Muon capture plan at PSI (Villigen)

Daniya Zinatulina (JINR)

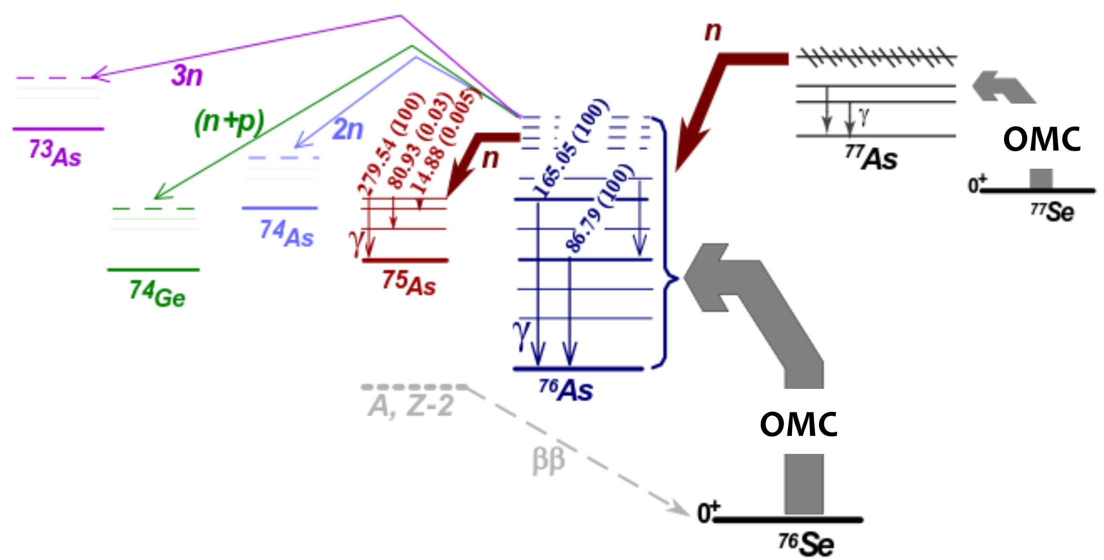
MuX meeting

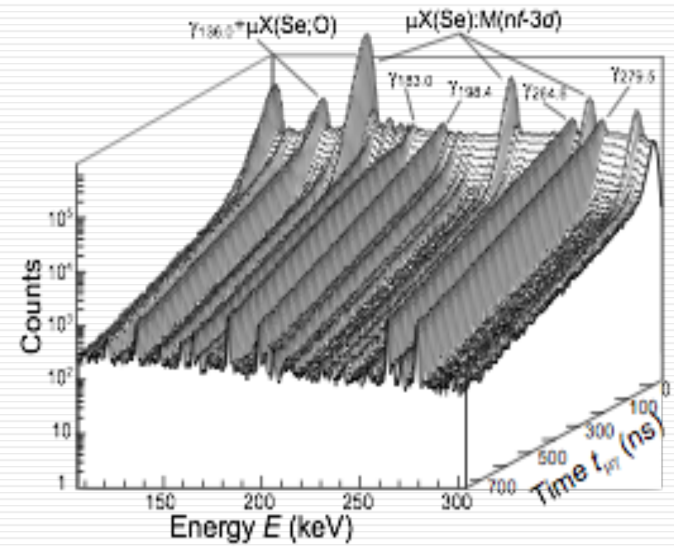
19.06.2019

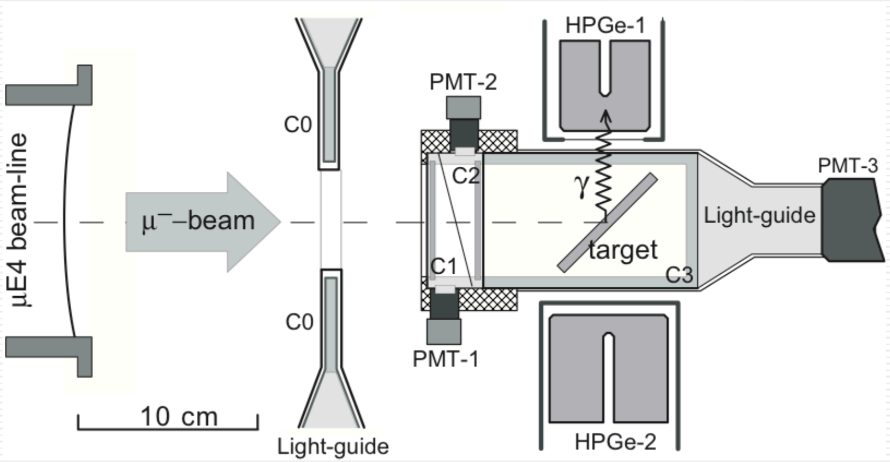
Ordinary Muon Capture (OMC)

