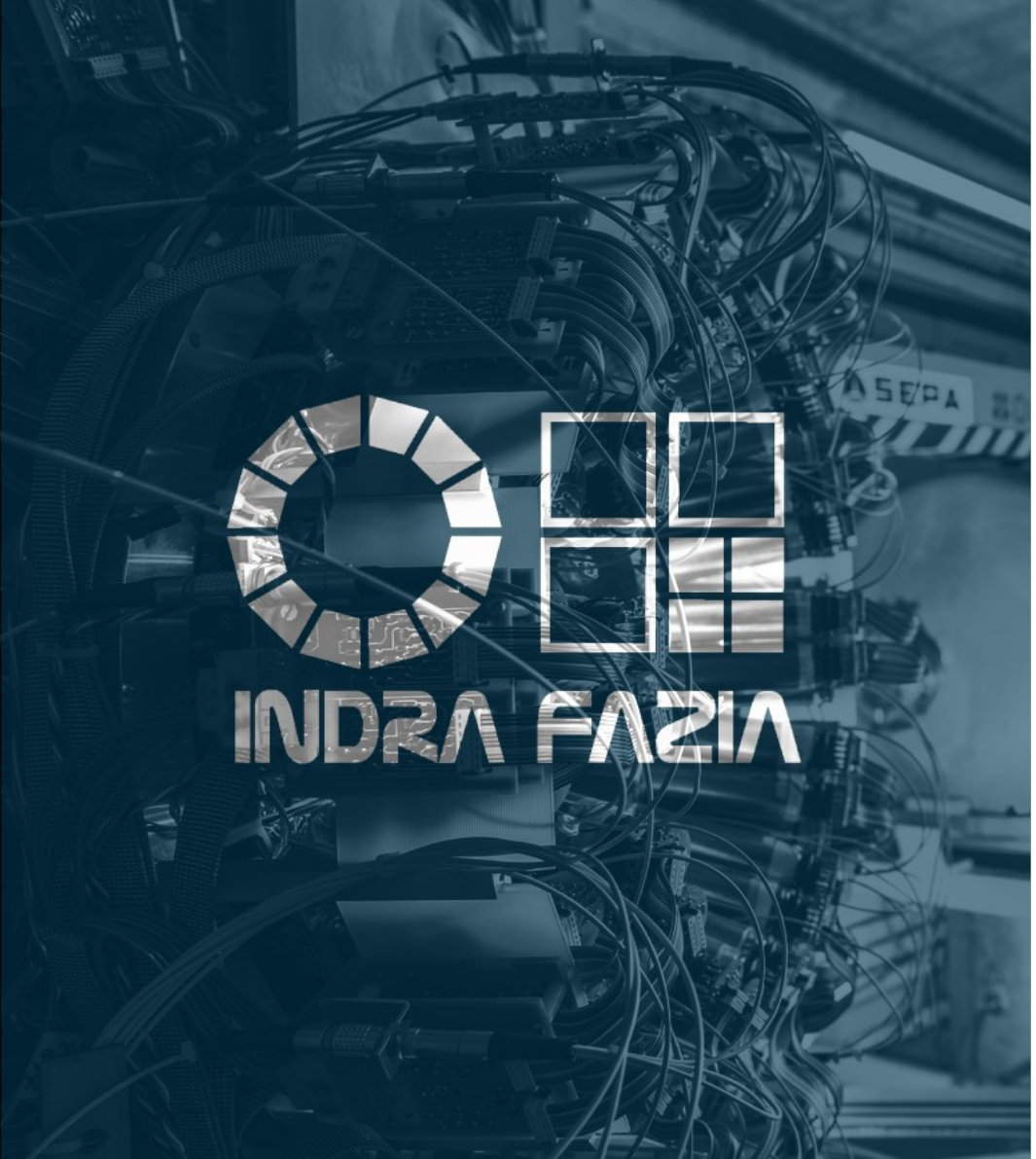


EoS experiment "à la" E789 at FRIB

D. Gruyer[1,2], C. Ciampi[2], I. Dekhissi[1,2]
R. Bougault[1], J. Frankland[2], A. Chbihi[2],
N. Le Neindre[1]

[1] LPCC, Caen, France
[2] GANIL, Caen, France

E789 experiment @ GANIL

Isospin transport ratio computed from quasi-projectile N/Z
using 4 reactions (^{58,64}Ni + ^{58,64}Ni @ 32 MeV/nuc.)
Impact parameter infered from P(b|M) deduced from P(M)

Symmetry energy constraint

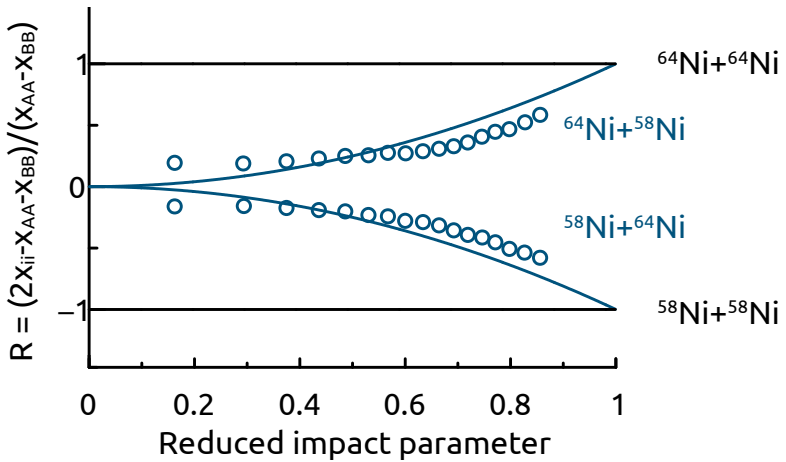
Experimental data compared to BUU calculations with various interactions expressed in terms of EoS empirical parameters
→ Two-dimentional constraint in the symmetry energy – density plane ready to be injected into Bayesian inference !

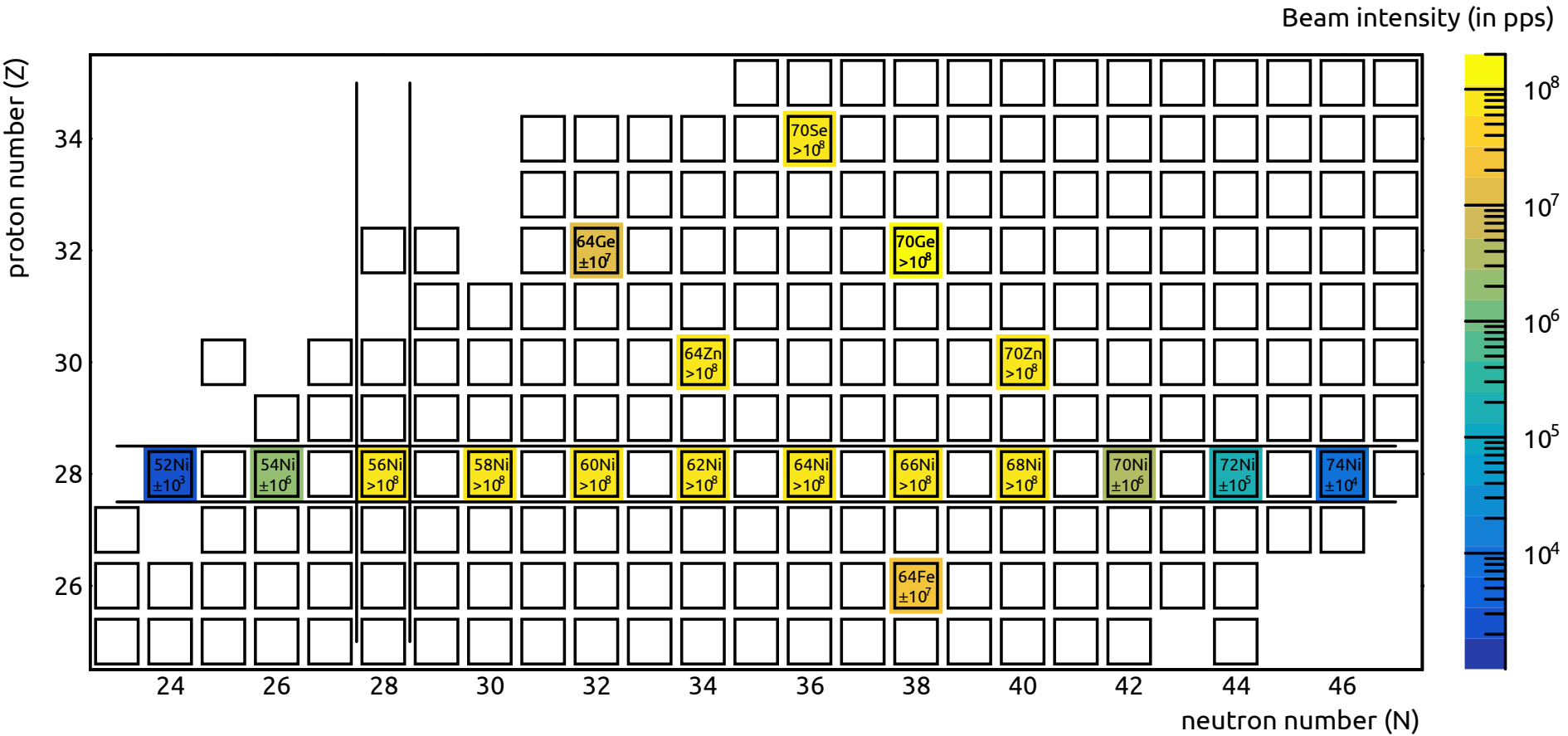
Key ingredients

→ Excellent isotopic resolution at forward angles (FAZIA)
→ Good angular coverage to measure P(M) (INDRA+FAZIA)
→ All 4 reactions measured in the same conditions
→ Consistent estimate of the density region probed

Can we do better ?

