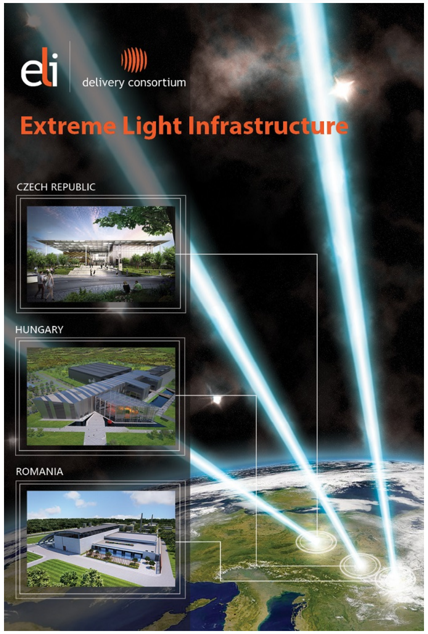
# ACPA@ELI

## From Nuclei to the Cosmos with Brilliant Gamma Beams





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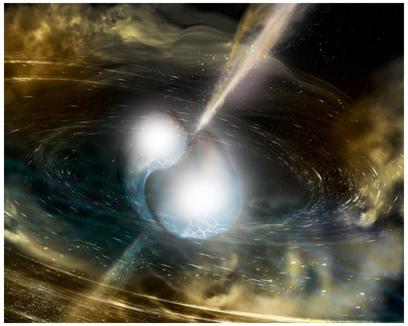
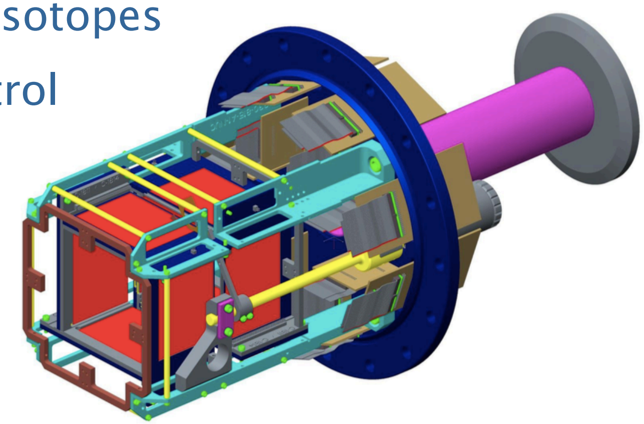


Warwick Meeting
6-7th January 2020

# From Nuclei to the Cosmos with Brilliant Gamma Beams

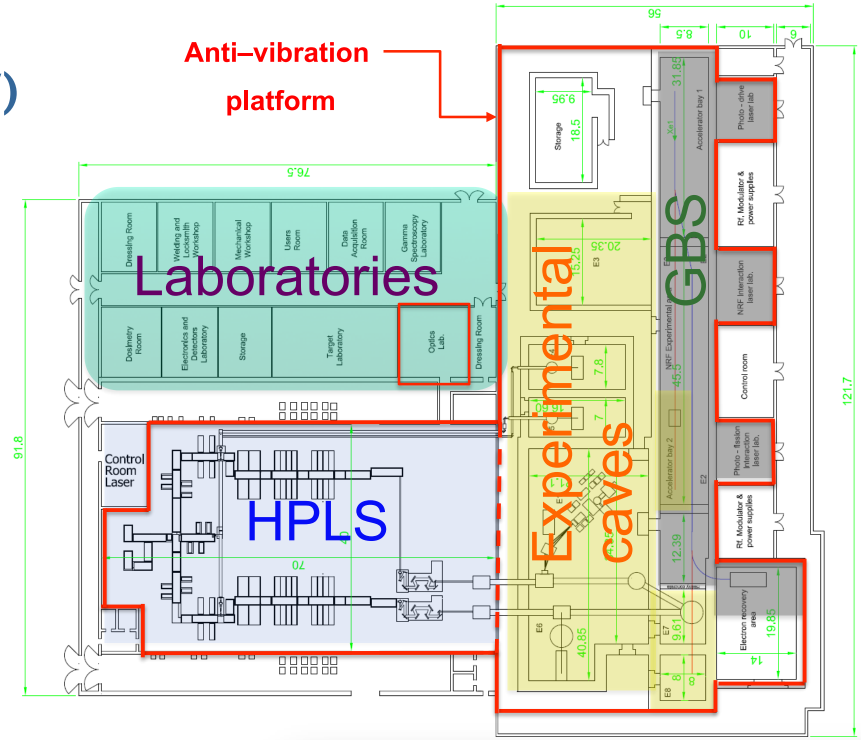
- **How and where were the elements, we are made of, created?**
  - Big Bang Nucleosynthesis – **Flagship experiment for ELI-NP: $^{7}$Li(γ,t)α**
  - The p-process in hot stellar environments (e.g. supernovae)
  - The r-process in neutron-star – neutron-star mergers
- **How does the collective dynamics of nuclei drive reactions?**
  - The dynamics of fission processes
  - Collective shapes in p-process transition metals as well as rare-earth isotopes
  - Clustering in light nuclei
- **And how can we use this understanding to improve our welfare?**
  - Unique opportunities for production of new medical isotopes
  - Improved nuclear data for security and radiation control