$(A, Z) + \mu^- \rightarrow (A, Z\text{-}1)^* + \nu_\mu$

$\rightarrow (A, Z\text{-}1) + \gamma + (0n, 1n, 2n, n{+}p, 3n\ldots)$ $\quad m_\mu \sim 105$ MeV







- Set-up adapted to solid and gaseous targets
- (E,t) distribution following OMC in targets
- Yields of short-lived RI during exposure

- PhD thesis of D.Zinatulina (June,2019)
- **PRC 99** (2019) **024327**

Overview of the method

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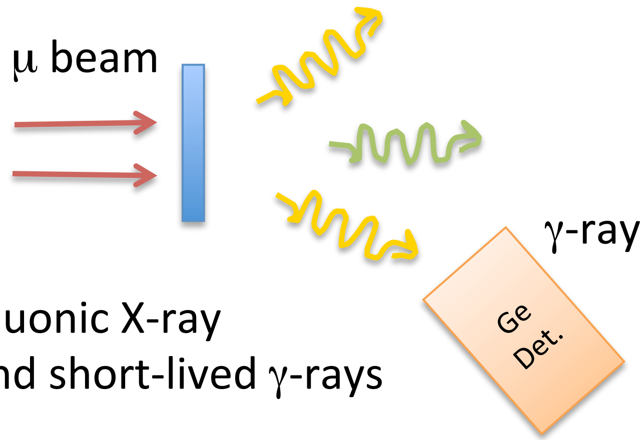
Irradiation of target



muonic X-ray
and short-lived γ-rays

Measurement of delayed γ-rays

^{100}Mo + μ- ➔ Nb*+ν_μ+xn

Nb*+β^-+$\bar{\nu}_e$+ γ

Exp. data give the dist. of isotope mass population of the final nuclei after neutron emission.

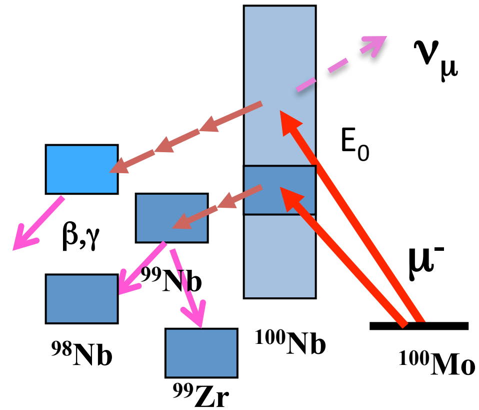
Muon capture reaction

Weak/ neutrino nuclear response

compare

Calculation by proton and neutron emission model

Provides initial capture strength ^{100}Nb after muon capture



Distribution of initial strength can provide the final nuclei isotope population

Relative capture strength

- Provide μ capture rate
- If pnQRPA with g_A can reproduce the μ capture rate or they need to adjust g_A.