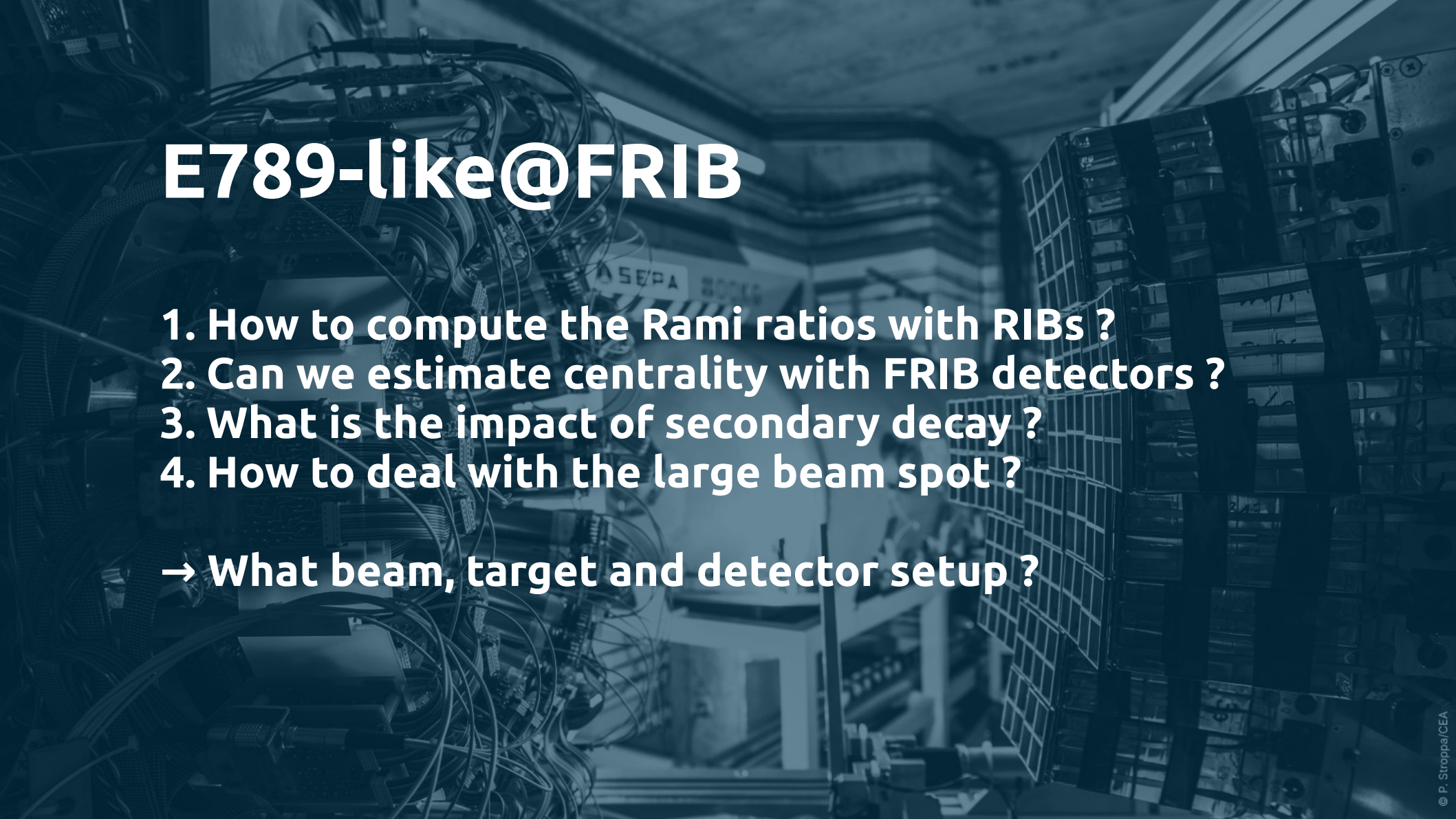
→ Better sensitivity with higher the N/Z difference : FRIB !





→ Beam intensity around Nickel at FRIB (frib.msu.edu/user-facilities/frib/calculator)

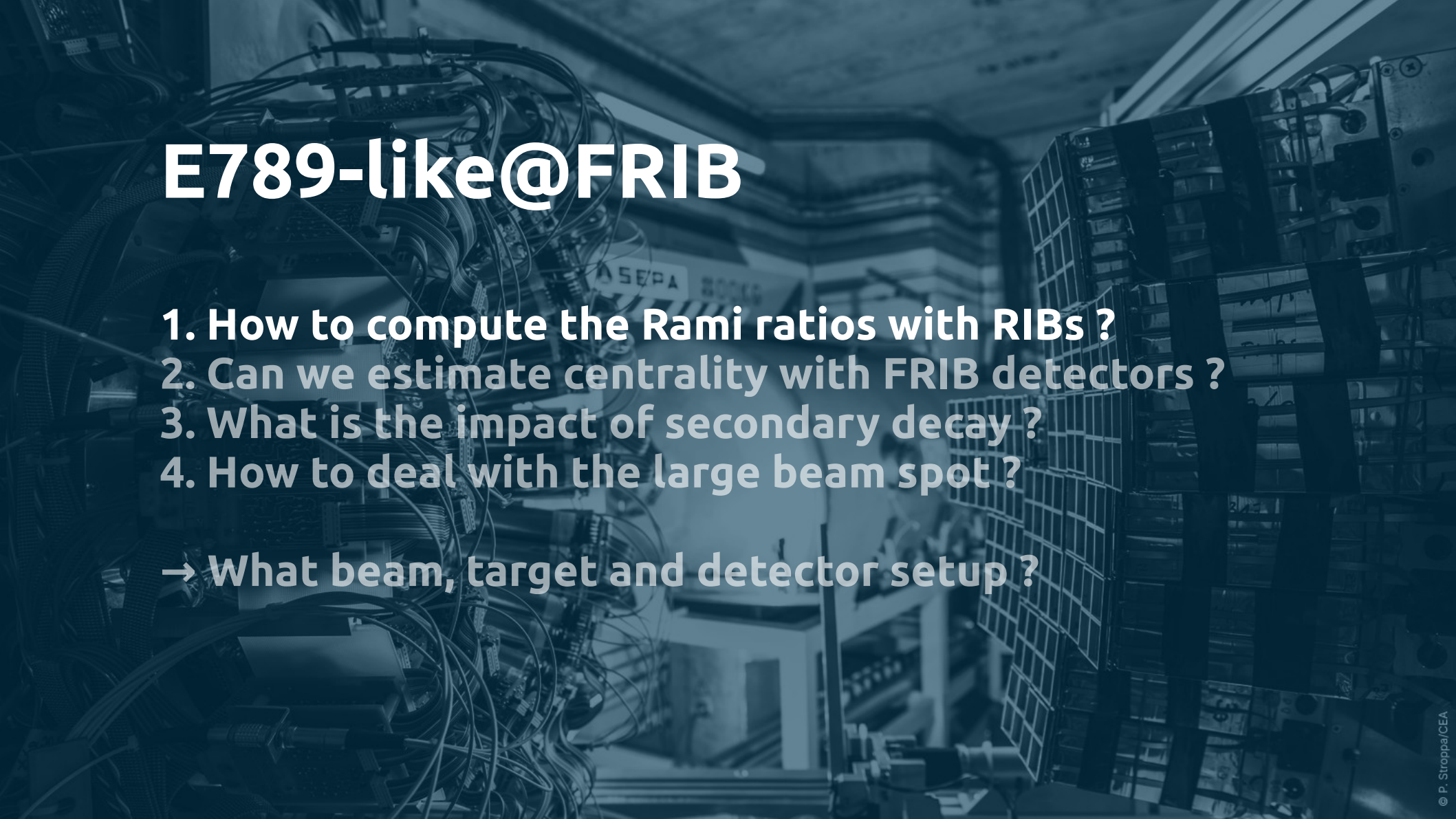
→ 32 MeV/nuc. : average between full energy and stopped beam intensities



E789-like@FRIB

1. How to compute the Rami ratios with RIBs ?
2. Can we estimate centrality with FRIB detectors ?
3. What is the impact of secondary decay ?
4. How to deal with the large beam spot ?

→ What beam, target and detector setup ?



