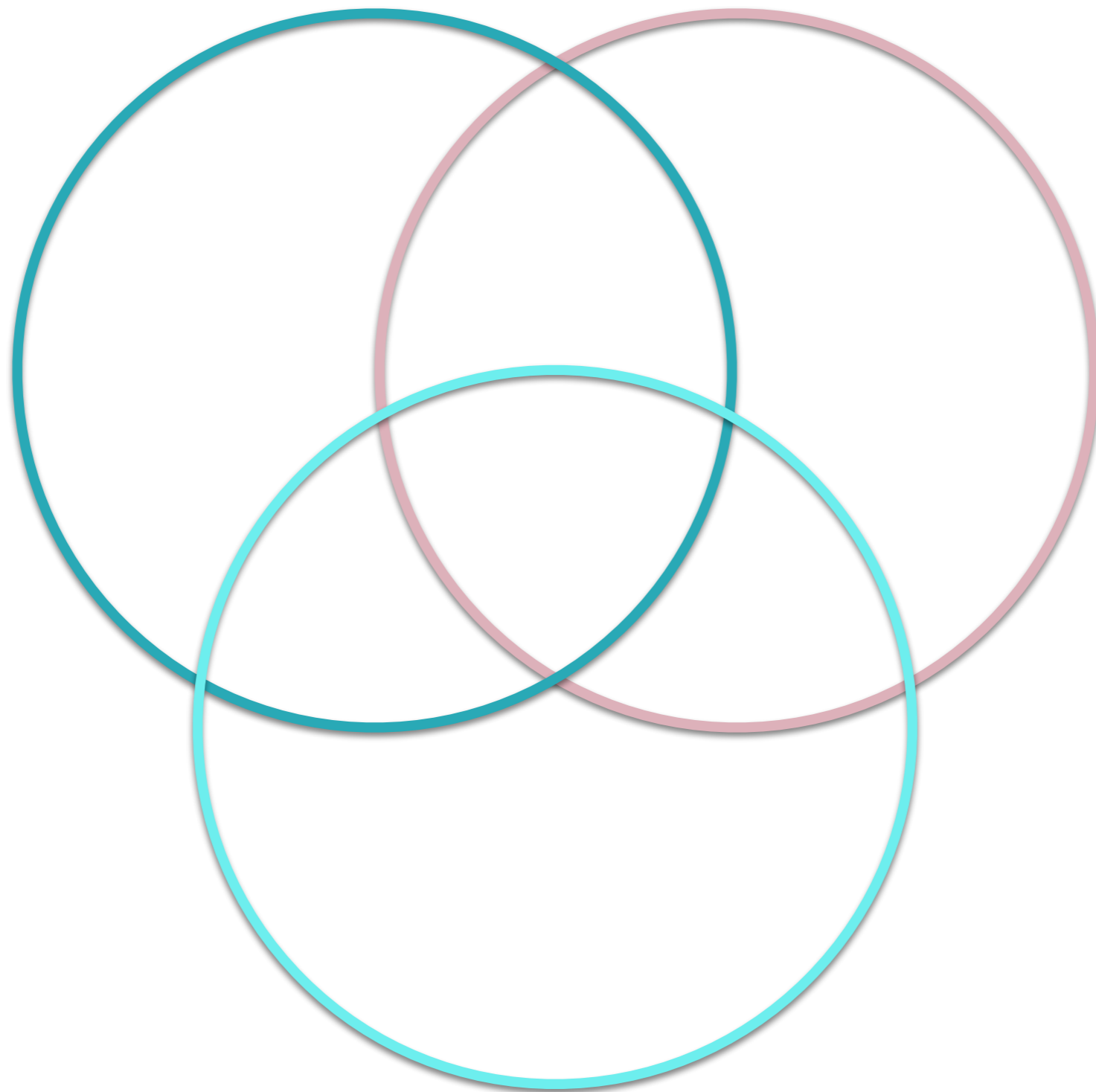


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# Gamma-ray Astrophysics at MeV energies

MEV ENERGY  
COVERAGE

POLARIZATION



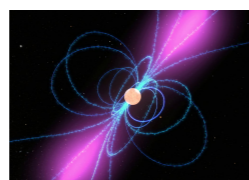
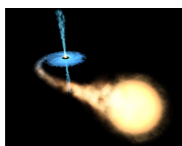
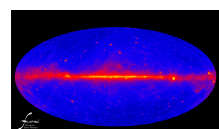
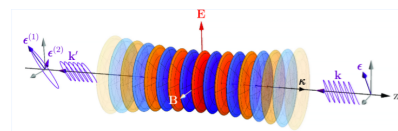
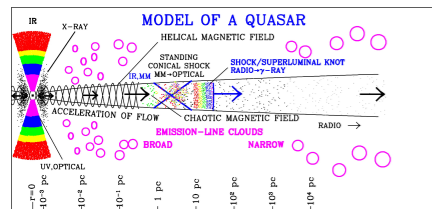
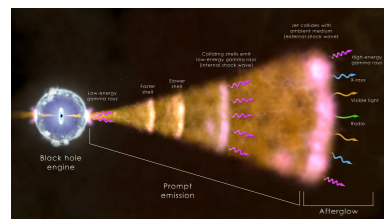
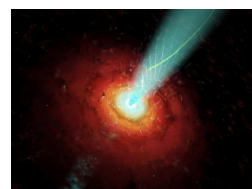
HIGH ANGULAR  
RESOLUTION

# 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

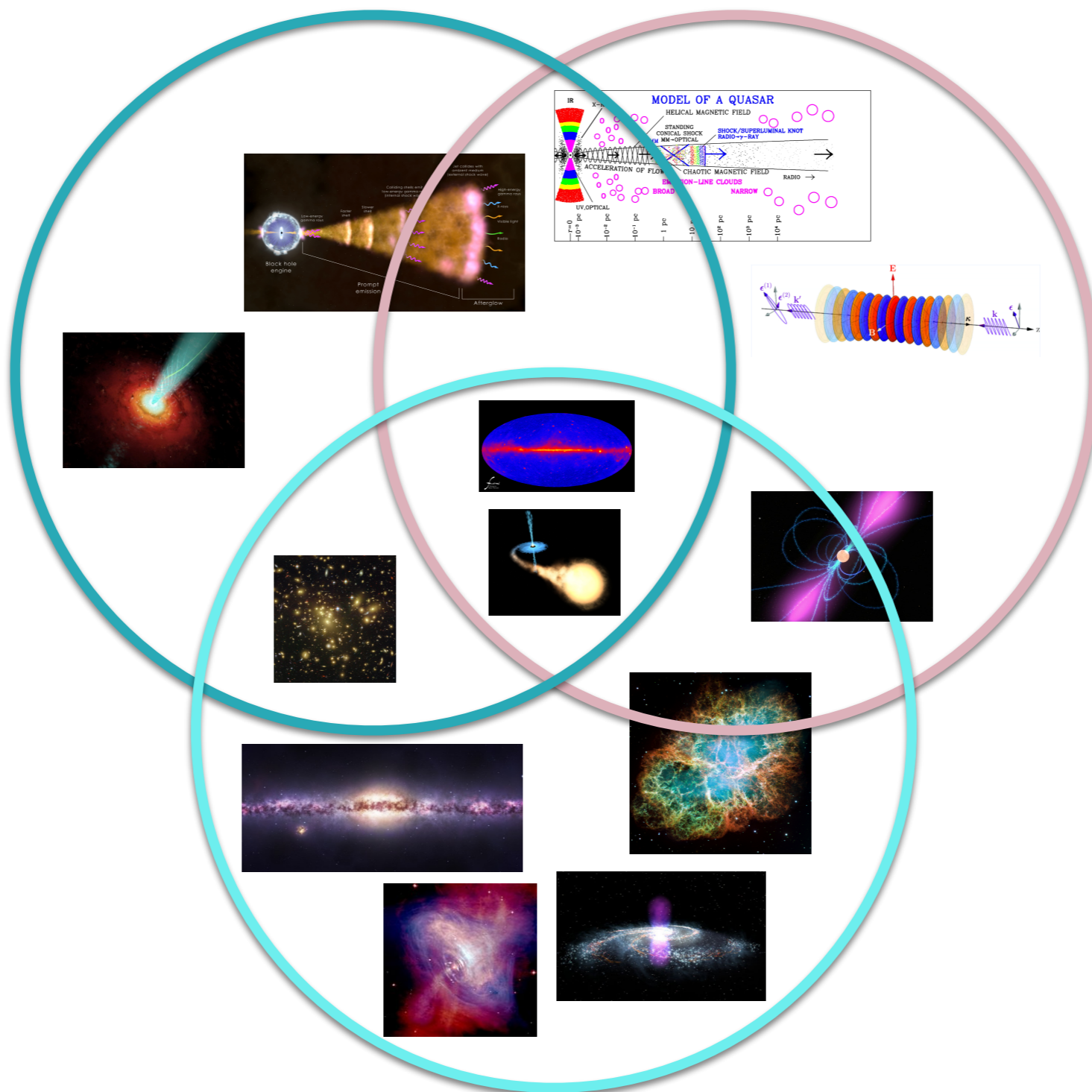
LORENTZ INVARIANCE

SUPERNOVA REMNANTS

# Gamma-ray Astrophysics at MeV energies

MEV ENERGY  
COVERAGE

POLARIZATION



HIGH ANGULAR  
RESOLUTION

# Gamma-ray Astrophysics at MeV energies

**MEV ENERGY  
COVERAGE**

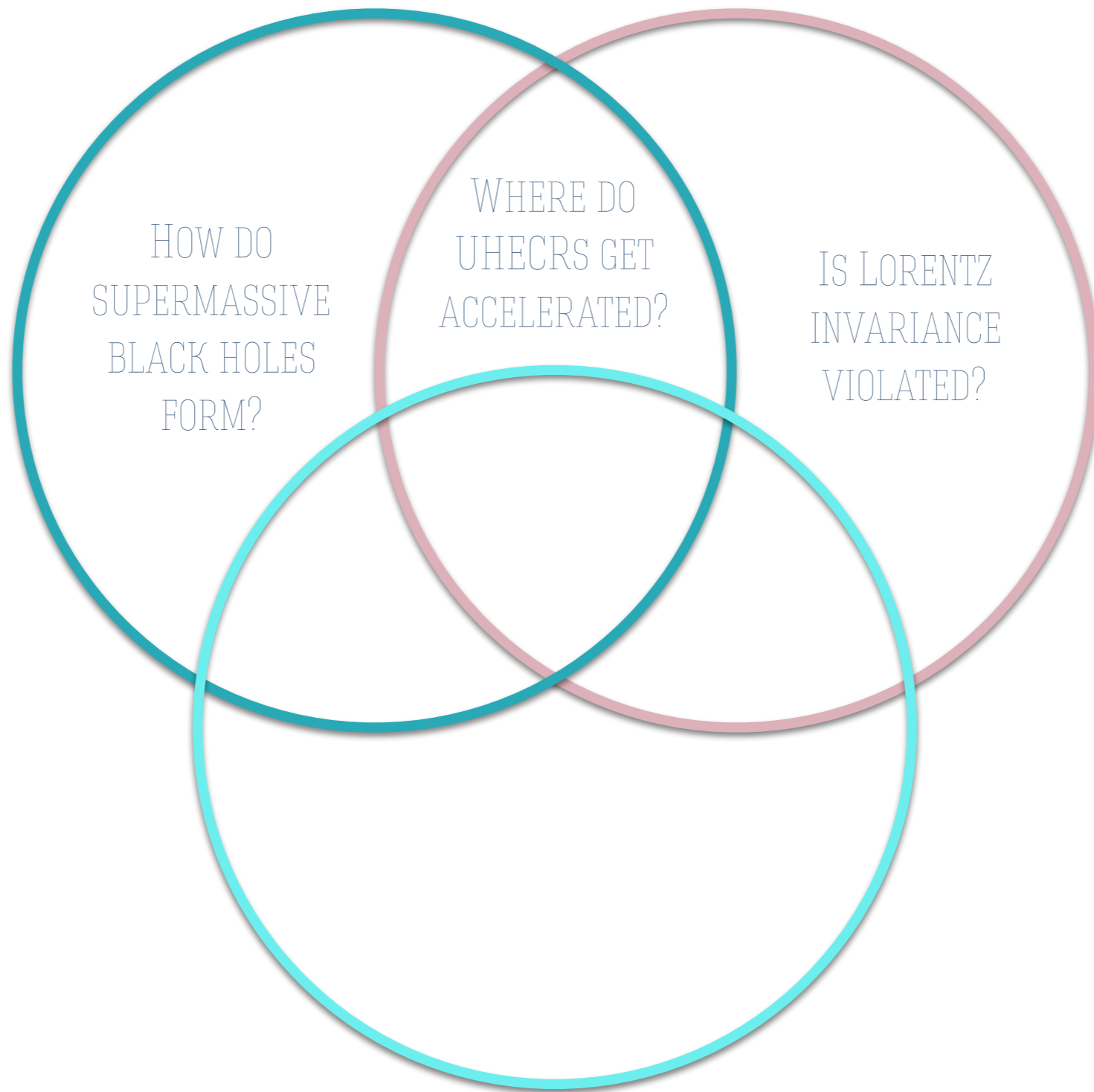
HOW DO  
SUPERMASSIVE  
BLACK HOLES  
FORM?

WHERE DO  
UHECRS GET  
ACCELERATED?

IS LORENTZ  
INVARIANCE  
VIOLATED?

**POLARIZATION**

**HIGH ANGULAR  
RESOLUTION**



# Gamma-ray Astrophysics at MeV energies

**MEV ENERGY  
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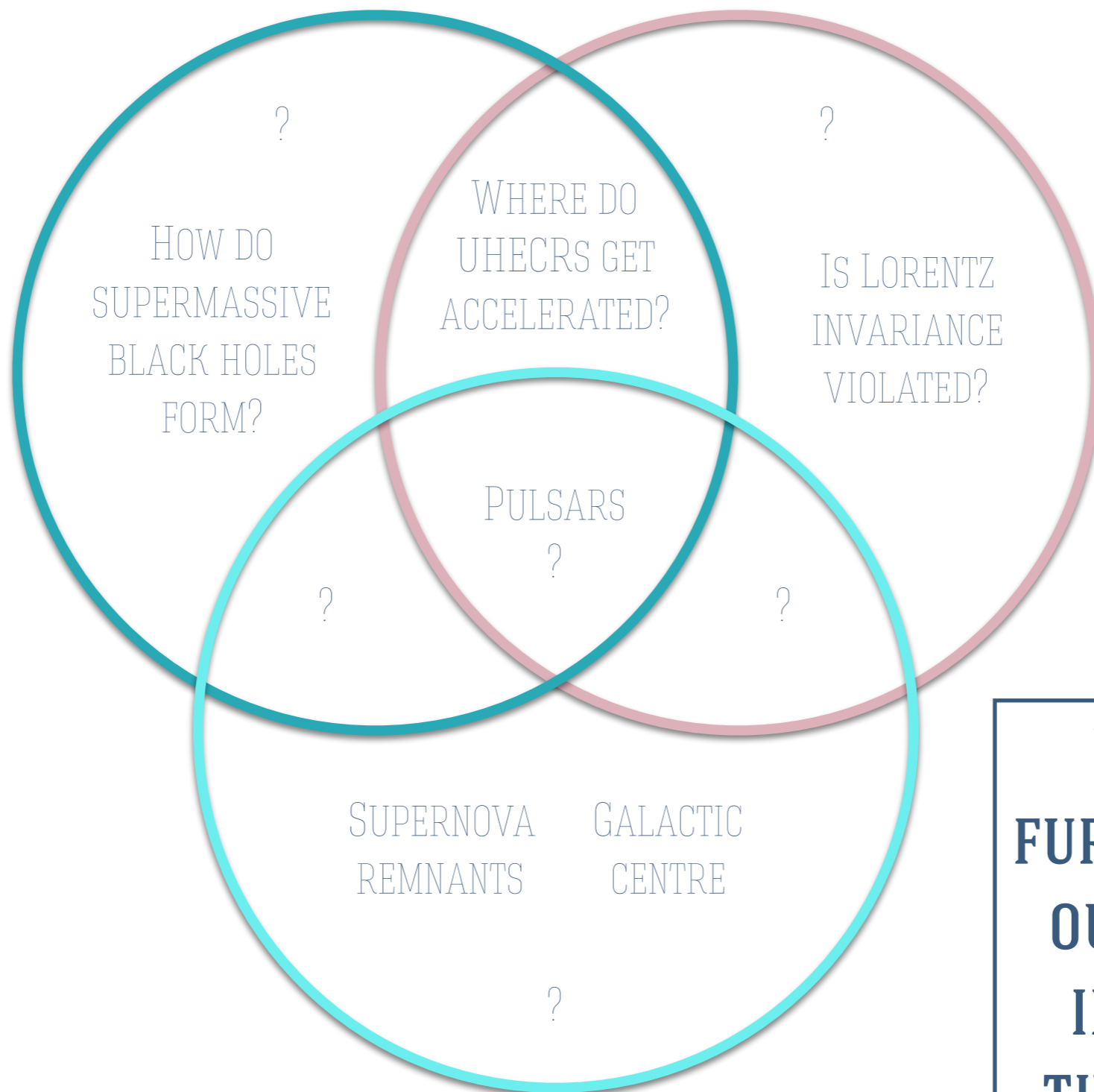
SUPERNOVA  
REMNANTS    GALACTIC  
CENTRE

PULSARS

**HIGH ANGULAR  
RESOLUTION**

# Gamma-ray Astrophysics at MeV energies

**MEV ENERGY  
COVERAGE**



**POLARIZATION**

**HIGH ANGULAR  
RESOLUTION**

**WE HOPE TO  
FURTHER DEVELOP  
OUR SCIENTIFIC  
IDEAS DURING  
THIS WORKSHOP  
... THANKS TO YOU**



# Overview of project

## Ground phase



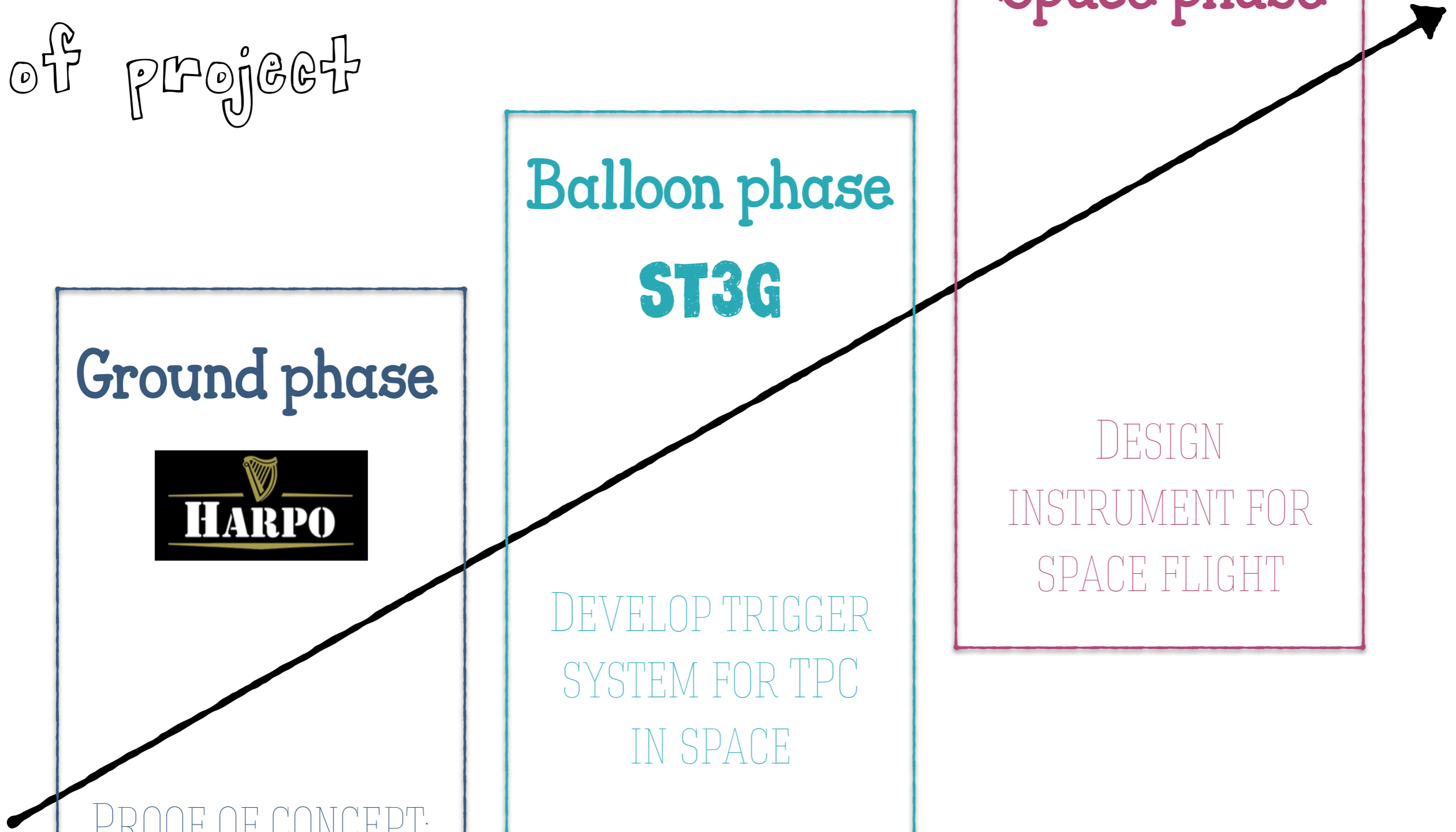
PROOF OF CONCEPT:  
USE TPC TO MEASURE  
POLARISATION

## Balloon phase ST3G

DEVELOP TRIGGER  
SYSTEM FOR TPC  
IN SPACE

## Space phase

DESIGN  
INSTRUMENT FOR  
SPACE FLIGHT



Ground phase



2012

2013

2014

2015

2016

2017

the Hermatic ARgon POLarimeter (2012 - 2017)