Absolute capture strength

Nuclear matrix element, NME for DBD

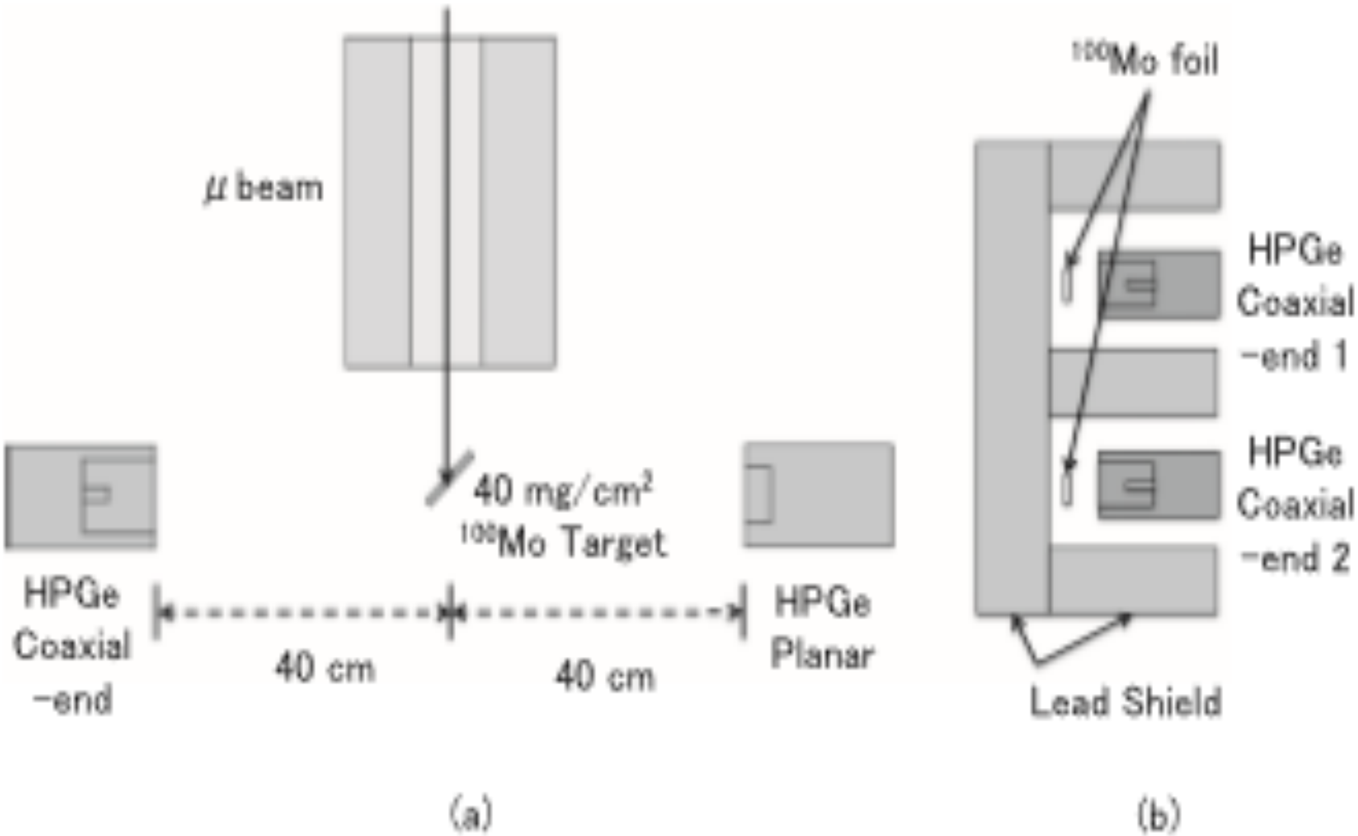
- Used adjusted g_A to calculate DBD NME

Running plan for October, 2019

Isotope, A	Quantity	Exposure on-line/off-line time	Purposes
^{82}Kr	**1 l.**	3 d. / 3 d.	mX, gamma
^{Nat}Kr	**1 l.**	3 d.	mX, gamma
^{100}Mo	**1 g.**	2 d./ 2 d.	mX, gamma
^{24}Mg	**2 g.**	3 d./3 d.	mX, g-g coincidences

- The rest time needs for tuning or may be measure more xtra days Mg-24.

Muon Irradiation @ J-PARC Experiment



(a) Online setup for the γ rays with half-lived 0 to 1.5 hours.