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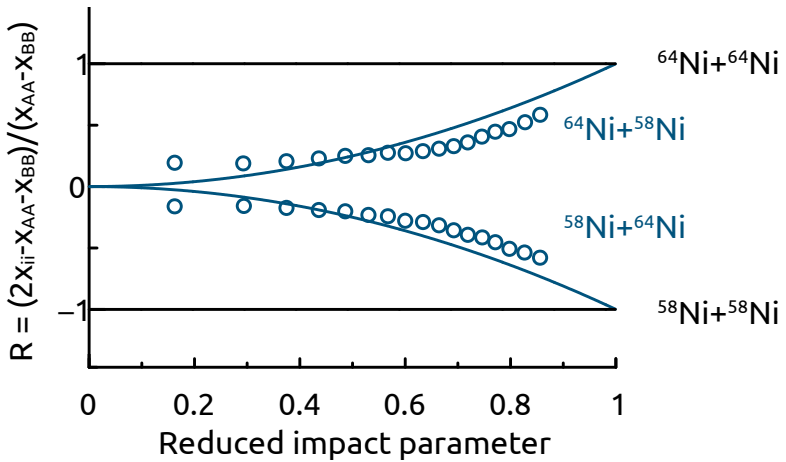
Using RIBs

Improve the sensitivity by increasing the isospin difference between projectile and target : radioactive beams !

→ many Nickel beams @ FRIB, but only two targets…

→ we cannot measure all the required systems, especially the two extreme ones…



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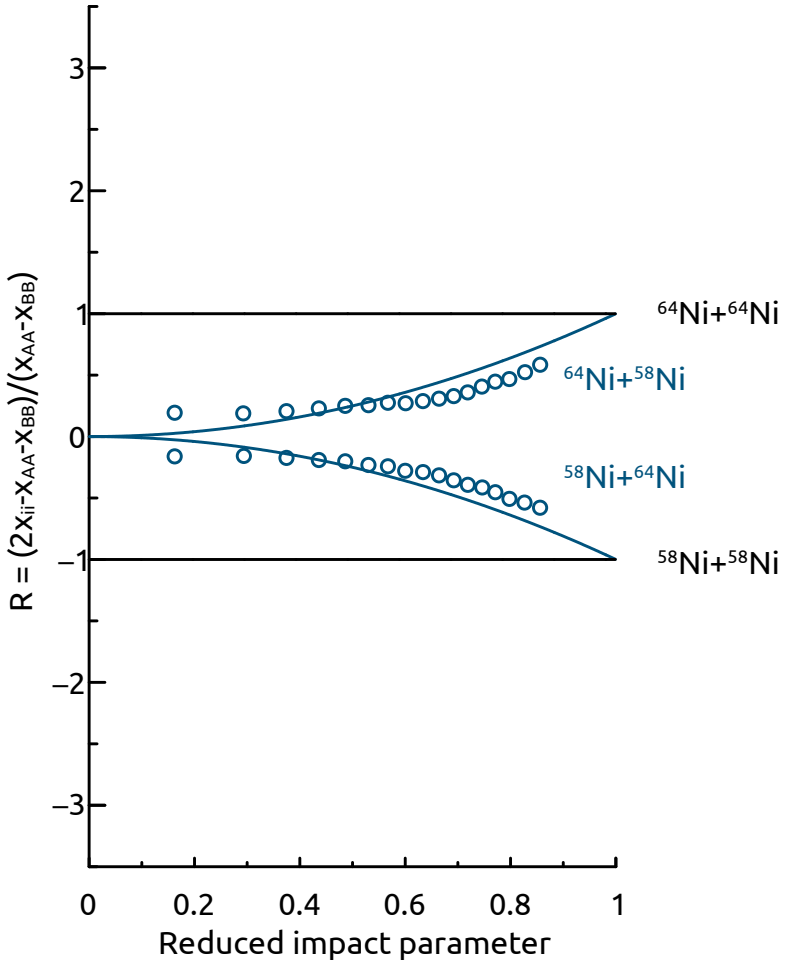
Rami ratio does not define the boundaries (BB < ii < AA), it just defines the ‘scale’ !



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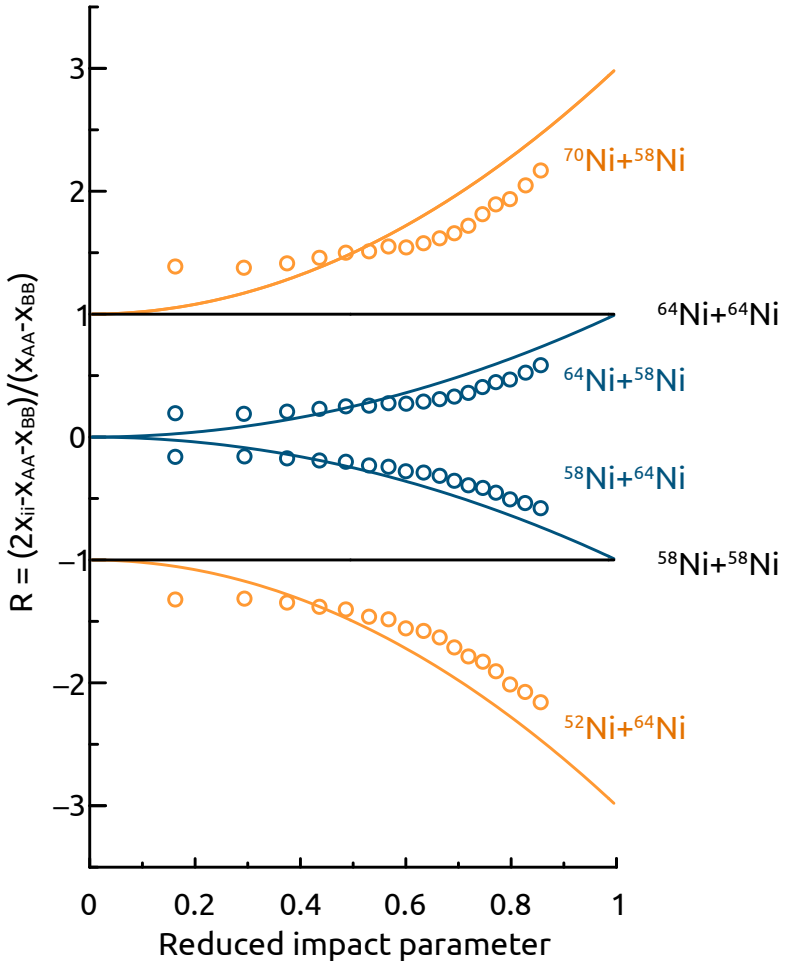
From Rami to Ciampi ratio

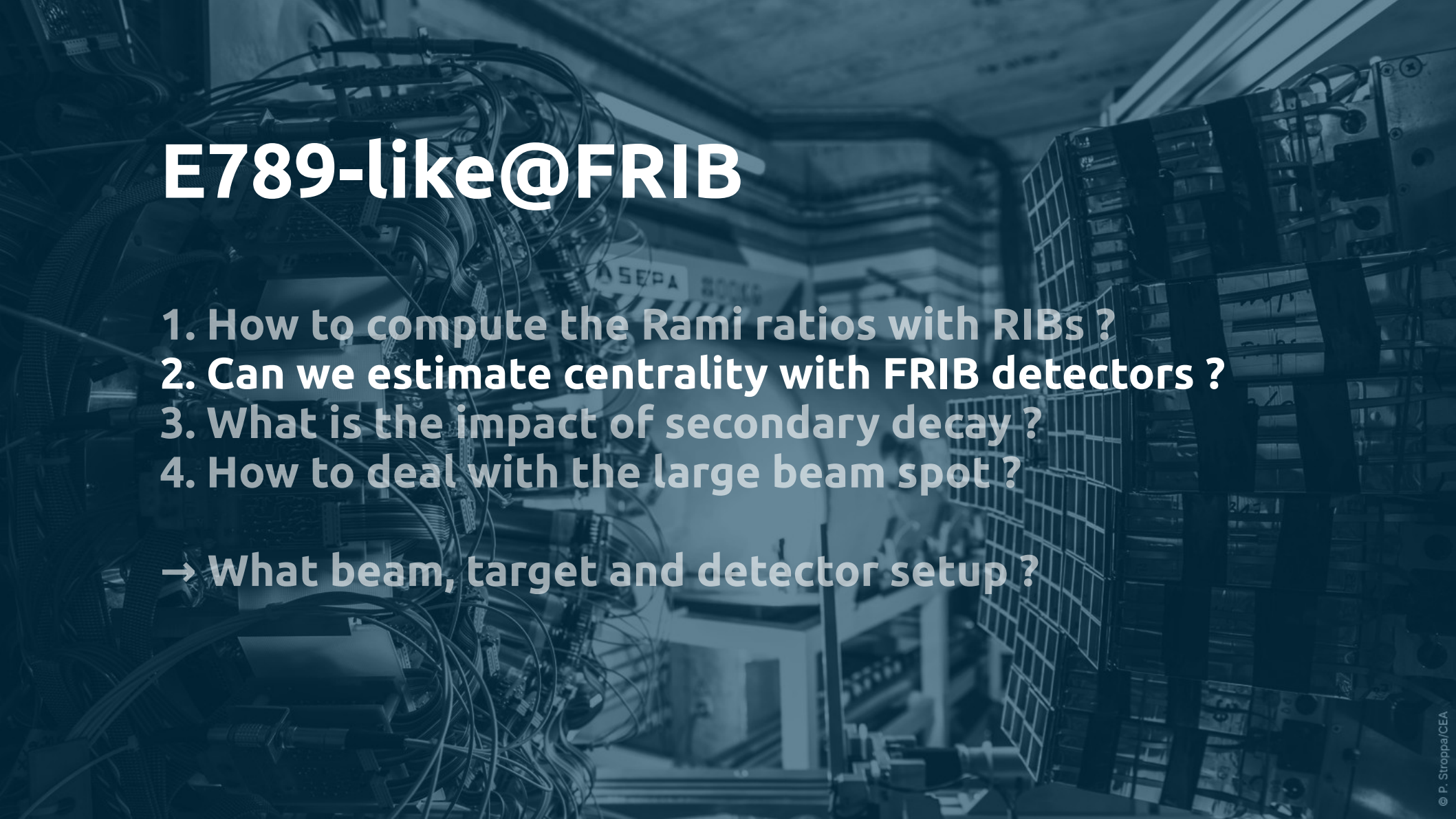
Rami ratio does not define the boundaries (BB < ii < AA), it just defines the 'scale' !

