The Tetra-Ball single moderator neutron spectrometer

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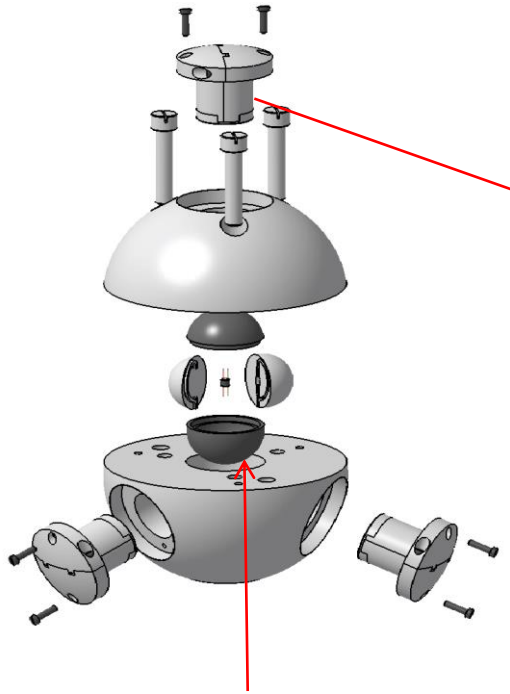
Talk summary

- T-Ball: nearly isotropic, single-exposure, active neutron spectrometer from thermal to GeV
- Main purpose: monitoring the n background in the CMS cavern in the Phase II of LHC-High Luminosity (CERN)
- Monte Carlo simulations to compute response matrices
- Simulate measurements in neutron fields
  - ❑ Representative neutron source spectrum
  - ❑ Simulation of T-Ball readings
  - ❑ Unfolding tests
- Conclusions

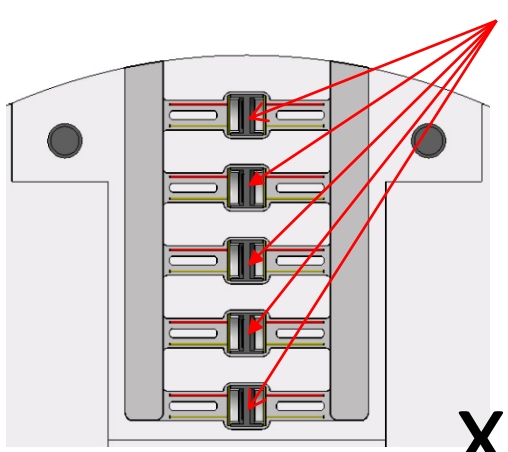
Tetra-Ball

28 cm diameter
polyethylene sphere



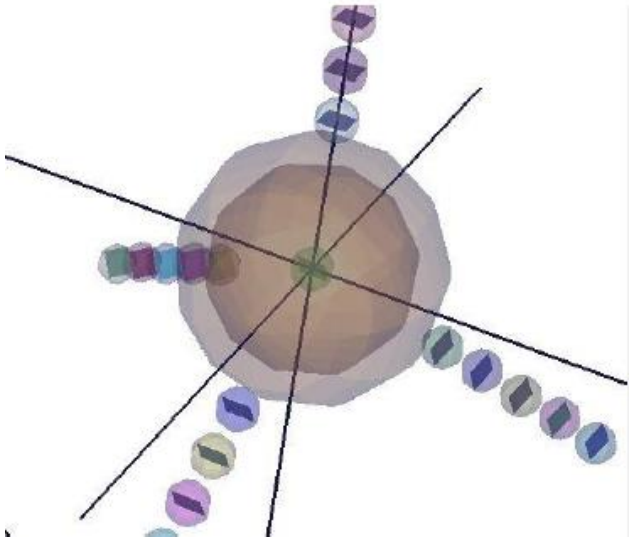
Internal lead shell for
high-E neutrons detection
(from R=3.5 to 4.5 cm)

For each of the 4 axes,
5 active thermal n sensors at different radii
(5.8, 7.5, 9.2, 10.9 and 12.6 cm)
+ central sensor
= 21 sensors