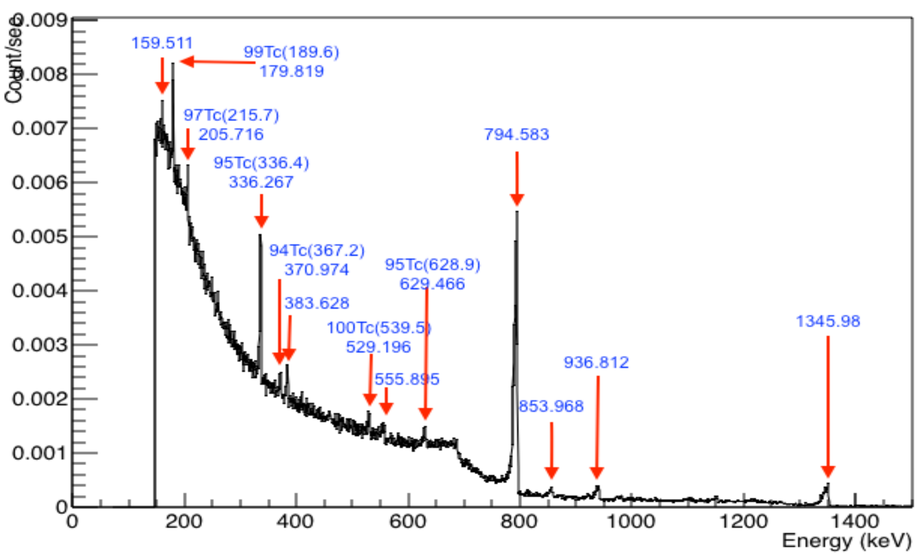
(b) Off-line setup for the delayed γ rays with half-lived 0.5 hours onwards.

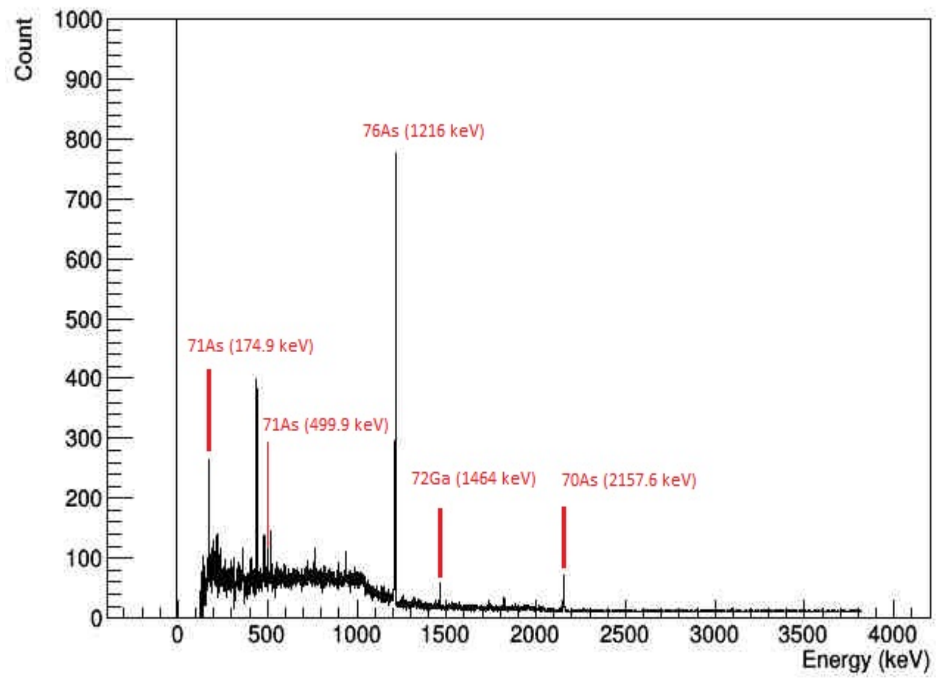
I. H. Hashim PhD Thesis Osaka 2015I.
I. H. Hashim H. Ejiri , 2015. MXG16,
I. H. Hashim H. Ejiri , et al PR C 97 2018

RI distribution by prompt and delayed γ-rays (under progress)

- To determine the partial capture rates from prompt gamma.
- To evaluate GR peaks from proton and neutron emission model by comparison of short lived and long-lived RI gamma rays.