→ Still use ^{64}Ni+^{64}Ni and ^{58}Ni+^{58}Ni to compute the ratio

→ R = 1, -1 represents full equilibration (no more R = 0)

→ Not ideal but we can live with it…





E789-like@FRIB

1. How to compute the Rami ratios with RIBs ?
2. **Can we estimate centrality with FRIB detectors ?**
3. What is the impact of secondary decay ?
4. How to deal with the large beam spot ?

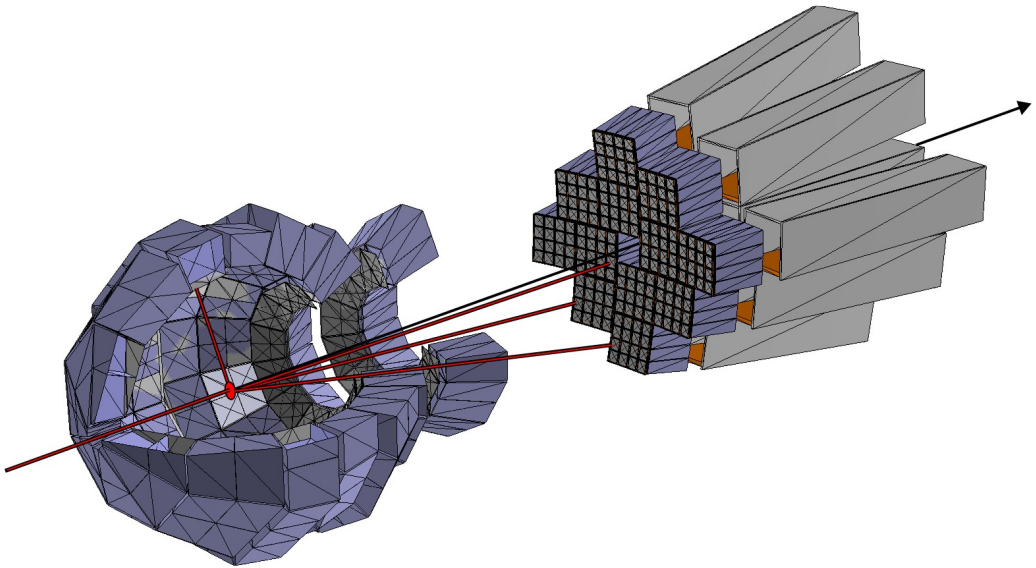
→ What beam, target and detector setup ?

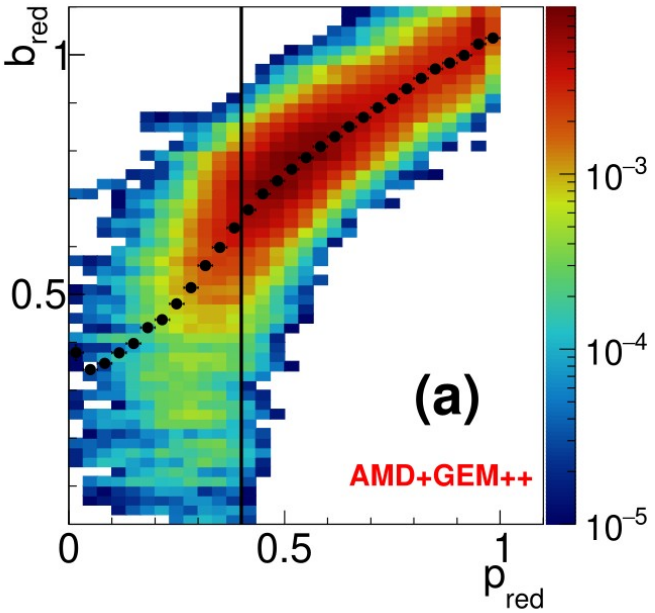
Impact parameter

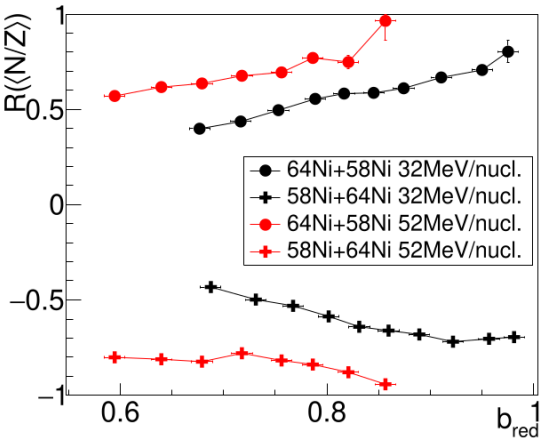
Probably not using the total multiplicity but we could use p_{red}...

→ C. Ciampi et al., PRC 106 (2022) 024603

→ Coupled to debluring techniques ?







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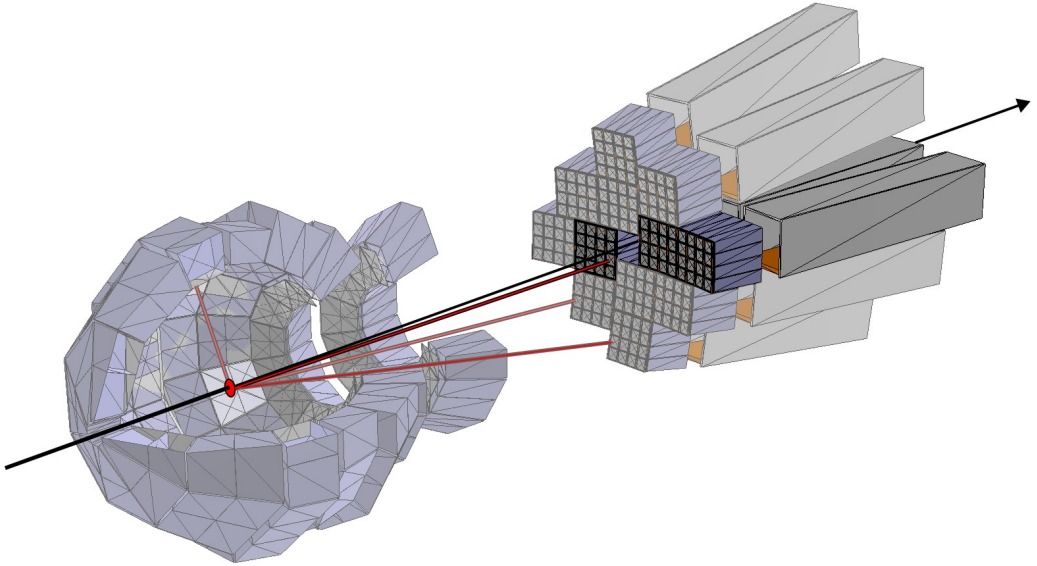
Consequences

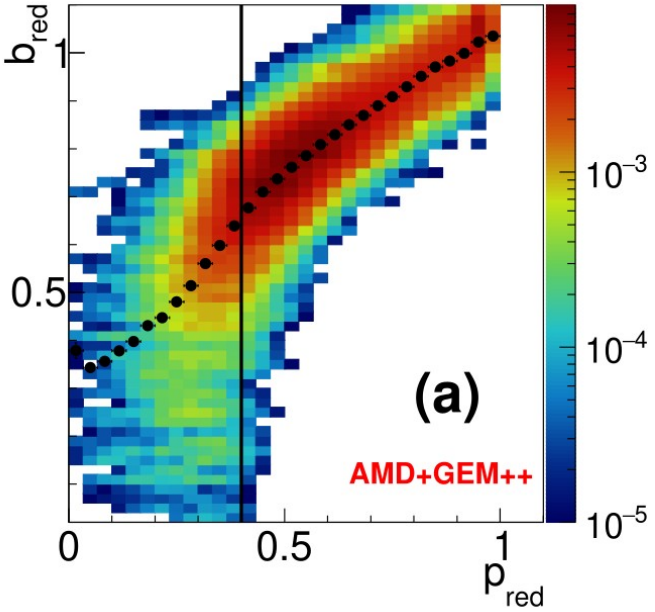
No need to measure P(M) but model dependent...

