GaNESS: Detecting CEνNS with noble gases.

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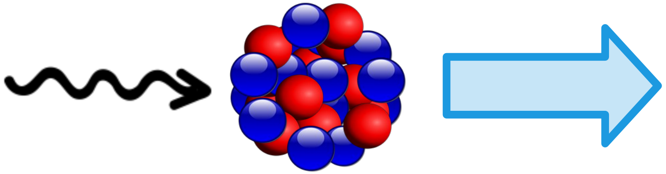
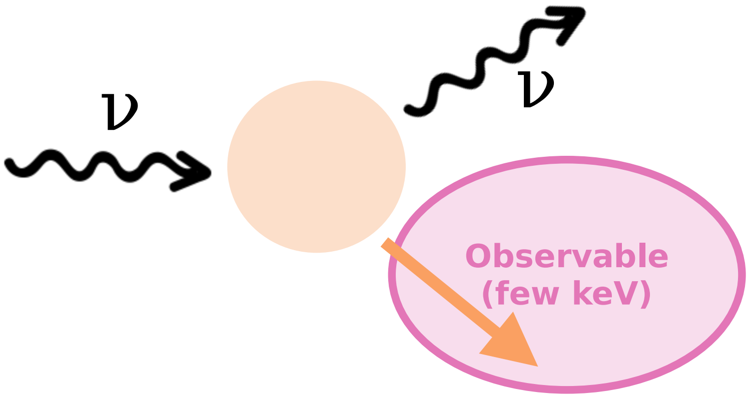
CEνNS

ν (~10s MeV)





Long wavelength, “sees” all nucleons simultaneously

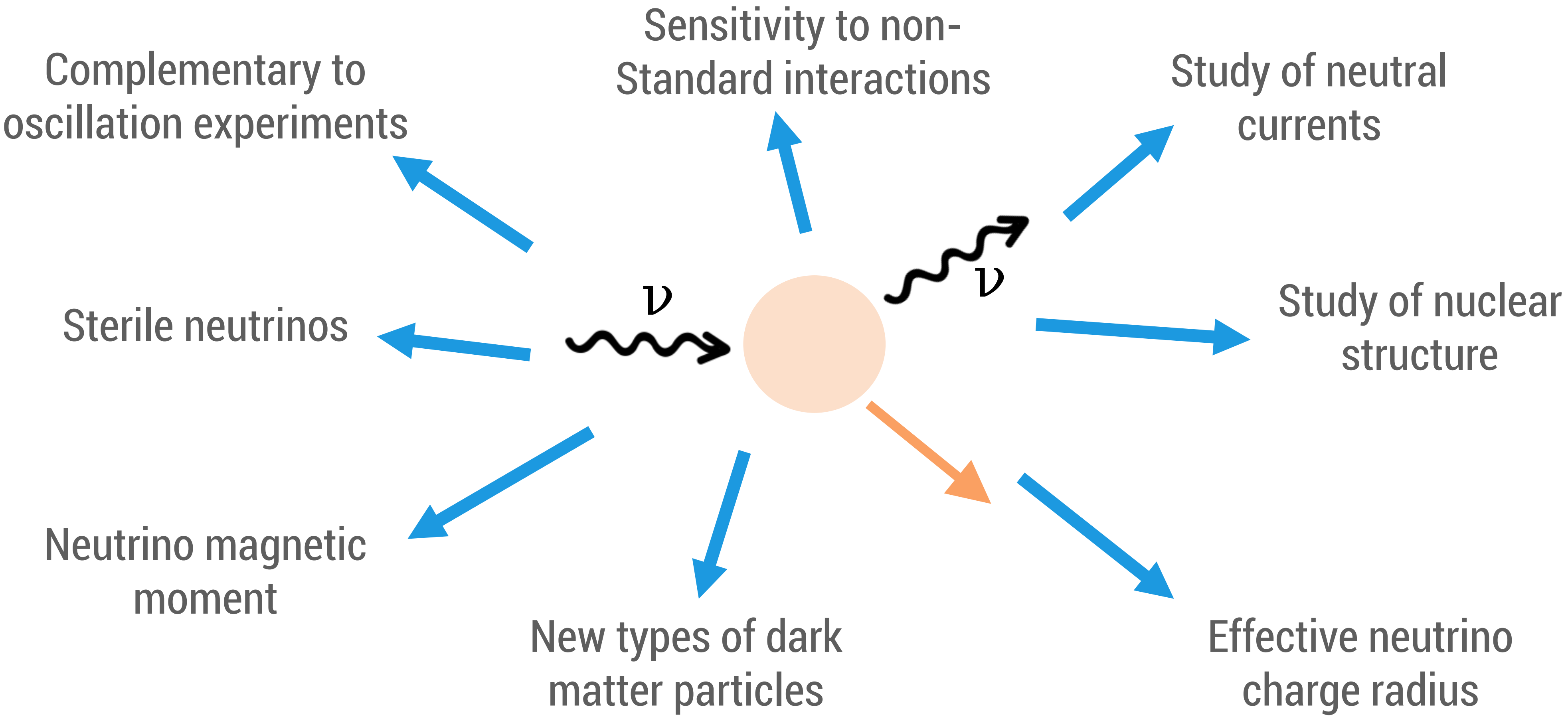
$$\sigma \sim N^2$$

Few kg detectors can be competitive

Predicted in SM for decades

First detected 6 years ago

Coherent Elastic Neutrino-nucleus scattering (CEνNS)



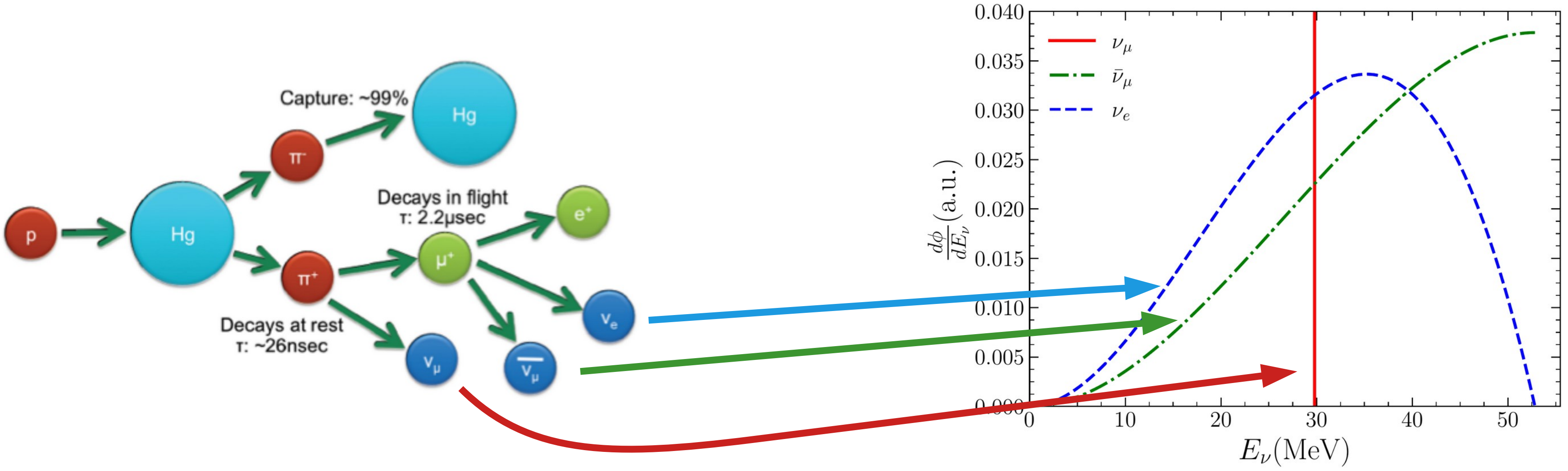
Detecting CEvNS: Source

Requirements

- Sufficiently intense in yield.
- Neutrino energy low enough.
  - Coherence condition: |Q| < 1/R