^{nat}Ru (off-line)





Summary:

-- we need to make on-line and off-line measuring after exposure target;

-- for the off-line we will need 1 HPGe detector with big volume preferable;

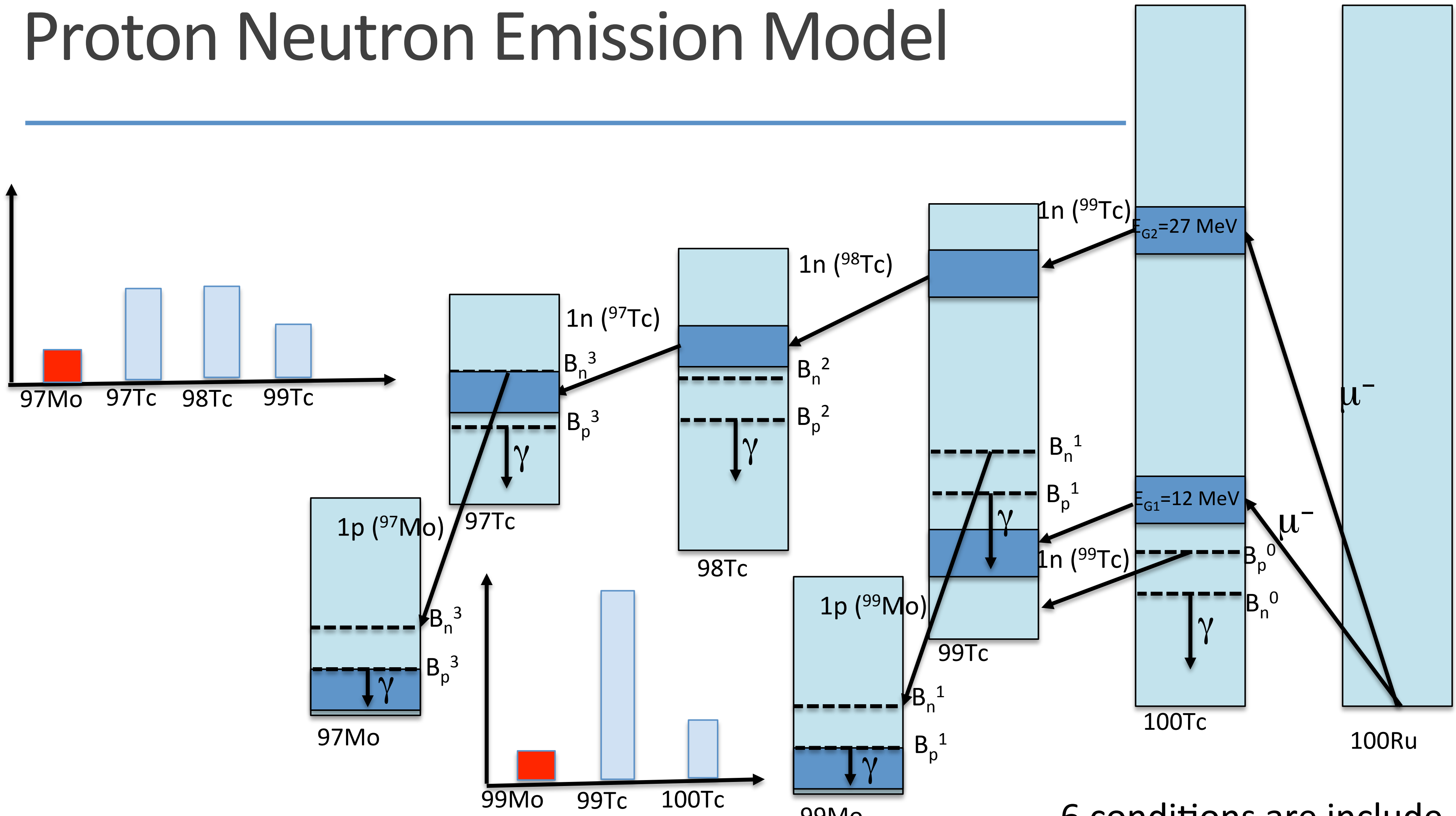
-- do we need to come earlier than the beam-time for Mu-capture?

-- our team: Daniya Zinatulina, Mark Shirchenko, Egor Sehvchik, Nadezda Rumyantseva, Sergey Kazarcev, Izyan Hasim (UTM) and Aisha Hamzah (UTM), Prof. Ejiri Hiro (RCNP).

Thank you for your attention!

BACK SLIDES

Proton Neutron Emission Model



6 conditions are include in current PNEM.

