Academia-Industry Matching event devoted to neutron MPGD
14-15 October 2013
Lessons from the first workshop

B. Guérard, R. Hall-Wilton, F. Murtas

Objective

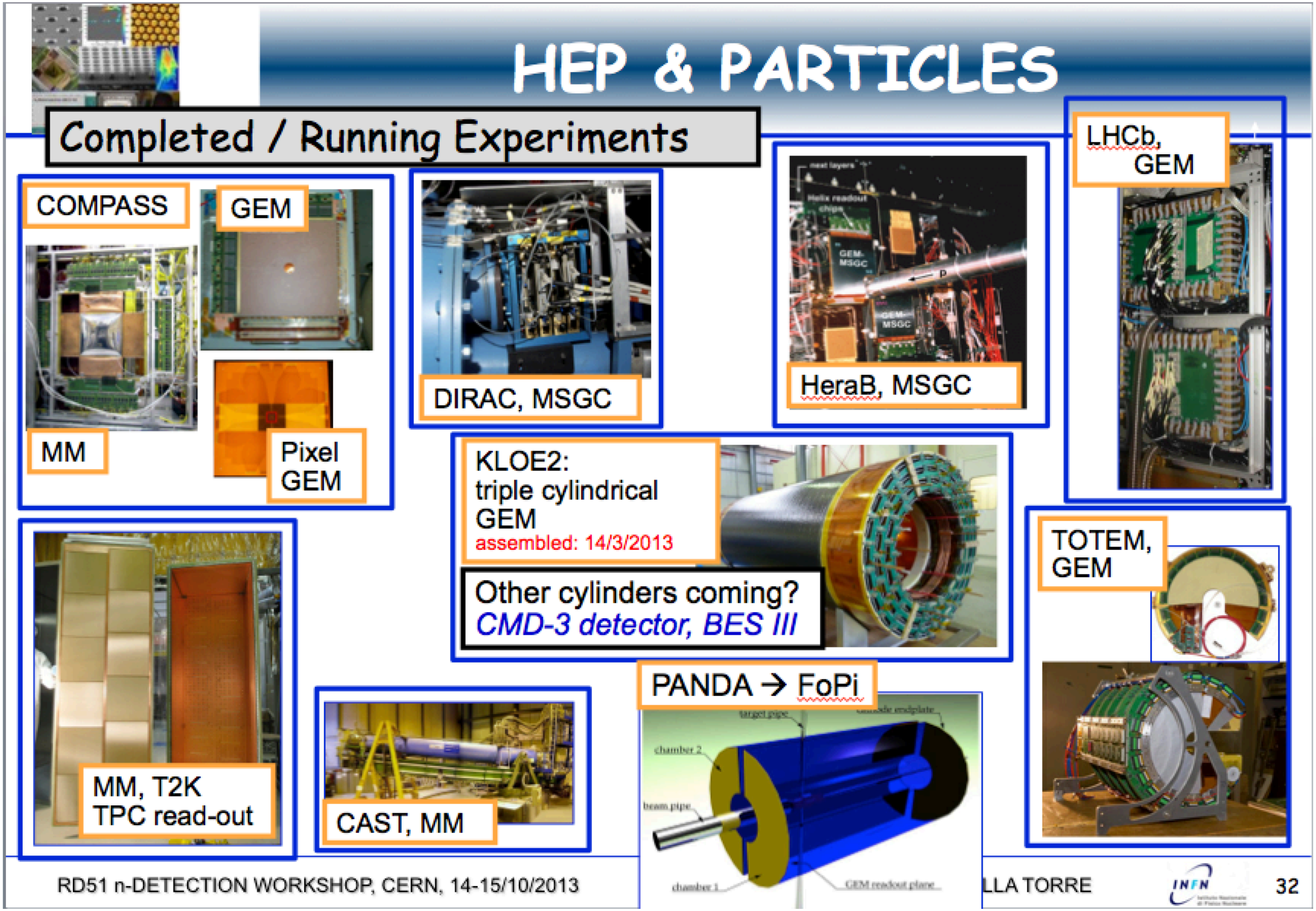
help disseminating MPGD technologies beyond High Energy Physics, and give the possibility to academic institutions, potential users and industry to meet together

The selection made for this short overview is not guided by any consideration of importance of the results, methods, and detector concepts presented during the workshop.

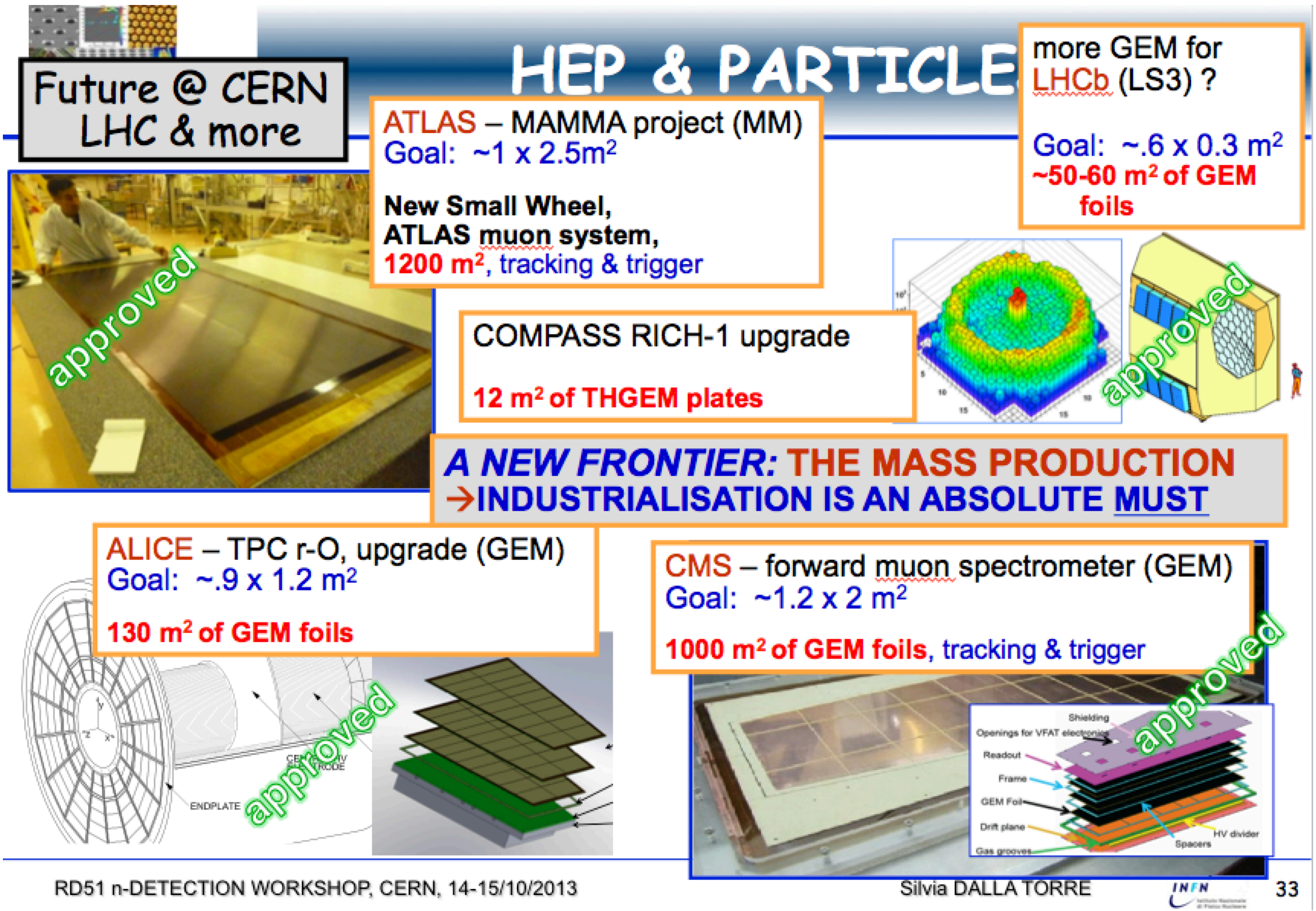
More info : RD51 Note 2014-003 / arXiv_1410.0107