Radial positions for a
single axis

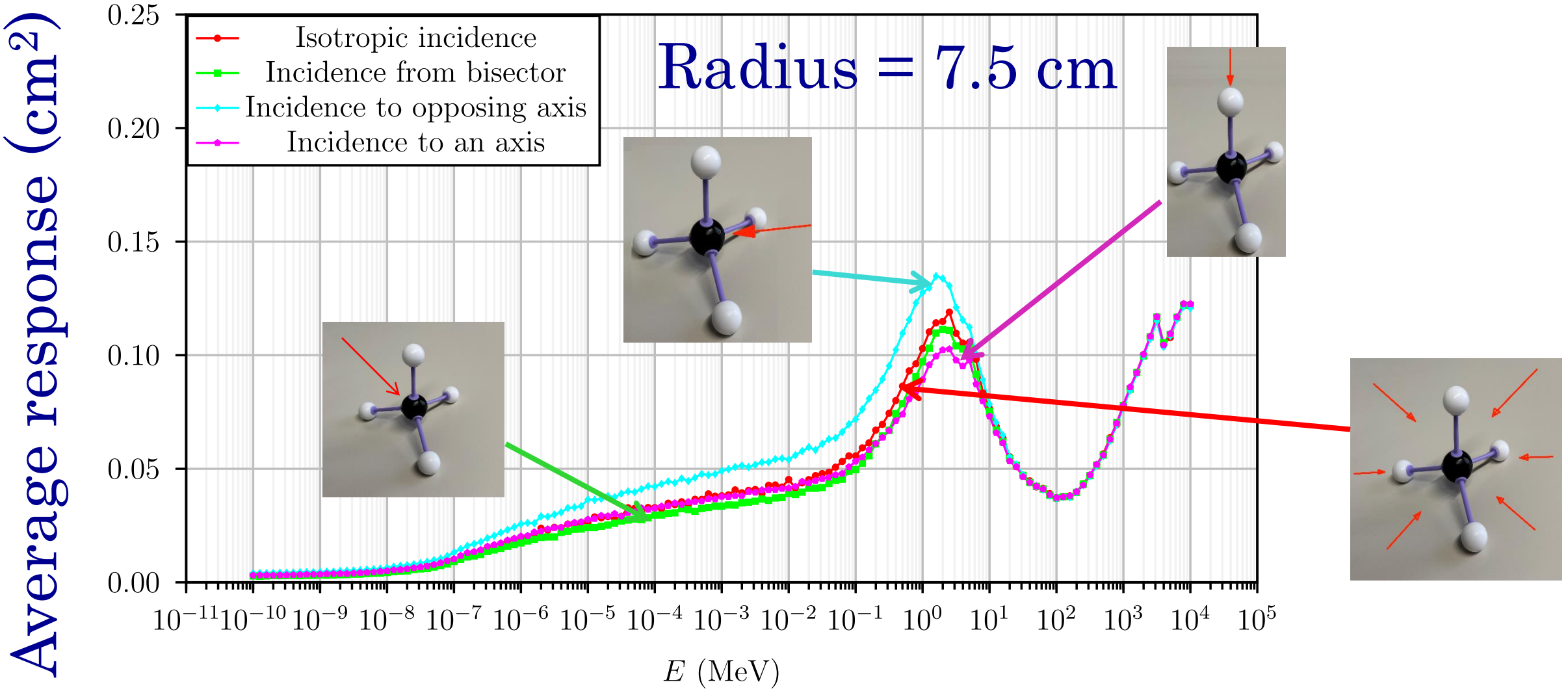
General description and main advantages of Tetra-Ball