Ground phase



# the Hermetic ARgon POLarimeter (2012 - 2017)

TPC



\*mostly

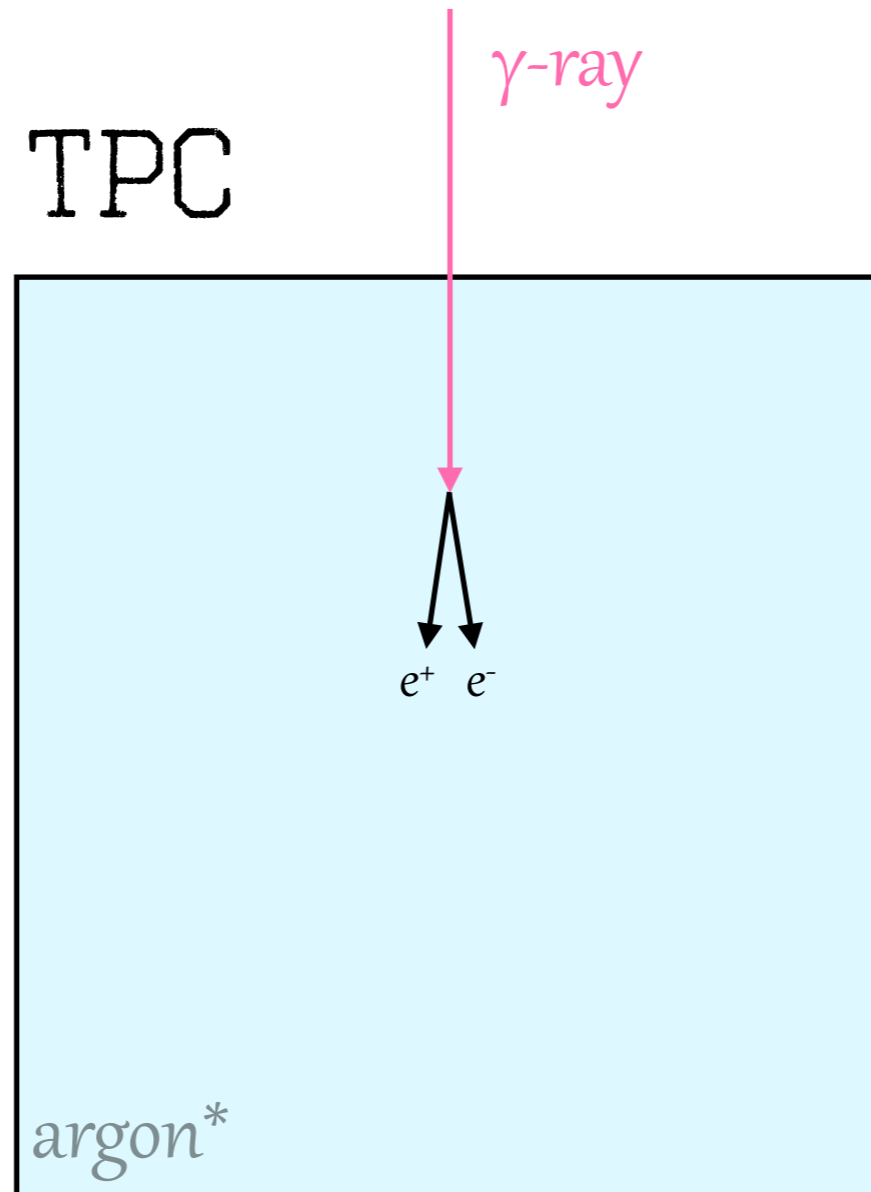


Ground phase



# the Hermatic ARgon POlarimeter (2012 - 2017)

- PAIR PRODUCTION  
→ NUCLEUS OF AR ATOM



\*mostly



Ground phase

2012

2013

2014

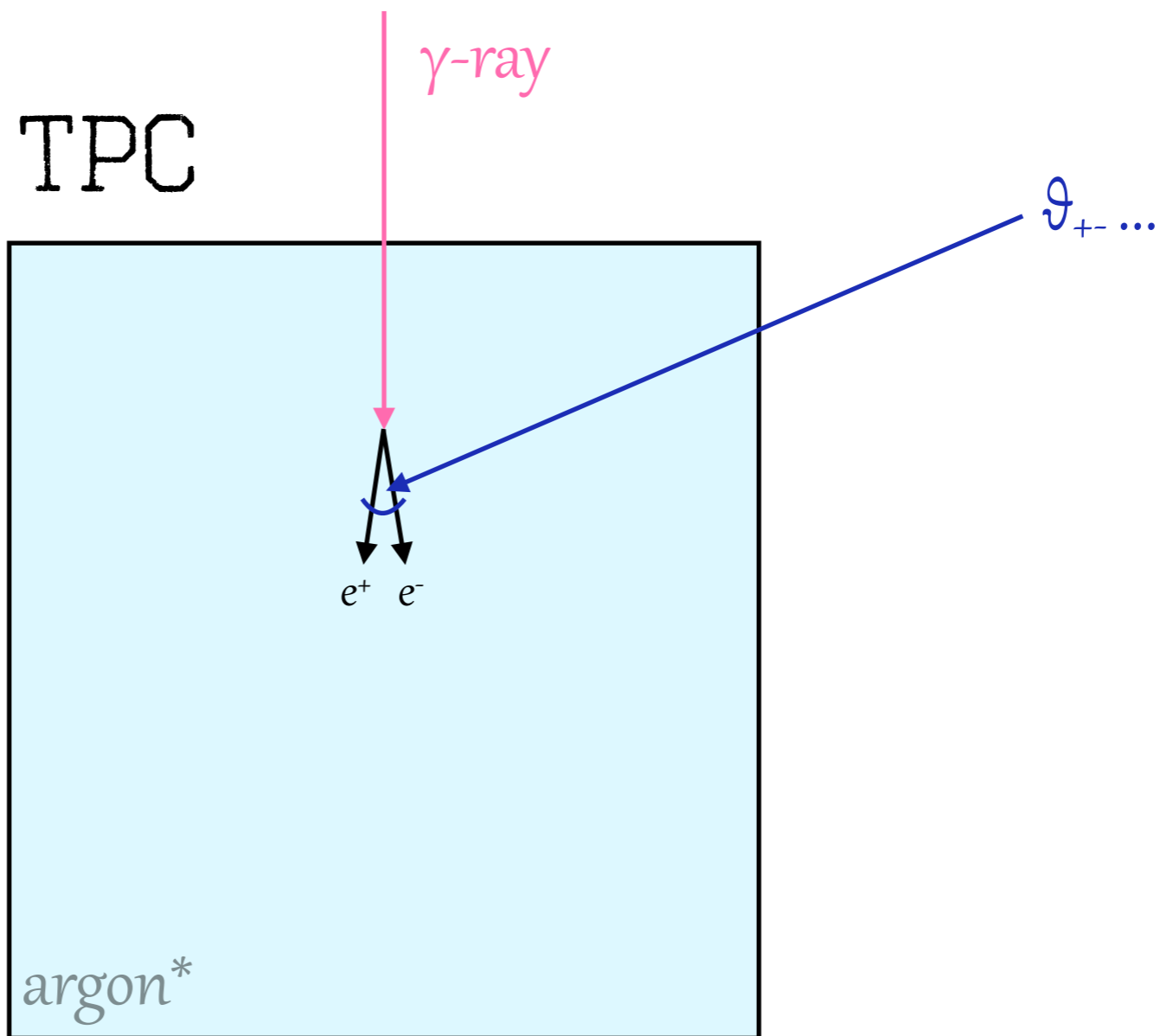
2015

2016

2017

# the Hermatic ARgon POlarimeter (2012 - 2017)

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



\*mostly

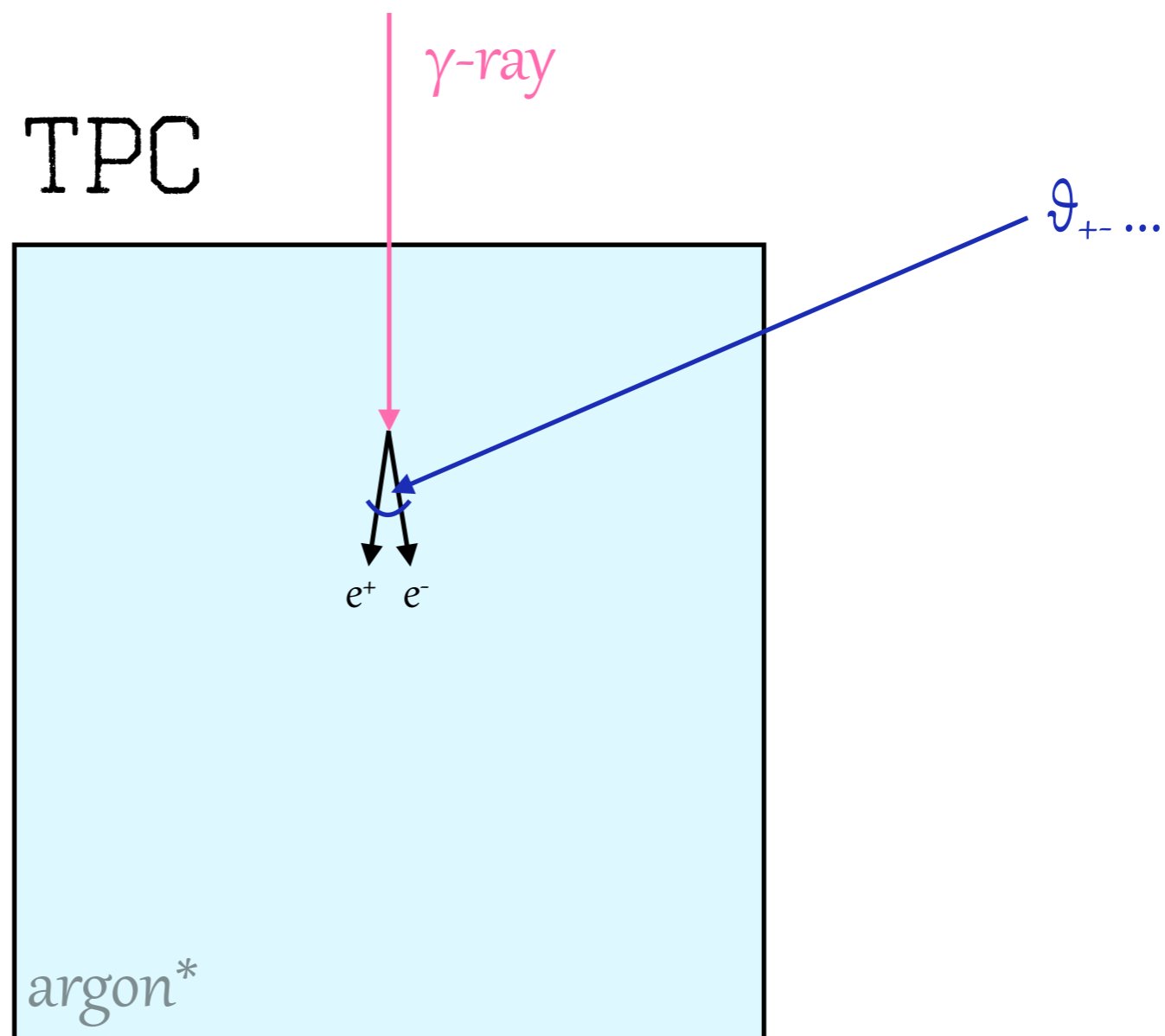


Ground phase



# the Hermatic ARgon POlarimeter (2012 - 2017)

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



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

\*mostly

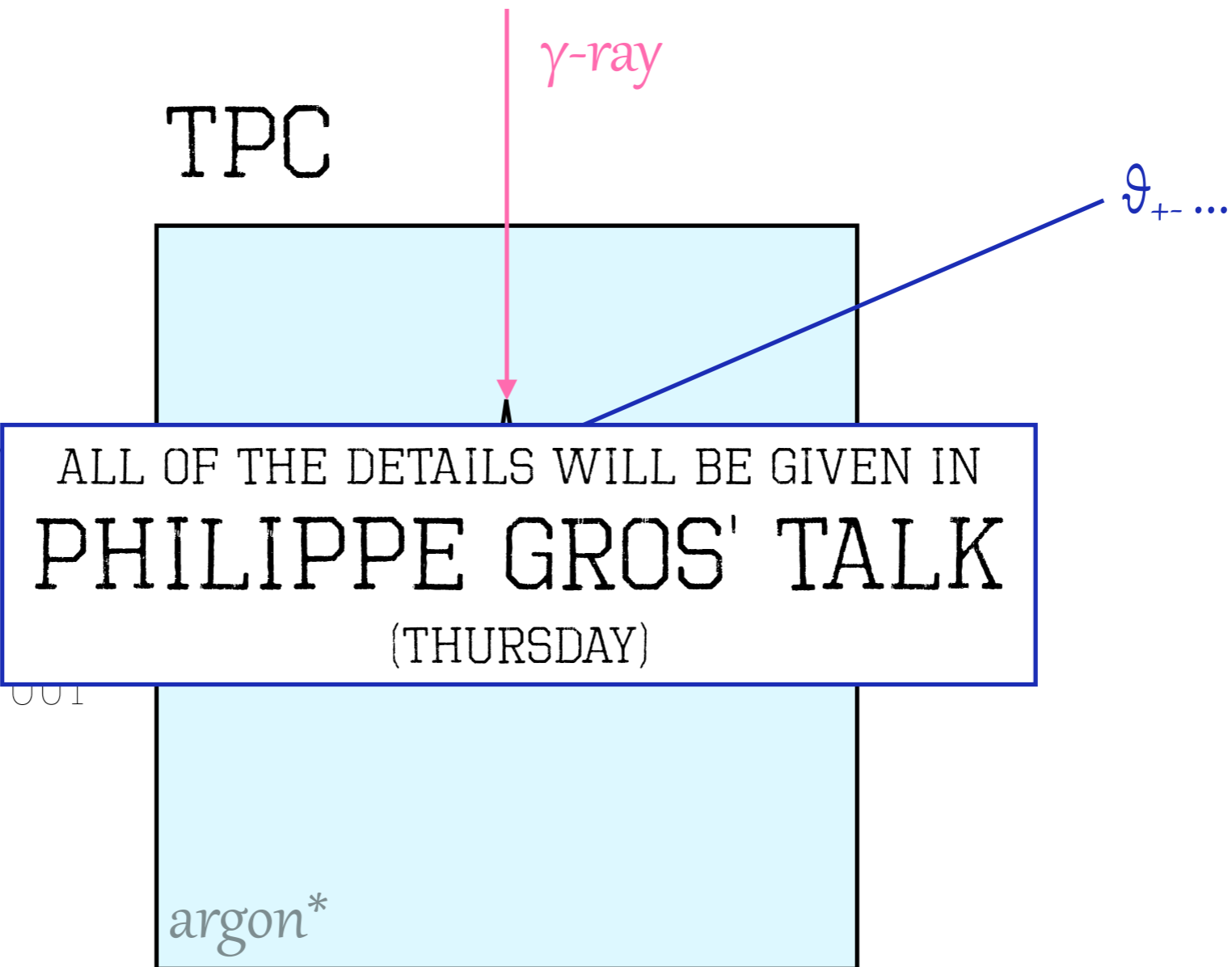


Ground phase



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2012

2013

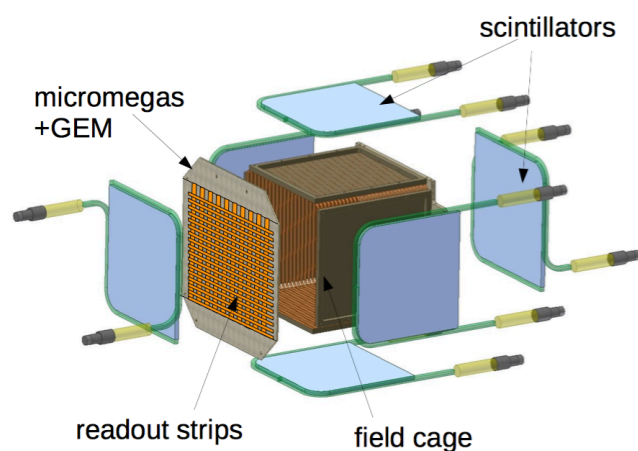
2014

2015

2016

2017

## the Hermetic ARgon POLarimeter (2012 - 2017)







# Ground phase

2012

2013

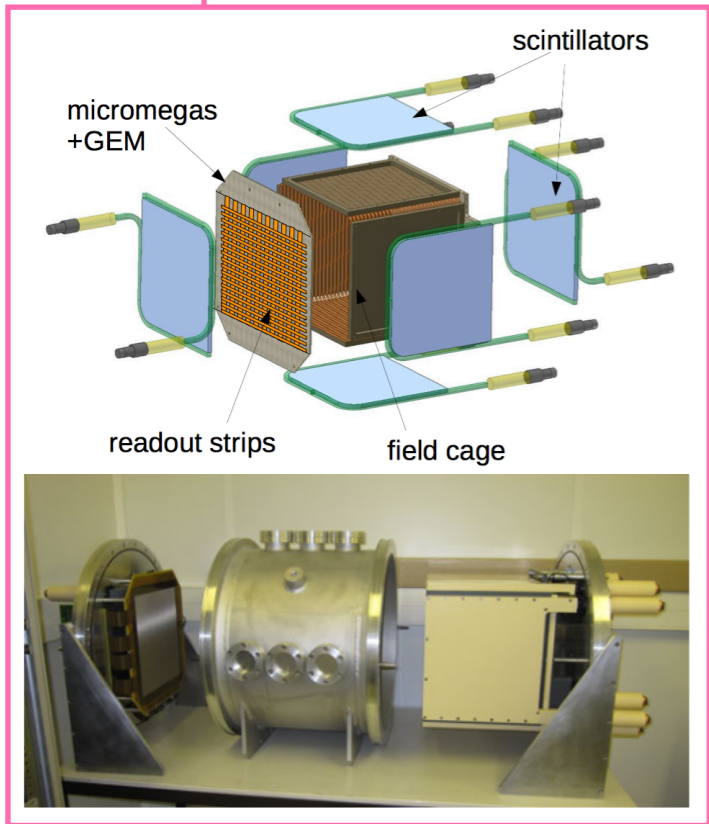
2014

2015

2016

2017

# the Hermatic ARgon POLarimeter (2012 - 2017)



**Polarimetry of cosmic gamma-ray sources above e<sup>+</sup>e<sup>-</sup> pair creation threshold**  
 D. Bernard\*  
 ILL, 60610 Meyzieux, CNRS/IN2P3, 91128 Palaiseau, France

**ARTICLE INFO**  
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**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 SPINIC event generator.  
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**1. A science case for gamma polarimetry**  
 In many sources of gamma rays, the models proposed to explain the emission have very different polarization signatures. Depending

**TPC in  $\gamma$ -ray astronomy above pair-creation threshold**  
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 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 [300–600] MeV energy range, even with the modest detector parameters of this study. In addition, gas TPCs show an improvement in angular resolutions of about one order of magnitude.  
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**1. Introduction**  
 High-energy astrophysics focuses on the study of complex objects such as active galactic nuclei (AGNs), pulsars and  $\gamma$ -ray bursts (GRBs), the spectral energy distributions (SEDs) of which complex contributions from a number of processes [1], including synchrotron emission, synchrotron self-Compton scattering (SSC), the inverse scattering of external thermal photons from the accretion disk (ED), and  $\pi^0$  decays. These studies suffer from the existence of gaps in the sensitivity of the available instruments, such as that between the Compton-scattering-based telescopes, that are mostly sensitive below 1 MeV, and the pair-based telescopes, that are mostly sensitive above 100 MeV. Pair-based telescopes also suffer from a poor angular resolution at low energy, making the analysis of these regions of the sky difficult.  
 In this paper we present a characterization of the use of a thin-electron as an active target for cosmic  $\gamma$ -ray detection in the pair-creation regime, with the aim of improving the angular resolution and the sensitivity at low energy. The past missions and the presently operated Fermi/LAT and AGILE use thick detectors for which the photon conversion probability is close to unity and the effective area  $A_{\text{eff}}$  is the product of the geometrical area of the detector  $A$  and the reconstruction efficiency  $\epsilon$ :  
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2012

2013

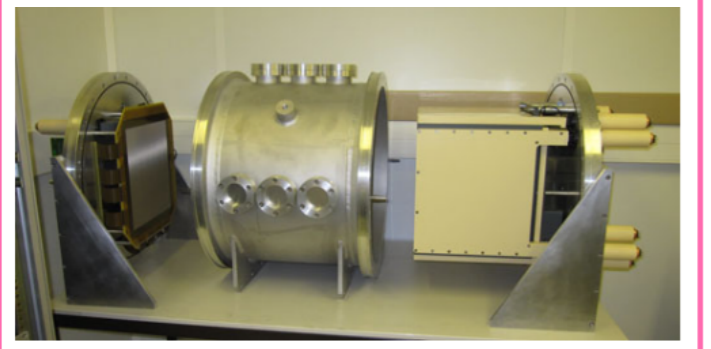
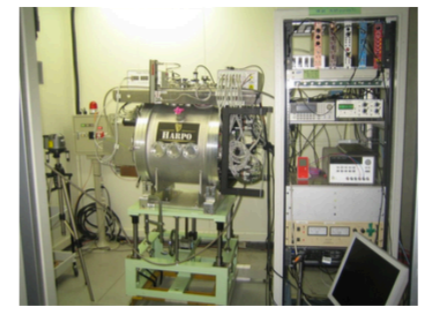
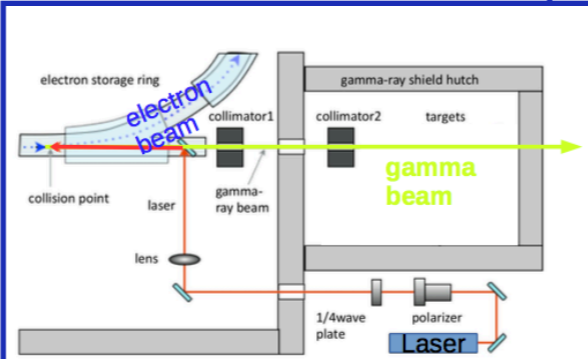
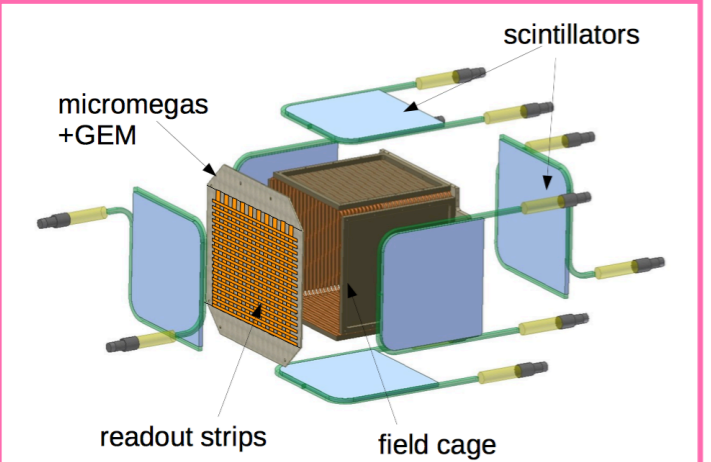
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2015