MPGDs for HEP

Silvia DALLA TORRE (INFN)

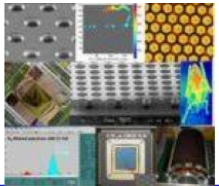


Silvia DALLA TORRE (INFN)



A NEW FRONTIER: THE MASS PRODUCTION
→INDUSTRIALISATION IS AN ABSOLUTE MUST

→ new opportunities for neutron detectors



CONCLUSIONS

Some basic messages clearly emerge:

- To reach the maturity of a MPGD architecture:
  - initial brilliant intuitions
  - efforts for a mature technology → reliable detectors
  - severe engineering processes → operation in challenging experiments
- **MPGDs originate from HEP needs and the R&D is driven by this needs**
- About technology transfer to applications beyond HEP:
  - a difficult task for gas detectors because of
    - (i) the intrinsic delicate operation; (ii) the lack of a reliable industrial production
  - for MPGDs today BETTER perspectives, thanks to the request of very large MPGD systems in fundamental research →
    - (i) fully non critical operation required; (ii) industrial mass production is a must
- Relevant progress in recent years thank to an upgrade of the community:
  - from uncorrelated groups of MPGD developers to a world-wide Collaboration
    - continuous, open exchange of information
    - infrastructural needs (tools) analysed and built thanks to the critical mass

- MPGDs originate from HEP needs and the R&D is driven by this needs

Differences between HEP and neutrons detection → specific R&D is needed for neutrons

- About technology transfer to applications beyond HEP:
  - a difficult task for gas detectors because of
    - (i) the intrinsic delicate operation; (ii) the lack of a reliable industrial production
  - for MPGDs today BETTER perspectives, thanks to the request of very large MPGD systems in fundamental research →
    - (i) fully non critical operation required; (ii) industrial mass production is a must

→ it's all about finding the good matching between the demand for neutron detectors, and what MPGD can offer

Rui de Oliveira (CERN)

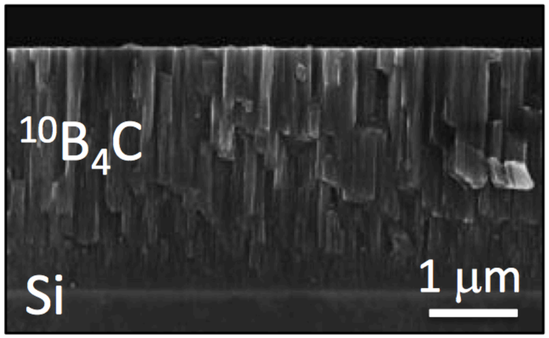
Conclusion

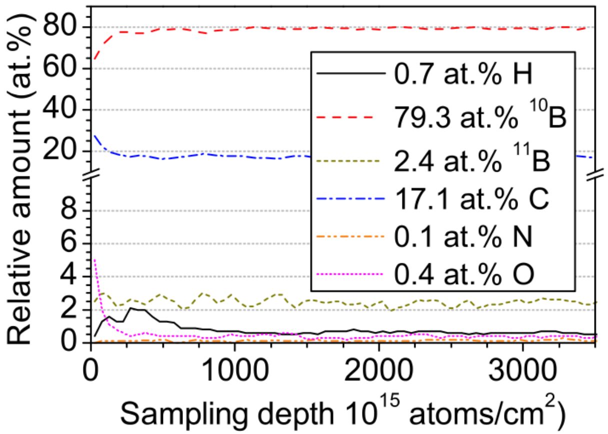
- ***MPGDs are already in the hands of industry***
- ***Mass production in industry already possible for small and medium size detectors.***
- ***Still many possibilities to investigate in future for new MPGDs***

Solid convertor films for neutron detectors

Carina Höglund (ESS)

DC magnetron sputtering of $^{10}B_4C$ (PVD)

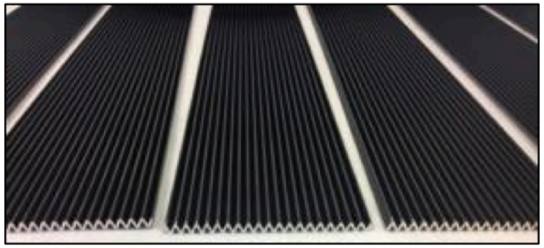


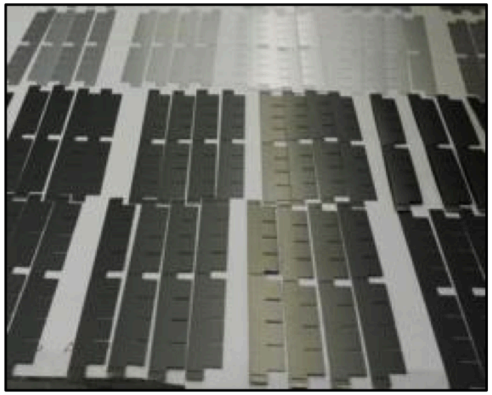


CemeCon CC800/9 deposition machine:

- Almost 80 at.% ^{10}B
- Impurities H +N + O only ~1 at.%
- Good adhesion onto Al, Si, Al_2O_3, etc
- Thicknesses up to above 4 μm
- Very low residual stress (0.09 GPa at 1 μm)
- Densities of 2.45 g/cm^3 (bulk 2.52 g/cm^3)
- No damage by neutron radiation
- 2-sided substrates
- Large area (>5 m^2/week)

➔ Prototypes!





Patent SE 535 805 C2

C. Höglund et al., J. Appl. Phys. 111 104908 (2012)

Neutron scattering science
European Spallation Source

Richard Hall Wilton (ESS)

Detector requirements for reference suite

Instrument	Detector Area $[m^2]$	Wavelength Range [Å]	Time Resolution [μs]	Resolution [mm]
Multi-Purpose Imaging	0.5	1-20	1	0.001 - 0.5
General Purpose Polarised SANS	5	4-20	100	10
Broad-Band Small Sample SANS	14	2-20	100	1
Surface Scattering	5	4-20	100	10
Horizontal Reflectometer	0.5	5-30	100	1
Vertical Reflectometer	0.5	5-30	100	1
Thermal Powder Diffractometer	20	0.6-6	<10	2x2
Bi-Spectral Powder Diffractometer	20	0.8-10	<10	2.5x2.5
Pulsed Monochromatic Powder Diffractometer	4	0.6-5	<100	2 x 5
Material Science & Engineering Diffractometer	10	0.5-5	10	2
Extreme Conditions Instrument	10	1-10	<10	3x5
Single Crystal Magnetism Diffractometer	6	0.8-10	100	2.5x2.5
Macromolecular Diffractometer	1	1.5-3.3	1000	0.2
Cold Chopper Spectrometer	80	1 -20	10	10
Bi-Spectral Chopper Spectrometer	50	0.8-20	10	10
Thermal Chopper Spectrometer	50	0.6-4	10	10
Cold Crystal-Analyser Spectrometer	1	2-8	<10	5-10
Vibrational Spectroscopy	1	0.4-5	<10	10
Backscattering Spectrometer	0.3	2-8	<10	10
High-Resolution Spin Echo	0.3	4-25	100	10
Wide-Angle Spin Echo	3	2-15	100	10
Fundamental & Particle Physics	0.5	5-30	1	0.1
Total	**282.6**			

Estimates

Table 2.5: Estimated detector requirements for the 22 reference instruments in terms of detector area, typical wavelength range of measurements and desired spatial and time resolution.

- Specifications very varied
- Typically superior to what is presently state-of-the-art at existing sources
- In many cases, instrument performance dominated by S:B rather than raw specifications here

COST!

Positive indicators

- Maturity of the MPGD techniques
- Opportunitiy to fabricate MPGDs in the industry
- Adaptability, modularity of the detector design
- Important demand from neutron instrumentation (in quantity + performance)
- 3He shortage → Need to secure neutron instrumentation everywhere
- Boron film convertor: Well understood technique; promising alternative to 3He. Production well established at ESS.