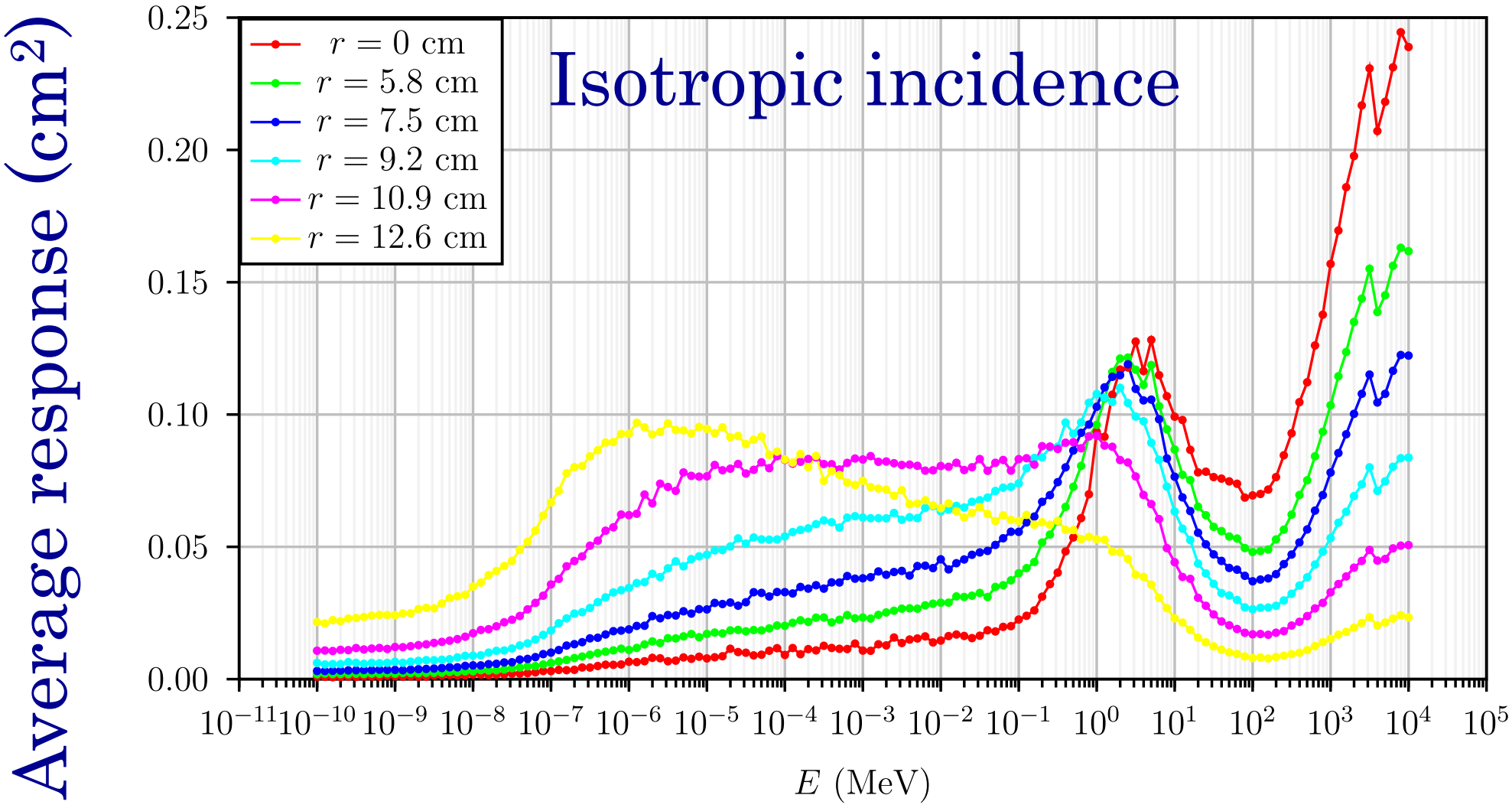
- A single sensor has anisotropic response BUT the AVERAGE of all sensors at the same RADIUS is nearly ISOTROPIC
- With respect to the SP^2 (6 semi-axes x 5 detectors/axis + central one = 31), the tetrahedral geometry has less detectors but anyway keeping isotropic response

① Does the 21 sensors tetrahedral structure provide sufficient spectrometric information?
② Is the AVERAGE of the sensors at same radius accurate enough for spectrometry?