2016

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**Polarimetry of cosmic gamma-ray sources above e<sup>+</sup>e<sup>-</sup> pair creation threshold**  
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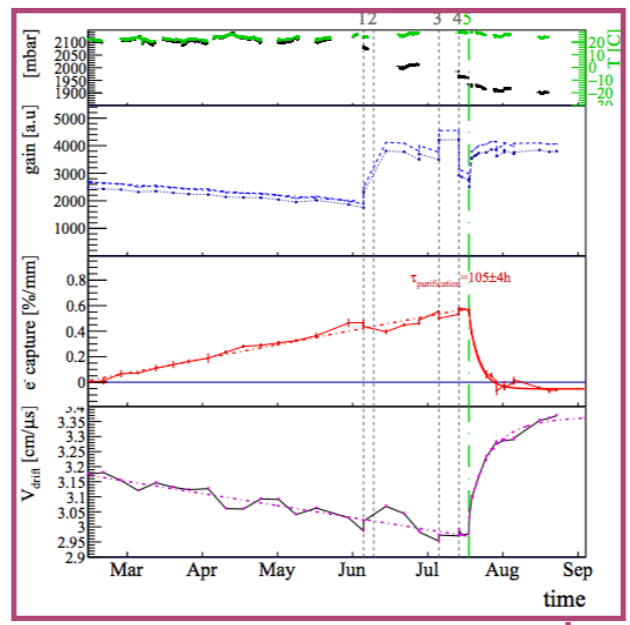
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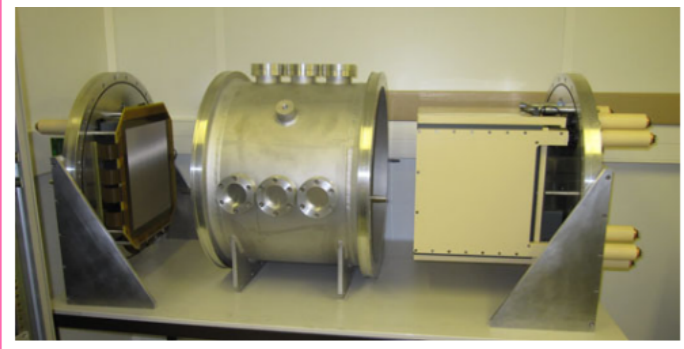
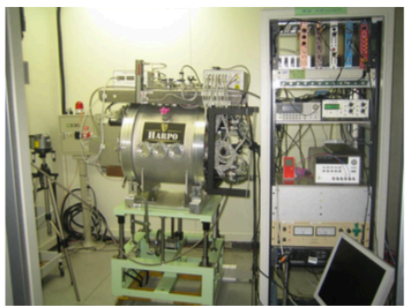
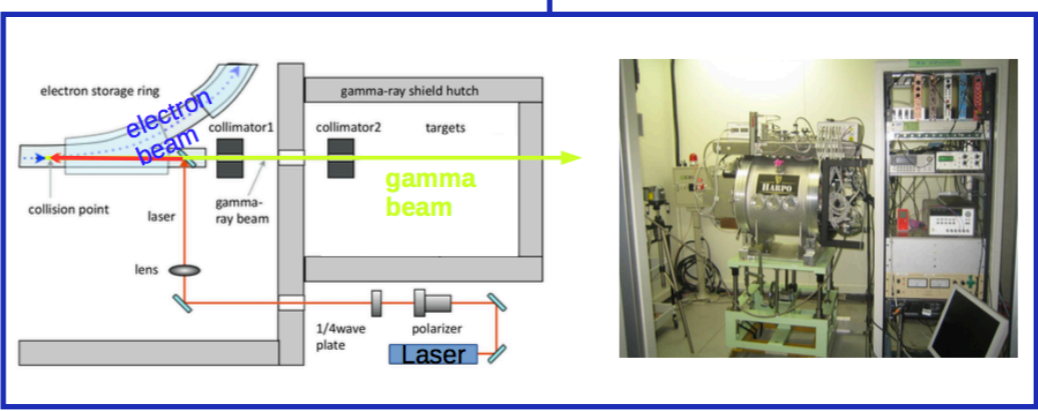
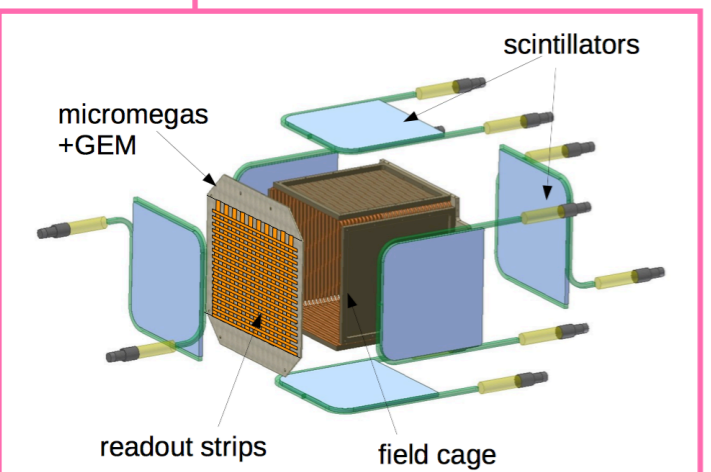
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# Ground phase



# the Hermetic ARgon POLarimeter (2012 - 2017)



Nuclear Instruments and Methods in Physics Research A 720 (2013) 705–710

Contents lists available at ScienceDirect

Nuclear Instruments and Methods in Physics Research A

Journal homepage: [www.elsevier.com/locate/nima](http://www.elsevier.com/locate/nima)

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LLR, Univ Polytéchnique, CNRS/IN2P3, 91128 Palaiseau, France

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ARTICLE INFO

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- Accepted 13 July 2013
- Available online 4 August 2013

Keywords:

- Polarimetry
- Gamma rays
- TPC
- Pair conversion
- Event generator

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We examine the potential of 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-ray sources. For this purpose we implement, validate and use an event generator based on the GEANT4 amplitude calculator and on the SPRING event generator.

We characterize several ways to improve the polarization sensitivity by the selection of a fraction of the events in a subset of the available phase space and are found to be ineffective, due to the lack in statistics. The use of an optimal variable that isolates the full  $50\%$  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 parameterize the depolarization of the precision due to experimental effects such as multiple scattering. In a detector made with a succession of converter slabs and nuclear 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 where tracking and triggering 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 10% like source on the full energy range to be approximately 1.4%.

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In Section 1 we present a physics case for gamma polarimetry in the MeV–GeV photon energy range. Section 2 is an introduction to the measurement technique, focused on pair conversion. In Section 3 various aspects of the measurement are studied at generator level, that is in the absence of any experimental effect. The generator is validated by comparison with published results based on analytical calculations. The distributions of several kinematic variables of interest, such as the opening angle and the transferred momentum, are studied. Some differences between nuclear and triplet conversion are pointed out. We examine several past proposals to improve the  $P$  sensitivity, after which we apply the technique of “optimal variables” to make use of all the information present in the  $50\%$  probability density function (pdf). We then study the effects of multiple scattering and of experimental cases in Section 5. Finally we describe the performance of a realistic detector, a 1 m<sup>3</sup> 5-bar-argon gas TPC.

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1. A science case for gamma polarimetry

In many sources of gamma rays, the models proposed to explain the emission have very different polarization signatures. Depending

on the orientation of the magnetic field at the source and on the primary emission mechanisms, different degrees and directions of polarization are anticipated. Gamma-ray polarimetry can therefore be used to probe the nature and geometry of many objects including pulsars, binary systems, gamma-ray bursts and active galactic nuclei. In neutron-powered pulsars (RNPs), the pulsed, non-thermal radiation from relativistic particles in the magnetosphere of the neutron star is highly beamed along its magnetic field lines. This means that the emitted radiation should be highly polarized either parallel or perpendicular to the field lines [1]. Although the different high-energy emission models share common emission mechanisms, these processes occur at different locations in the pulsar system depending on the geometry of the particular emission model. Thus, the polarization signatures of these models are expected to differ greatly from each other. Ref. [2] shows the different polarization signatures expected at optical wavelengths. Similar degrees of polarization are expected in the self-steady energy range but with a different polarization angle [3]. This energy-dependent variation of the polarization direction could be used to locate the sites of emission and to probe the emitting particle population and their energies [3]. Polarized high-energy emission has also been detected from the Crab pulsar wind nebula (PWN) between 200 keV and 800 keV [4] and between 100 keV and 1 MeV [5]. In both cases the polarization was aligned with the spin axis of the neutron star.

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**TPC in  $\gamma$ -ray astronomy above pair-creation threshold**

D. Bernard\*

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ARTICLE INFO

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- TPC
- Pair production
- Angular resolution
- Sensitivity

ABSTRACT

We examine the performance of a TPC as a  $\gamma$ -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. Ideally, the measurement of track momenta 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 [300 keV–GeV] energy range, even with the modest detector parameters of this study. In addition, gas TPCs show an improvement in angular resolution of about one order of magnitude.

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1. Introduction

High-energy astrophysics focuses on the study of complex objects such as active galactic nuclei (AGN), pulsars and  $\gamma$ -ray bursts (GRB), the spectral energy distributions (SEDs) of which comprise contributions from a number of processes [1], including synchrotron emission, synchrotron self-Compton scattering (SSC), the inverse scattering of external thermal photons from the accretion disk (EDSC) and  $m^0$  decays. These studies suffer from the existence of gaps in the sensitivity of the available instruments, such as that between the Compton-scattering-based telescopes, that are mostly sensitive below 1 MeV, and the pair-based telescopes, that are mostly sensitive above 100 MeV. Pair-based telescopes also suffer from a poor angular resolution at low energy, making the analysis of dense regions of the sky difficult.

In this paper we present a characterization of the use of a thin-conversion region, with the aim of improving the angular resolution and the sensitivity at low energy. The past missions and the presently operated Fermi/LAT and AGILE use thick detectors for which the photon conversion probability is close to unity and the effective area  $A_{\text{eff}}$  is the product of the geometrical area of the detector  $A$  and the reconstruction efficiency  $\epsilon_r$ :  $A_{\text{eff}} = A \cdot \epsilon_r$ . In a thin detector for which the conversion probability is small, the effective area becomes proportional to the pair-conversion mass attenuation coefficient  $\mu$  and to the detector

mass  $M$ :  $A_{\text{eff}} = \mu \cdot M \cdot \epsilon_r$ . In a thick detector, the optimization of the aspect ratio (height/surface) is therefore critical, while for a thin detector it does not affect the effective area to first order. Note that in a thick detector, the various possible conversion processes are in competition with each other, and Compton scattering prior to  $e^+e^-$  pair creation would become a problem at the lowest energy if low  $Z$  material were considered, an effect strongly reduced for a thin detector. A sample of previous works on the use of gas detectors for the detection of cosmic  $\gamma$  rays above the pair-creation threshold, sometimes in relation with a Compton telescope, can be found in Refs. [2–4].

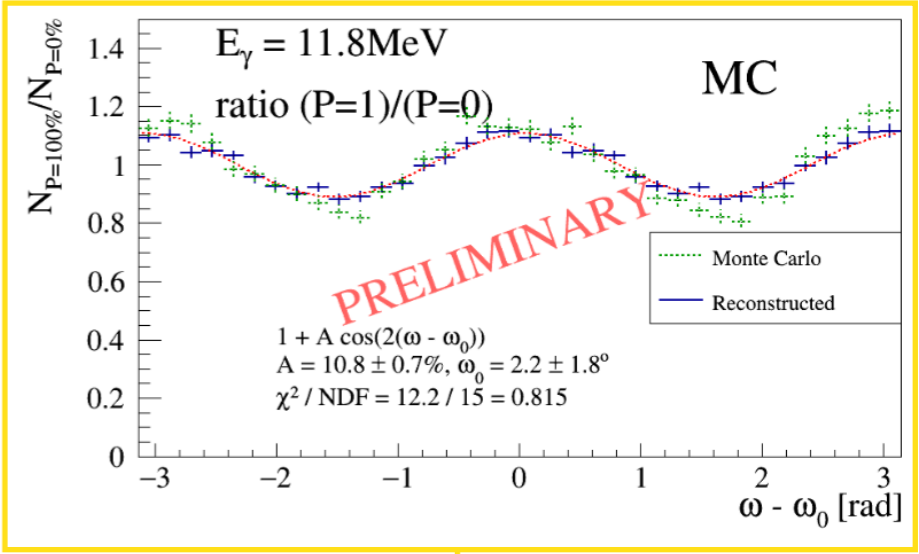
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2. Test detector parameters

We use a time projection chamber (TPC) as a test model of a thin detector. A TPC is a chunk of homogeneous matter, located inside a (nearly) uniform electric field  $E$  [5], and a recent review [6]. Charged tracks crossing the TPC ionize atoms/molecules in their paths, after which the ionization electrons drift to the anode plane where (in a gas TPC) they are amplified, and collected. The collecting plane can be segmented so as to provide two coordinates  $x, y$  of the location of the ionization. The third coordinate  $z$  is provided by the drift time  $t$ :  $z = v_d \cdot t$ . The drift velocity  $v_d$  ranges from  $\sim 10^7$  cm/s at saturation for liquids and solids, to  $v_d = 0$  (cm/s) for gases when used with an appropriate quencher. A multi-atomic molecule to which drifting electrons collide and are cooled down. The size of the electron “cloud” increases during the drift due to diffusion, which places a limit on the useable drift

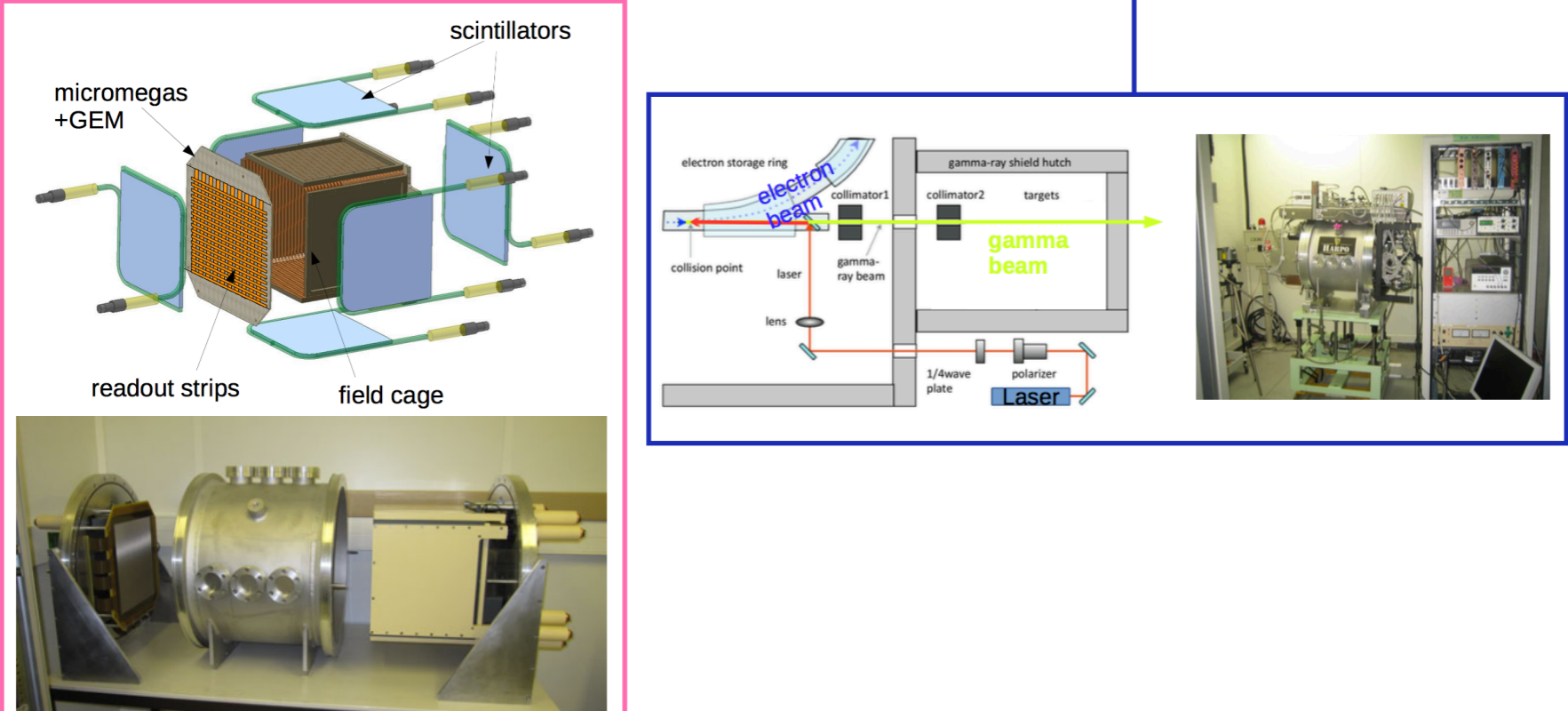
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# Ground phase



2012    2013    2014    2015    2016    2017

## the Hermatic ARgon POlarimeter (2012 - 2017)



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

D. Bernard\*

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**ARTICLE INFO**

**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-ray sources. For this purpose we implement, validate and use an event generator based on the VEGAS amplitude calculator and on the SPRING event generator.

We characterize several ways to improve the polarization sensitivity by the selection of a fraction of the events in a subset of the available phase space are found to be ineffective, due to the lack in statistics. The use of an optimal variable that isolates the full 50% 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 parameterizes the depolarization of the precision due to experimental effects such as multiple scattering. In a detector made with a succession of converter slabs and nuclear 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 tracker 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 detector, and for an effective exposure of 1 year, we estimate the precision for a 100 h source on the full energy range to be approximately 1.4%.

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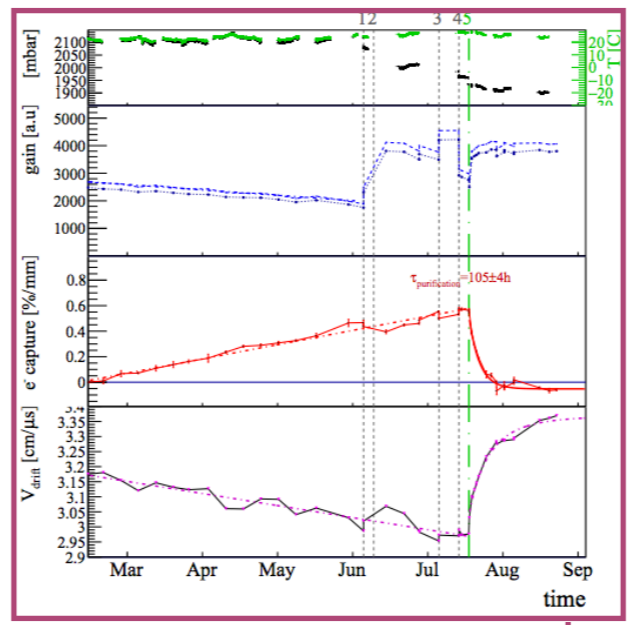
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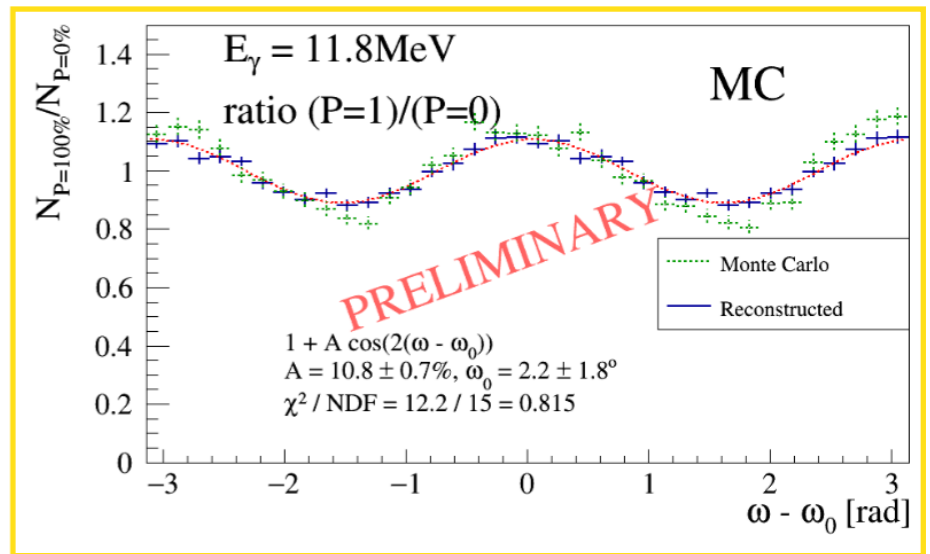
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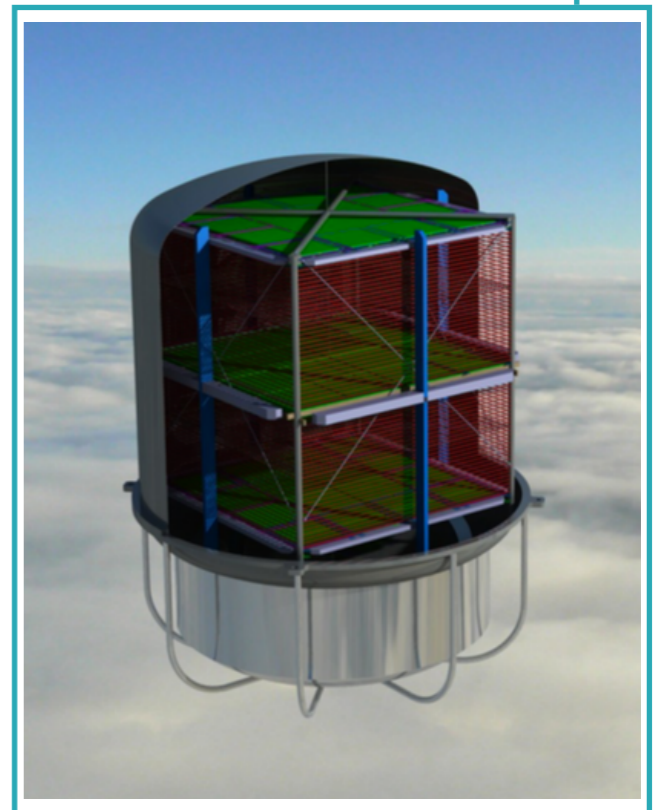
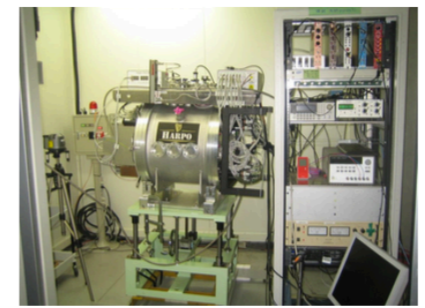
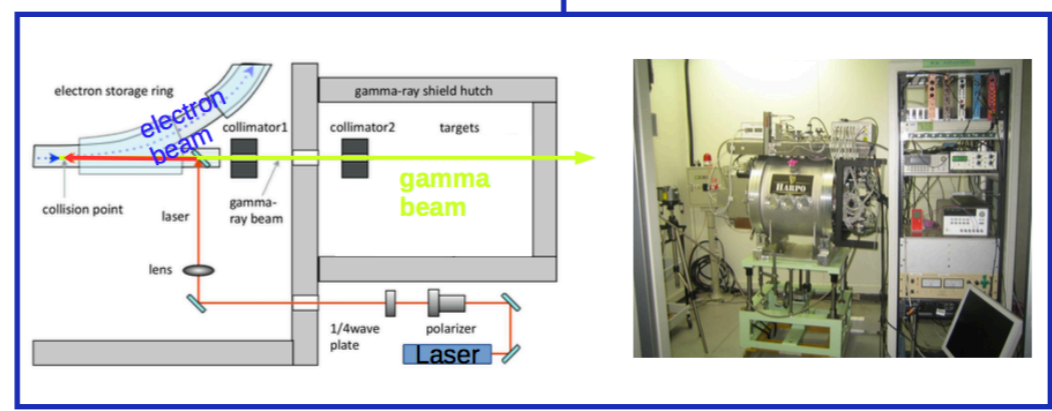
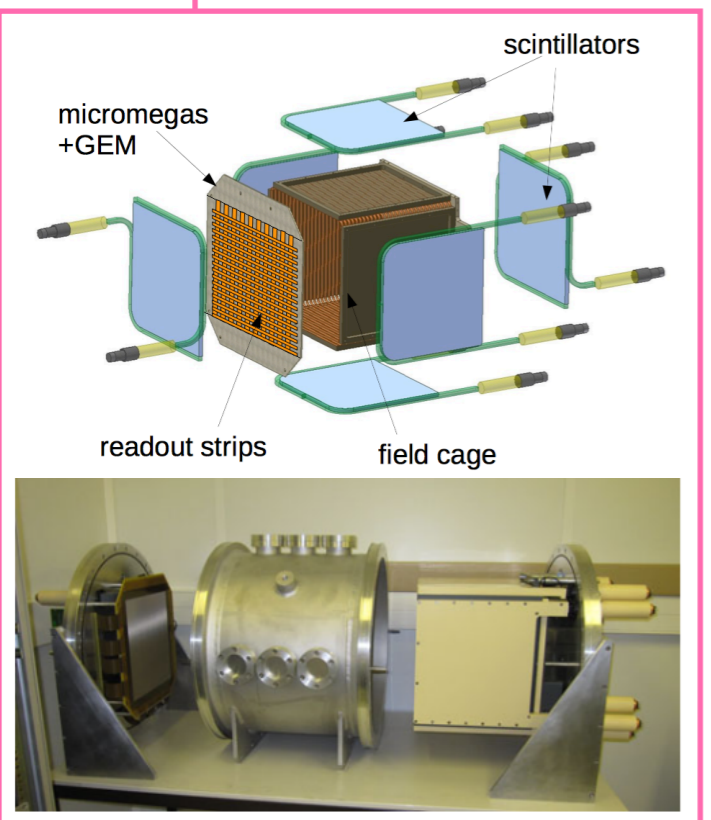