MPGDs + solid convertor films for neutron detectors

1/ Low efficiency detectors

WHY AND HOW TO USE GEMS TO DETECT NEUTRONS

- GEM detectors born for tracking and triggering applications (detection of charged particles)

- In order to detect neutral particles you need a converter
  - Fast Neutrons: Polyethylene converter + Aluminium
    - Neutrons are converted in protons through elastic scattering on hydrogen
  - Thermal Neutrons: ^{10}Boron converter
    - Neutrons are detected using the productus (alpha,Li) from nuclear reaction ^{10}B(n,alpha)7Li

- GEMs offer the following advantages
  - Very high rate capability (MHz/mm^2) suitable for high flux neutron beams like at ESS
  - Submillimetric space resolution (suited to experiment requirements)
  - Time resolution from 5 ns (gas mixture dependent)
  - Possibility to be realized in large areas and in different shapes
  - Radiation hardness
  - Low sensitivity to gamma rays (with appropriate gain)

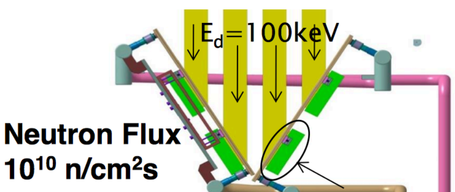
Gabriele Croci (IFP-CNR & INFN)

Fast and slow neutron beam monitoring
The low detection efficiency is not an issue

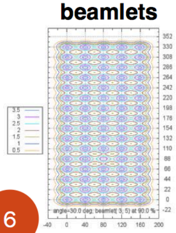
Mainframe Projects

CNSEM (Close Contact Neutron Surface Emission Mapping) diagnostic for ITER NBI Prototypes (SPIDER & MITICA)

Deuterium Beam (100 Kev)

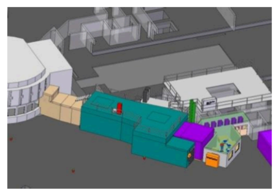


Deuterium Beam composition: 5x16 beamlets



Aim: Reconstruct **Deuterium beam profile** from neutron beam profile. **Angular resolution and directionality property needed**

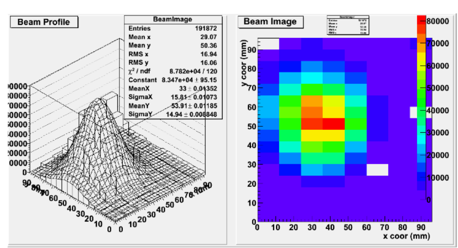
Beam monitor for **ChipIr** @ ISIS and **ESS**



ChipIr CAD model at ISIS-TS2

ESS Model

Aim: Construct large area, real-time and high rate beam monitors for fast neutron lines



See G.Gorini Talk

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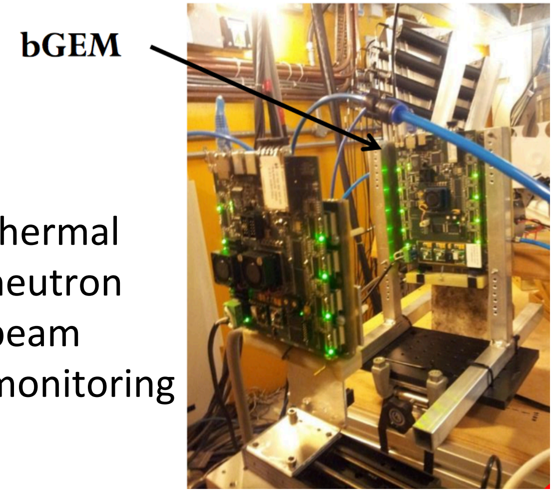
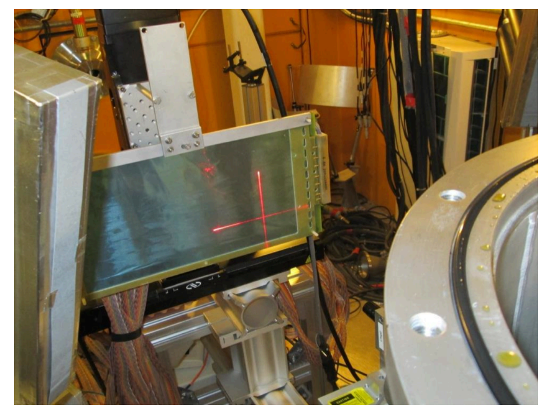


thermal neutron beam monitoring

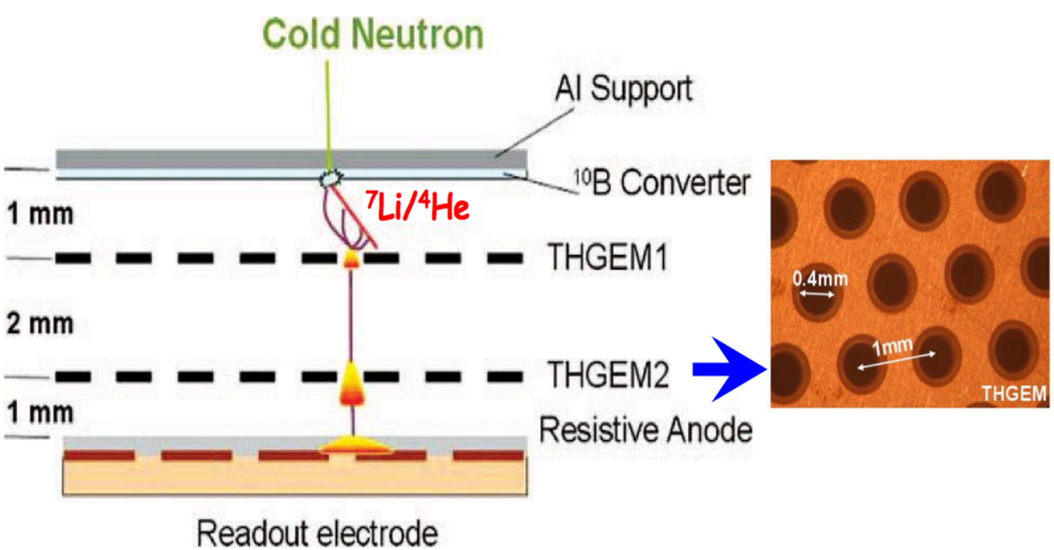


Deuterium beam diagnostic (Nuclear Fusion)

thGEM and G-GEM

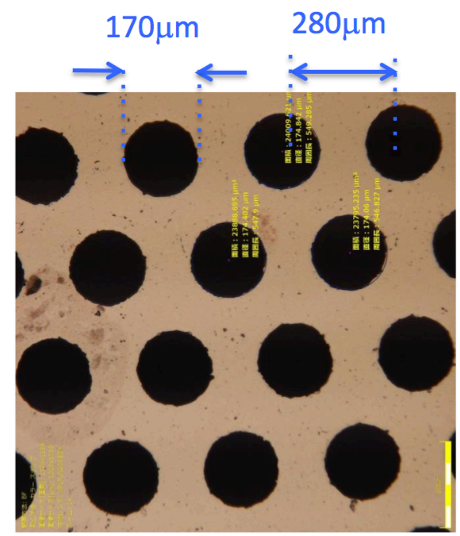
Advantages: self-supported

R. Adams (ETH, Zurich)



Hiroyuki Takahashi (Tokyo Univ.)