Response function for different directions of incidence

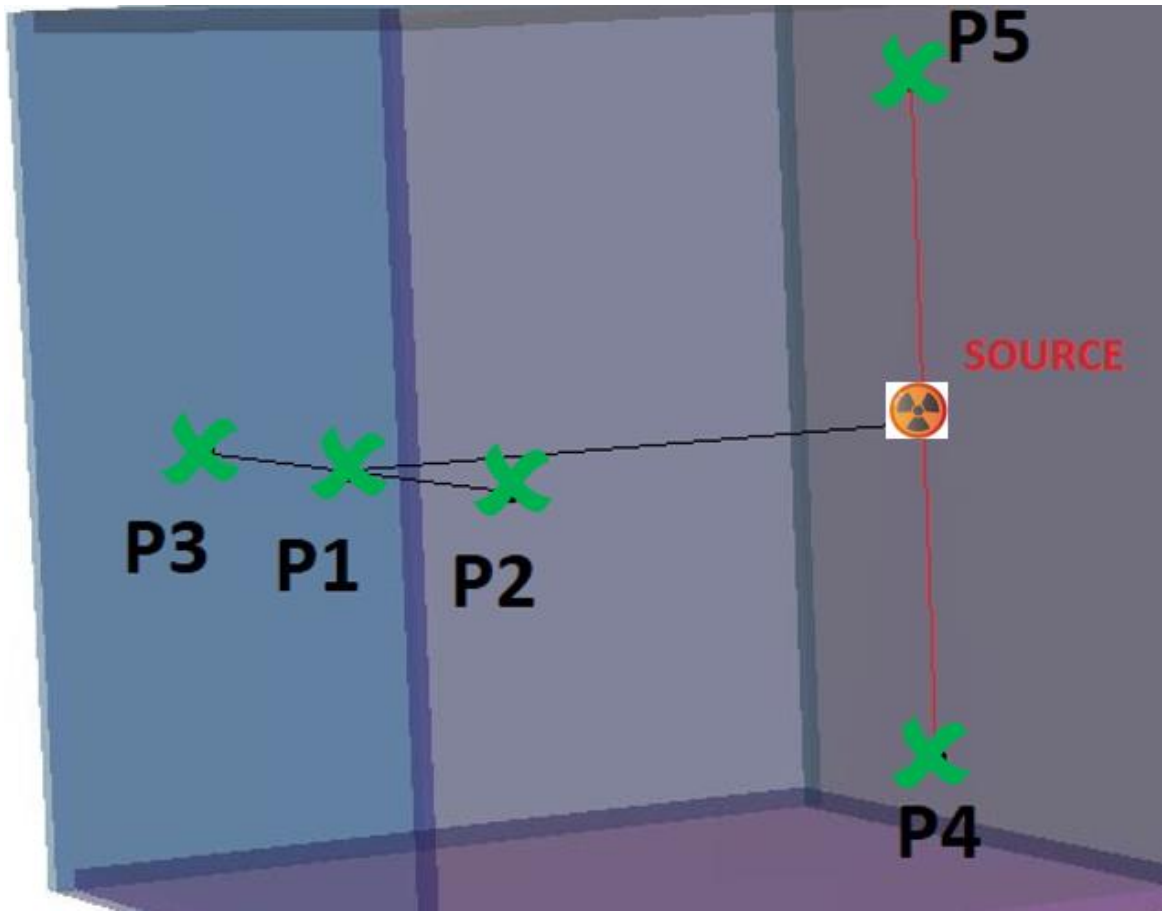


Monte Carlo simulations to study