Candidates

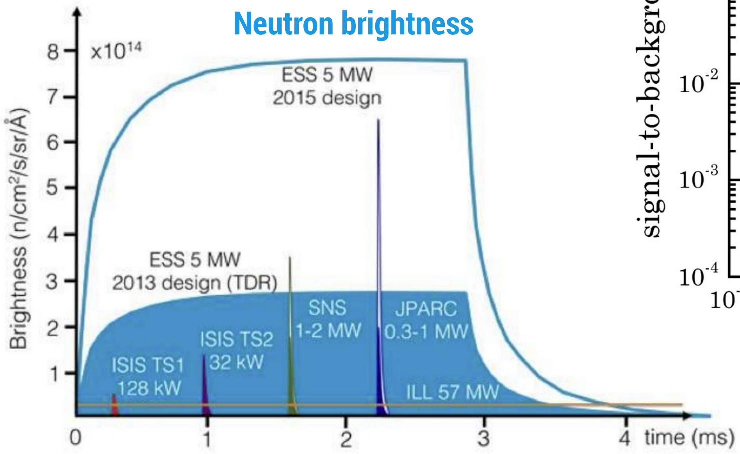
- **Spallation sources** (π^+ DAR)
- Nuclear reactors



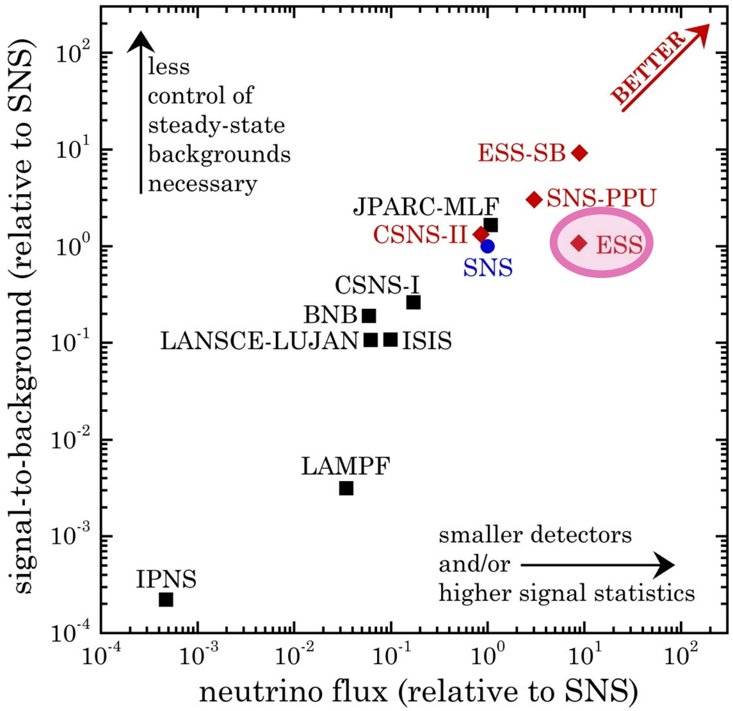
European Spallation Source (ESS)

- The ESS will generate the most intense neutron beams for multi-disciplinary science.
- But also, the largest low-energy neutrino flux!
- ν production @ ESS is x9.2 @ SNS
- Similar s/b to SNS but much higher statistics.

Neutron brightness

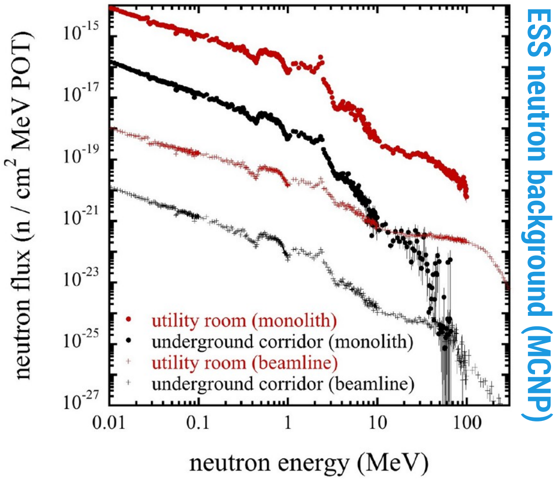


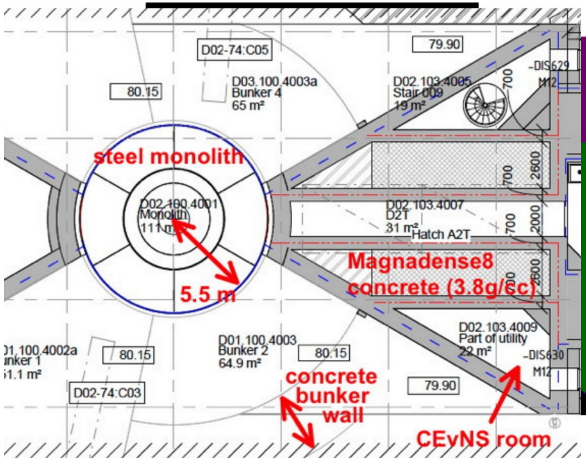
Neutrino production at different facilities

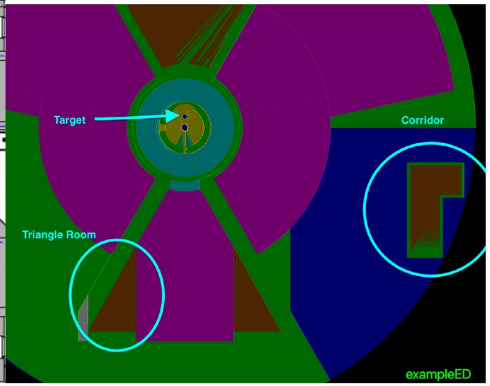


Backgrounds at ESS

- Steady-state backgrounds can be subtracted.
- Beam-induced prompt neutrons are the main source of background.
- Simulations undergoing to evaluate deployment locations.
  - 2 candidate locations under study.
- On-site measurements planned:
  - Neutron camera built at DIPC.