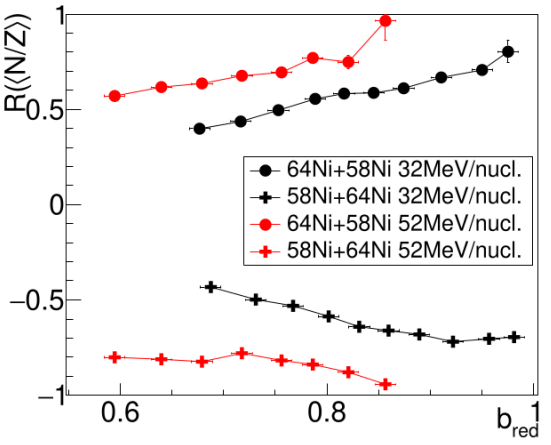
All information comes from the quasi-projectile

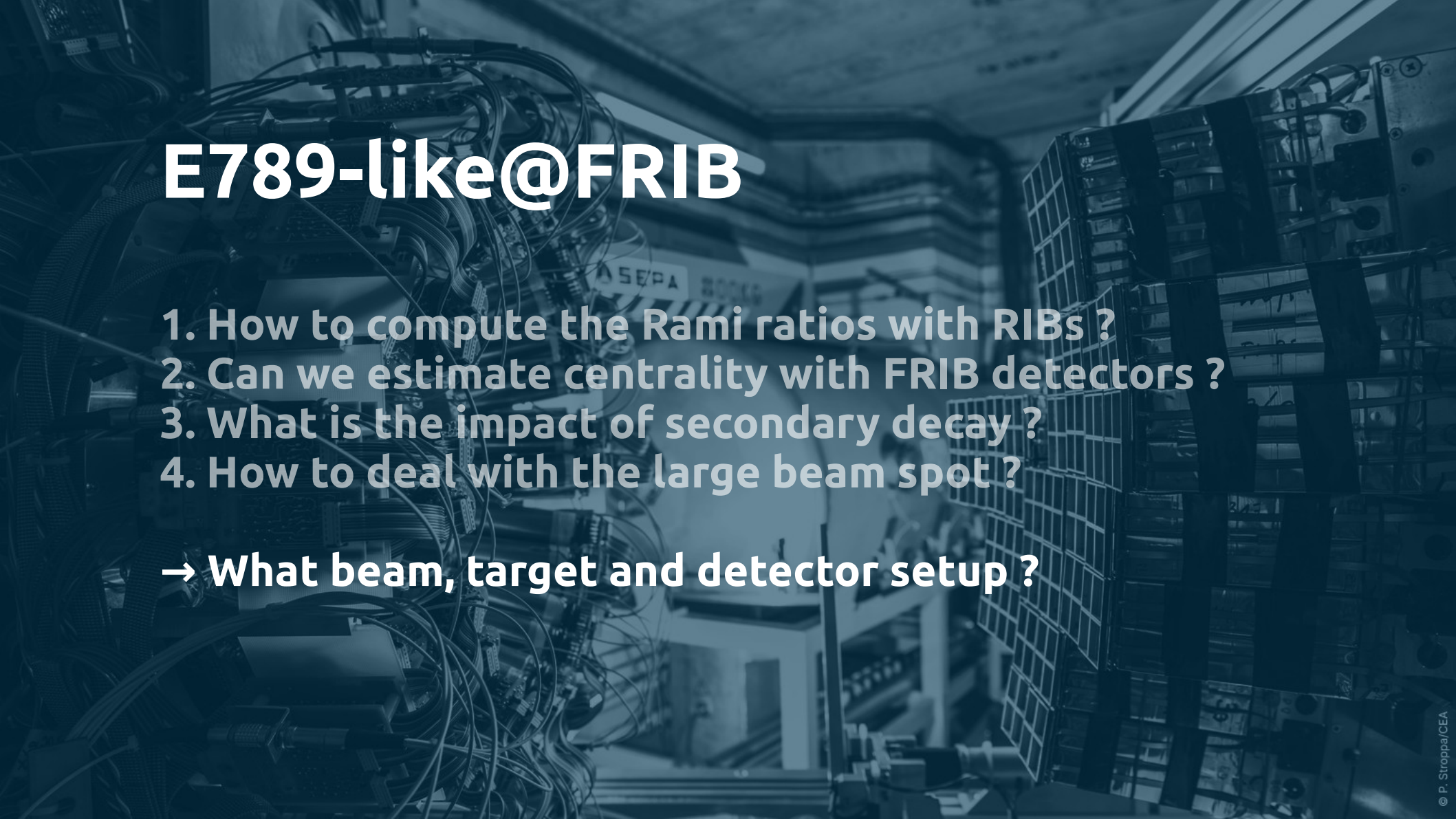
→ Few FAZIA blocks in belt configuration could be enough !

→ Since we use only FAZIA, we can compare with E789 data !









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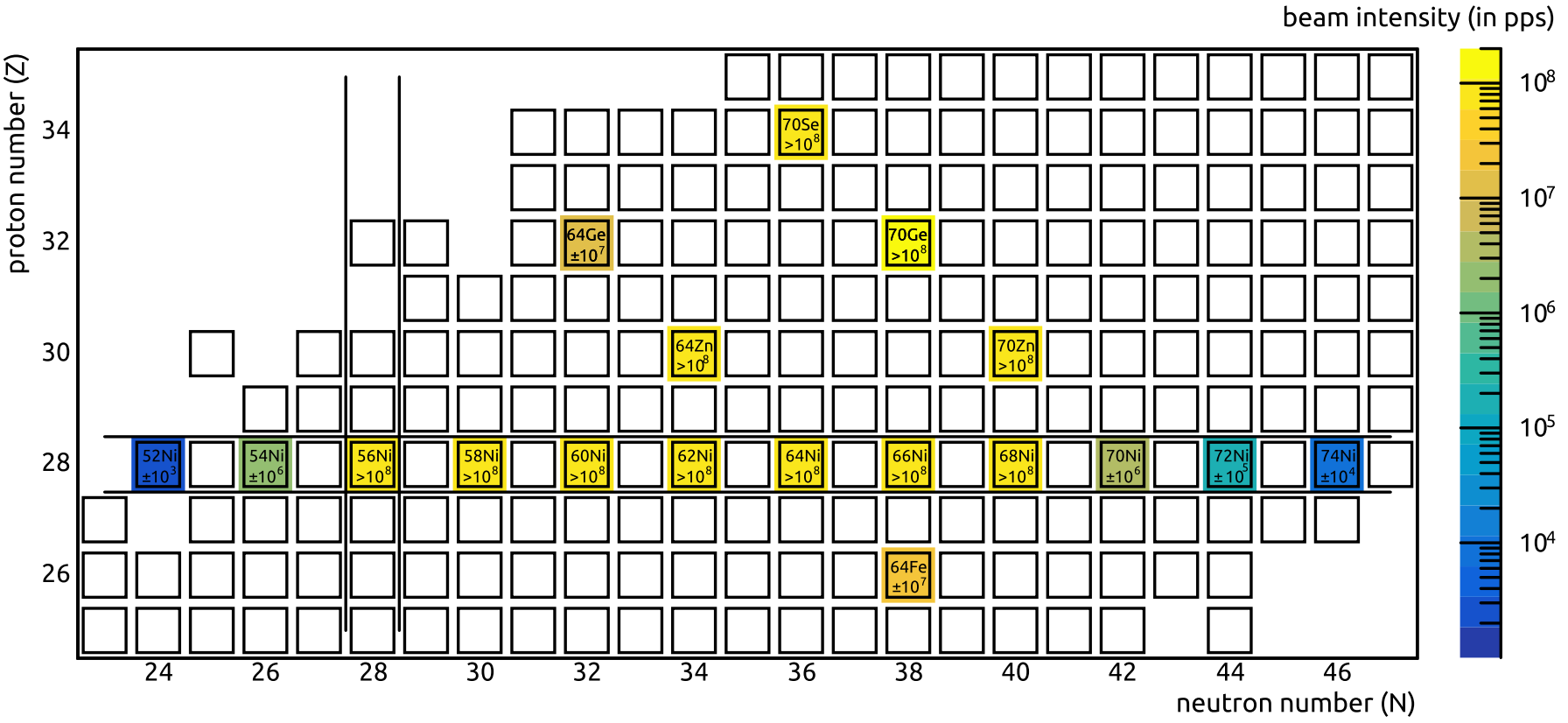
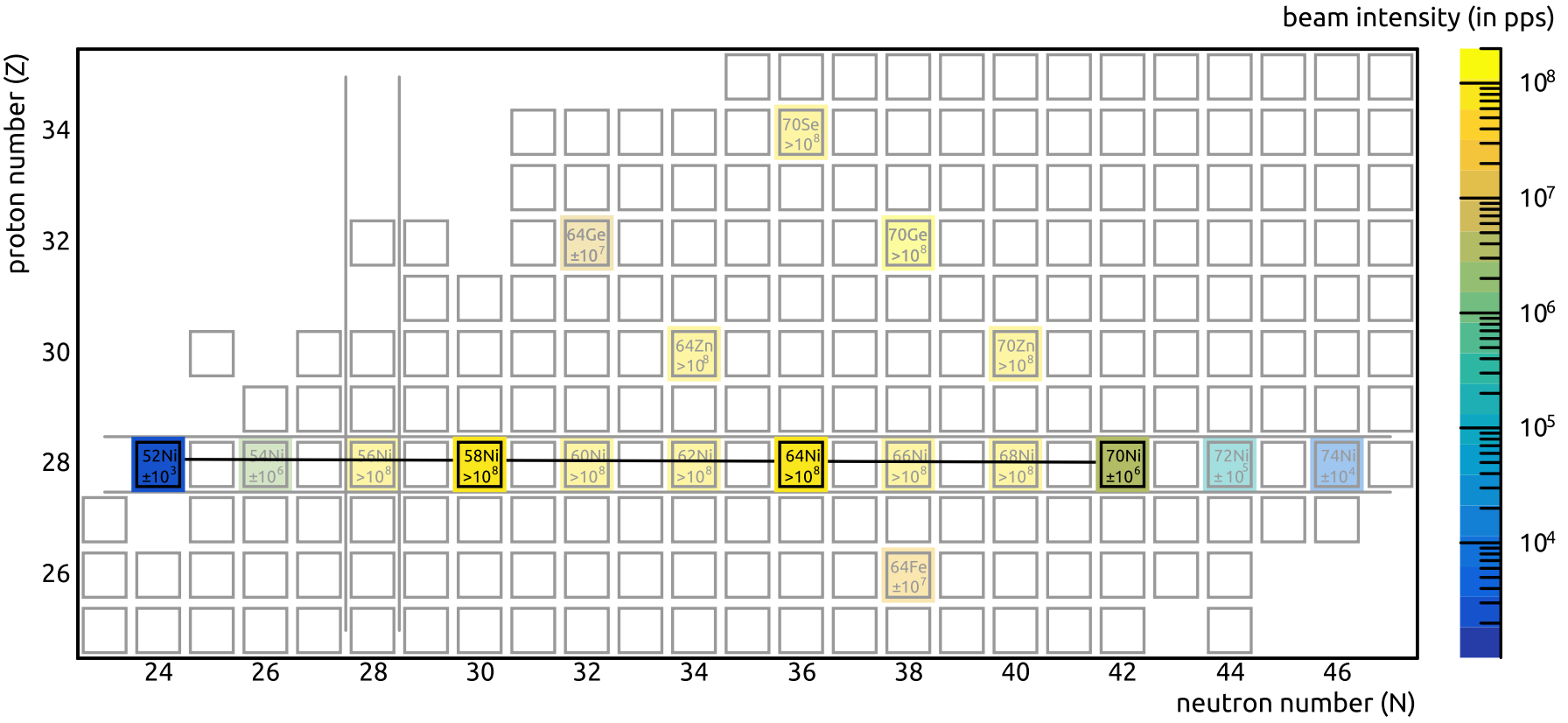