the response function

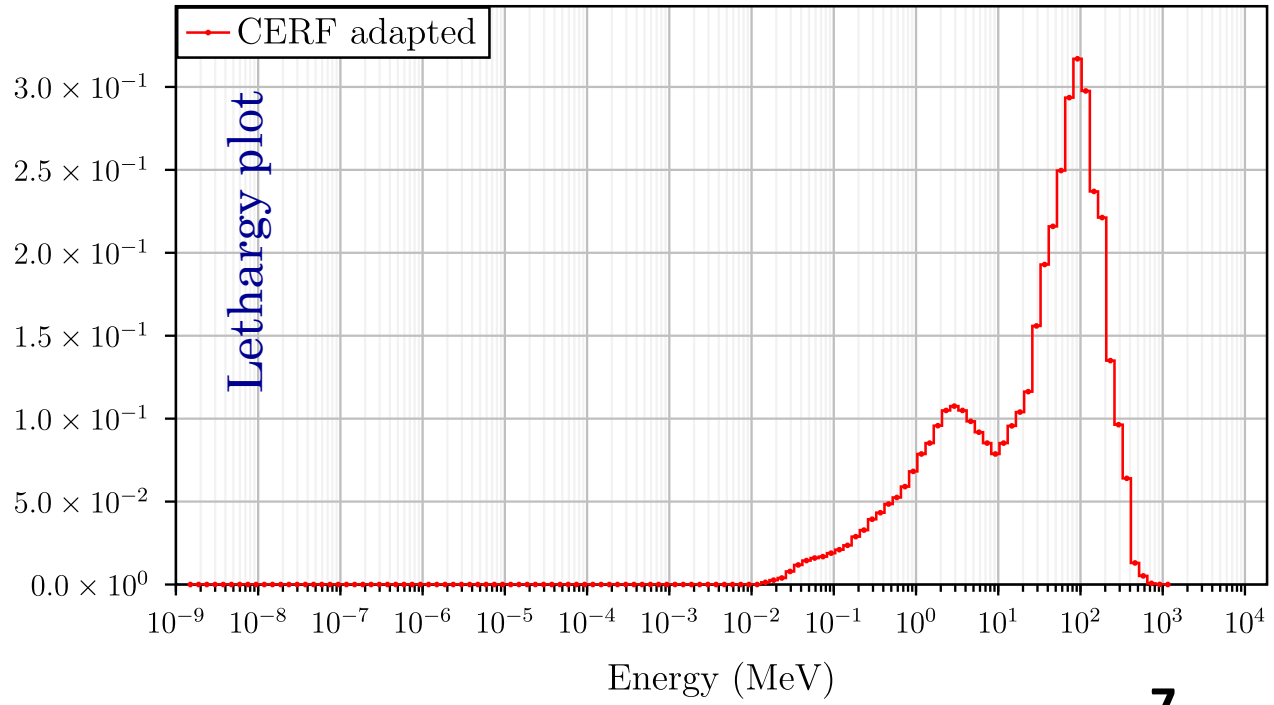


Simulated workplace testing

Simulated scenario with MCNP6.2:



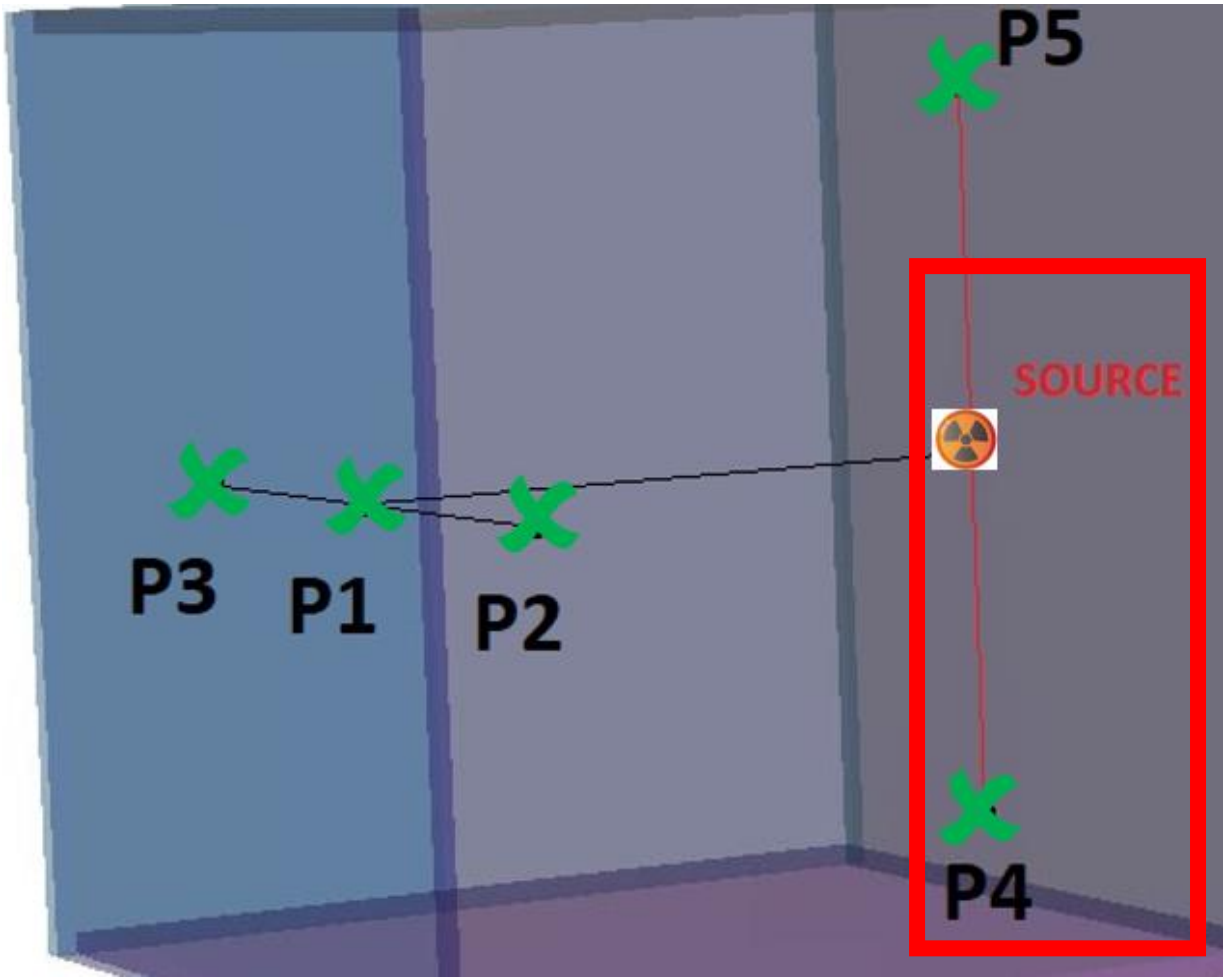
- Room 20 m x 20 m x 20 m with 50 cm walls
- Isotropic source with CERF spectrum
- T-Ball in different positions P1, ..., P5 receiving various proportions of direct and room-scattered neutrons

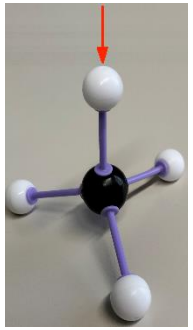


Simulated workplace testing

1. Compute the REFERENCE neutron spectra in P1, …, P5 without T-Ball
2. Place Tetra-Ball in P1, …, P5
3. Compute the readings of the 21 detectors
4. Average the detectors at the same radius
5. Unfold the 6-elements array “centre, R1 average, …, R5 average” using:
   - Different guess spectra
   - Response matrices derived under different irradiation geometries
6. Compare the unfolded spectra with the reference one