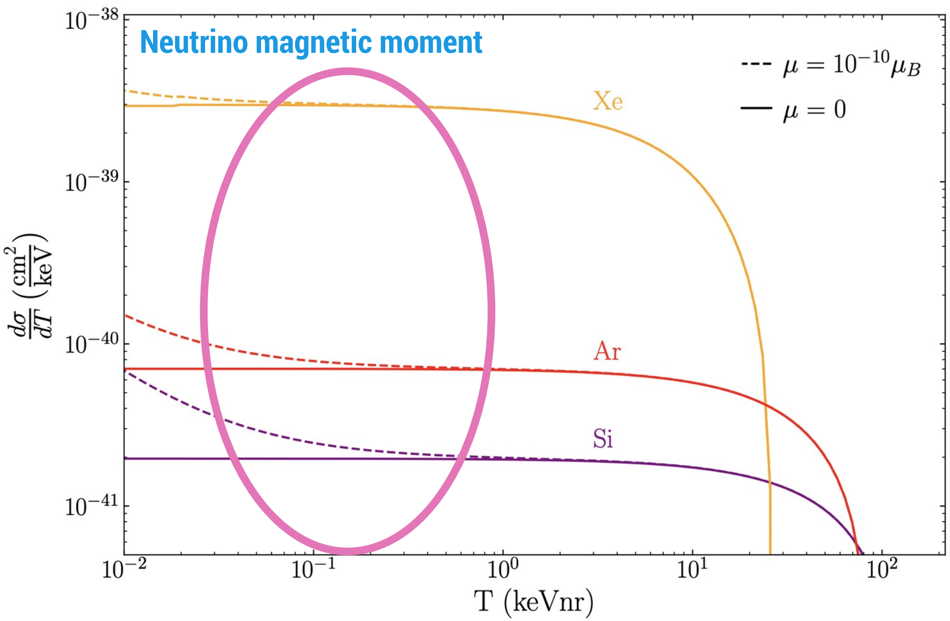


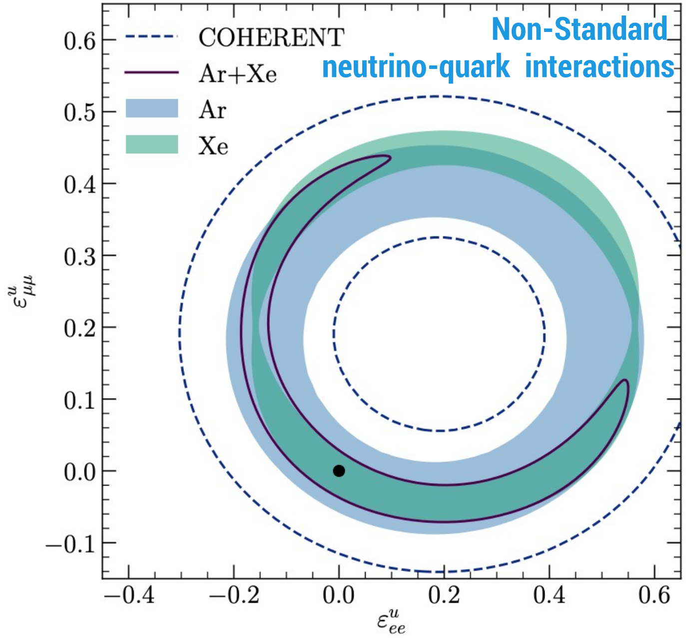
Detecting CEvNS: Detectors

Physics potential maximized with:

- Low energy threshold
  - Interesting physics at low energy

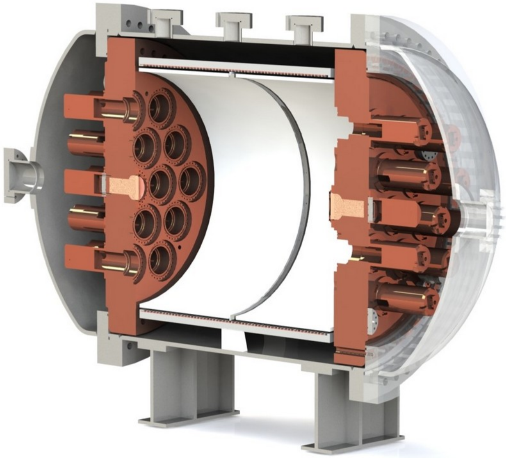
- Different nuclei
  - Breaks degeneracies

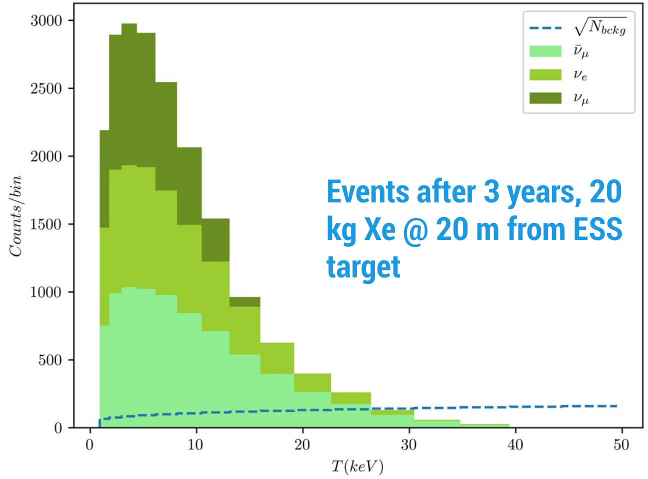




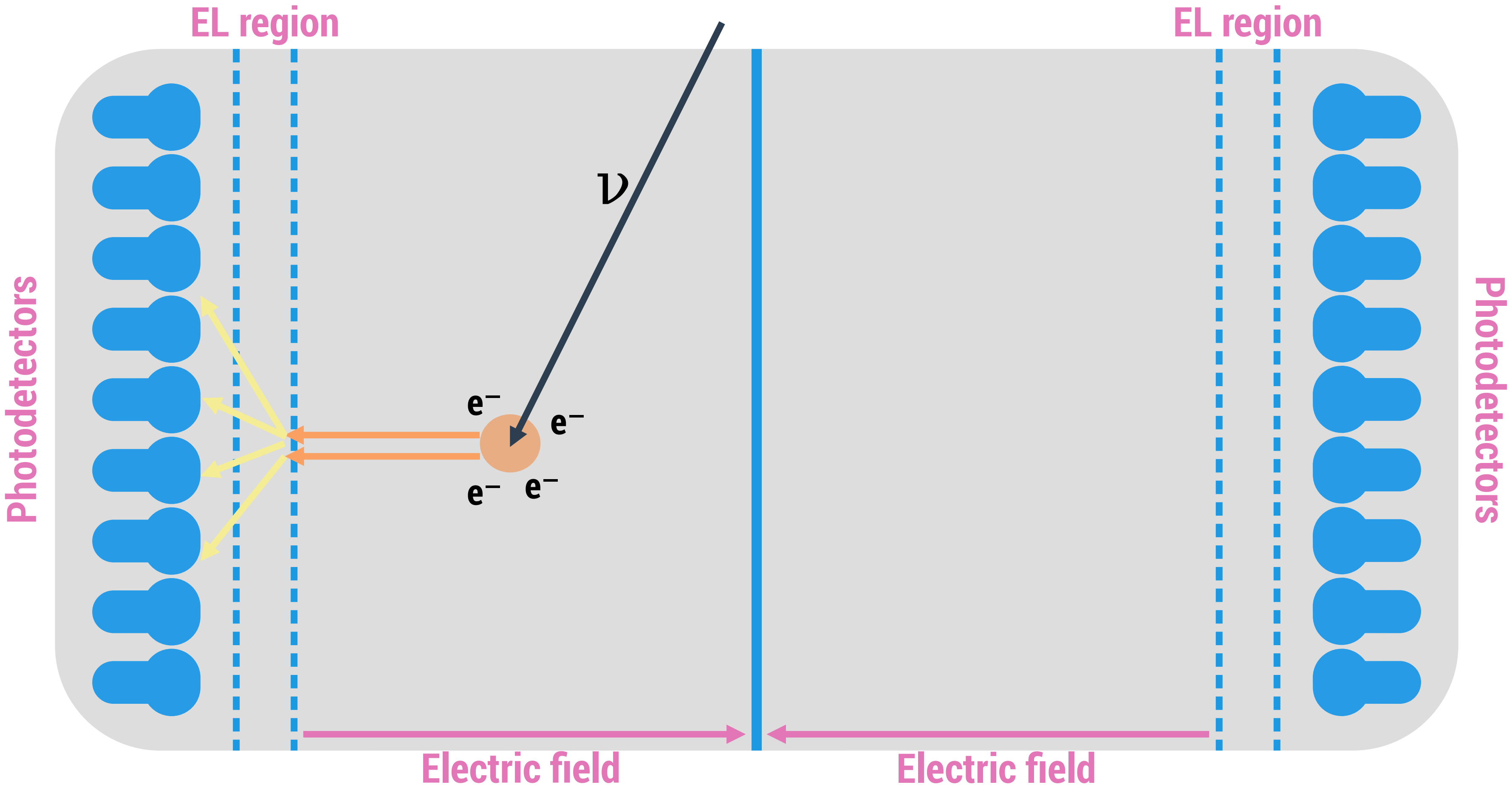
GaνESS: A high pressure noble gas TPC for CEνNS

- Operation with different nuclei (Kr, Ar, Xe).
- Simple, no cryogenic operation
- Potential low energy threshold (1-2 e^-) via electroluminescence (EL) amplification.
- Technology developed by the PI within NEXT experiment.
  - Low-background solutions already developed by NEXT collaboration.
  - R&D needed for higher pressures and lower energy regime.
- Lower density than other techniques → Bypassed by large ESS neutrino flux → 20 kg detector is enough.