# Ground phase



2012 2013 2014 2015 2016 2017

## the Hermatic ARgon POLarimeter (2012 - 2017)



**Polarimetry of cosmic gamma-ray sources above e<sup>+</sup>e<sup>-</sup> pair creation threshold**

D. Bernard\*  
 ILL, 80570 Meyzieux, CNRS/IN2P3, 91128 Palaiseau, France

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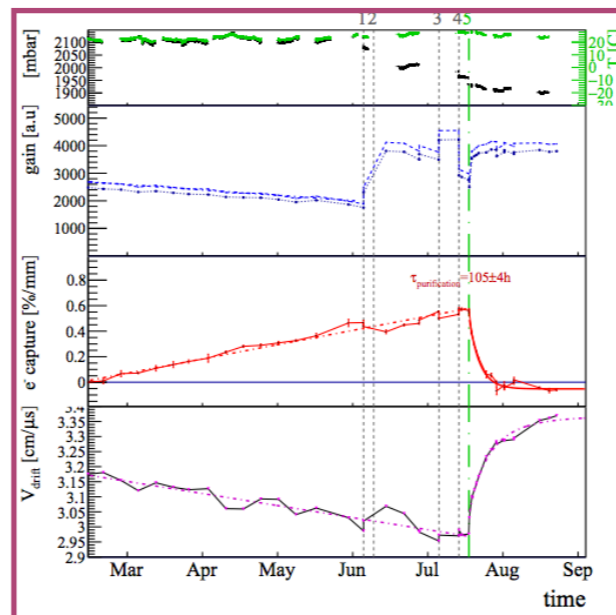
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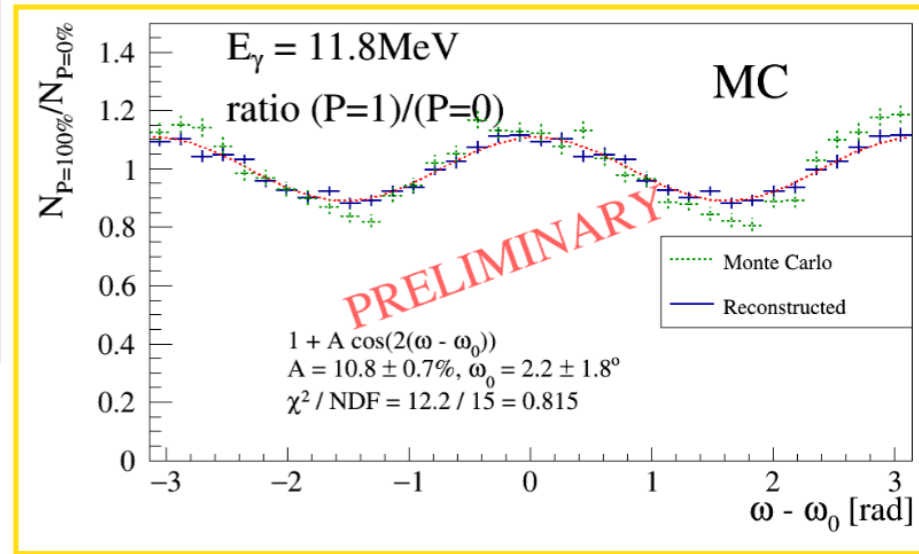
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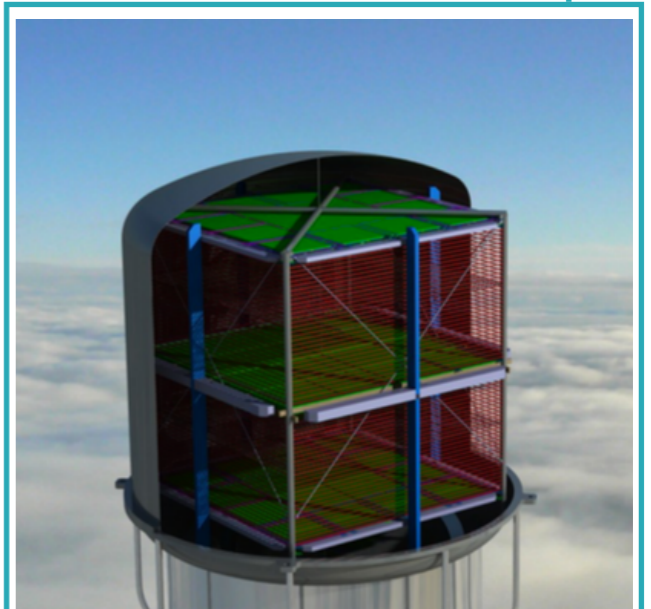
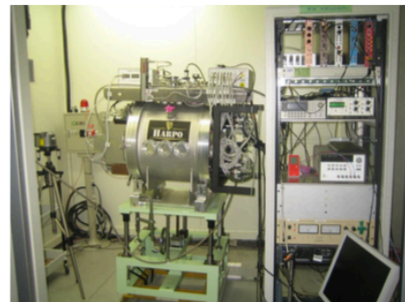
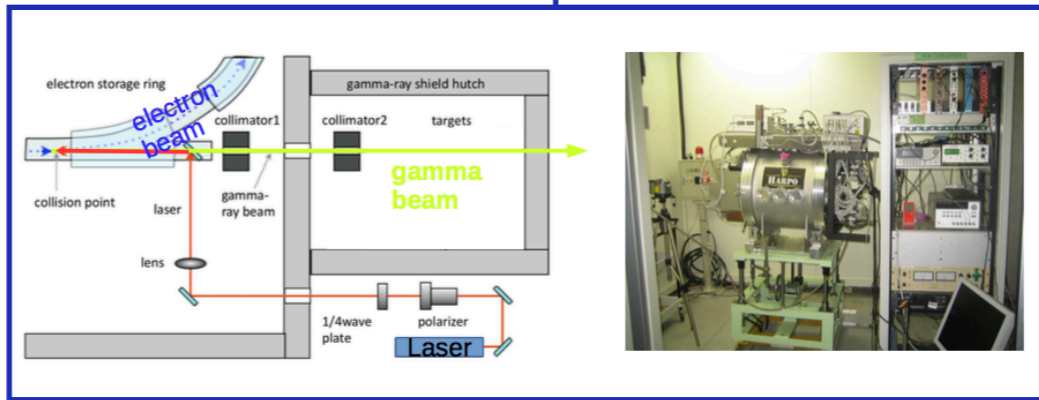
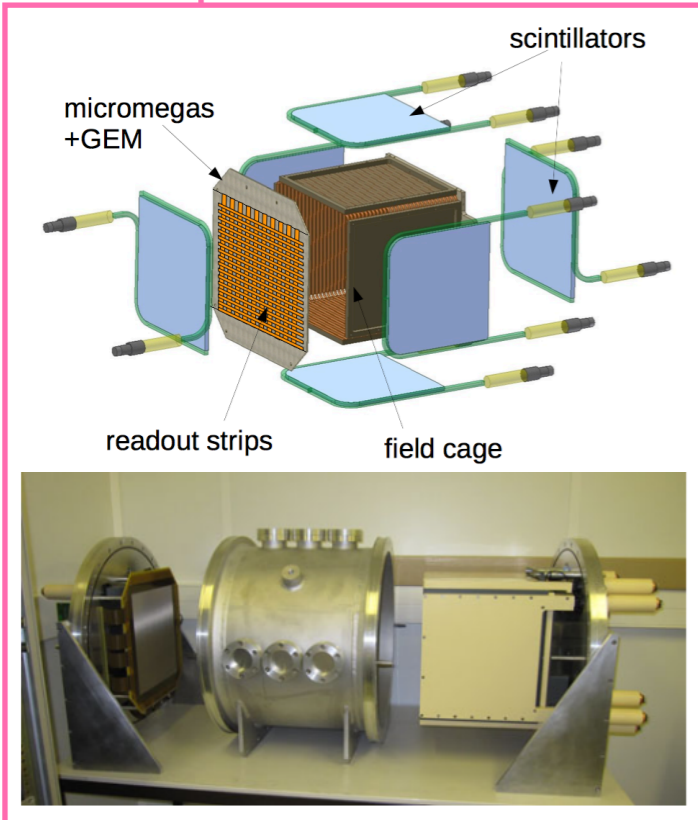


**Ground phase**



2012                                  2013                                  2014                                  2015                                  2016                                  2017

**the Hermatic ARgon POLarimeter (2012 - 2017)**



**Balloon phase**

# Overview of project

## Ground phase



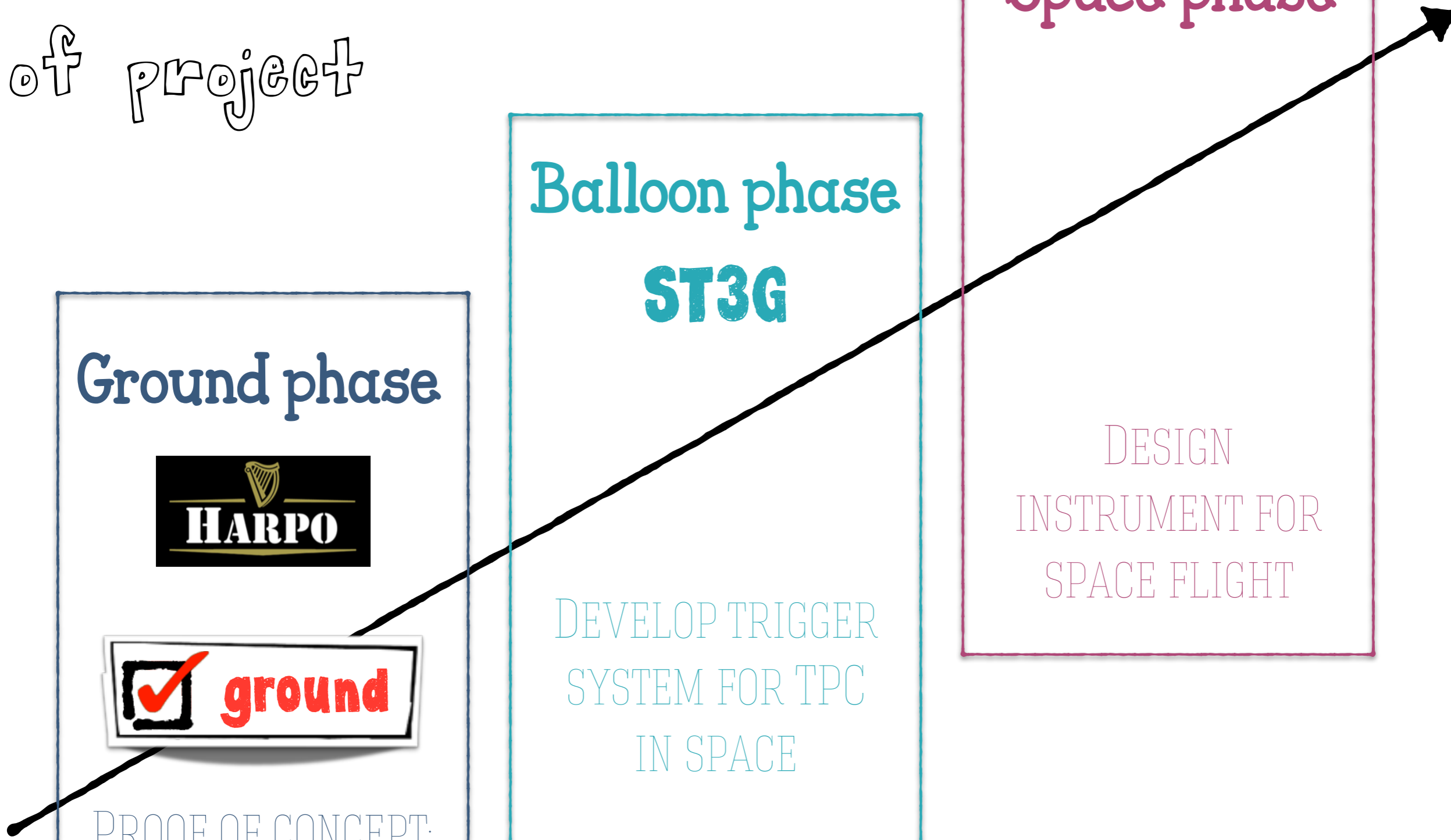
PROOF OF CONCEPT:  
USE TPC TO MEASURE  
POLARISATION

## Balloon phase ST3G

DEVELOP TRIGGER  
SYSTEM FOR TPC  
IN SPACE

## Space phase

DESIGN  
INSTRUMENT FOR  
SPACE FLIGHT



# Overview of project

Space phase

Balloon phase  
ST3G

DESIGN  
INSTRUMENT FOR  
SPACE FLIGHT

Ground phase

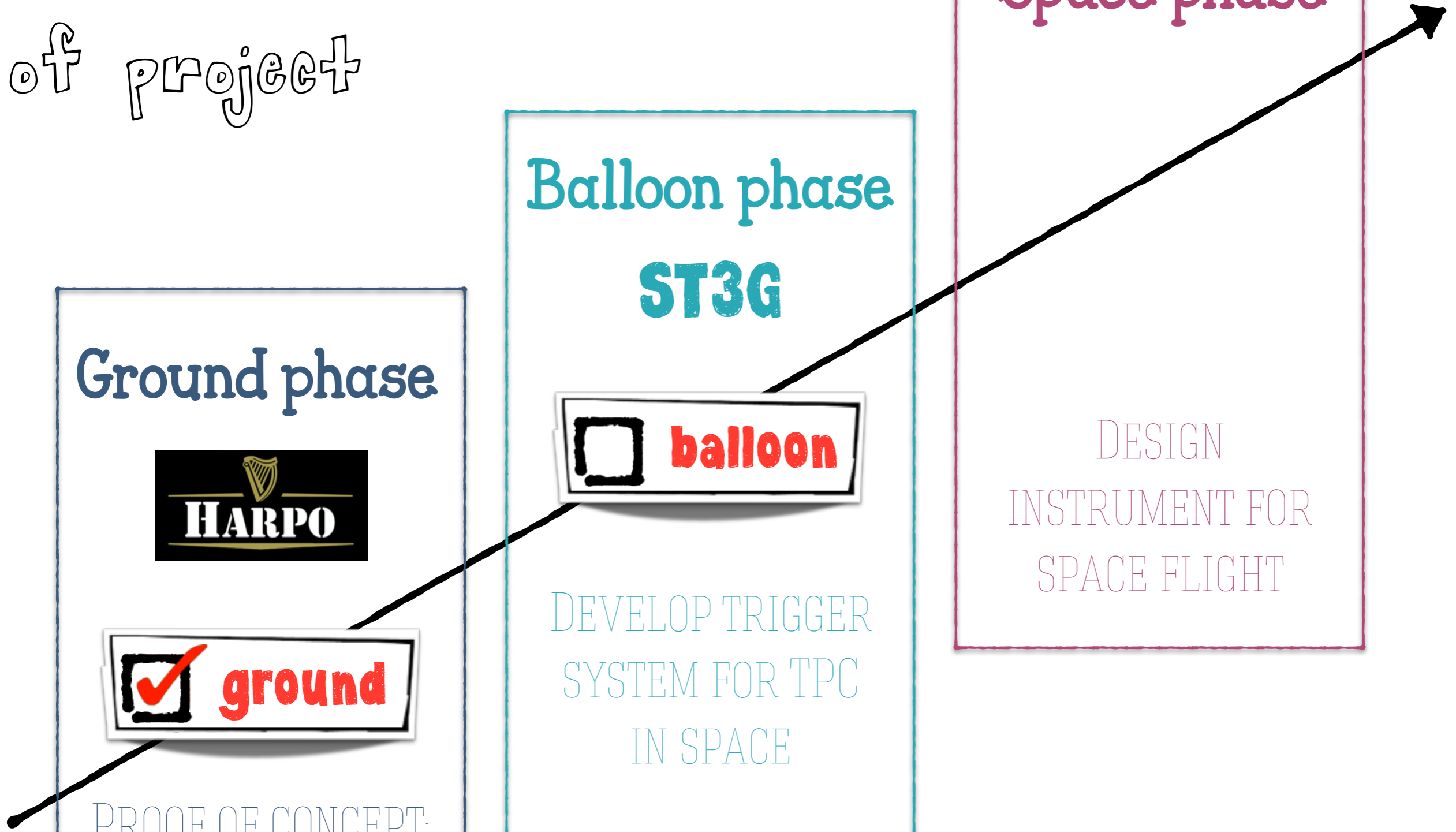


balloon

DEVELOP TRIGGER  
SYSTEM FOR TPC  
IN SPACE

ground

PROOF OF CONCEPT:  
USE TPC TO MEASURE  
POLARISATION





# Balloon phase

## ST3G

DEVELOP TRIGGER  
SYSTEM FOR TPC  
IN SPACE

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

# Balloon phase

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**WE WOULD LIKE TO BUILD A LARGER TEAM OF SCIENTISTS  
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# Balloon phase

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# ST3G

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## KEY CHARACTERISTICS

- ENERGY: A FEW MEV - GEV
- POLARISATION CAPABILITIES
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# ST3G

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- ENERGY: A FEW MEV - GEV\*
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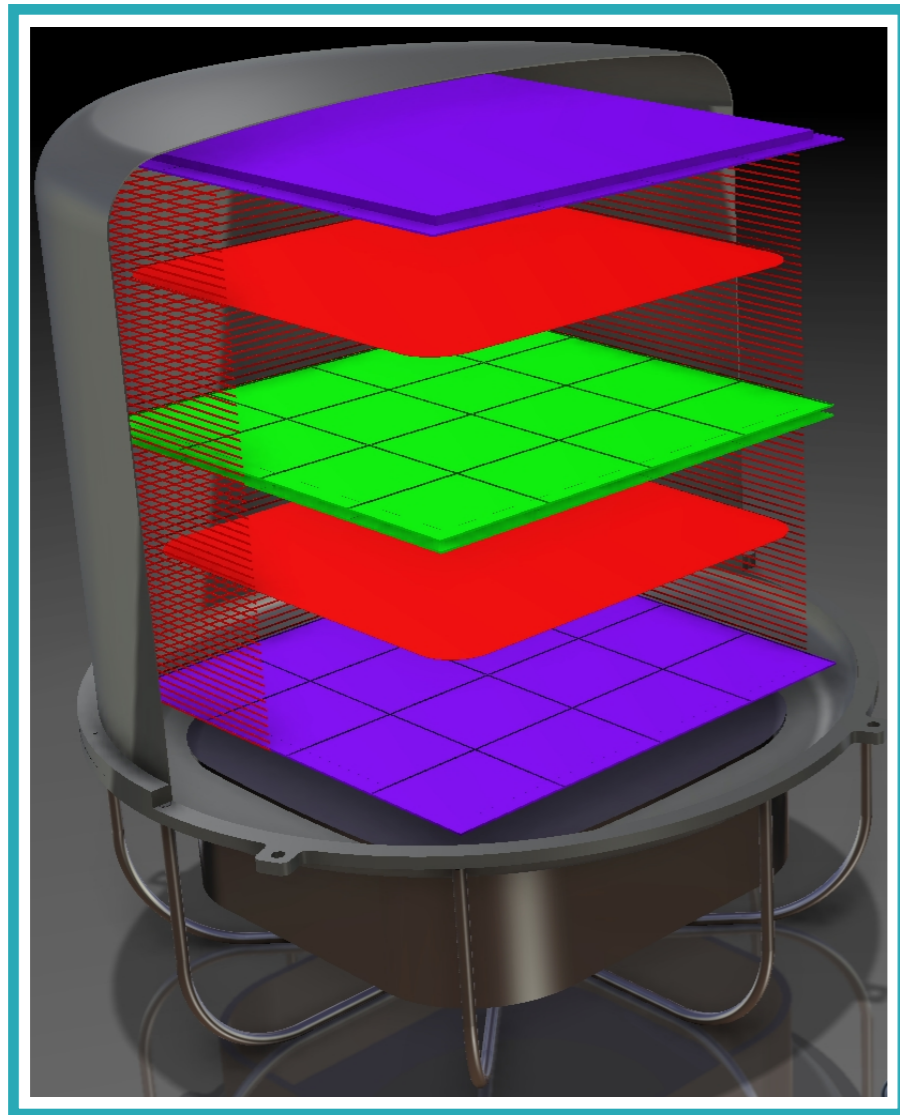
\*WE WILL ONLY HAVE LIMITED  
CAPABILITIES DURING A BALLOON FLIGHT