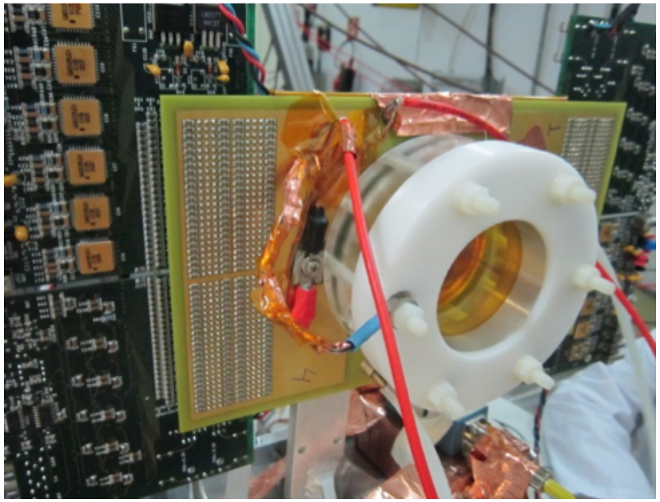
Glass GEM (Hoya PEG3 photo Etchable Glass)
no outgasing → 3He compatible



- Substrate: 145 mm x 145 mm
- Effective area: 100 mm x 100mm
- Thickness: 680μm (300~1000μm)

MicroMegas

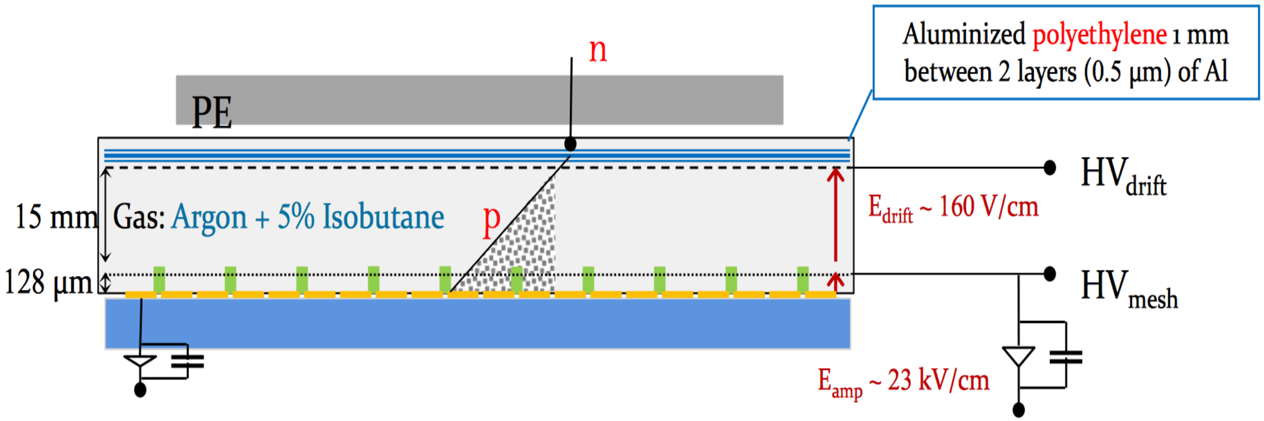
Éric Berthoumieux (CEA/IRFU)



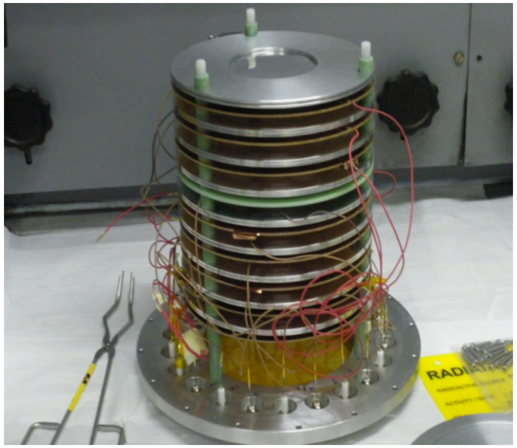
Application: Beam profiler for n-TOF

Paul Colas (CEA Saclay)

Application: fast neutrons neutronography (to see hydrocarbons through metal or glass)



MicroMegas TPC



Application: Fission Cross Section Measurement

MPGDs + solid convertor films for neutron detectors

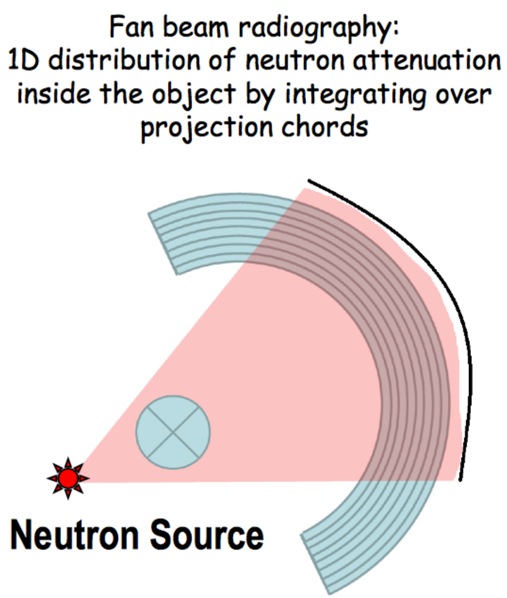
2/ Ways to increase detection efficiency

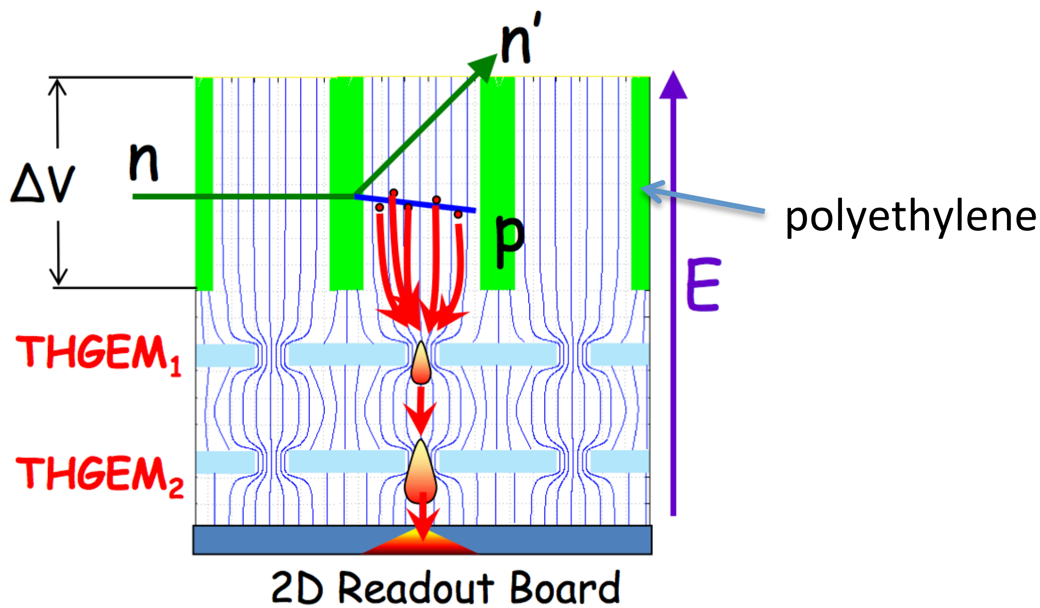
GEM and th-GEM in Comb geometry

1D detectors

Robert Adams (ETH, Zurich)

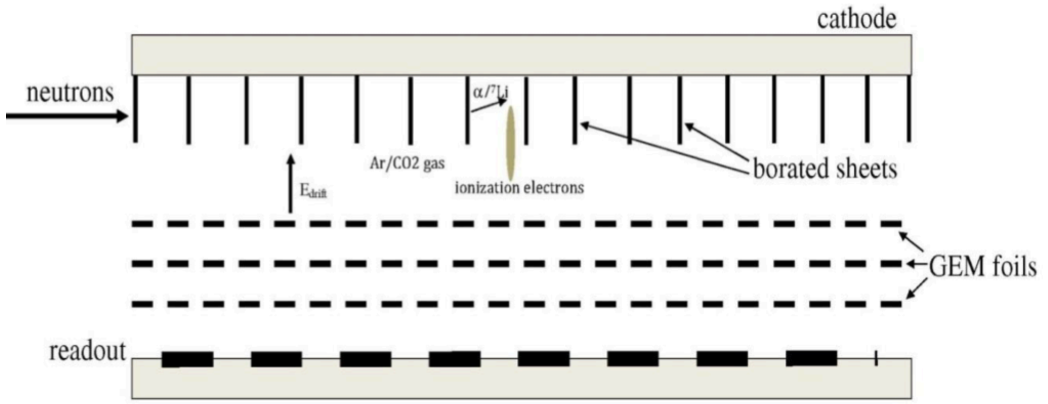
Application: Fast neutron detector for 2D tomography