# Down–to–Earth Nuclear Physics with Brilliant γ–beams

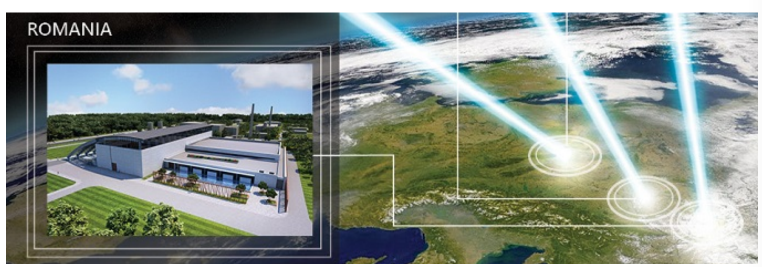
## ELI–NP (Romania), Electron Linac Compton Back–scatter (0.2–20 MeV)

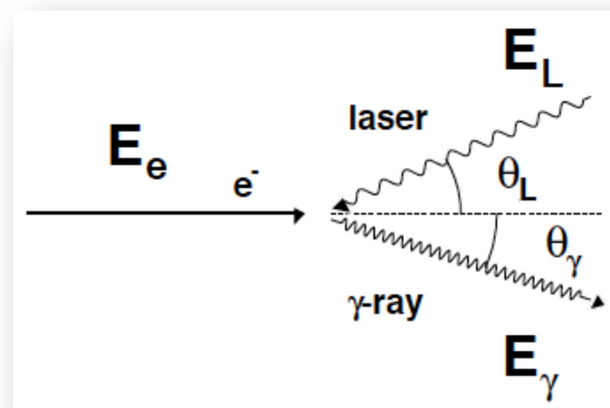
- Intense γ–beams at ELI–NP:
  - Pure, fully polarised, EM–probe
  - Narrow–bandwidth selectivity
  - γ–induced breakup/emission/fission
  - Time–reverse capture





**As part of the flagship Extreme Light Infrastructure**






H.R. Weller et al., Prog. Part. Nucl. Phys. 62 (2009) 257

# The ELI-NP Gamma Beam Facility — Plans and Status

- **New ELI-NP VEGA Gamma-Beam System:**
  - New GBF contract signed (4th Oct 2019, VEGA System, USA)
  - ELI-NP VEGA GBF commissioning: 2022-2023, with high-priority ACPA physics
  - The VEGA system is practice a continuous beam (30MHz structure), such that the instantaneous rate is down by 4 orders of magnitude compared to previous GBS.
- Comparison of ELI-NP GBF and HIγS (USA) γ-beam specifications, where **Sensitivity scales with Spectral Density,** offering unique opportunities:
  - **Investigation of weak structures** or low-cross section (astrophysical) reactions
  - Gamma-ray induced reactions on thin targets opening up for studies of extremely rare elements, including **long-lived radioactive isotopes**