# ST3G

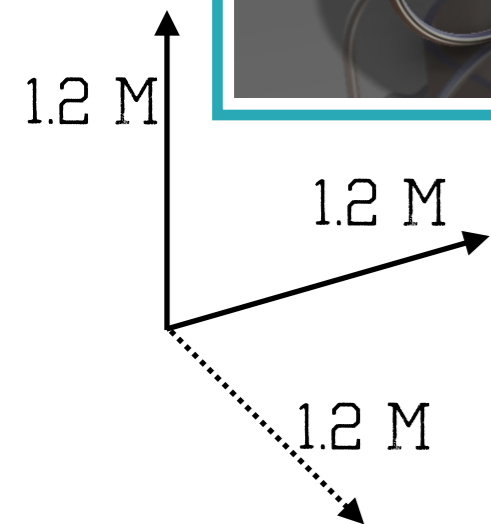
## KEY CHARACTERISTICS OF ULTIMATE INSTRUMENT

- 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

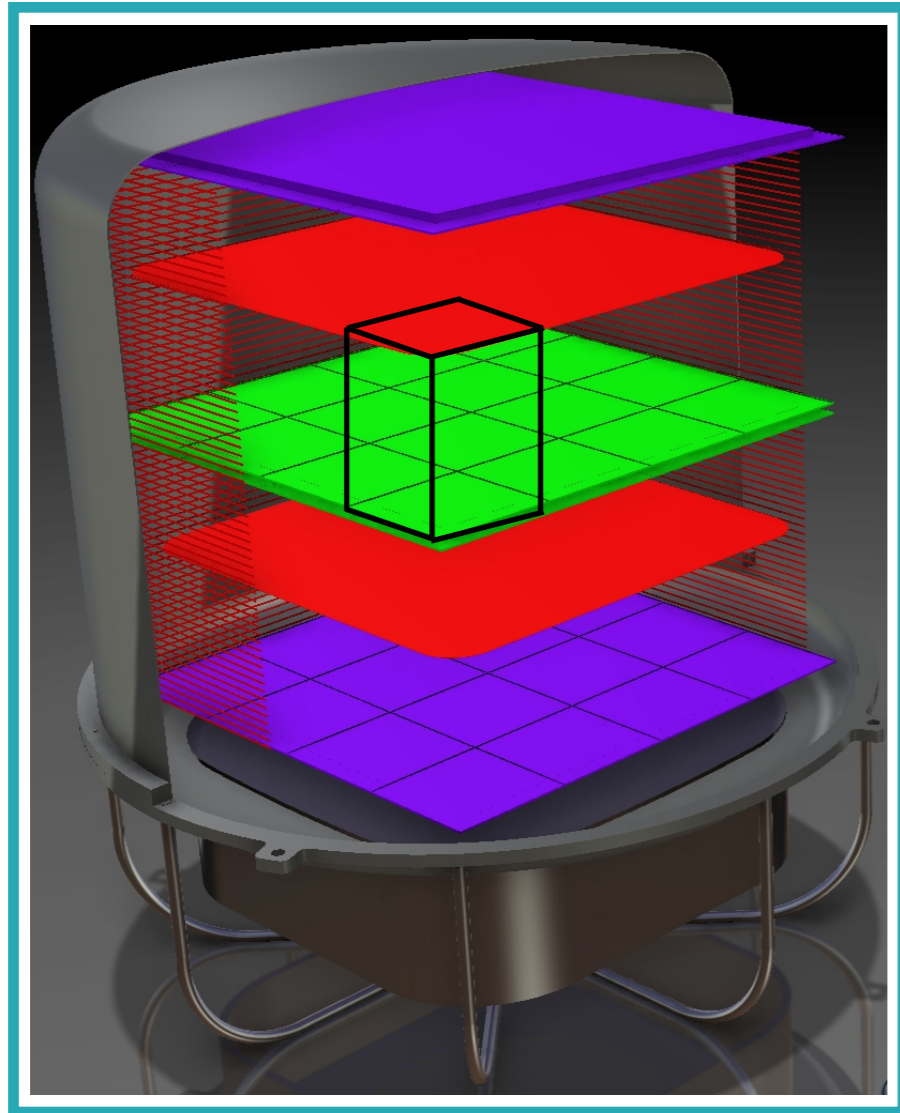
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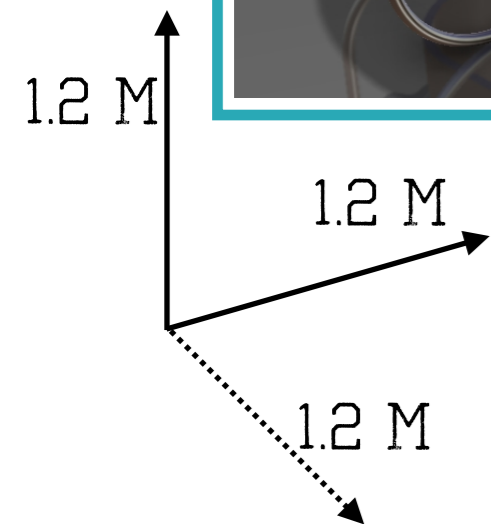
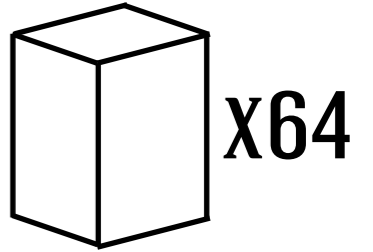
- 64 MODULES :
  - 1 MODULE = HARPO
- 32 TPCS :
  - 2 MODULES WITH A COMMON CATHODE
- 2 BAR ARGON GAS
- READOUT CHIP ASTRE



# ST3G

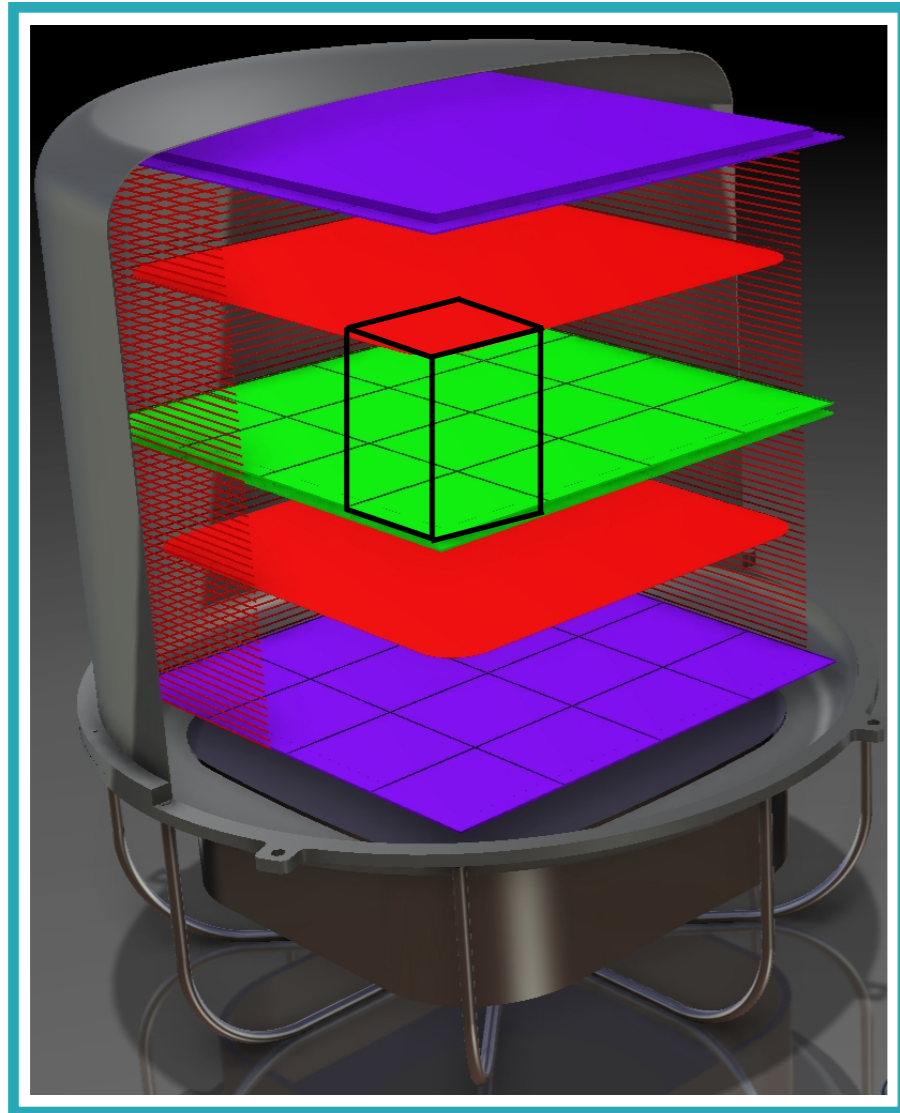


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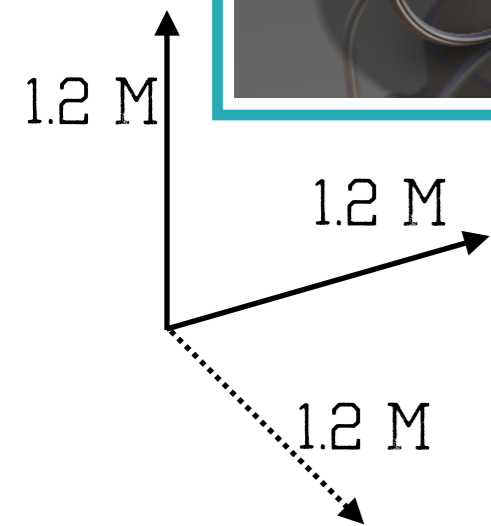
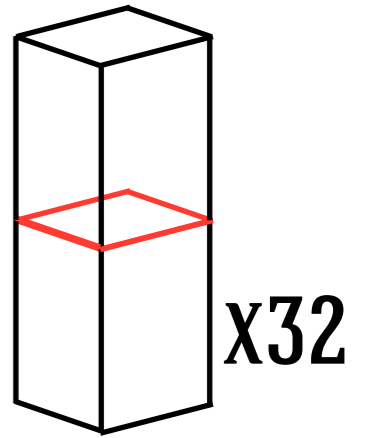




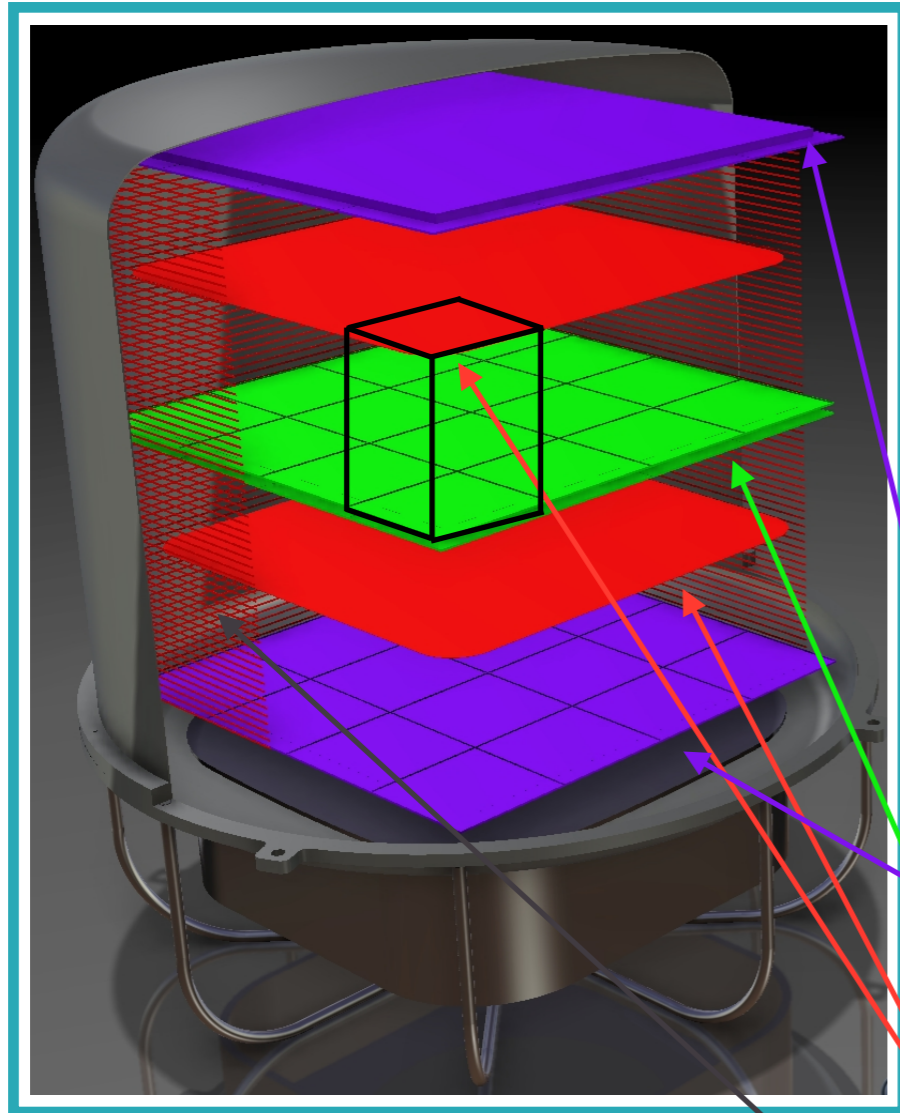
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- 32 TPCS :
  - 2 MODULES WITH A COMMON CATHODE
- 2 BAR ARGON GAS
- READOUT CHIP ASTRE



# ST3G



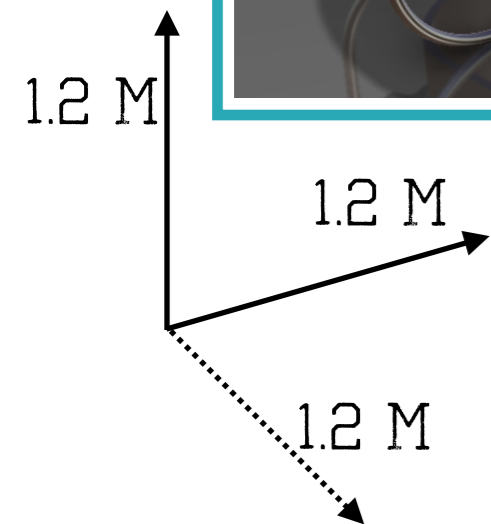
- 64 MODULES :
  - 1 MODULE = HARPO
- 32 TPCS :
  - 2 MODULES WITH A COMMON CATHODE
- 2 BAR ARGON GAS
- READOUT CHIP ASTRE

single amplification plane

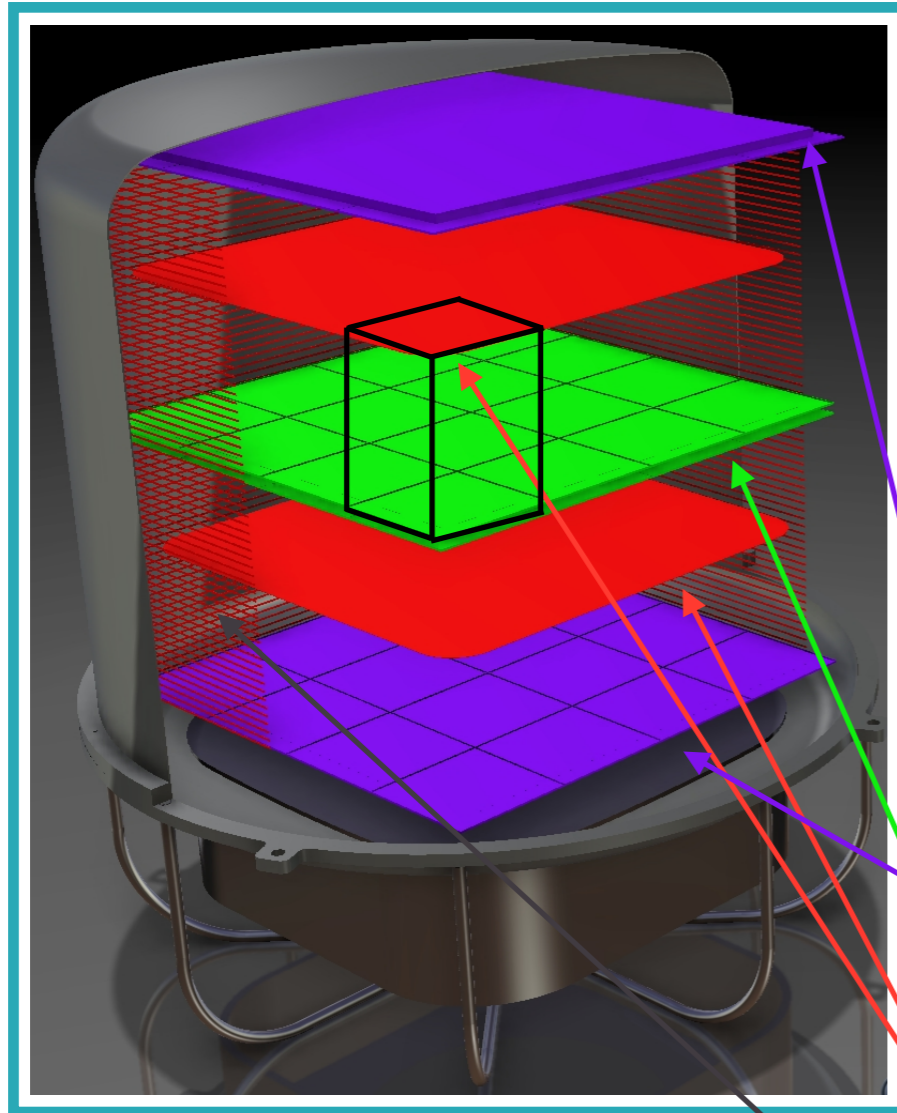
double amplification plane

cathode(s)

drift cage



# ST3G



- 64 MODULES\* :
  - 1 MODULE = HARPO
- 32 TPCS :
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single amplification plane