[1] H.Ejiri, I.H. Hashim. Private Comm. 2018

[2] I.H. Hashim. F.Soberi, F.Ibrahim. Private Comm. 2019

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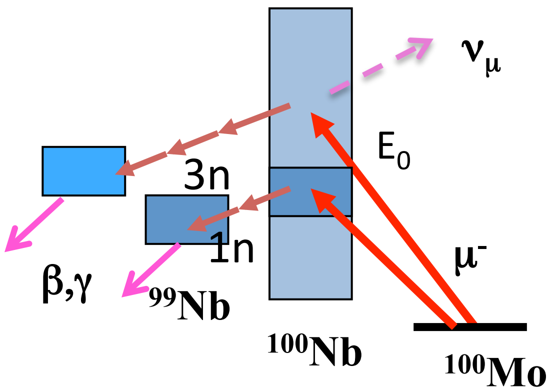
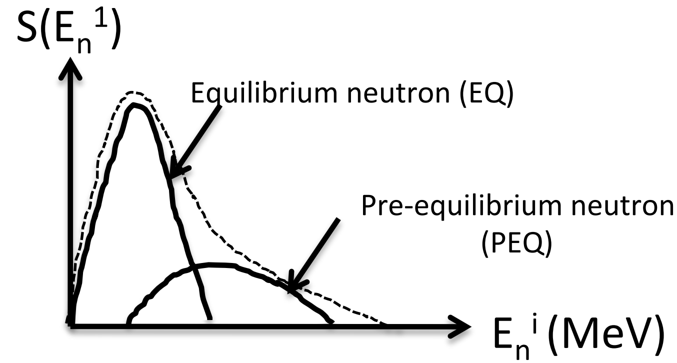
PRC 97(2018) 014617 (J-PARC 2014)





$$S(E_n^1) = k\left[E_n^1 exp\left(-\frac{E_n^1}{T_{\rm EQ}(E)}\right) + pE_n^1 exp\left(-\frac{E_n^1}{T_{\rm PEQ}(E)}\right)\right]$$