beam intensity (in pps)
10^8
10^7
10^6
10^5
10^4
proton number (Z)
34
32
30
28
26
24
26
28
30
32
34
36
38
40
42
44
46
neutron number (N)
70Se >10^8
64Ge ±10^7
70Ge >10^8
64Zn >10^8
70Zn >10^8
52Ni ±10^3
54Ni ±10^6
56Ni >10^8
58Ni >10^8
60Ni >10^8
62Ni >10^8
64Ni >10^8
66Ni >10^8
68Ni >10^8
70Ni ±10^6
72Ni ± 10^5
74Ni ±10^4
64Fe ±10^7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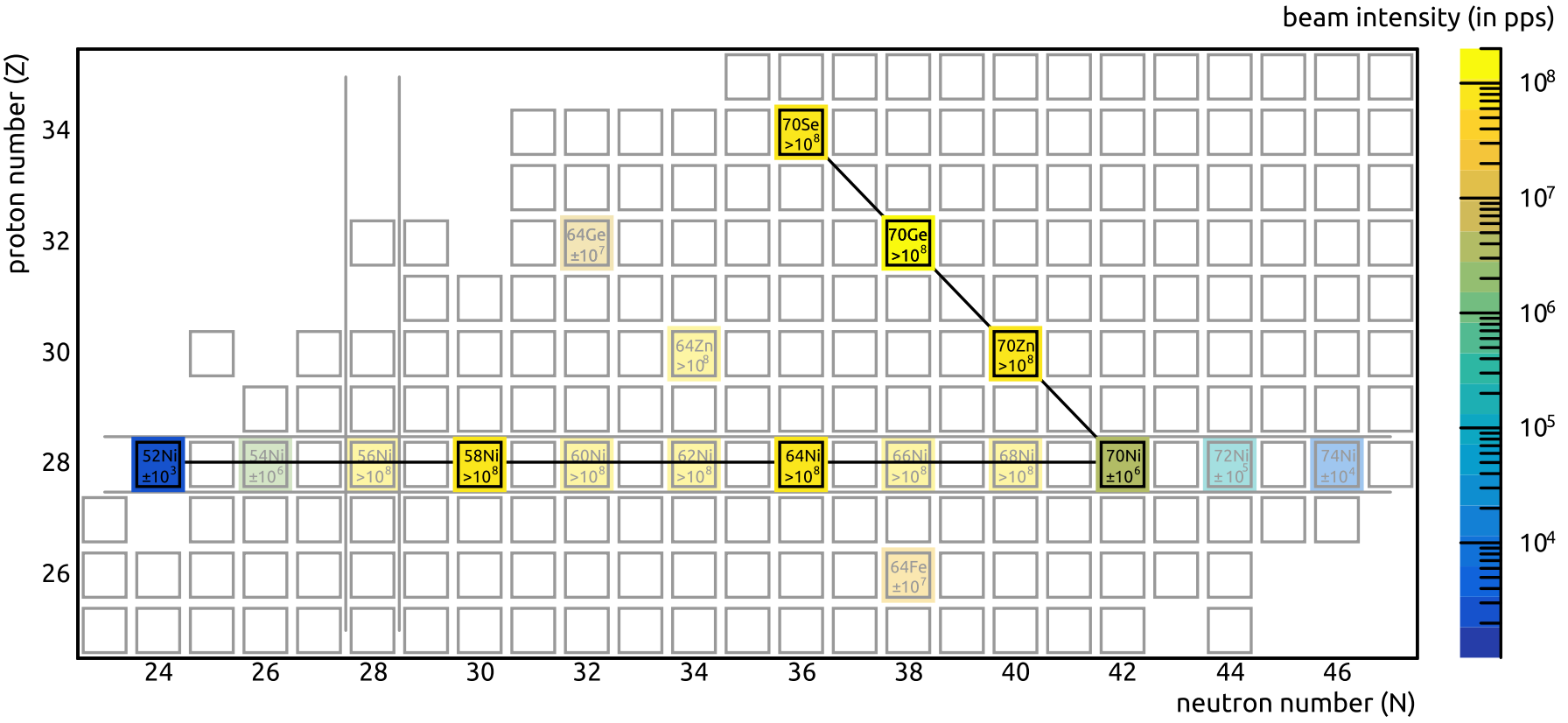
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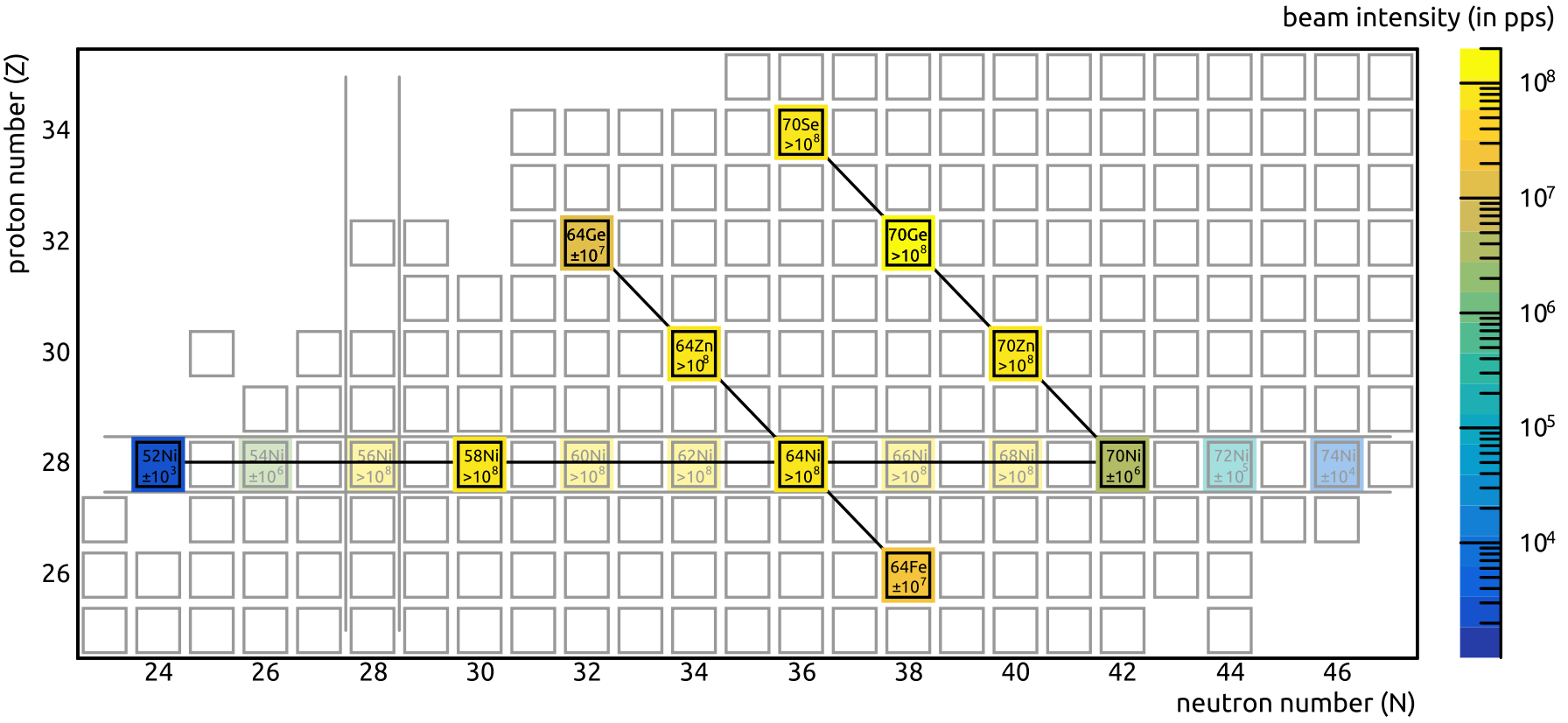
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64Fe ±10^7