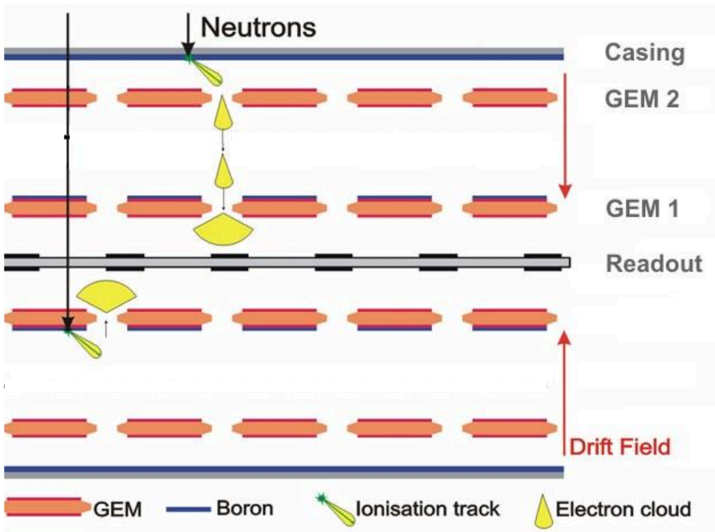


Gerardo Claps (INFN – LNF)

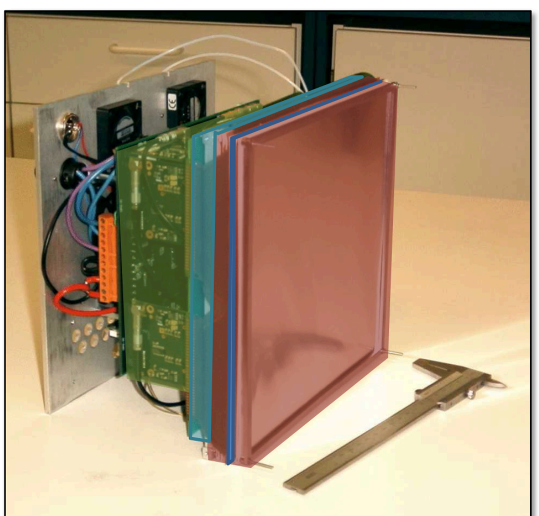
Boron coated on aluminium blades



Markus Köhli (CASCADE)



CASCADE detector without housing



CASCADE: N+1 GEMs perpendicular to the neutron trajectories.

N GEMs are used to support the 10B converter and to transmit the electrons (amplification gain = 1) to the last GEM which amplifies the signal (gain = 10-100).

2D localization + acceptable detection efficiency (at least for UCN)

Operational since several years at PSI

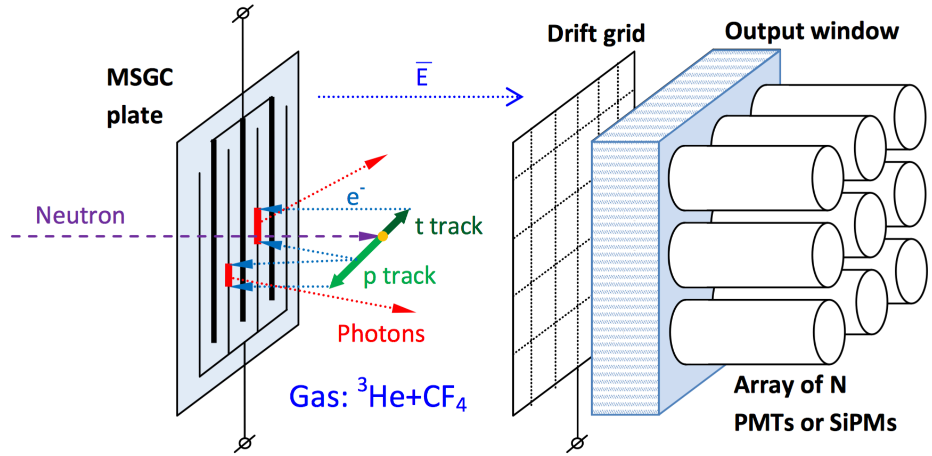
→ Most achieved concept of GEM detector for neutrons

MPGDs + 3He

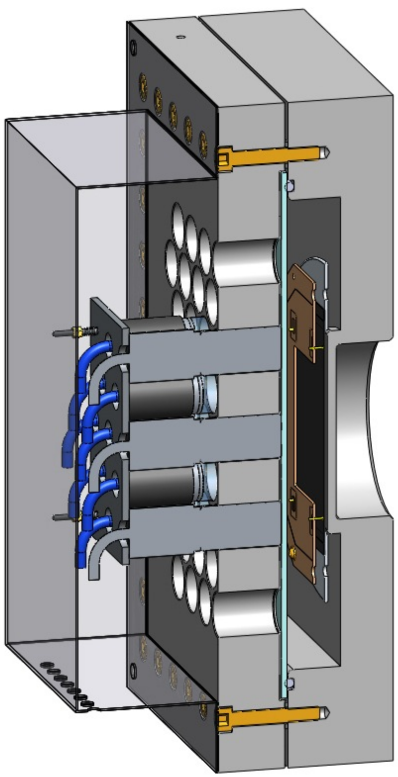
MSGC-GSPC + 3He
Light readout with PMTs
Application: NSS

Andrei Morozov (LIP)

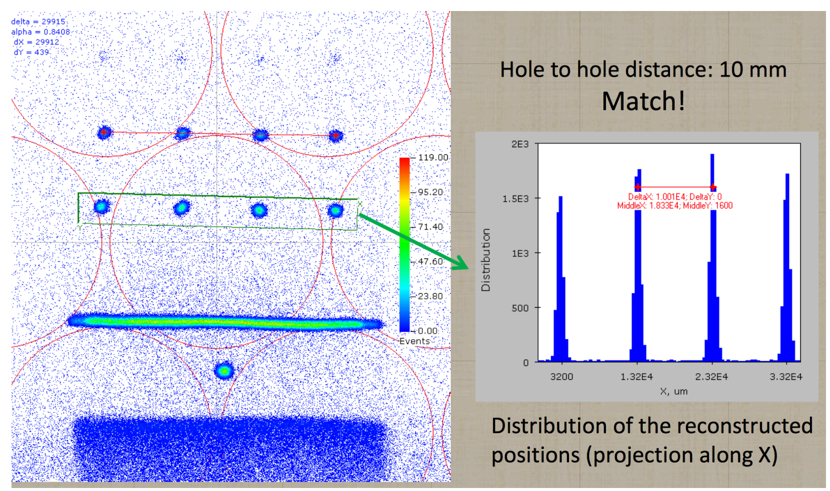
data analysis and simulation



Davide Raspino (STFC)

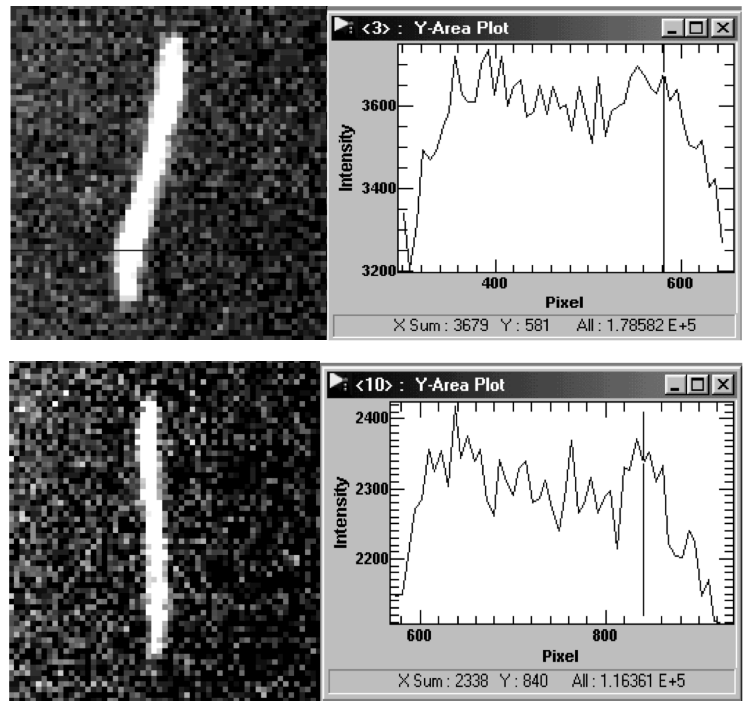


0.6 mm FWHM



GEM-GSPC + 3He
Light readout with CCD camera
(F. Fraga 2002, not presented at the workshop)

Fig. 8. Superimposed proton–triton tracks obtained with an exposition time of 1 s.