{EQ} {PEQ}

μ response(strength) distribution

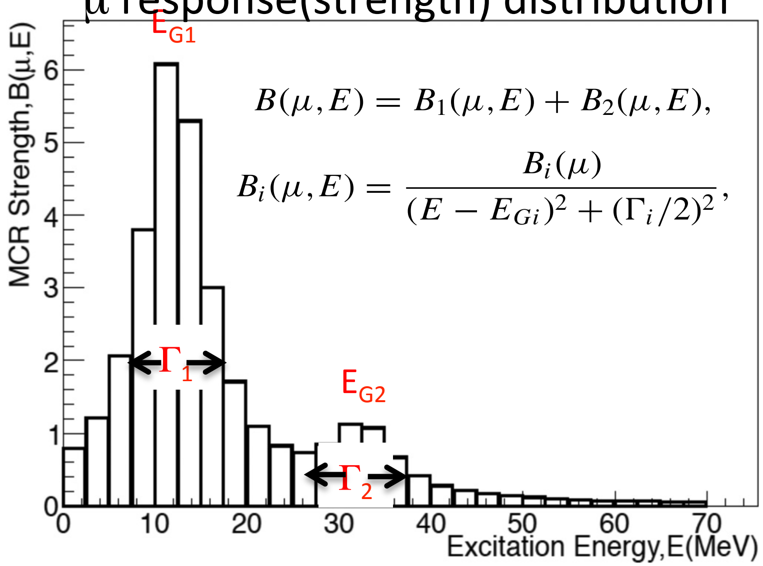
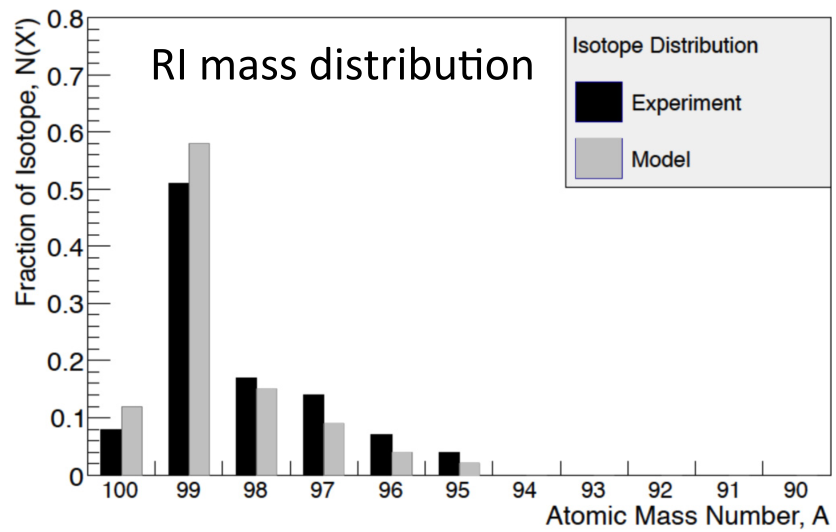
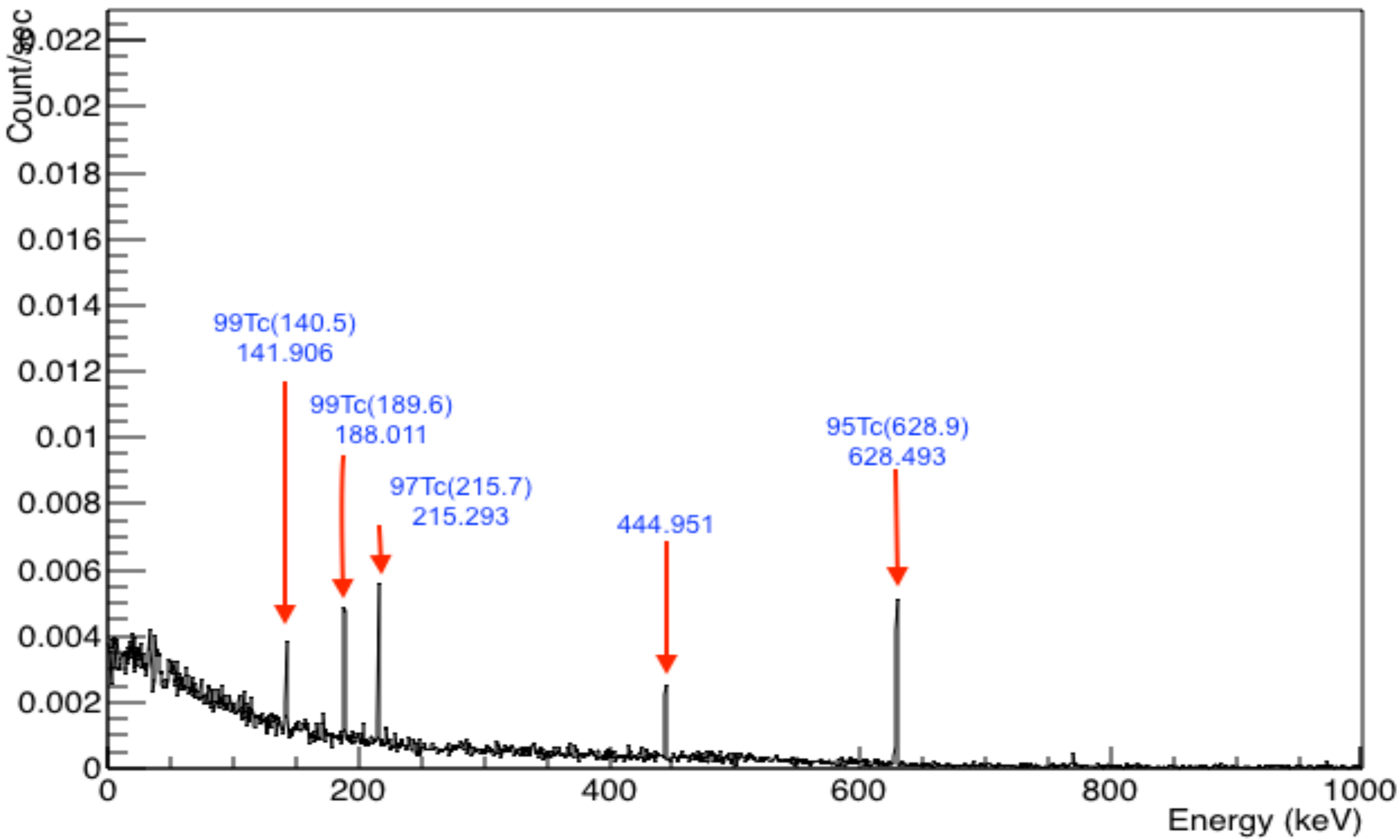