Z = 28 chain

64Ni + 64Ni (already measured E789)
58Ni + 58Ni (already measured E789)
70Ni + 58Ni (~10^6 pps)
52Ni + 64Ni (~10^3 pps) (not feasible)

A = 64 chain

64Ni + 64Ni (already measured E789)
64Zn + 64Zn (>10^8 pps) (GANIL?)
64Fe + 64Zn (~10^7 pps)
64Ge + 64Ni (~10^7 pps)

A = 70 chain

70Ge + 70Ge (>10^8 pps) (GANIL?)
70Zn + 70Zn (almost measured E884)
70Ni + 70Ge (~10^6 pps)
70Se + 70Zn (>10^8 pps)

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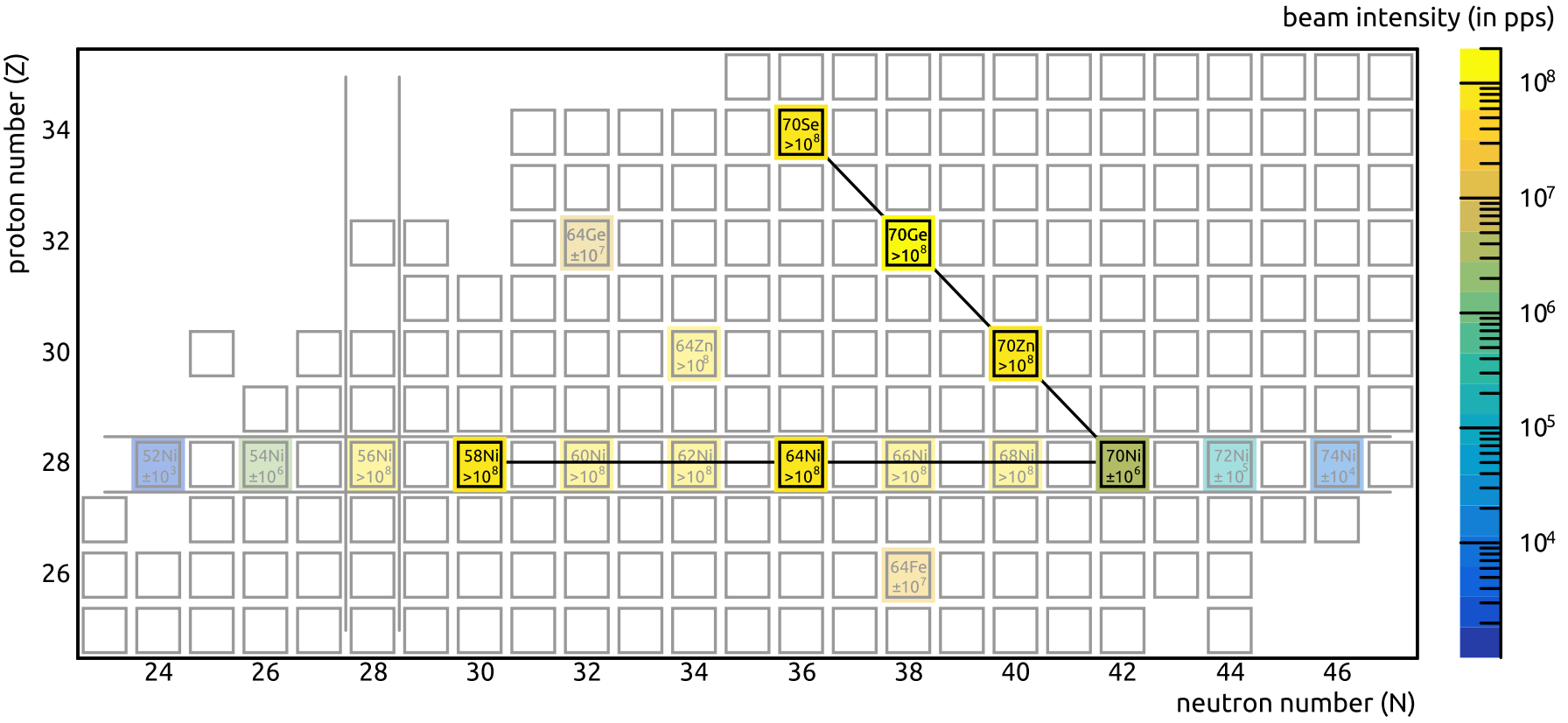
Possible strategy

→ Ask for 70Ni beam to measure 70Ni+58Ni (Z=28) and 70Ni+70Ge (A=70)
→ Ask for 70Se beam to measure 70Se + 70Zn (A=70)
→ Use existing data measured at GANIL when available
→ GANIL proposal to complete A=70 chain (70Ge-70Zn), constant-A E789-like ?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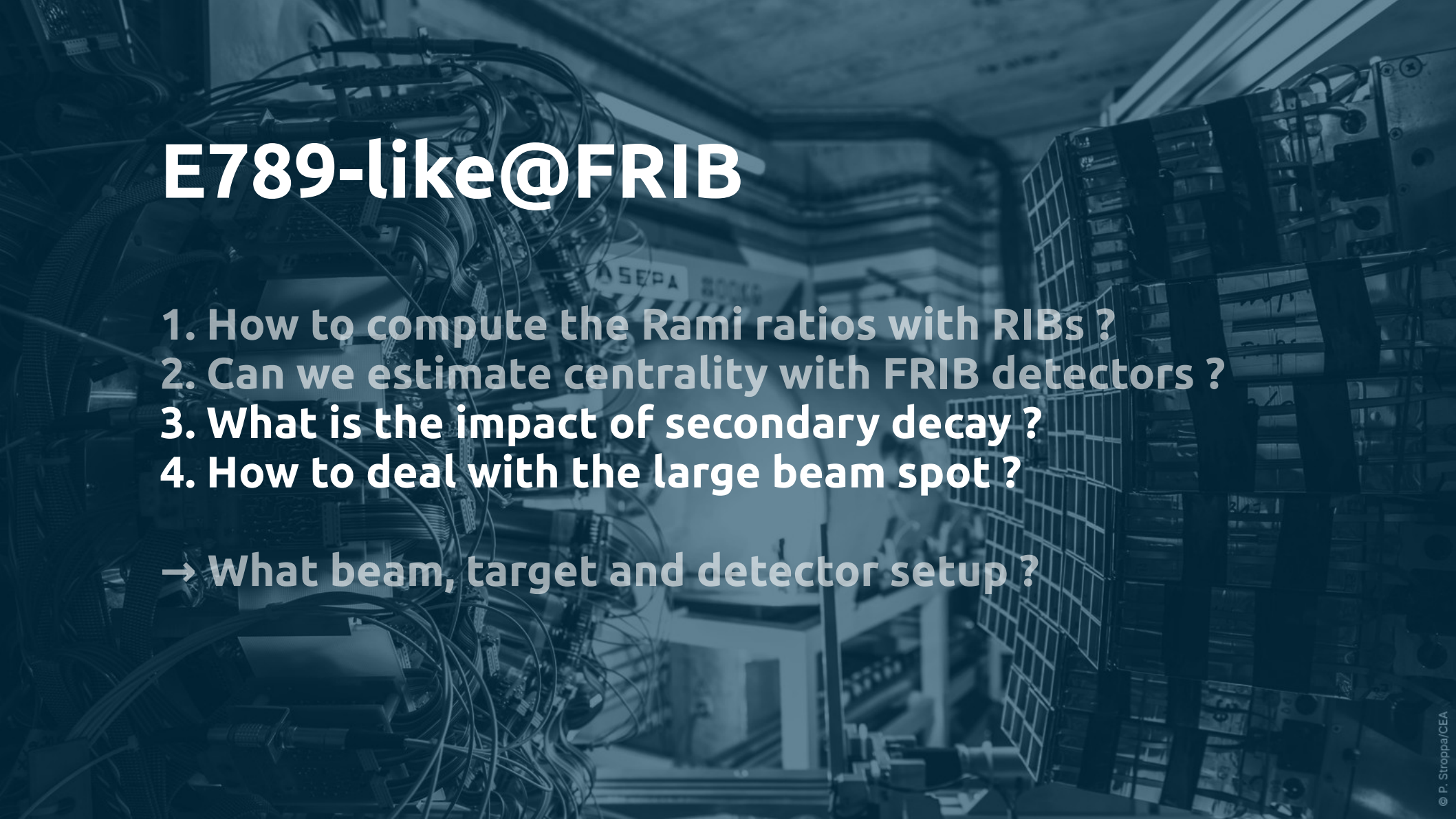