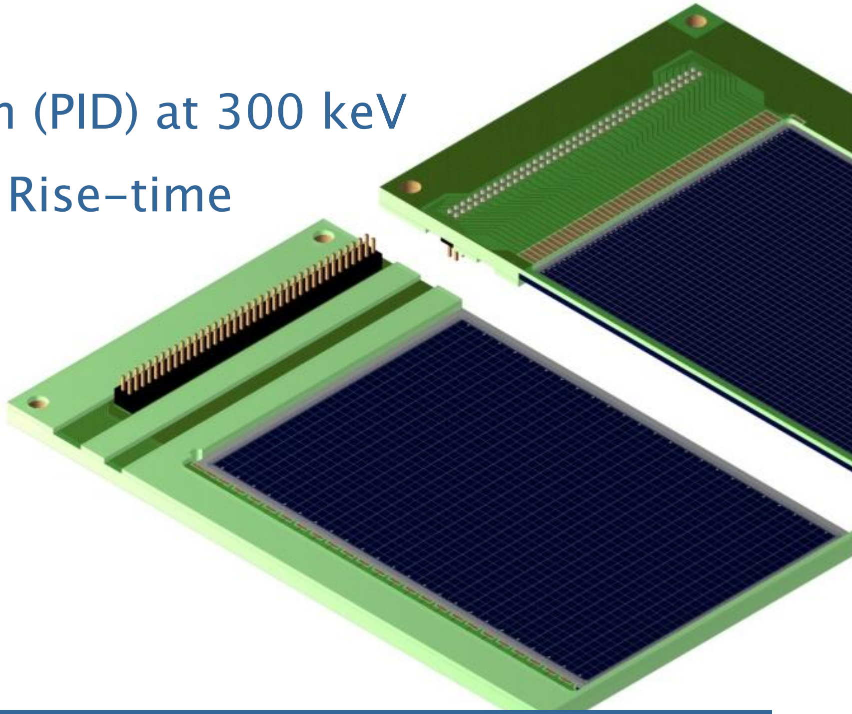
| Parameter [units] | ELI-NP | HIγS |
|---|---|---|
| Photon energy [MeV] | 0.2-20 | 2.0-100 |
| Bandwidth [relative] | < 0.5% | 5% |
| photons/sec (FWHM bandwidth) | $2.0\text{-}8.0*10^8$ | $0.1\text{-}2.0*10^8$ |
| Spectral density [ph/s/eV] | $> 10^4$ | $> 10^2$ |
| Linear polarization | > 95 % | (circular) |



S Gales et al 2018 Rep. Prog. Phys. 81 094301 doi: 10.1088/1361-6633/aacfe8

# Charged-particle detector array ACPA at ELI-NP

- **Dual-layer Silicon dE-E telescope array**
  - Low-threshold silicon: 100um double-sided readout silicon
  - Maximal-absorption silicon layer: 1500um double-sided Si
  - Known technology: 3-inch wafer nTD silicon technology
- **ACPA@ELI electron vs light-ion discrimination:**
  - e- signals are distributed, i.e. punch-through equivalent (existing electron response simulations)
  - Aiming for p vs e- Particle Identification (PID) at 300 keV
  - Implementation and bench-marking of Rise-time and max-current based algorithms
  - **Coupling to external detector arrays:**
  - External γ-ray and neutron scintillator arrays (**ELIGANT-GN**)
  - External HPGe γ-ray array (**ELIADE**).