double amplification plane

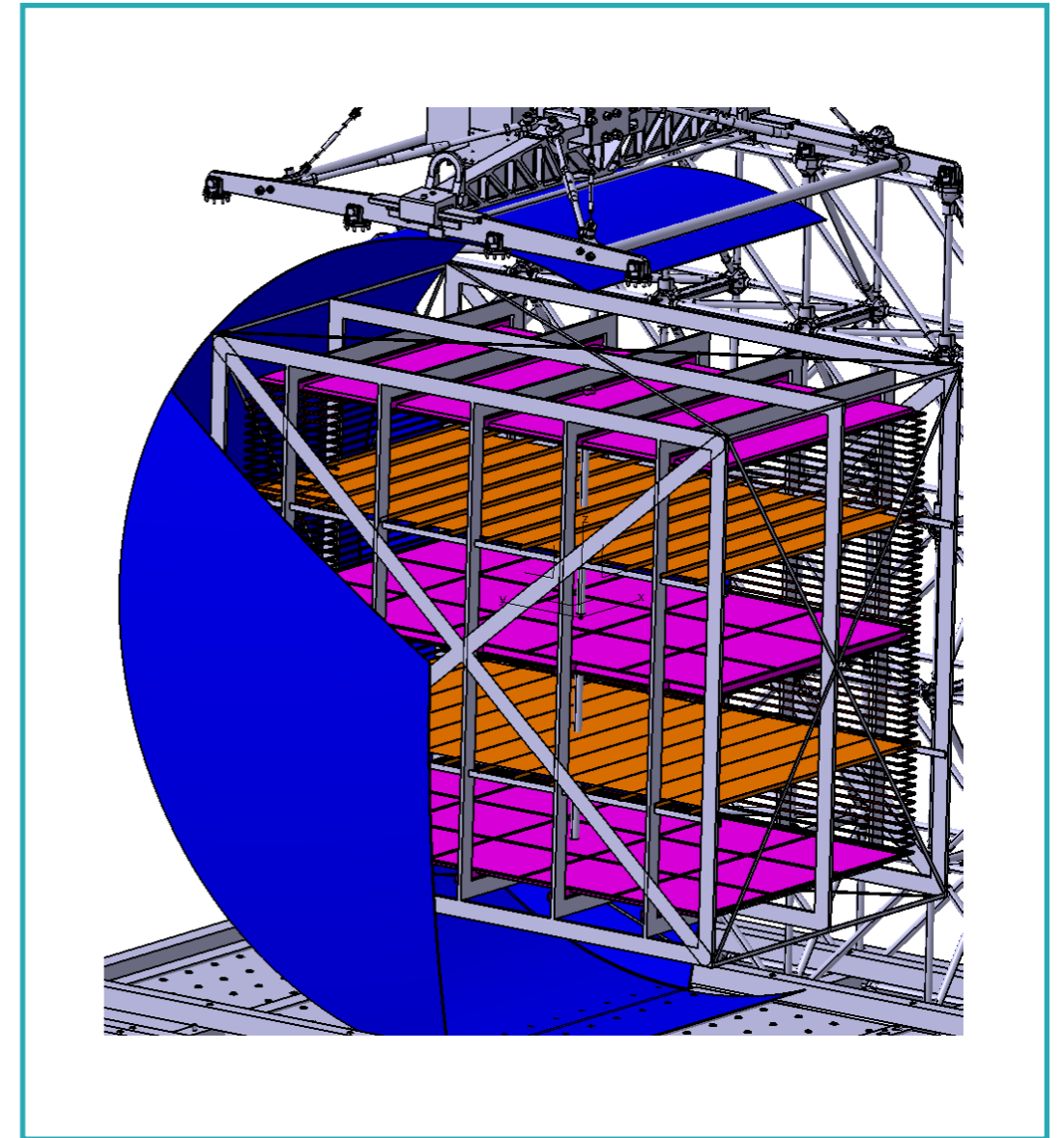
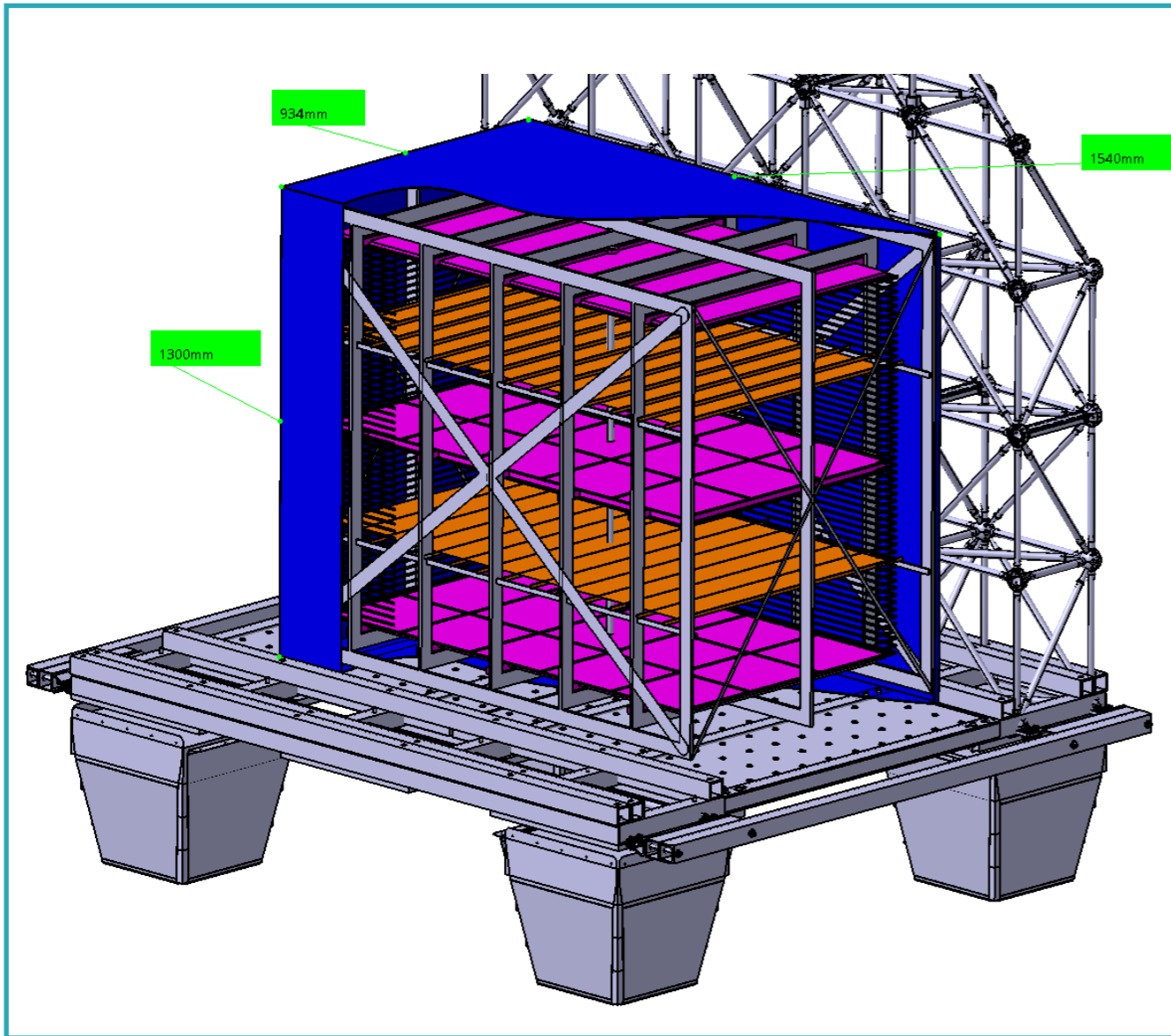
cathode(s)

drift cage

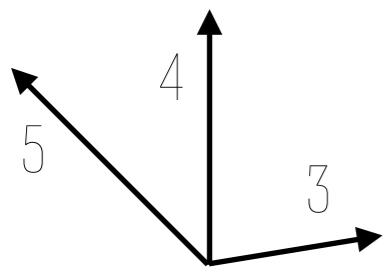
**Note:** \* PLAN TO SWITCH TO 3X4X5 (60 MODULES) DUE TO THE PLATFORM THAT CNES PROPOSE (CARMEN)