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Simulations are needed !

→ HIPSE for kinematics and centrality and decay studies
→ BUU for sensitivity to the EoS

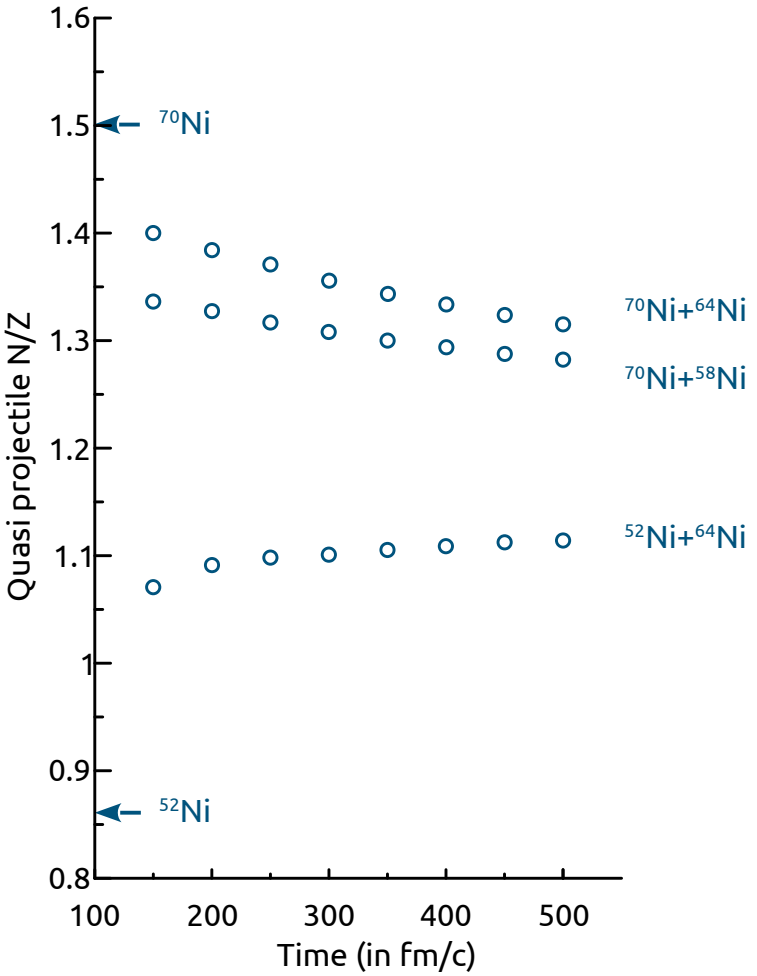
HIPSE simulations

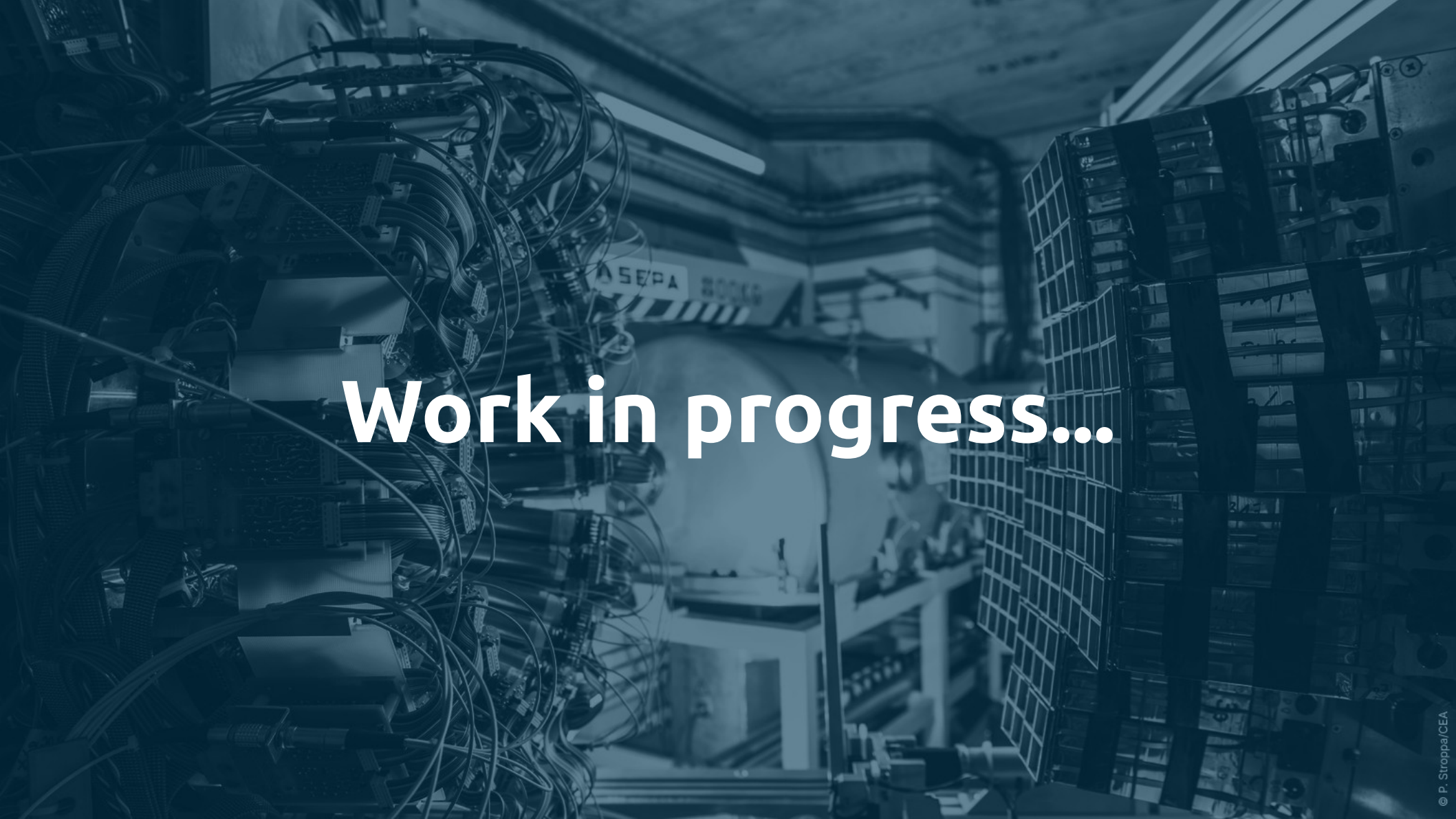
64Ni + 64Ni @ 32 MeV/nuc. (all b)
58Ni + 58Ni @ 32 MeV/nuc. (all b)
52Ni + 64Ni @ 32 MeV/nuc. (all b)
70Ni + 58Ni @ 32 MeV/nuc. (all b)
→ 100k events per system to be filtered and analyzed...

BUU simulations

70Ni + 64Ni @ 32 MeV/nuc. at b = 7 fm
70Ni + 58Ni @ 32 MeV/nuc. at b = 7 fm
52Ni + 64Ni @ 32 MeV/nuc. at b = 7 fm
→ only Ab-initio 7 interaction for now...

To be analyzed to decide the feasibility and optimize the setup...




Work in progress...
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