Simulated workplace testing



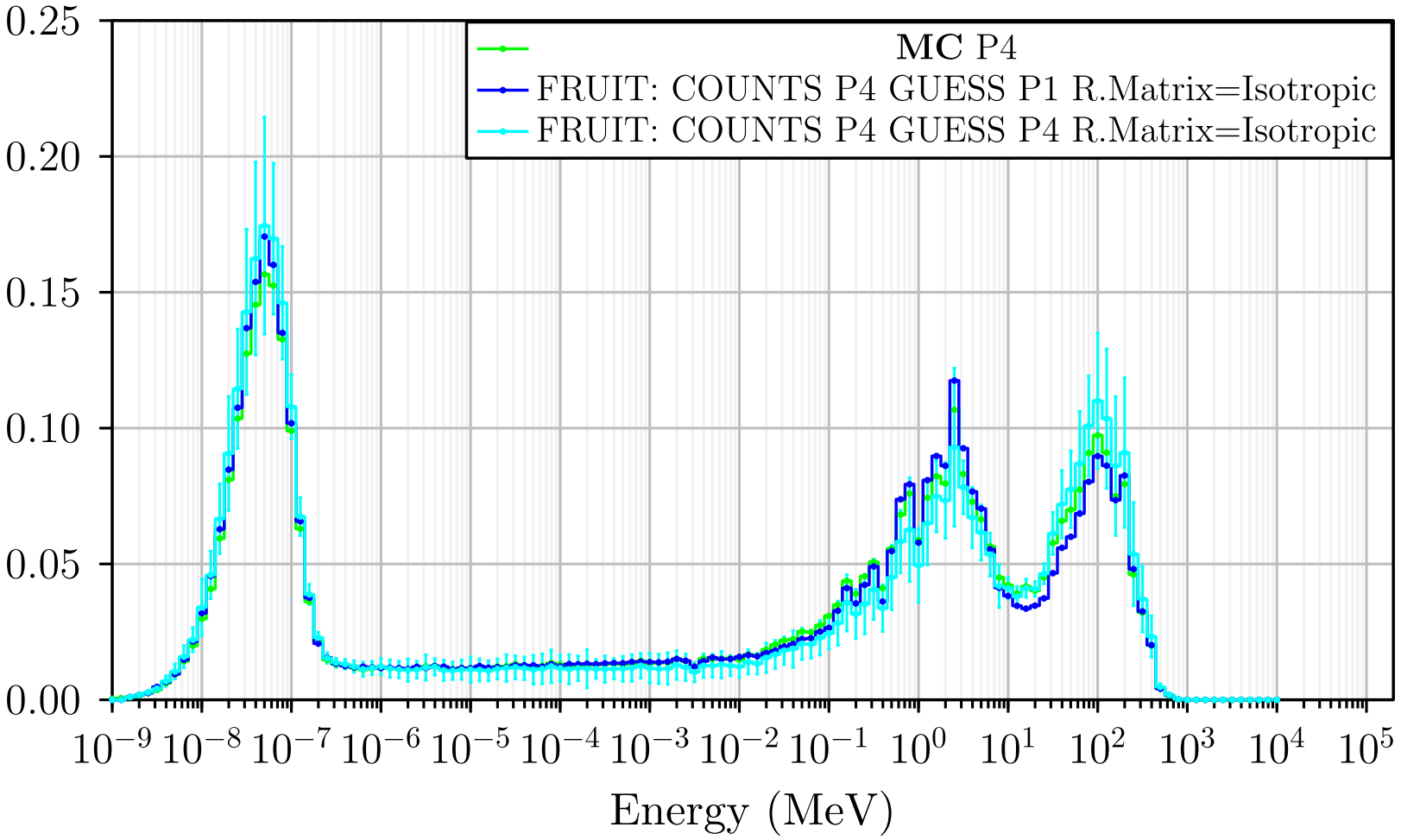


Test point P4

- "Favourable" response matrix = "axis" type
- "Generic" response matrix = "isotropic"
- "Favourable" guess spectrum = Ref P4
- "Generic" guess spectrum = Ref P1