3He + MPGD

- small sensitive area (due to 3He cost)
- high concentration of stopping gas needed to reach high spatial resolution
- sealed gas vessels, or purification systems (BNL)

MSGCs mounted in a clean vessel do not require gas purification and have demonstrated high spatial resolution with 6 bar of CF4.

GEM made of Kapton + other organic materials require a purification system
Question: operation at 6 bar CF4

Glass-GEMs looks interesting (operation at high pressure ?)

10B + MPGD for thermal neutron detector with detection efficiency = 1-5 %

Having the neutron convertor coated directly on the GEM allows to measure the first part of the signal produced close to the neutron capture point → simple and fast signal processing + high spatial resolution.

Suitable for neutronography and 2D beam monitors (no need for high efficiency).

Thermal neutron beam monitors: pb of scattering ?

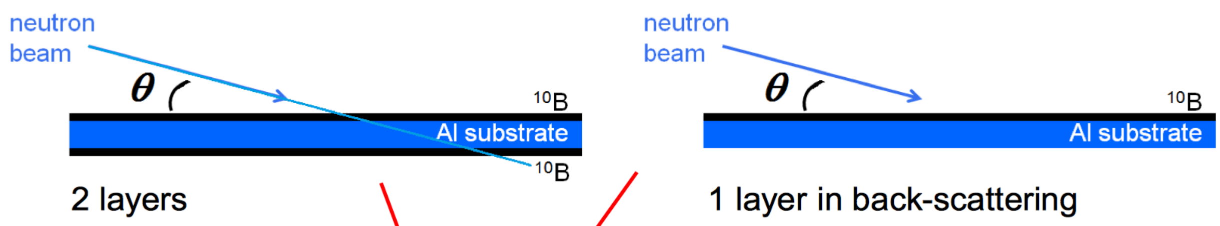
10B + MPGD for thermal neutron detector with detection efficiency >50%

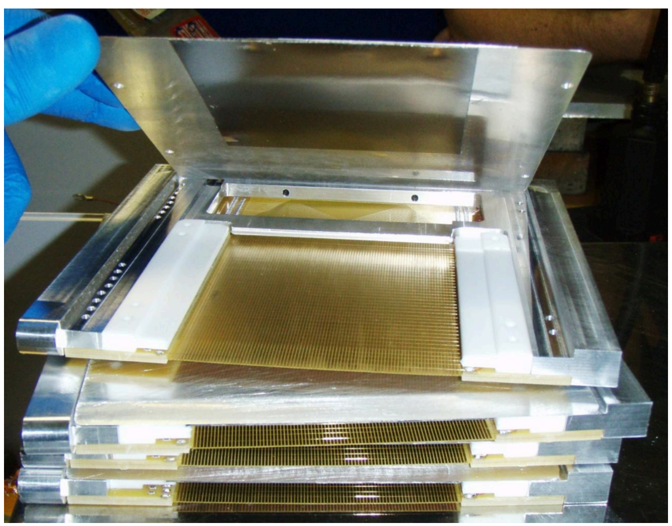
the equivalent of 30 to 50 micrometers of B4C film is required, but the mean range of alpha and Li7 particles is only 3.2 and 1.6 micrometers

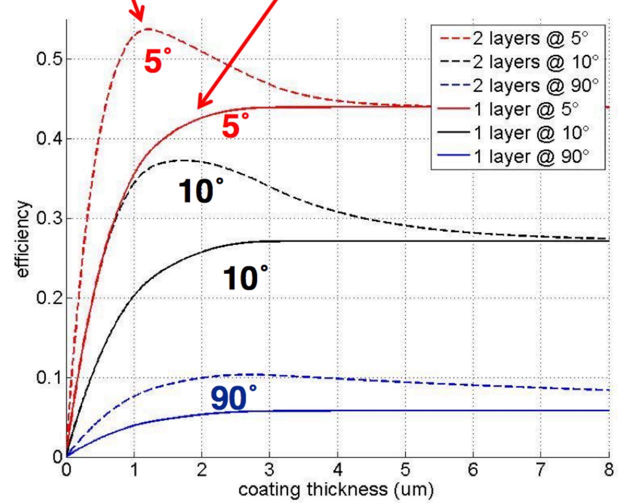
Francesco Piscitelli (ILL) *

* Now at ESS

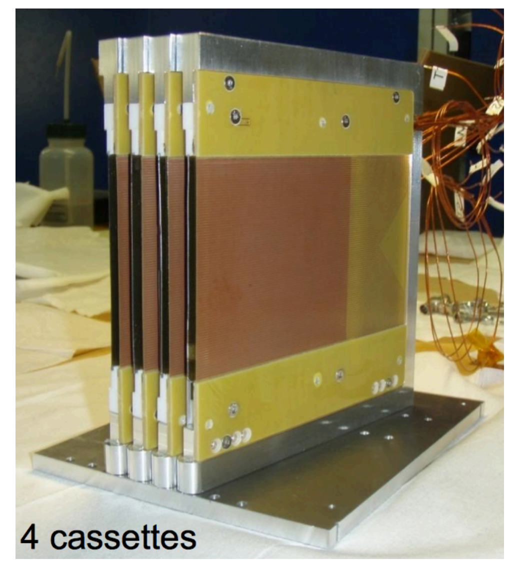
Substrates oriented at grazing angle (MultiBlade) + MWPC







Calculation at 2.5 A



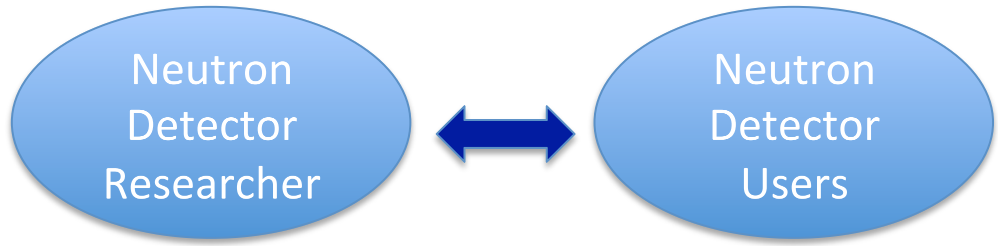
Enclined substrates (5°angle → factor 10 in the effective thickness)

Good to try with MPGD !