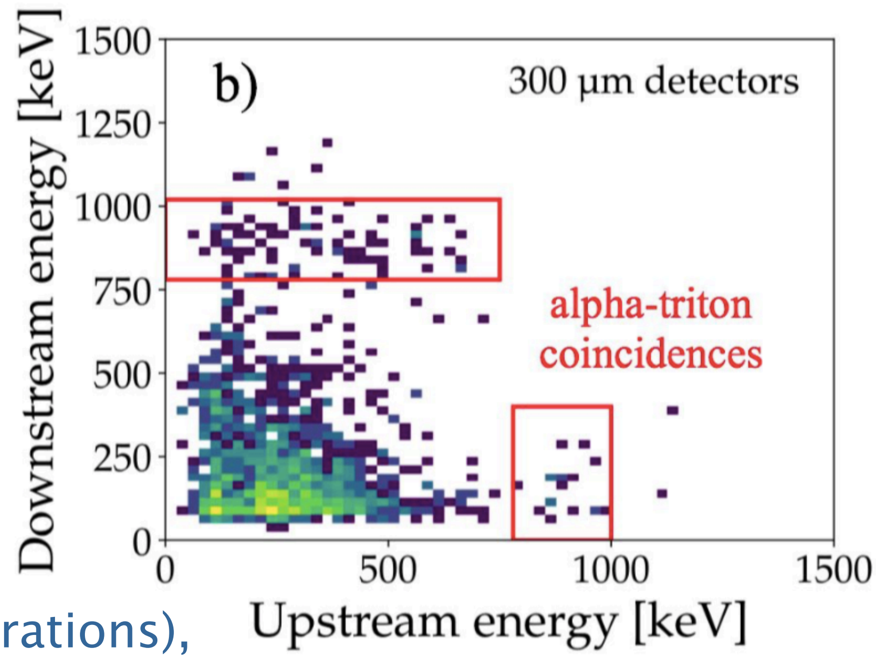


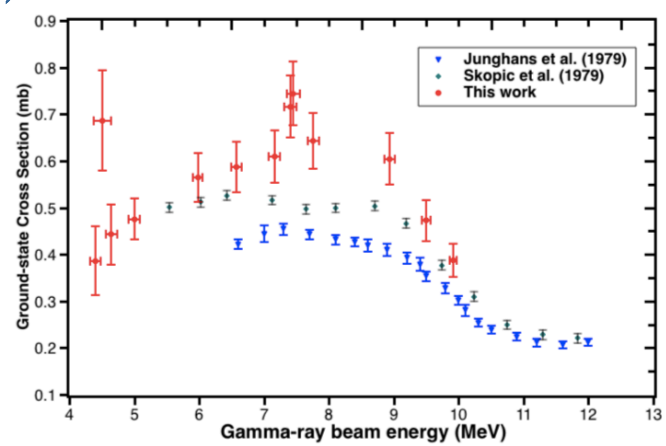
O. Tesileanu et al., Rom. Rep. Phys., Vol. 68, Supp., p. S699, 2016
Mengoni et al. NIMA 764:241 (2014)
Diget, et al. ,J. Inst, 6:P02005 (2011)

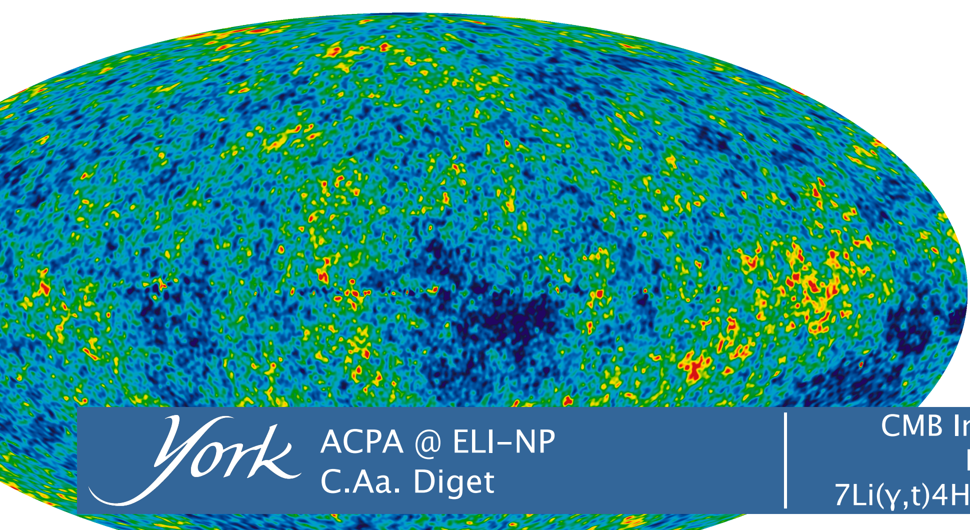
# First ACPA-collaboration experiment at HIγS: $^{7}Li(\gamma,t)\alpha$