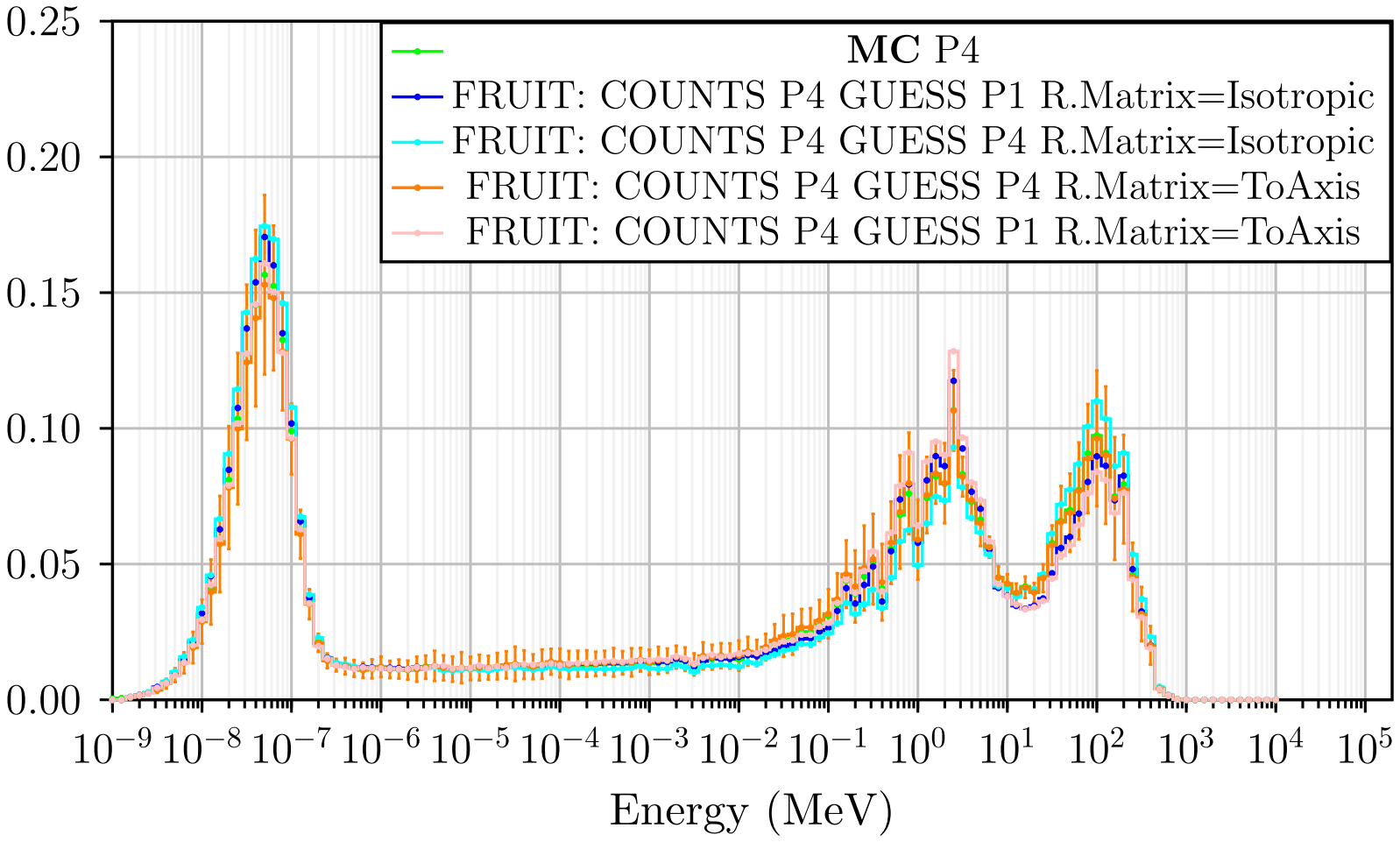
Unfolding #	Resp Matrix	Guess
1	Isotropic	generic (Ref P1)
2	Isotropic	Favourable (Ref P4)
3	Favourable	generic (Ref P1)
4	Favourable	Favourable (Ref P4)

Test point P4



Unfolding #	Resp Matrix	Guess
1	Isotropic	generic (Ref P1)
2	Isotropic	Favourable (Ref P4)
3	Favourable	generic (Ref P1)
4	Favourable	Favourable (Ref P4)

Test point P4



Unfolding #	Resp Matrix	Guess
1	Isotropic	generic (Ref P1)
2	Isotropic	Favourable (Ref P4)
3	Favourable	generic (Ref P1)
4	Favourable	Favourable (Ref P4)

Conclusions

- Tetra-Ball theoretical design optimised
- Tetrahedral geometry, 5 radial positions + centre
- Different response matrices were computed for different incident irradiation geometries
- Anisotropy effects are limited to the epithermal domain
- Unfolding tests were performed to evaluate the spectrometric performance by changing the guess spectrum and the, a priori, direction-dependent response matrix
- The isotropic matrix is adequate even for tests with “generic” guess
- More tests are in progress
- First prototype expected to be installed by Mid 2025

Thank you!