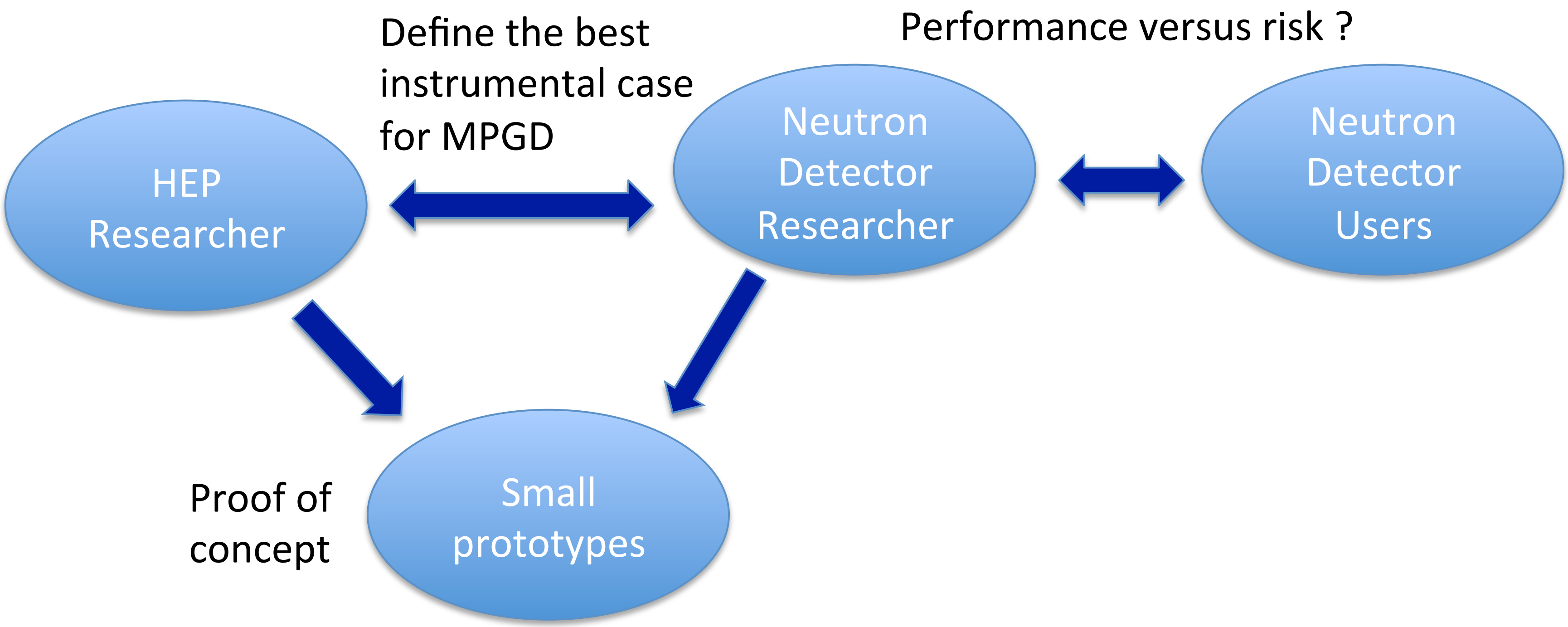
possible scenario for TT to Neutron Scattering Science

possible scenario for TT to Neutron Scattering Science

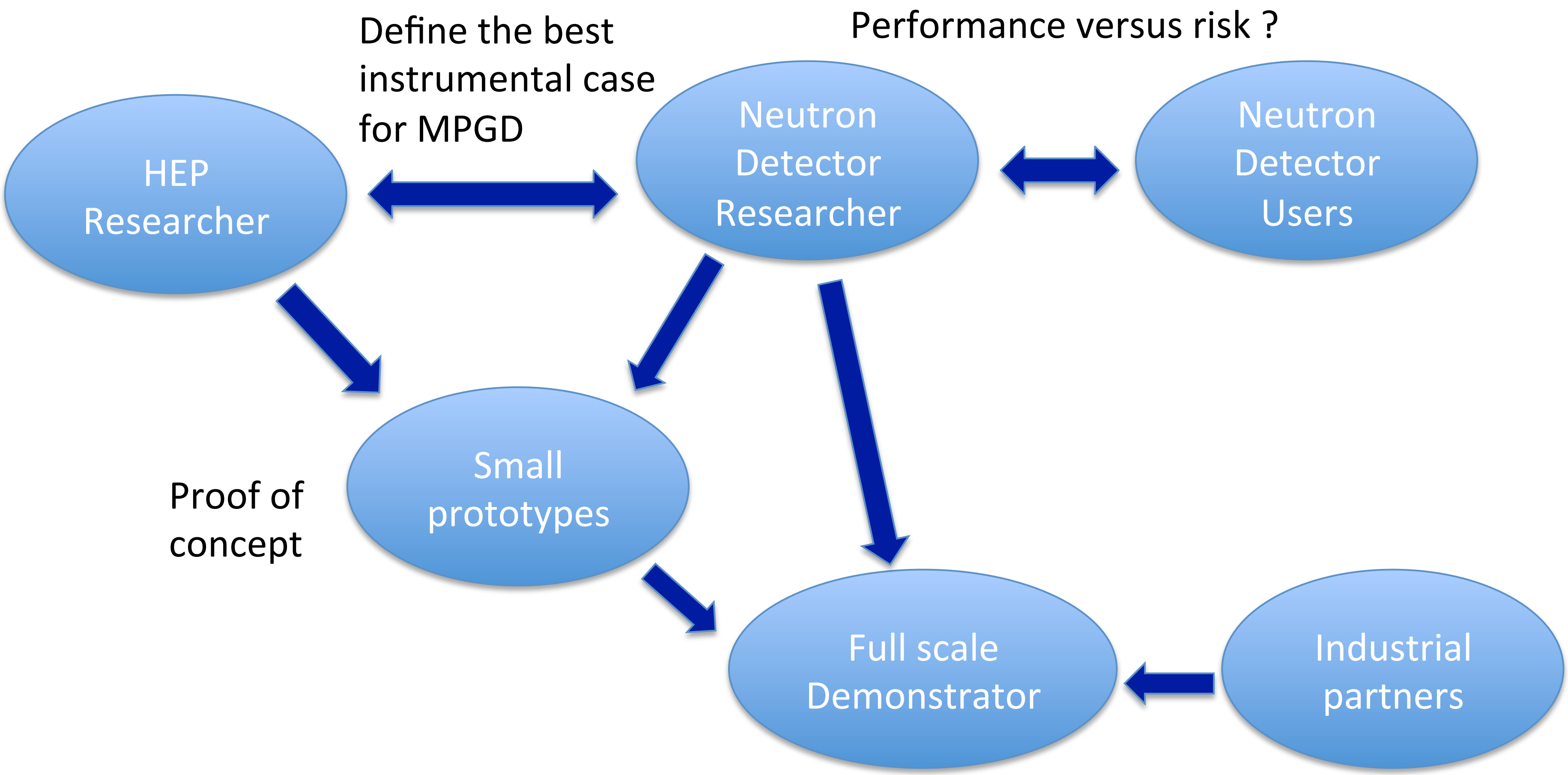
Performance versus risk ?