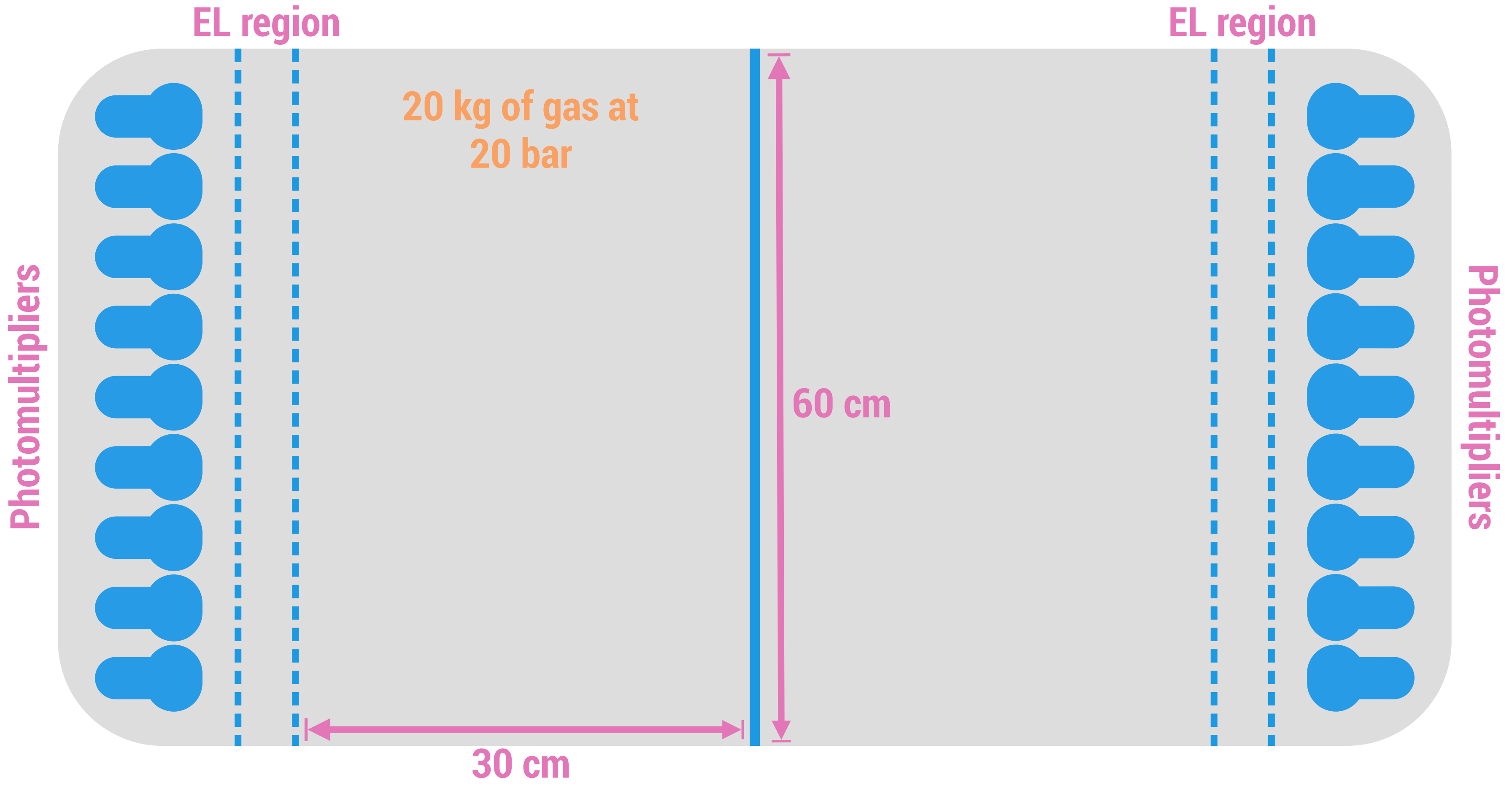




GaνESS: Detector concept



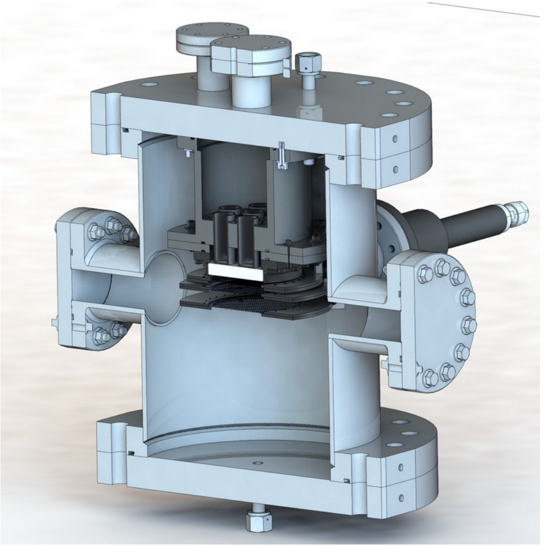
GaνESS: Detector concept

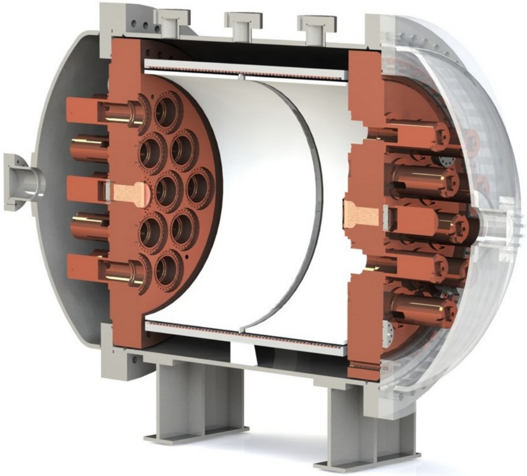


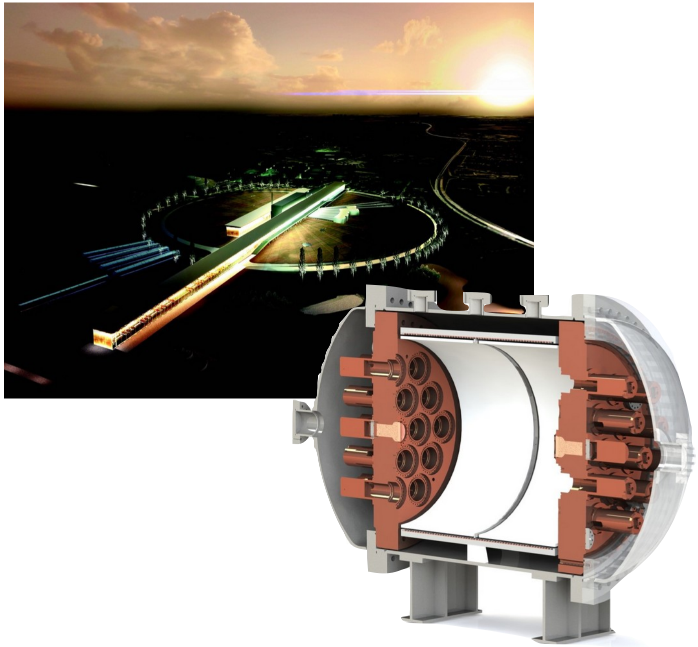
GaνESS project

GaνESS Prototype (GaP)
- R&D
- Study of nuclear recoils

→ **GaνESS construction at DIPC** → **Operation GaνESS at ESS**



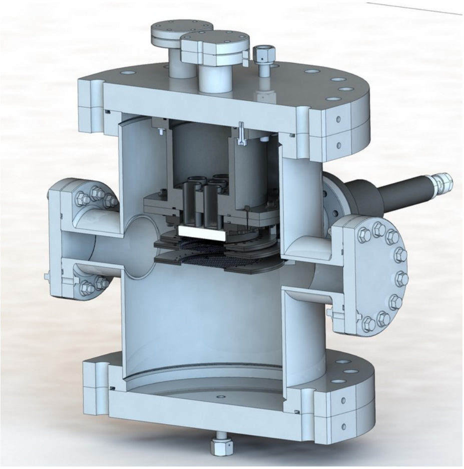




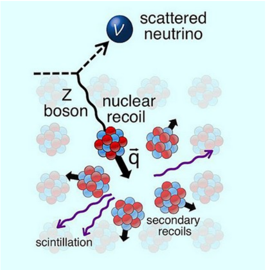
The Gaseous Prototype (GaP)