High Intensity $\gamma$-ray Source facility:

- **Unique selectivity full kinematics coincidence measurements**
- Addressing the “Lithium problem” in Big-Bang Nucleosynthesis
- Segmented silicon array (SIDAR) for first measurement of $^{7}Li(\gamma,t)\alpha$
- Electron background assessment, light ion PID from kinematics
- ELI-NP (ELISSA and ACPA@ELI collaborations), York, Aarhus (Denmark), HIγS and ORNL (USA)



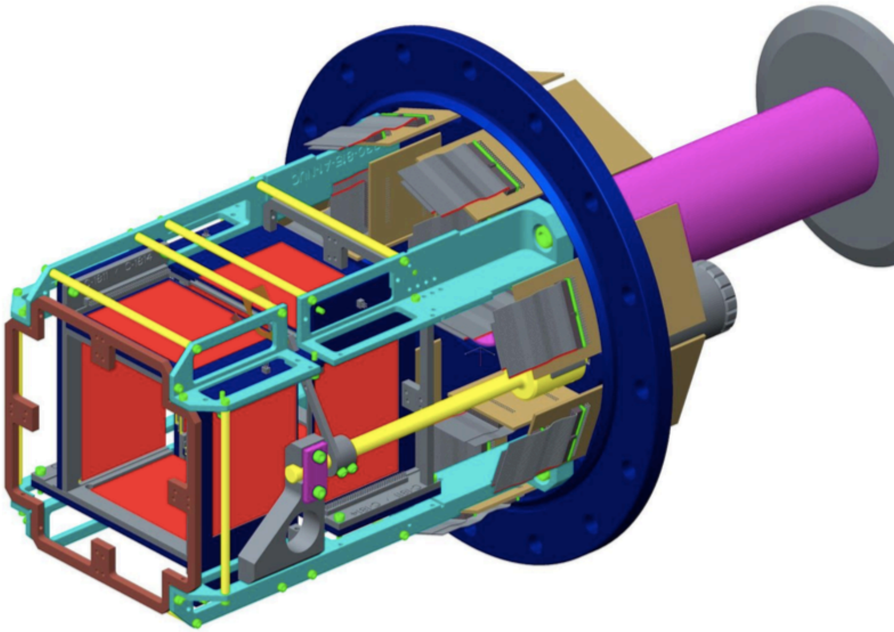





CMB Image Credits: Nine Year Microwave Sky, NASA / WMAP Team
Munch et al., PRC Submitted 2019, First Measurement of the 7Li(γ,t)4He Ground-state Cross Section Between Eγ = 4.4 and 10 MeV

# Unique opportunities with ACPA@ELI

- Charged-particle detector-array with **low-energy sensitivity** through an **eDAQ** implementation of **Pulse-Shape Discrimination** between light-ions and electrons.



- **Creation of elements:**
  - HIγS (2017) demonstration of $^{7}Li(\gamma,t)\alpha$ measurement [BBN]; $^{12}C(\gamma,\alpha)\alpha\alpha$ and $^{9}Be(\gamma,n)\alpha\alpha$ [α-fusion reactions]
- **Collective dynamics in reactions:**
  - The dynamics of fission processes
  - (γ,p) and (γ,α) on transition metals [p-process] and rare-earth elements
- **Societal Impact:**
  - Fission delayed-beta capability and coupling to external arrays (ELIGANT and ELIADE)
  - Radio-isotope production based on γ-ray induced reactions, in particular fission