possible scenario for TT to Neutron Scattering Science

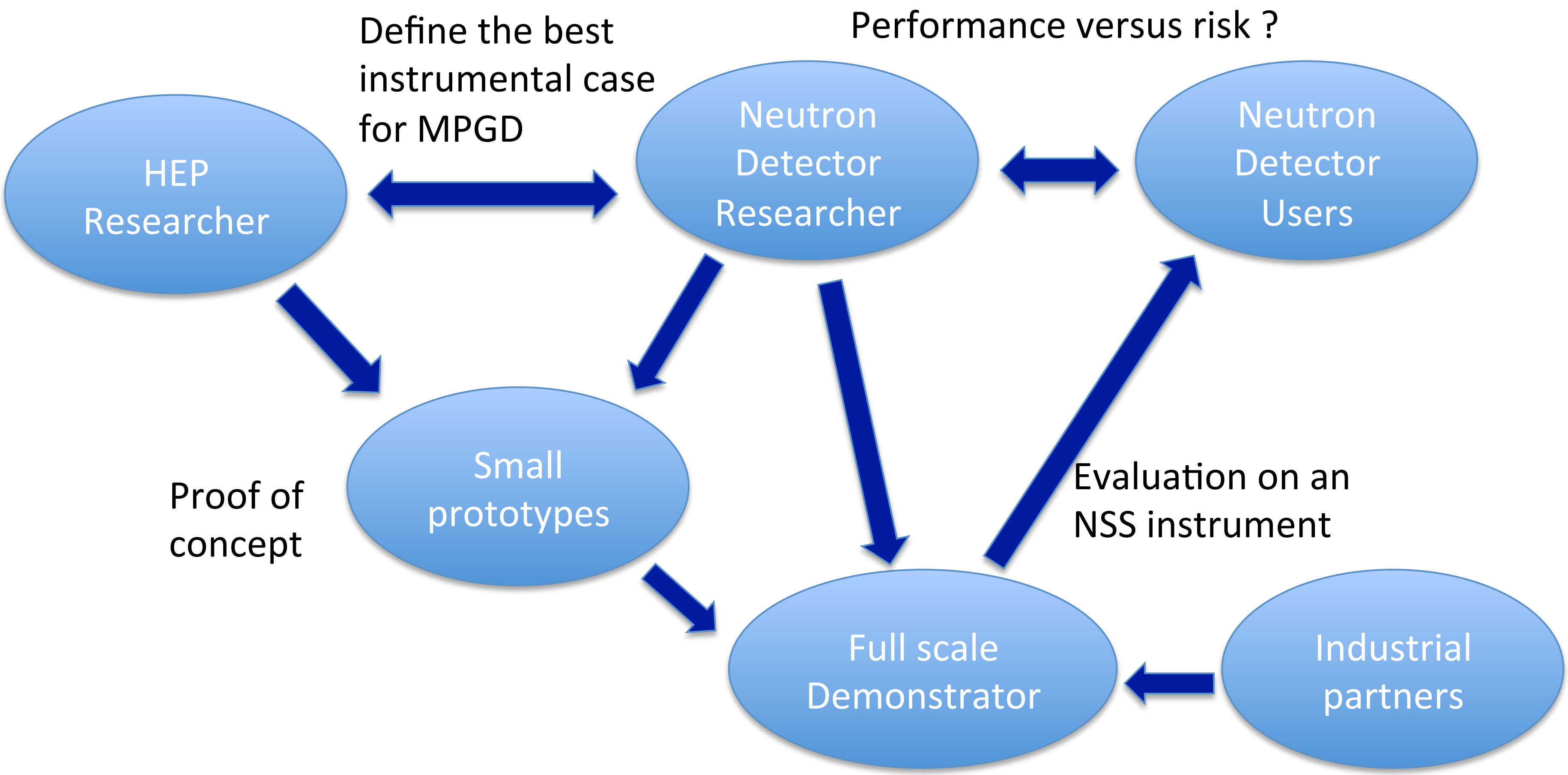


possible scenario for TT to Neutron Scattering Science



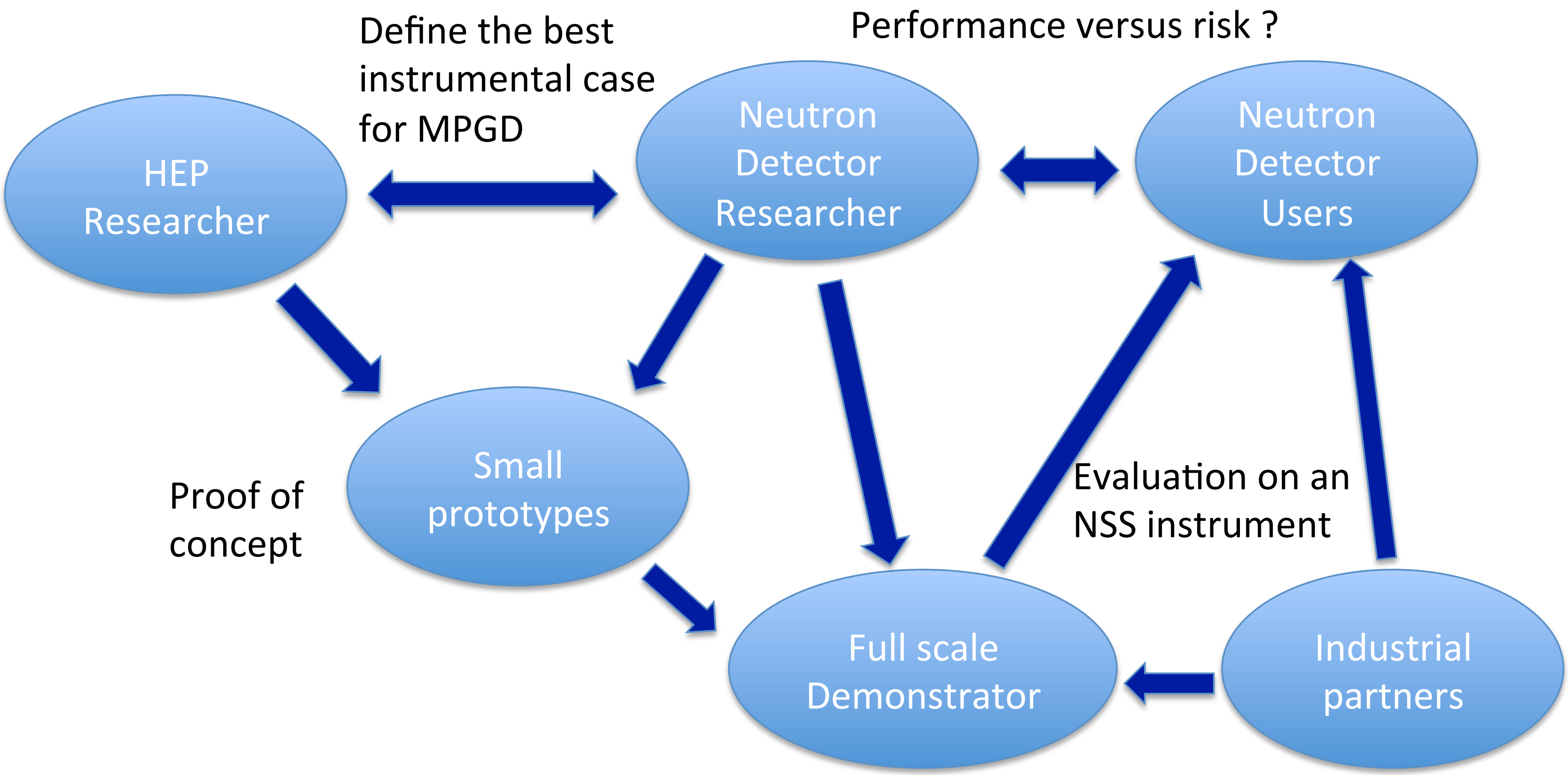
Industrial partners are involved in the fabrication of the full scale demonstrator → training

possible scenario for TT to Neutron Scattering Science



Industrial partners are involved in the fabrication of the full scale demonstrator → training

possible scenario for TT to Neutron Scattering Science



Industrial partners are involved in the fabrication of the full scale demonstrator → training

Remarks for TT to NSS

The landscape of neutron detectors has changed due to the 3He shortage, and to the new demand for ESS (larger and faster detectors, higher spatial resolution)

Some applications requiring neutron detectors can benefit from the high performances of MSGCs, GEMs, and MicroMegas

Industrialization of GEMs (for ALICE and CMS) creates an opportunity for neutron instrumentation

Capitalize former sucessful experiences of MPGDs for NSS (MSGC, GEM, and Micromegas) → Identify reluctances to use them (could be discussed during the round table)

Market survey : identify 1 or 2 instruments in several institutes where MPGD could be a decisive role to improve these instruments

To be discussed …

1/ Is it pertinent to use a **Micro**-pattern technology to build **Macro** detectors ?

2/ Small or medium size detectors with High counting rate capability and high precision are needed for SANS, reflectometry, macromolecular crystallography…. 3He remains available in small quantities and can still be considered for small or medium size detectors (20-100 liters)
→ Is it still good to consider MPGD + 3He ?

3/ can detection efficiency (in particular for ESS) be compromised in applications requiring high spatial resolution (0.2 mm)
→ We could use only a few layers of convertor films, or, for 3He detectors, signal processing/filtering (long development time = high precision)

4/ What about Ageing at ESS ? → New domain of study in the future (as it is for HEP)