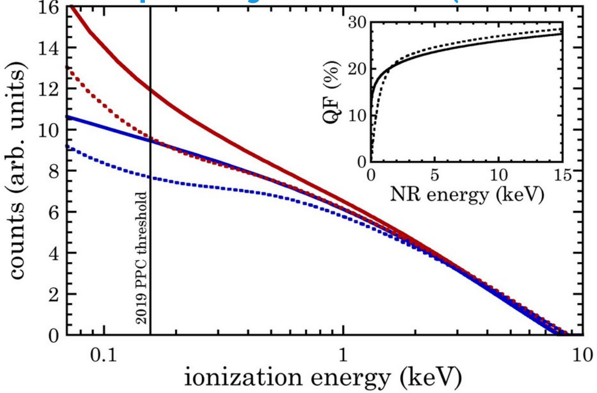
Goals

- Characterization of the low energy response of the detection technique:
  - Detection threshold.
  - **Nuclear recoil response (quenching factor).**
- Full evaluation of the technique with different gas conditions:
  - Different noble gases: Xe, Ar, Kr.
  - Pressure up to 50 bar.

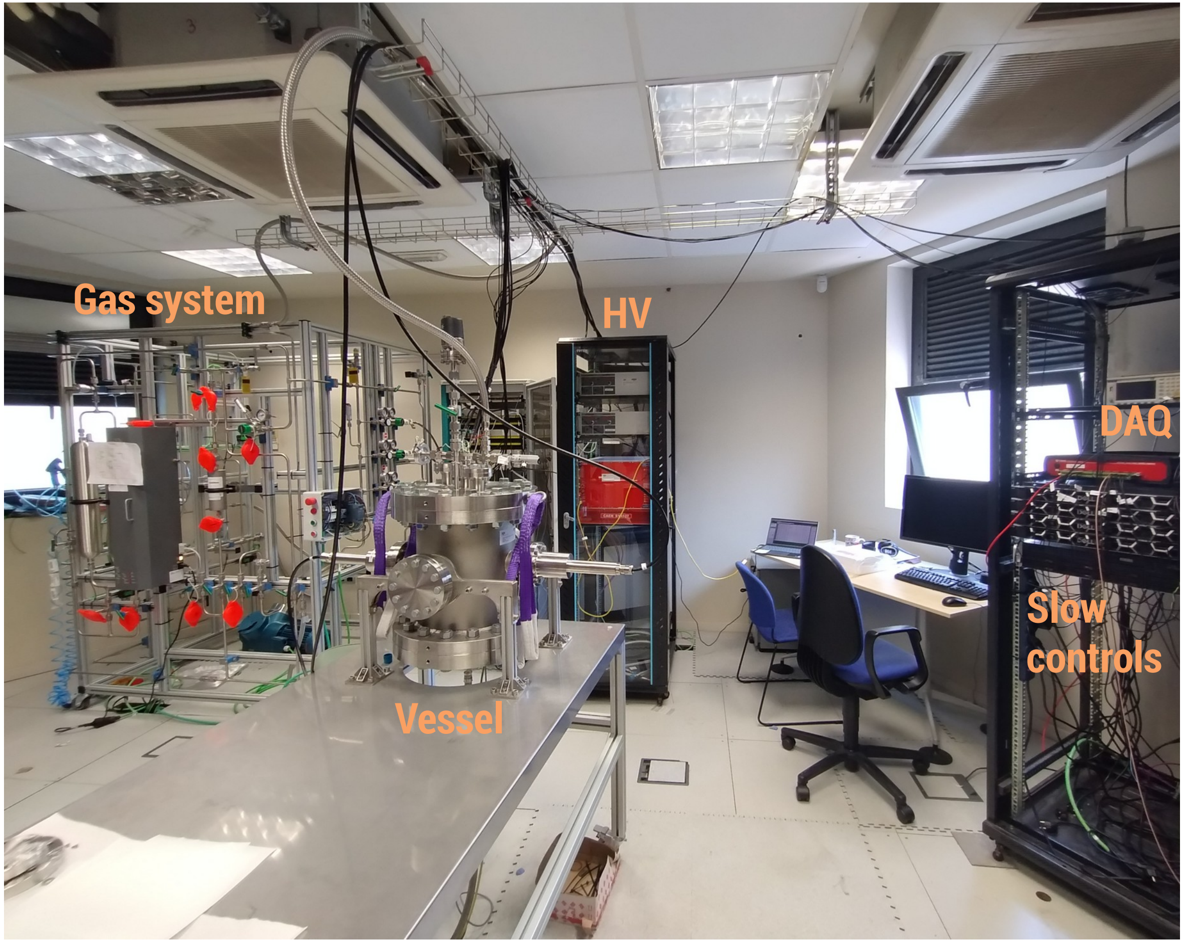


Differences in the expected distributions given different quenching factor models (solid/dashed)