1.2 M  
1.2 M  
1.2 M

# ST3G



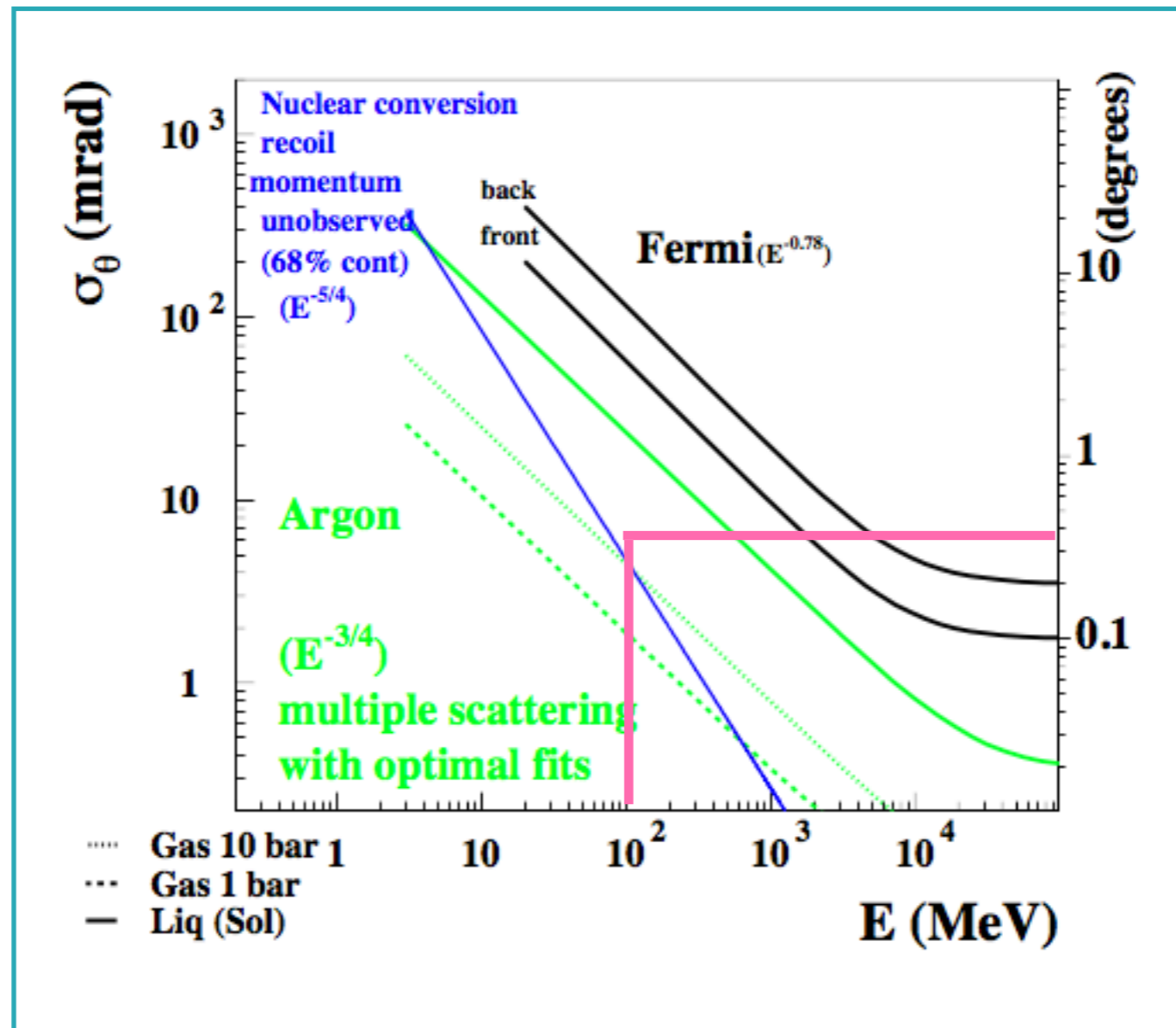
CREDIT: MIKAËL FROTIN



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

# ST3G

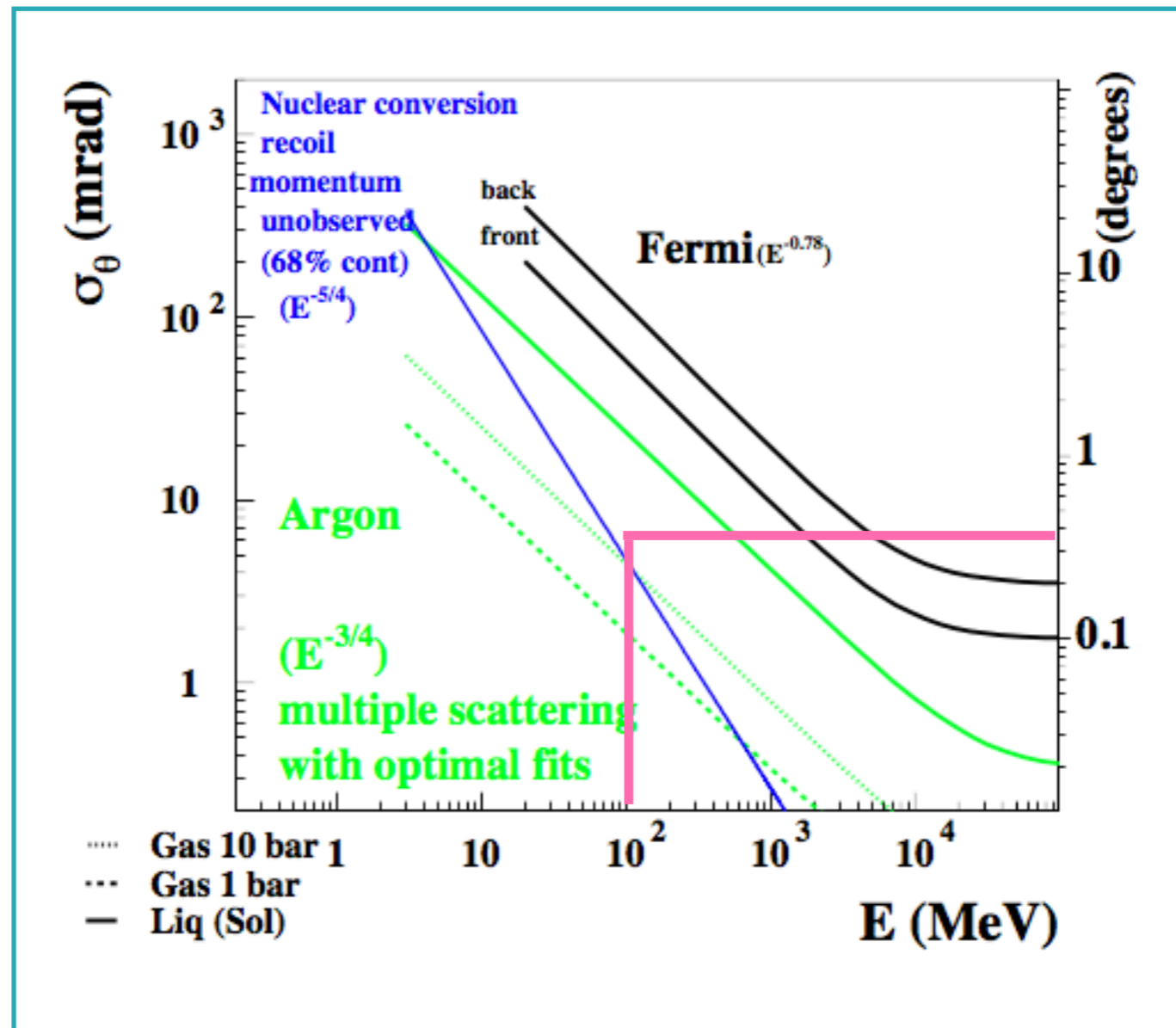
## ANGULAR RESOLUTION



FROM DOCUMENT CIRCULATED BY DENIS

# ST3G

## ANGULAR RESOLUTION

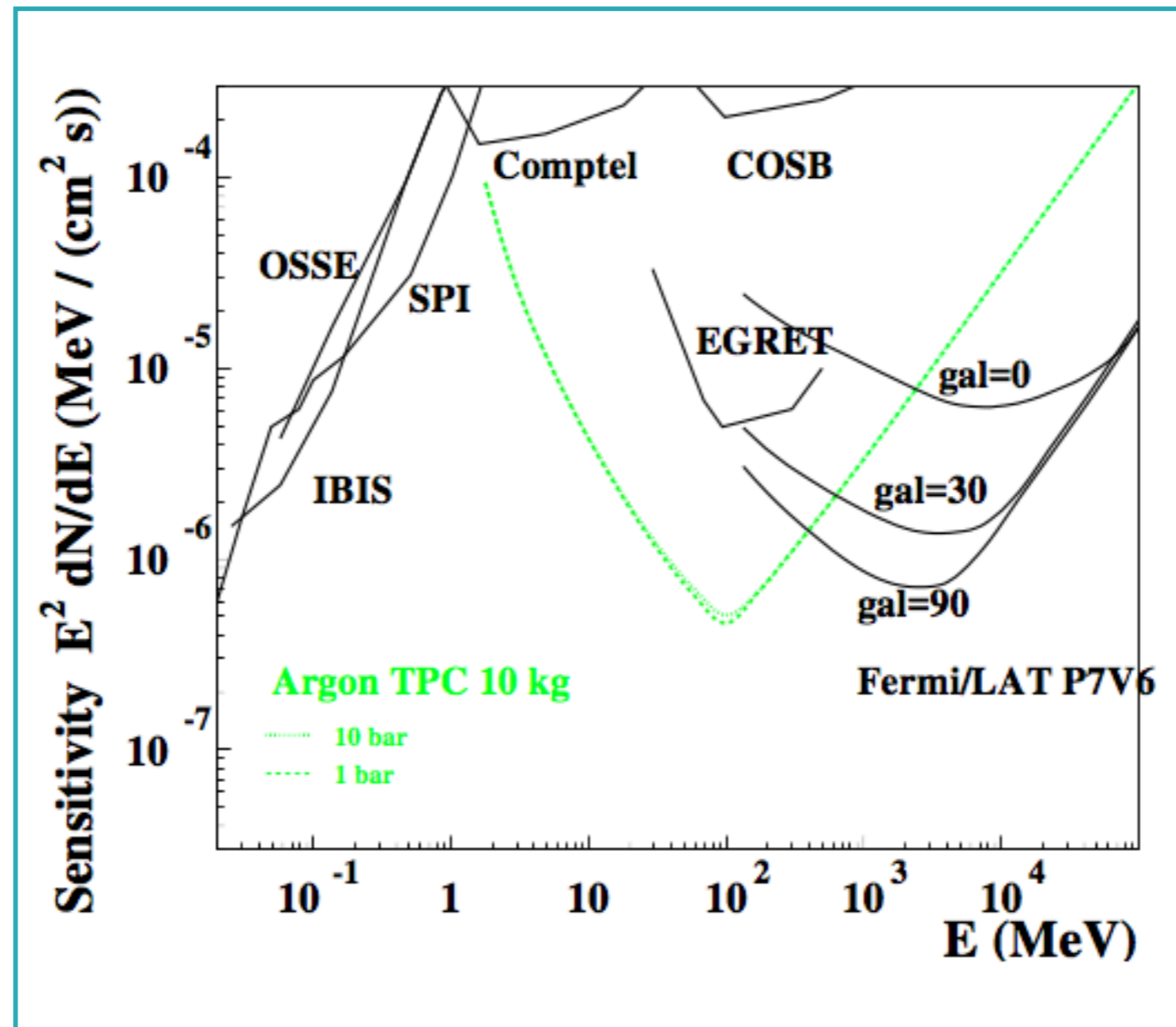


SEE DENIS  
BERNARD'S  
TALK

FROM DOCUMENT CIRCULATED BY DENIS

# ST3G

## SENSITIVITY

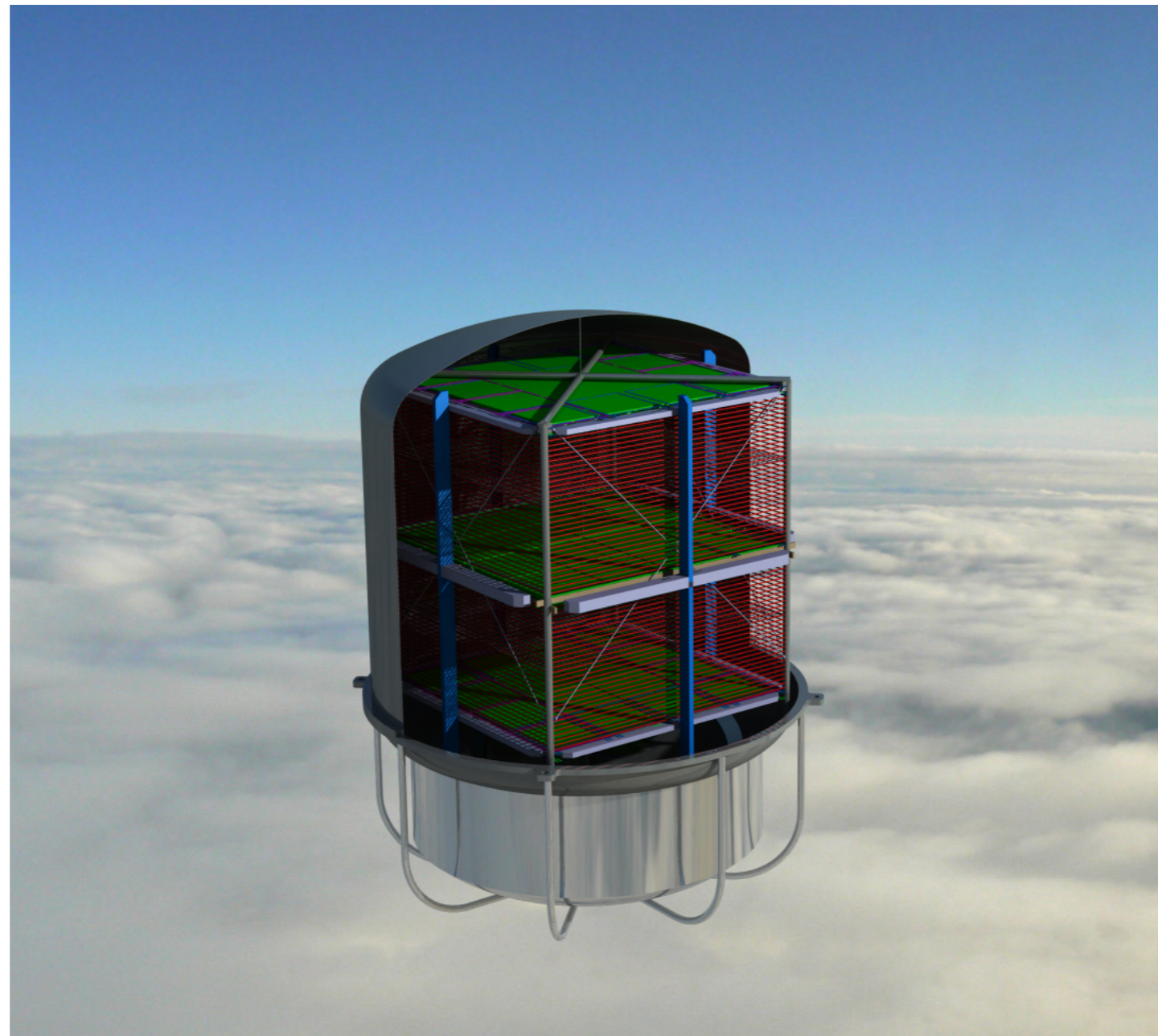


5 SIGMA  
3 YEARS  
10 PHOTONS  
90 DEG FROM GAL. PLANE  
4 ENERGY BINS PER DECADE

FROM DOCUMENT CIRCULATED BY DENIS

# ST3G

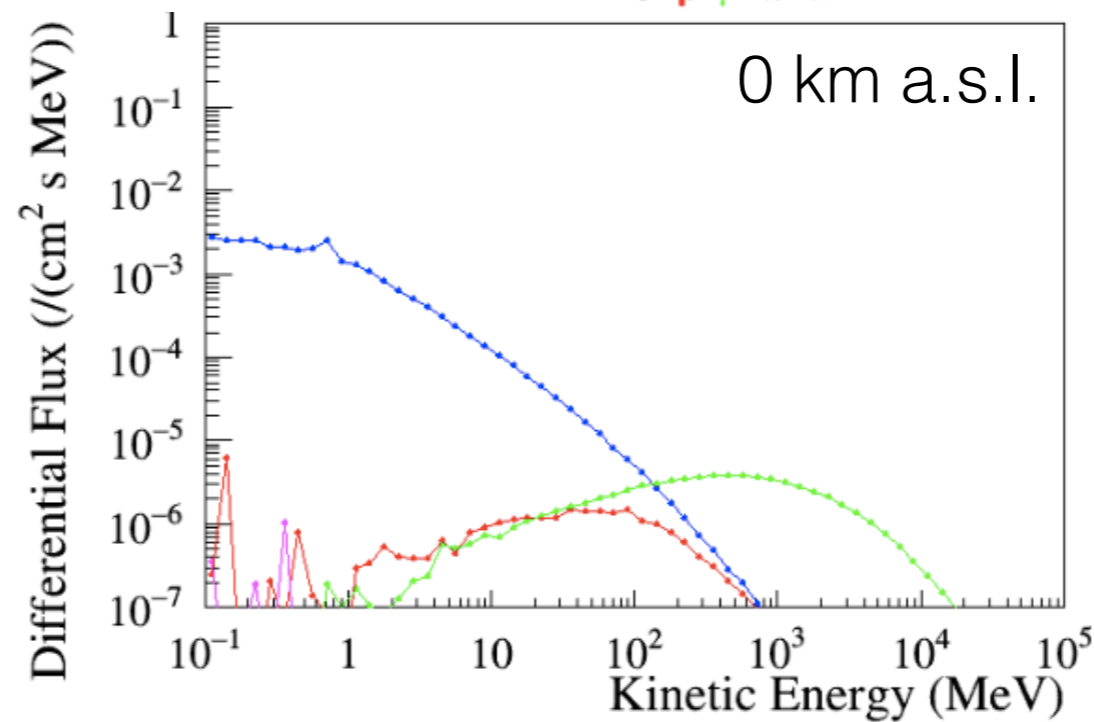
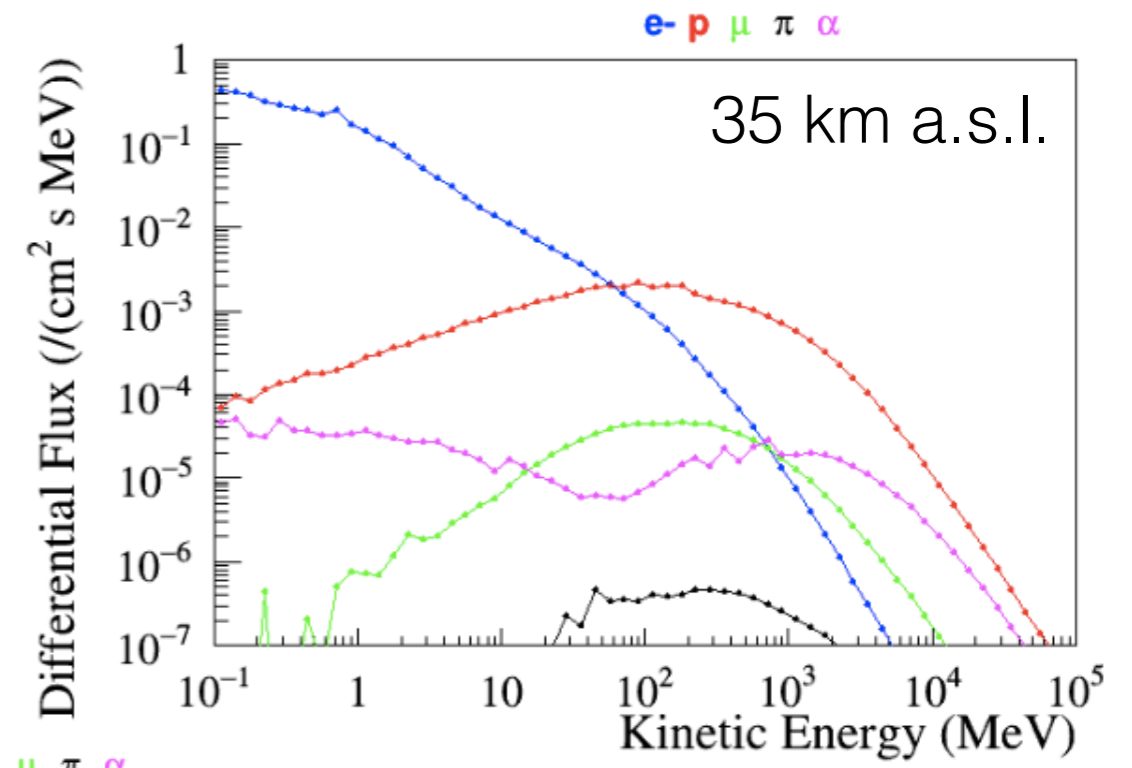
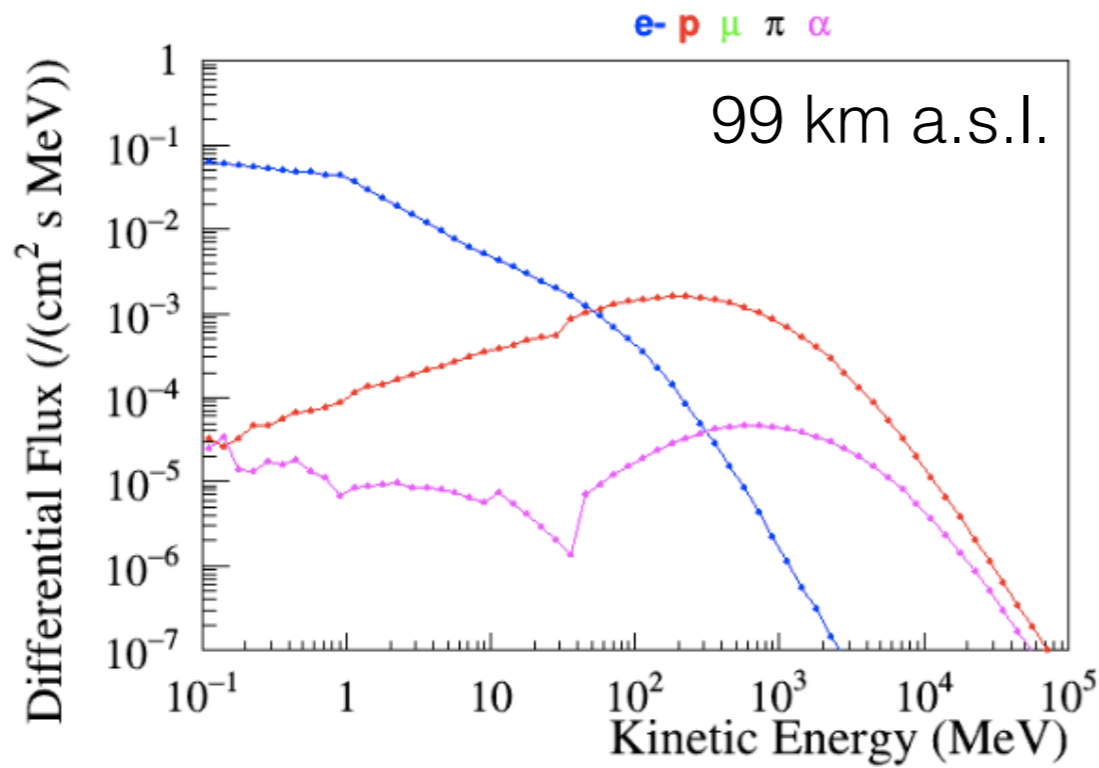
## KEY CHALLENGE:



→ SELF TRIGGERING ... IN REAL TIME ... IN SPACE

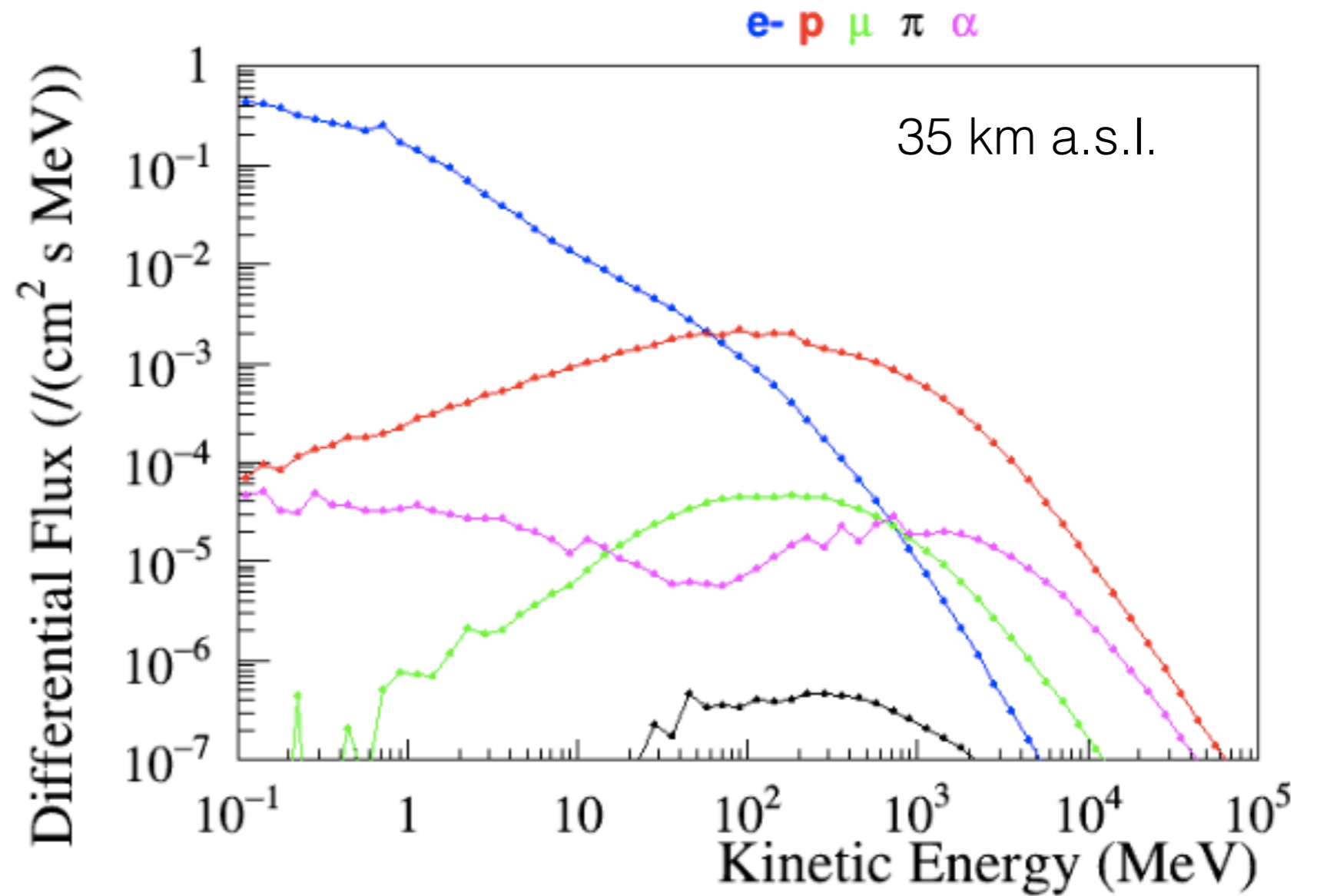
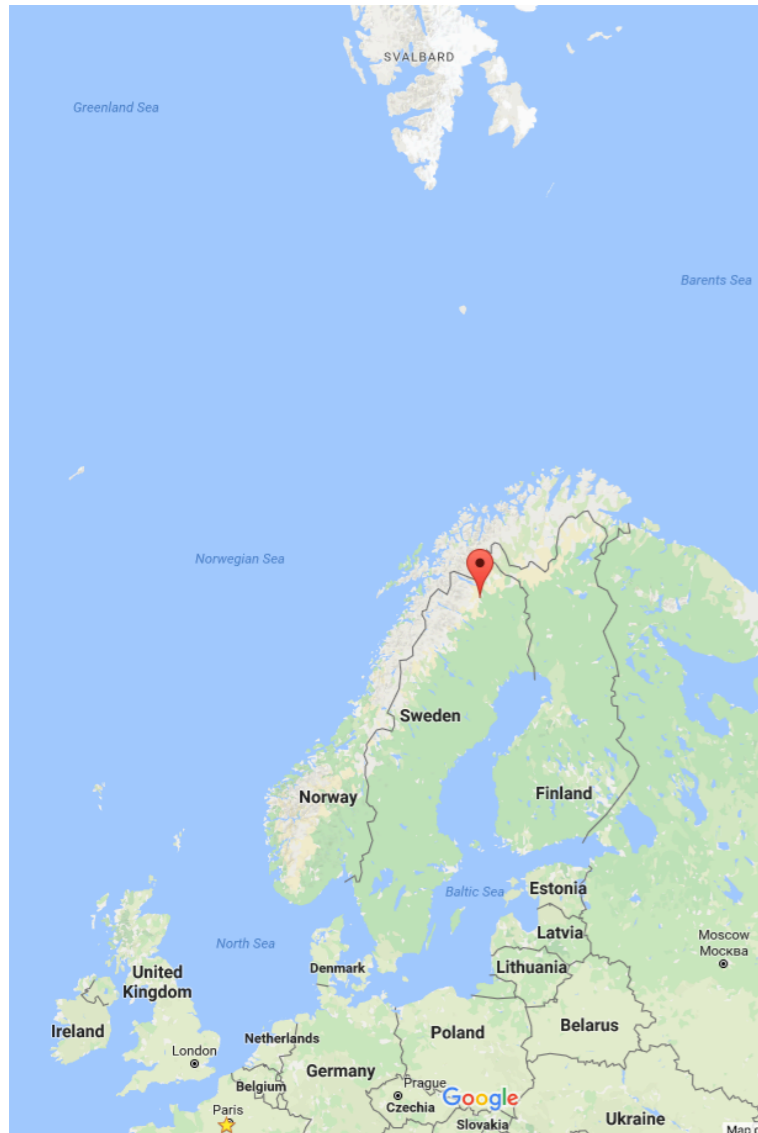


# ST3G



DATA RECORDED AT **KIRUNA**  
(NORTHERN SWEDEN) 20.01.1996  
(QUOTID ATMOSPHERIC RADIATION MODEL (QARM))

# ST3G

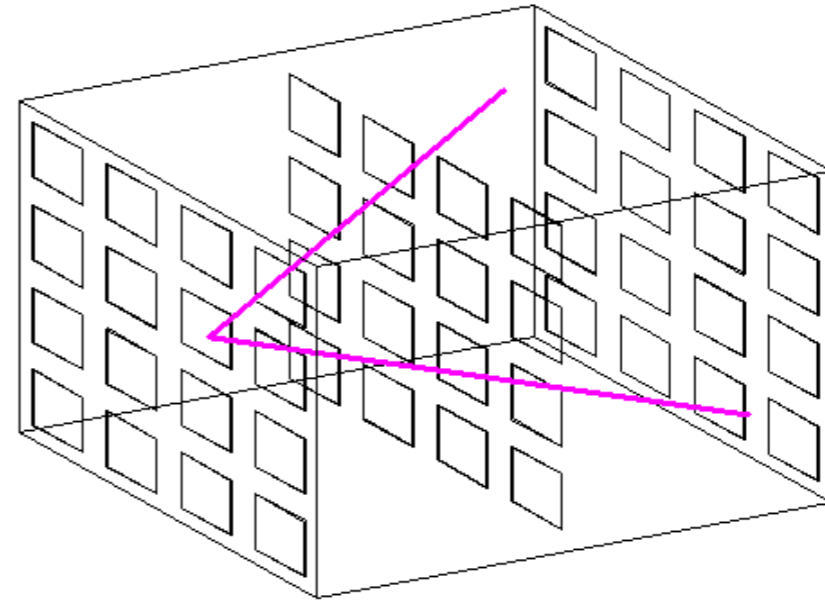
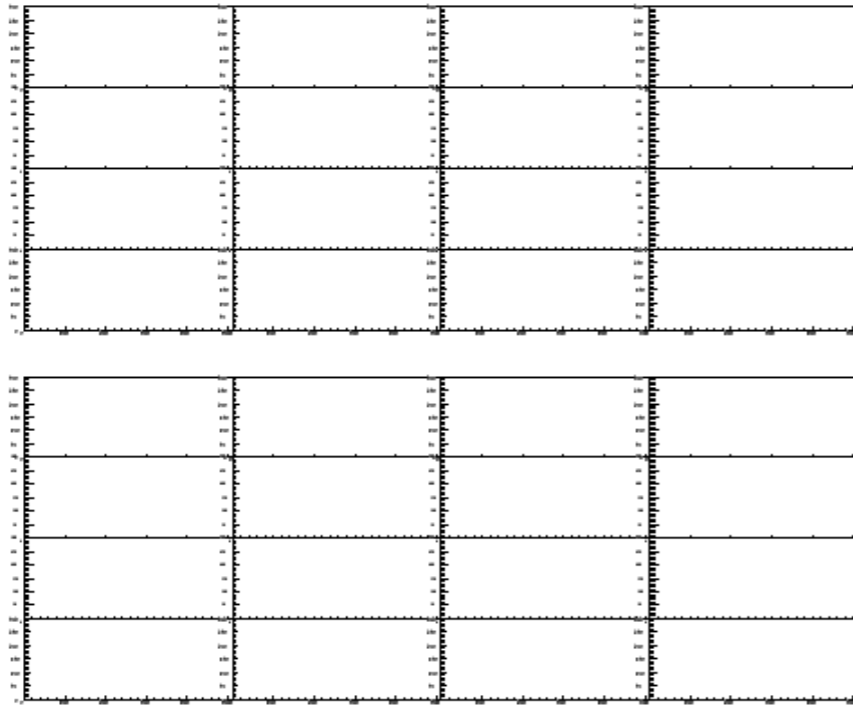


DATA RECORDED AT **KIRUNA**  
(NORTHERN SWEDEN) 20.01.1996  
(QUOTID ATMOSPHERIC RADIATION MODEL (QARM))

A.S.L. = ABOVE SEA LEVEL

# ST3G

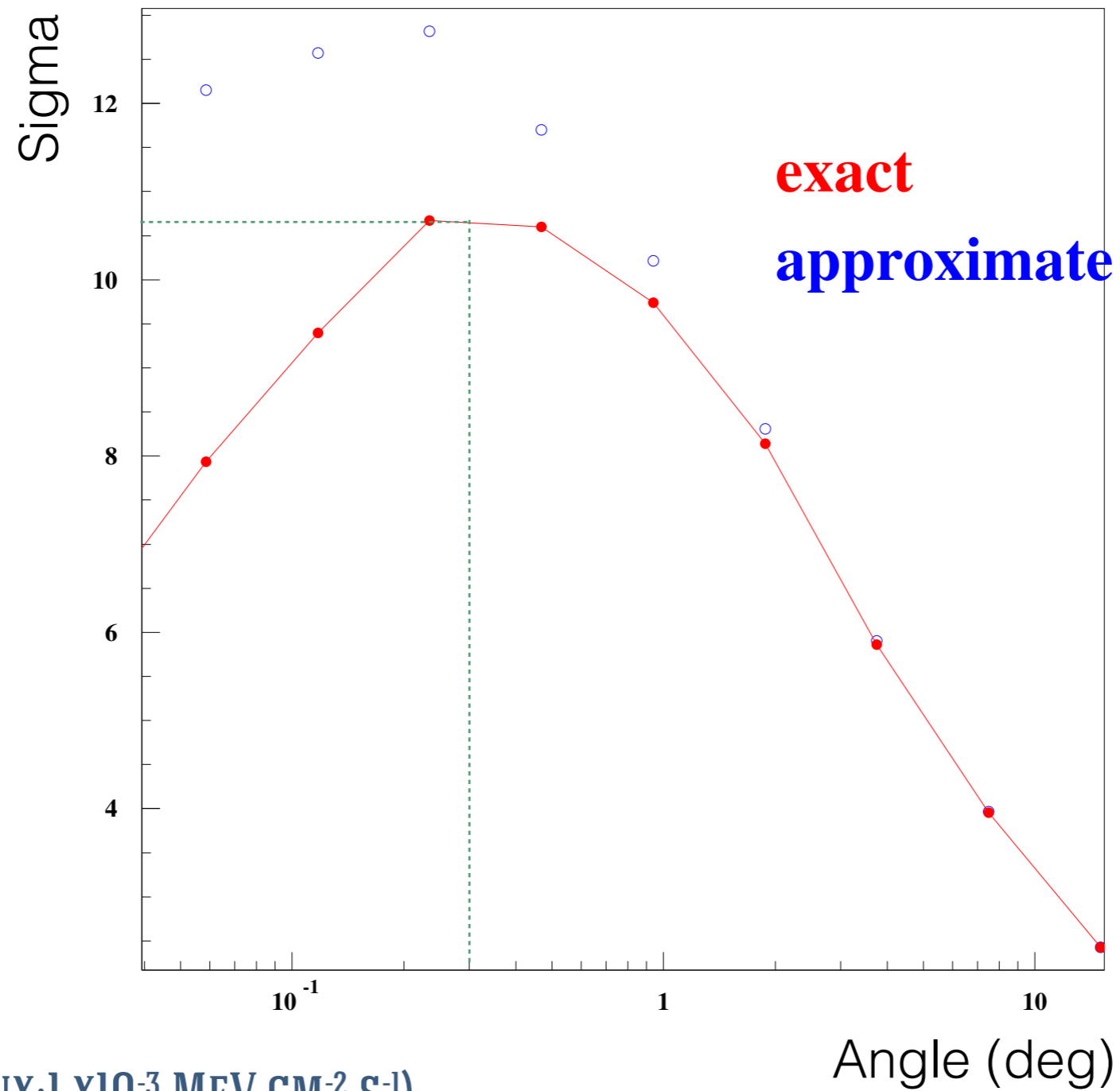
## SIMULATION OF EVENT IN ST3G



CREDIT: PHILIPPE GROS

# ST3G

## SIMULATION OF THE CRAB NEBULA



FROM DOCUMENT CIRCULATED BY DENIS

- CRAB (INDEX: 2; FLUX:  $1 \times 10^{-3} \text{ MEV CM}^{-2} \text{ S}^{-1}$ )
- 1 WEEK EFFECTIVE EXPOSURE WITH ST3G @35 KM (KIRUNE)
- 10.5 SIGMA FOR ANGULAR CUT OF 0.3 DEG

# ST3G

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- 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

---

- **WE WANT TO FLY ST3G ON A BALLOON TO:**
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**CNES APPEL D'OFFRE 2017: DEADLINE - 21 APRIL**

# ST3G

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## 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**
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**THANKS FOR YOUR ATTENTION**



# ST3G

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**THANKS FOR YOUR ATTENTION**

*and collaboration  
we hope!*

# References

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[HTTP://EARTHSKY.ORG/SPACE/MIND-BOGGLING-FERMI-BUBBLES-PROBED-VIA-QUASAR-LIGHT](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 ( $1.22 \times 10^{19} \text{GeV}$ )
- 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