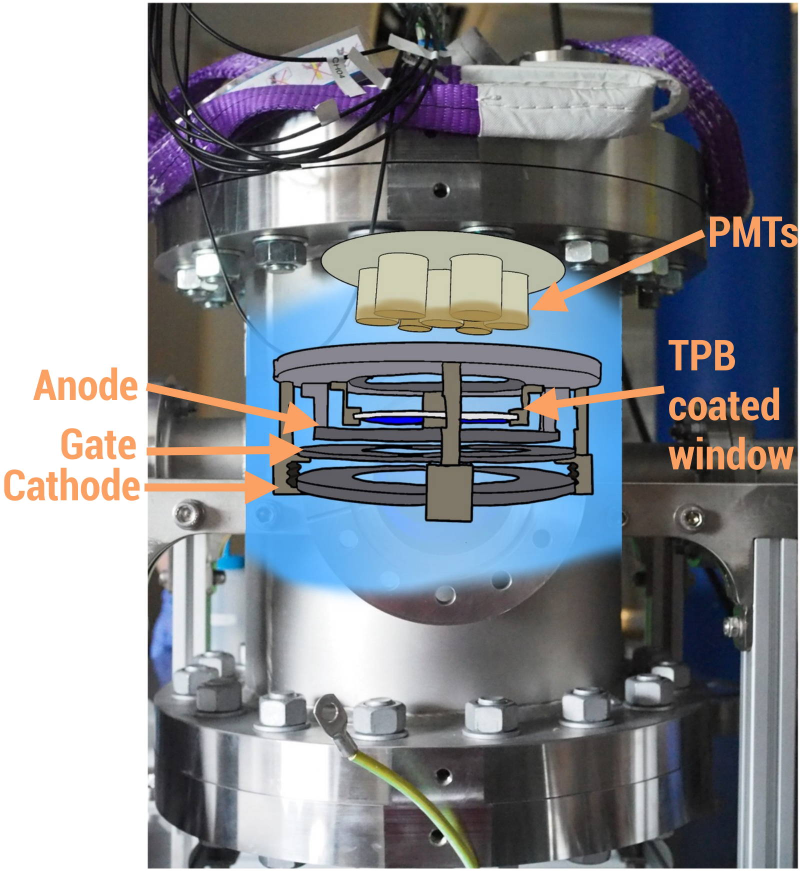


Laboratory

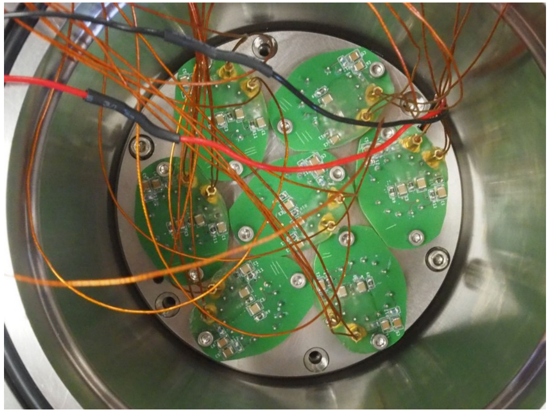


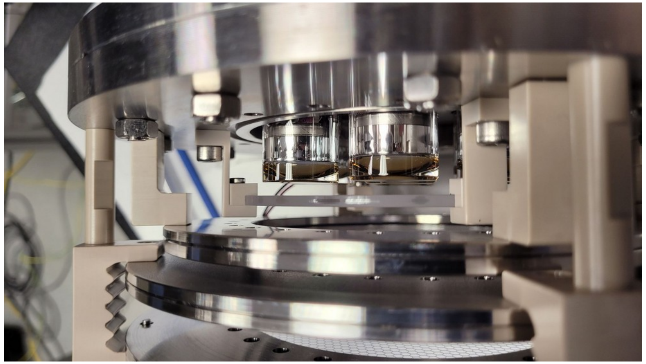
GaP current design

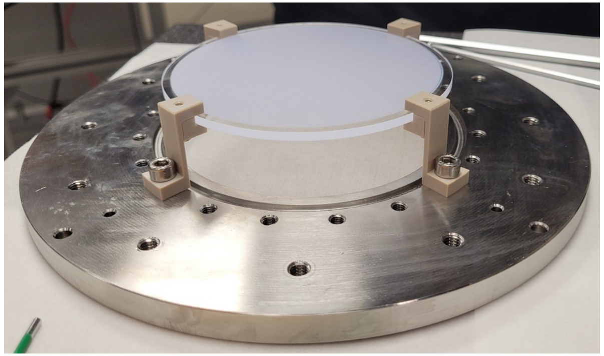
- Small vertical TPC:
  - 2 cm drift length.
  - 0.9 cm EL gap.
- 7 Hamamatsu R7378 PMTs on top.
  - TPB coated frontal window.

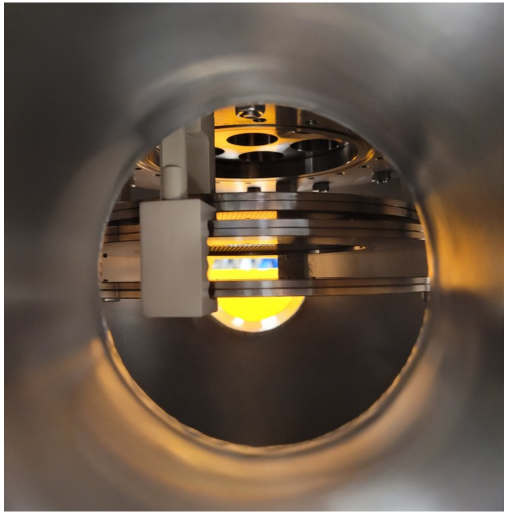


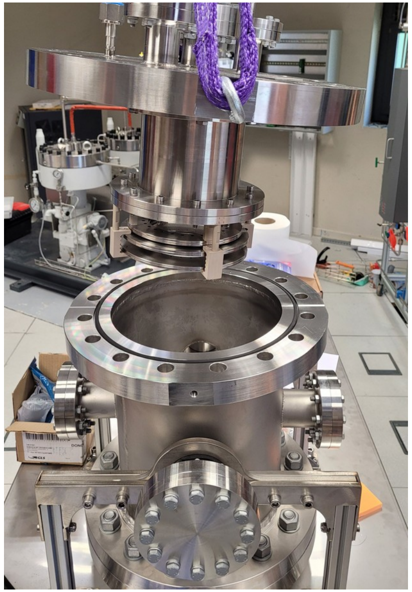
Inside GaP





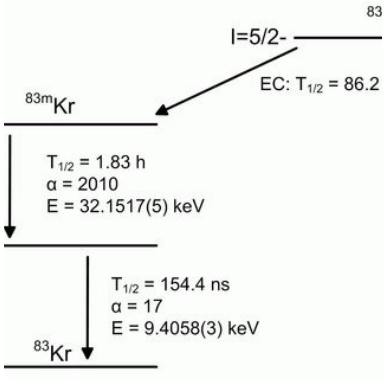


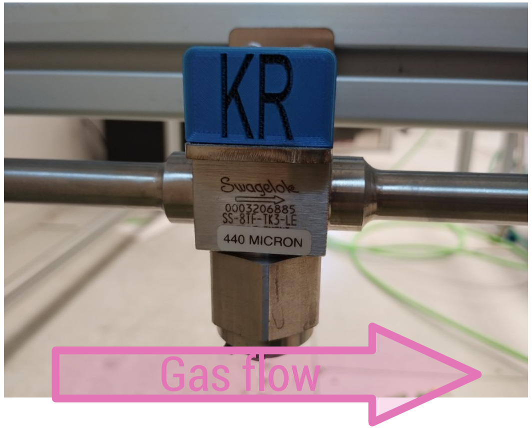


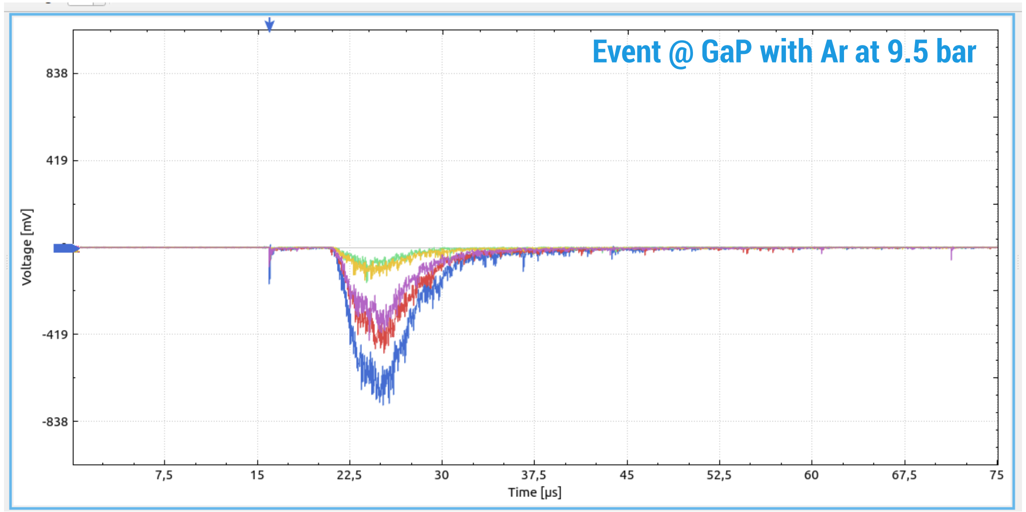


GaP status

- Started data-taking this summer.
- ^{83m}Kr source coupled to gas system.
- Ar at 9.5 bar. EL at 1.2 kV/cm (~480 ph/e)
- Unable to trigger on Kr events
  - Really bad light collection eff. + rudimentary trigger
- ^{241}Am alphas are detected.
- Now trying to understand the detector!



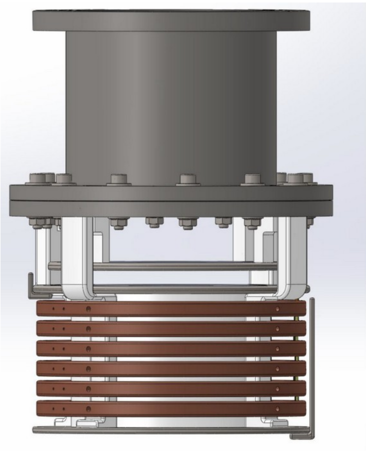


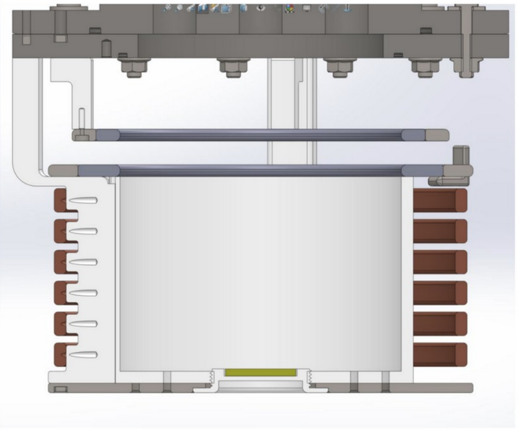


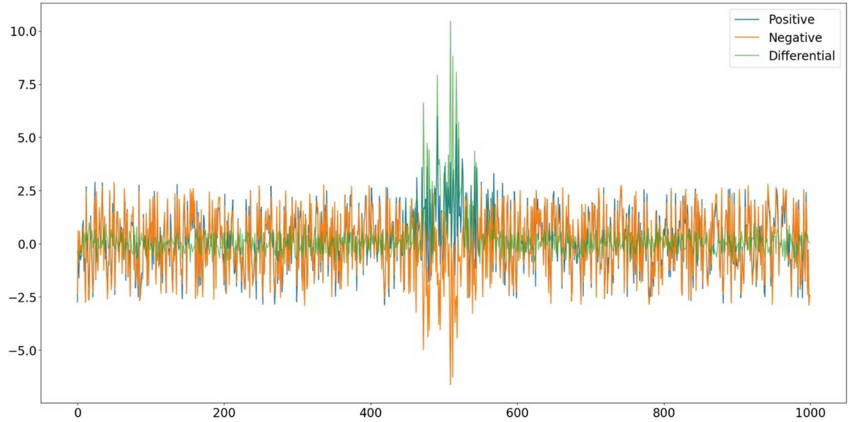
GaP short term plans

Coming weeks:

- Upgrade the detector:
  - Increased drift region (10 cm) to increase event rate and containment.
  - Add a TPB coated light-tube
  - Remove quartz window and coat PMTs with TPB, move them closer to EL.
- Develop new DAQ software:
  - More flexibility than commercial sw.
  - Trigger on differential signal.

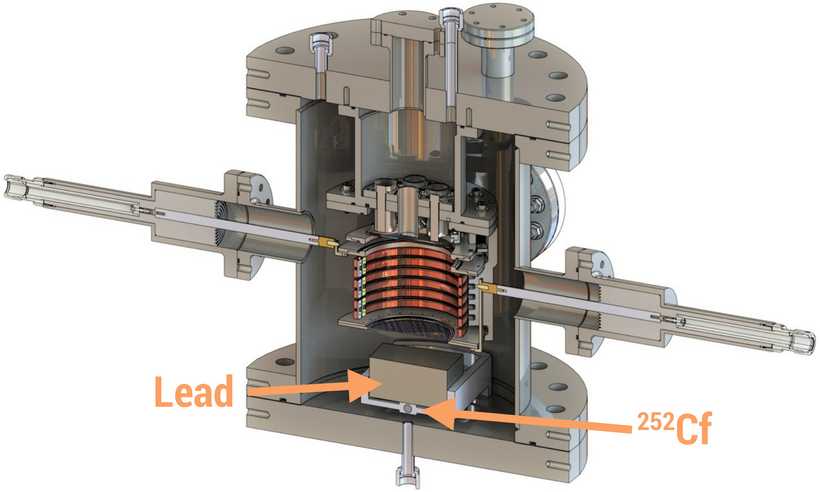


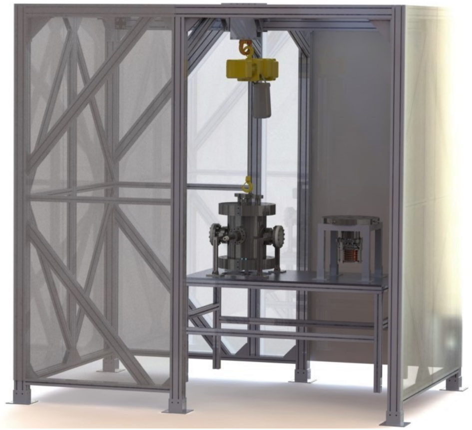




GaP medium term plans

- Replace PMTs with SiPMs.
- Start looking at nuclear recoils:
  - ^{252}Cf source
  - Needs to be exempt → Low activity (<1000 n/s)
  - Lead shield blocks source-induced gamma background.
- Clean tent in autumn for cleaner operation.

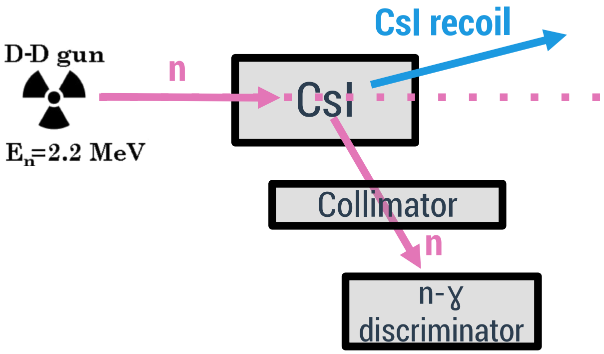




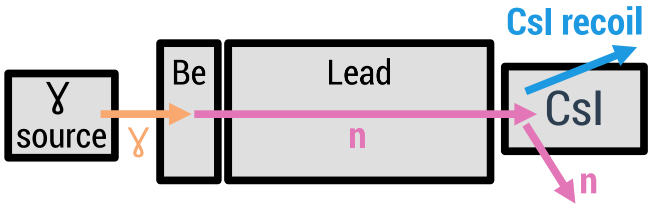
GaP medium-long term plans

- Move to Xe and repeat the studies done in Ar.
- Quasi-monoenergetic neutron sources for improved quenching factor measurements

D-D gun neutron scatter



Photoneutron sources



- Change Be for Al to obtain bckg.
- Get excess from signal – bckg.

^{88}YBe (~153 keV n) → E_{rec} < 4.6 keV
^{124}SbBe (~ 24 keV n) → E_{rec} < 0.7 keV

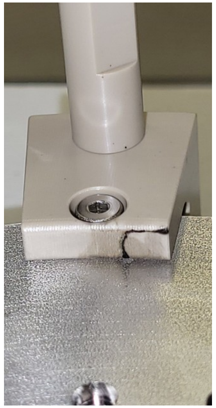
Summary

- CEvNS detection opens a new avenues in the search of physics beyond the Standard Model.
- ESS will become the largest low-energy neutrino source. Perfect facility to study this process.
- The GaνESS project, will produce a detector to observe the process at the ESS with a variety of nuclei and large discovery potential.
- The GaνESS Prototype (GaP) will allow to fully characterize the technique in the low energy regime.
- GaP data-taking and operation has just started with gaseous Ar at moderate pressures (up to 10 bar).

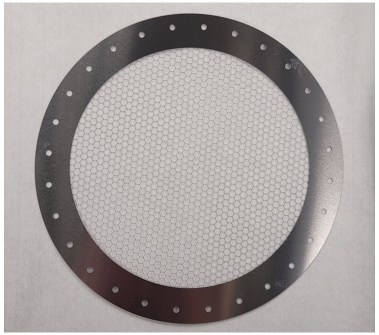
Backup

EL spark tests and troubleshooting

- First operation with Ar at pressure (up to 10 bar) in May.
- Lots of sparks at low fields.
  - Occurring at the PEEK holders.
  - Solved by holding the EL mesh from the bottom.
- More sparks, now between holder rings
  - Solved by moving the grid to the surface of the holder.
  - Long term solution using cryofitted wire mesh.