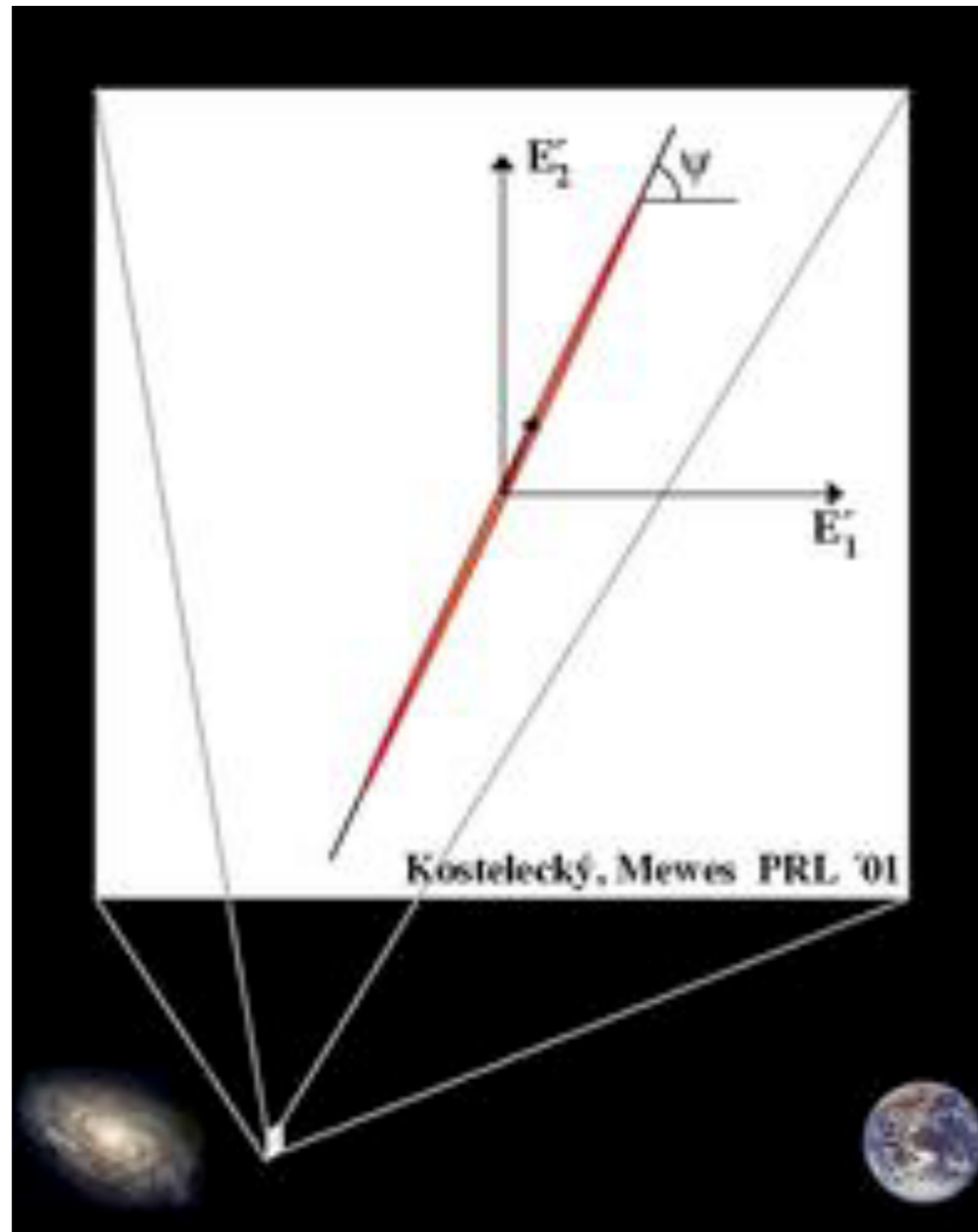
- when the rotation symmetry of the vacuum is broken, light still has two polarisation components but they travel at different speeds
- as a result, the net polarisation of the light changes as it propagates
- change in polarisation depends on the energy (frequency) of the light

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

sensitivity gain of  **$1/\omega$**  compared to time-of-flight measurements

# Is Lorentz Invariance violated?

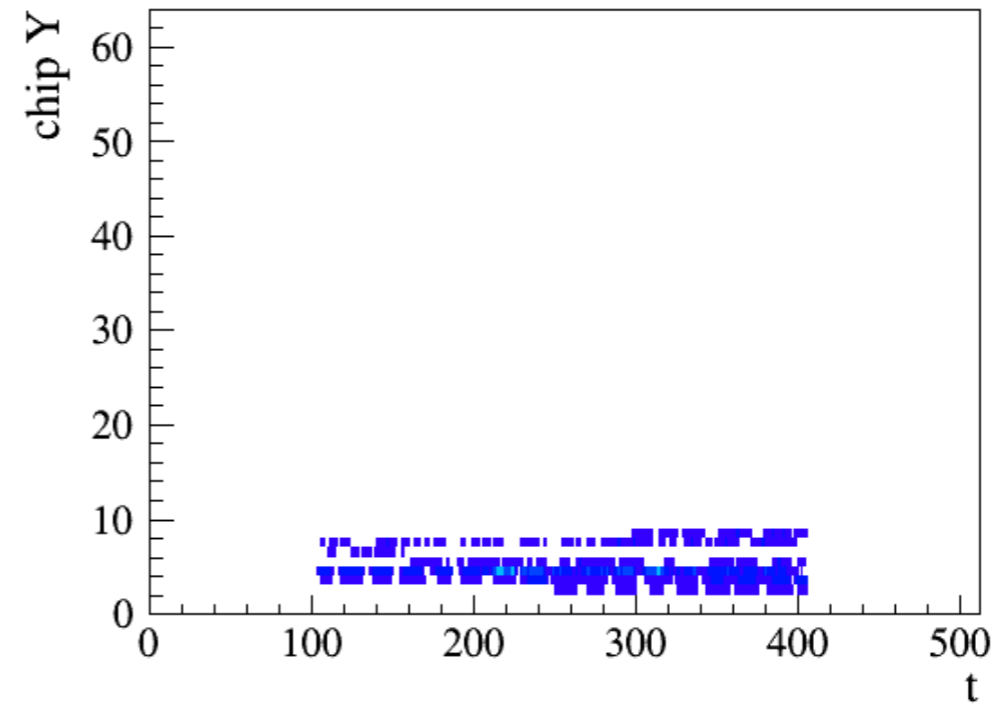
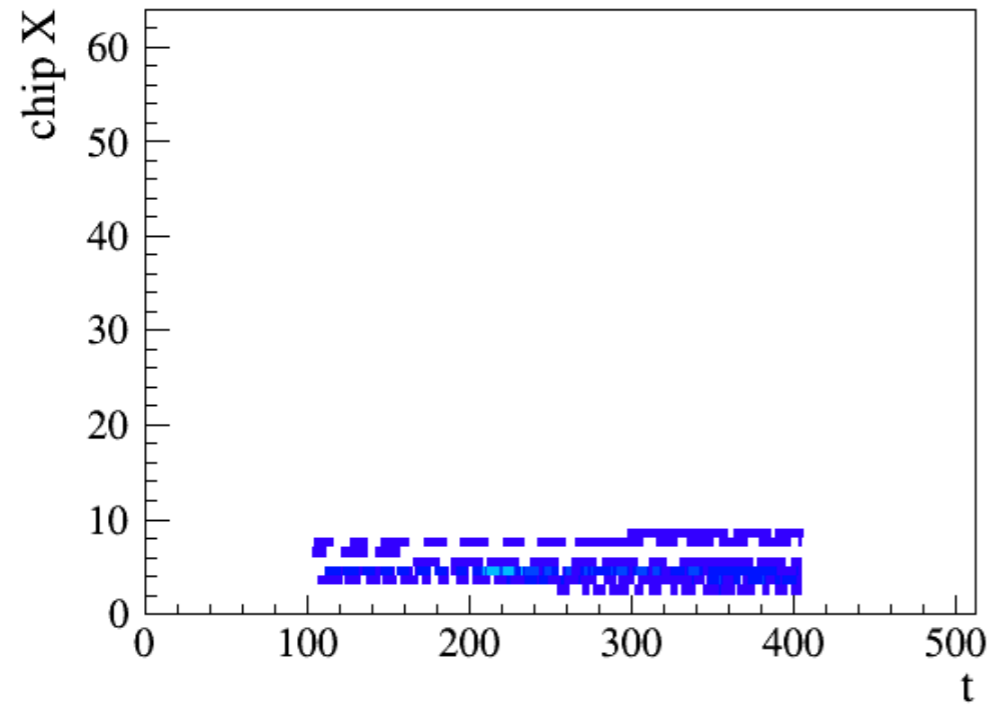
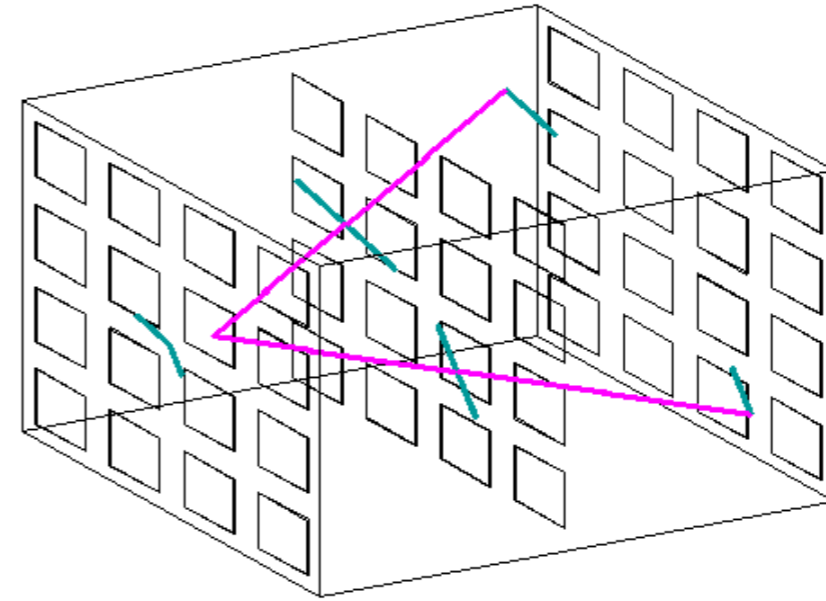
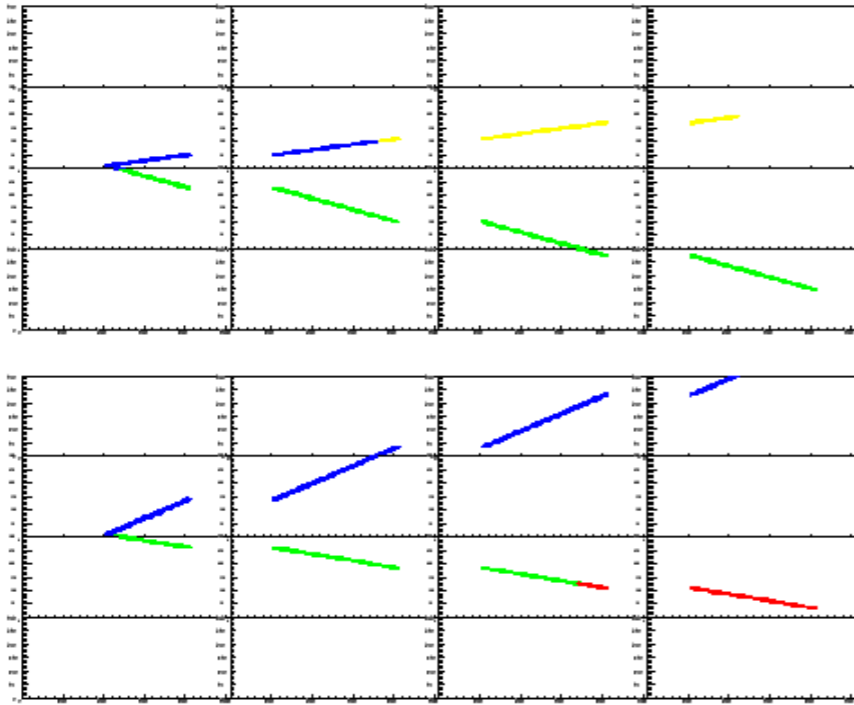
In the photon sector violations of Lorentz symmetry include **vacuum dispersion** and **vacuum birefringence**



## Vacuum birefringence

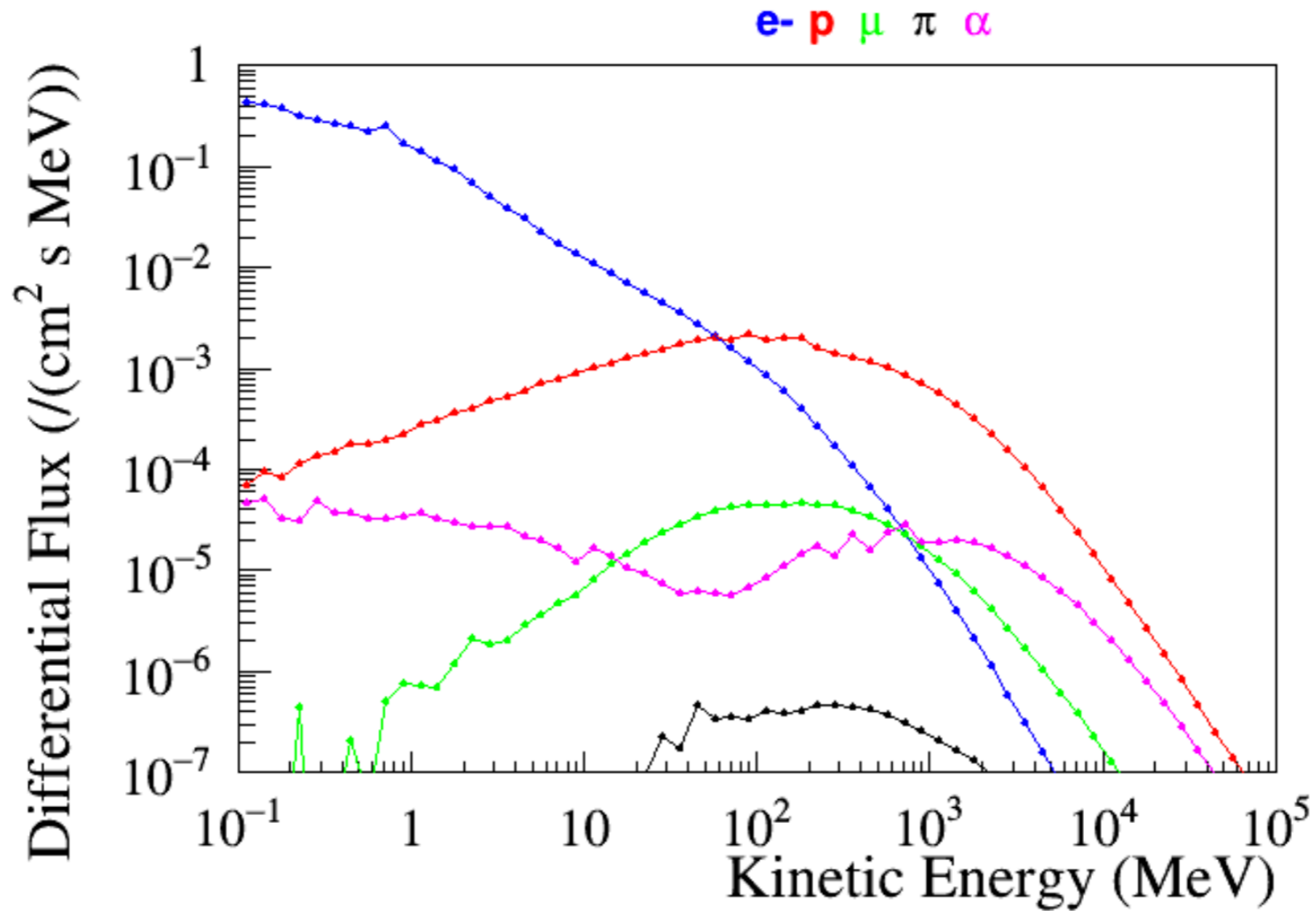
- light is shown propagating from a distant galaxy to the Earth
- the instantaneous electric-field vector in a plane transverse to direction of motion is shown as a black arrow
- the polarisation of the light is determined by 2 quantities:
  - the orientation of the ellipse ( $\omega$ )
  - its shape ( $E_1$  and  $E_2$ )
- 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



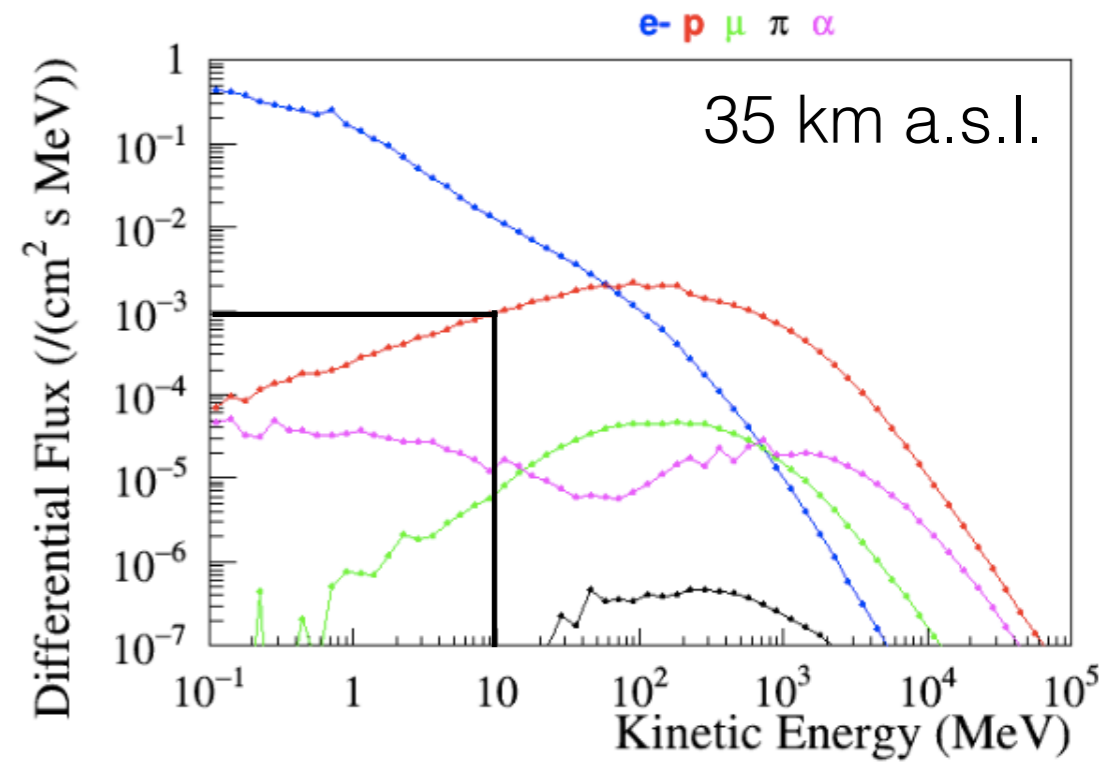
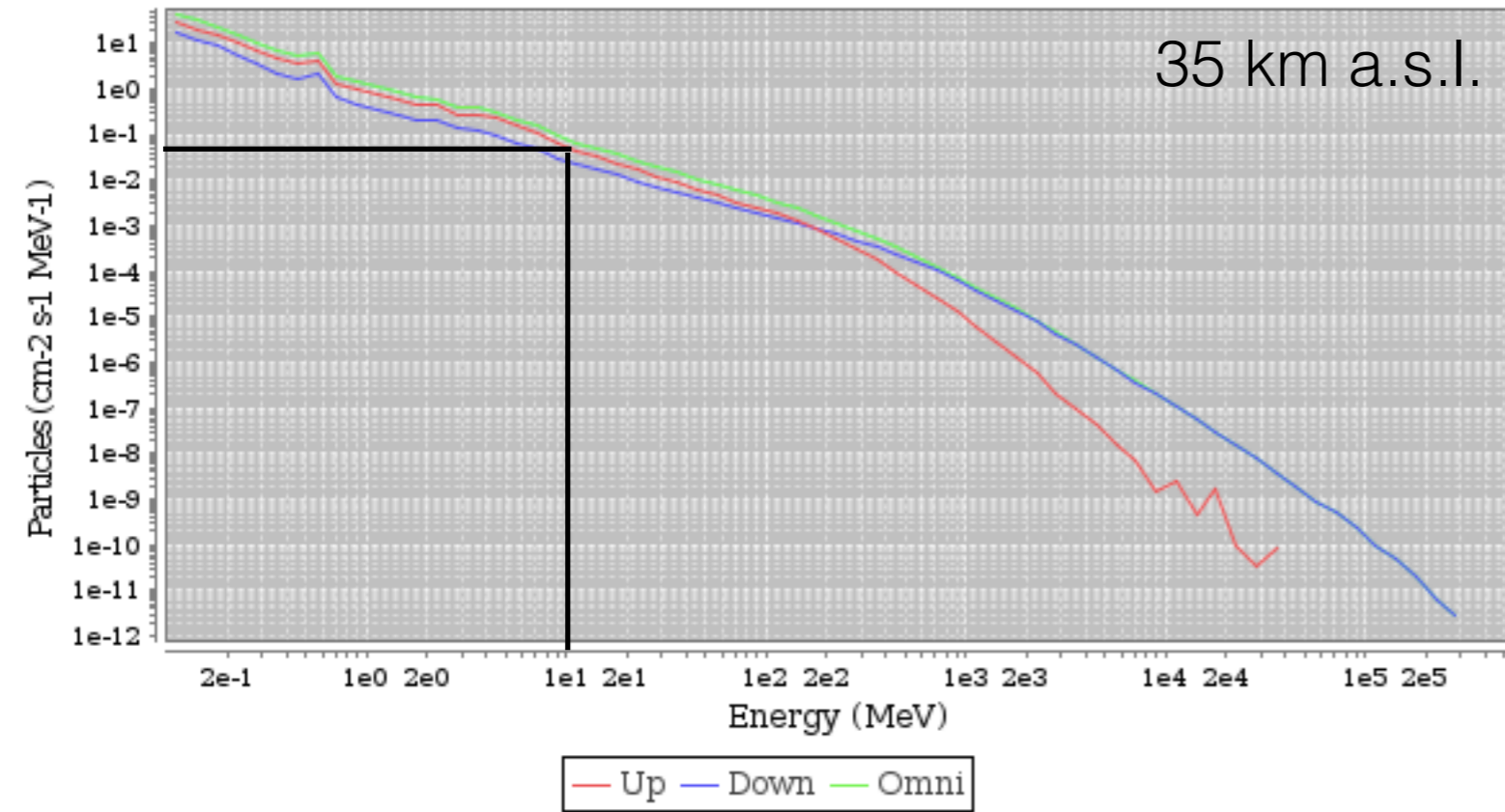


# ST3G



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