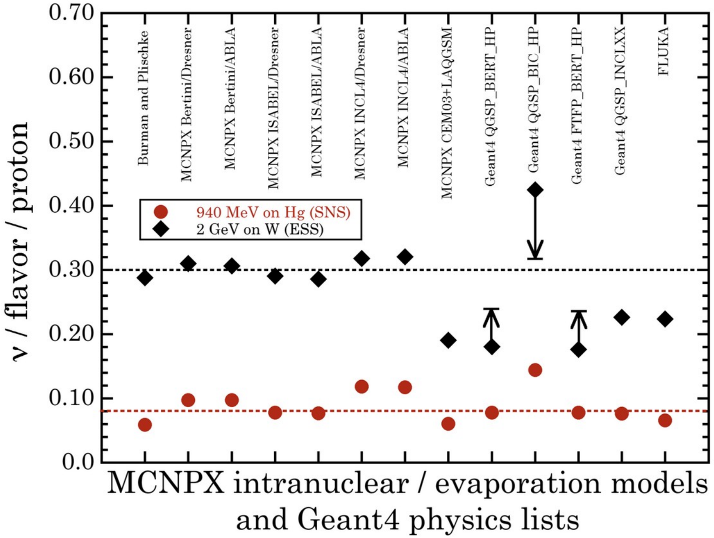
Photochemical etched mesh

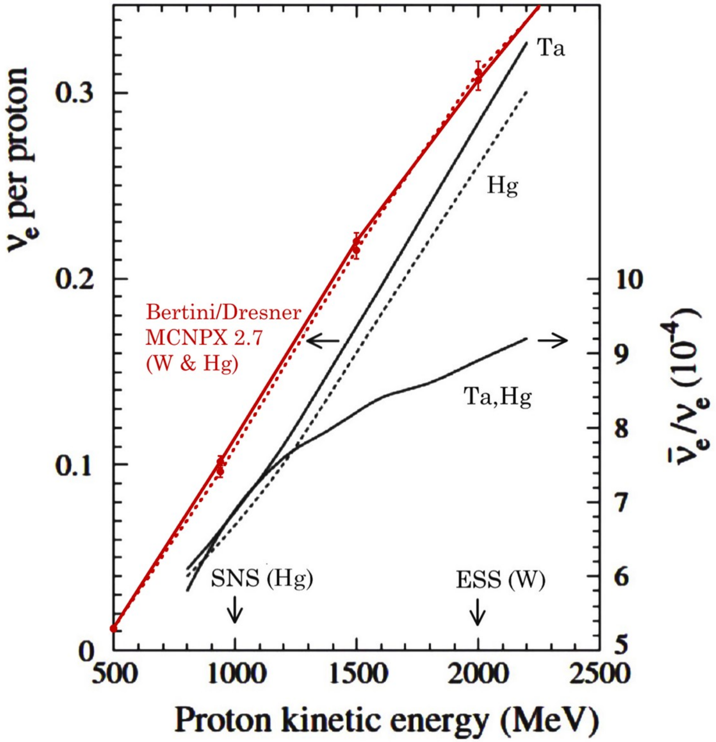


Wire mesh

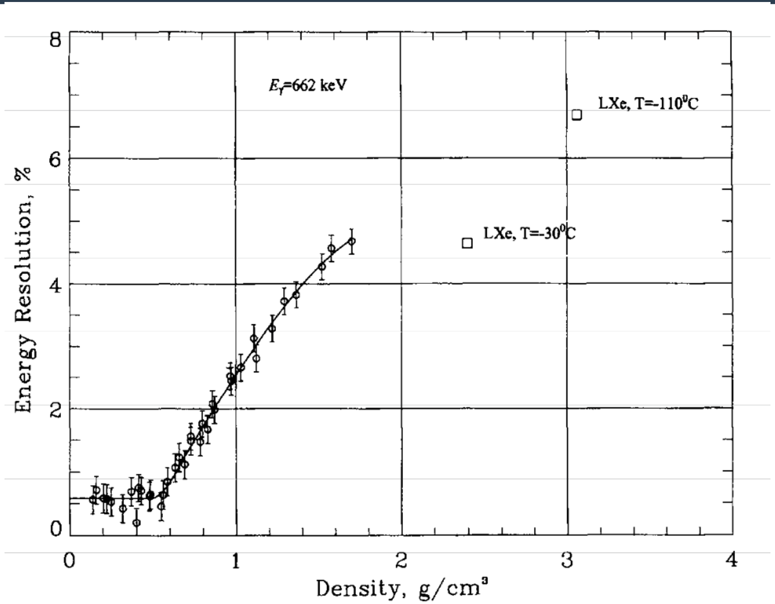
SNS vs ESS

	SNS	ESS
Average power	1.4 MW	5 MW
Proton pulse length	*695 ns*	*2.86 ms*
Peak power	34 GW	125 MW
Energy per pulse	**24 kJ**	**357 kJ**
Pulse repetition rate	60 Hz	14 Hz



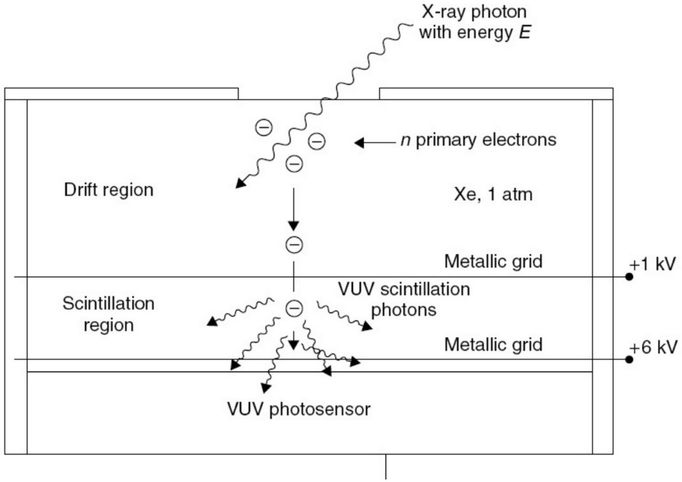


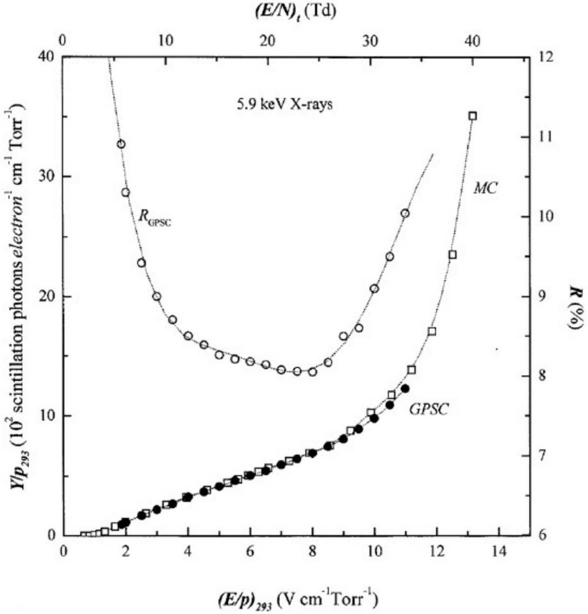
Energy resolution in HPGXe



- Very good energy resolution up to ~50 bar.
- Best experimental result: 0.6%@662keV.
- It will allow for a better spectrum reconstruction, thus better sensitivity to deviations from SM.

Electroluminescence





- Emission of scintillation light after atom excitation by a charge accelerated by a moderately large (no charge gain) electric field.
- Linear process, huge gain (1500 ph./e-) at 3 < E/p < 6 kV/cm/bar.
- Almost no extra fluctuations during the amplification process.
- More stable at high pressure, no need of quenchers.

Detector Technology	Target nucleus	Mass (kg)	Steady-state background	E_{th} (keV_{ee})	QF (%)	E_{th} (keV_{nr})	$\frac{\Delta E}{E}$ (%) at E_{th}	E_{max} (keV_{nr})	CEνNS $\frac{NR}{yr}$ @20m, $>E_{th}$
Cryogenic scintillator	CsI	22.5	10 ckkd	0.1	~10 [71]	1	30	46.1	8,405
Charge-coupled device	Si	1	1 ckkd	0.007	4-30 [97]	0.16	60	212.9	80
High-pressure gaseous TPC	Xe	20	10 ckkd	0.18	20 [104]	0.9	40	45.6	7,770
p-type point contact HPGe	Ge	7	15 ckkd	0.12	20 [118]	0.6	15	78.9	1,610
Scintillating bubble chamber	Ar	10	0.1 c/kg-day	-	-	0.1	~40	150.0	1,380
Standard bubble chamber	C_3F_8	10	0.1 c/kg-day	-	-	2	40	329.6	515