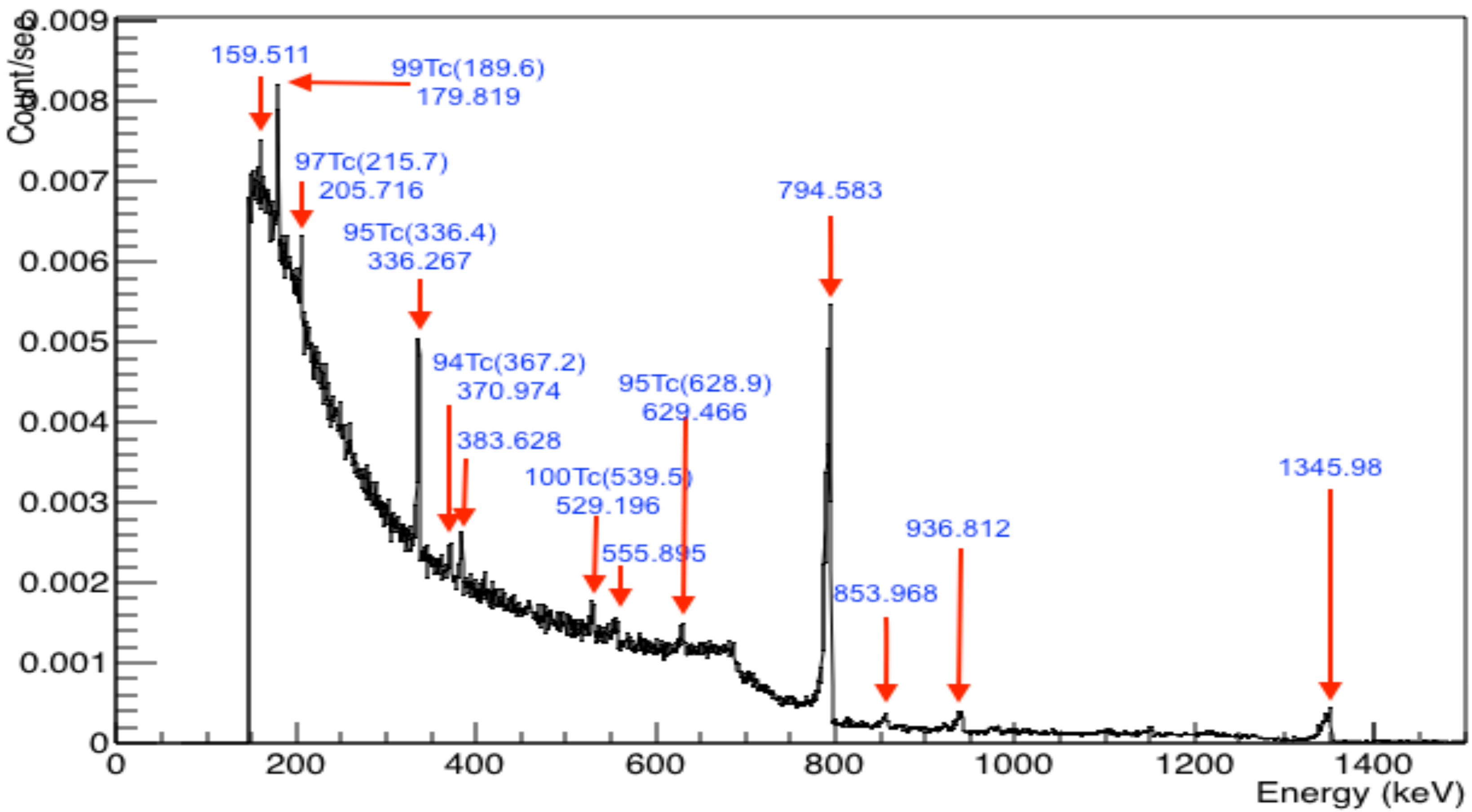
FIG. 6. The OMC strength distribution suggested from the experimental RI distribution. E_{G1} and E_{G2} are the OMC GRs at around 12 MeV and 30 MeV.

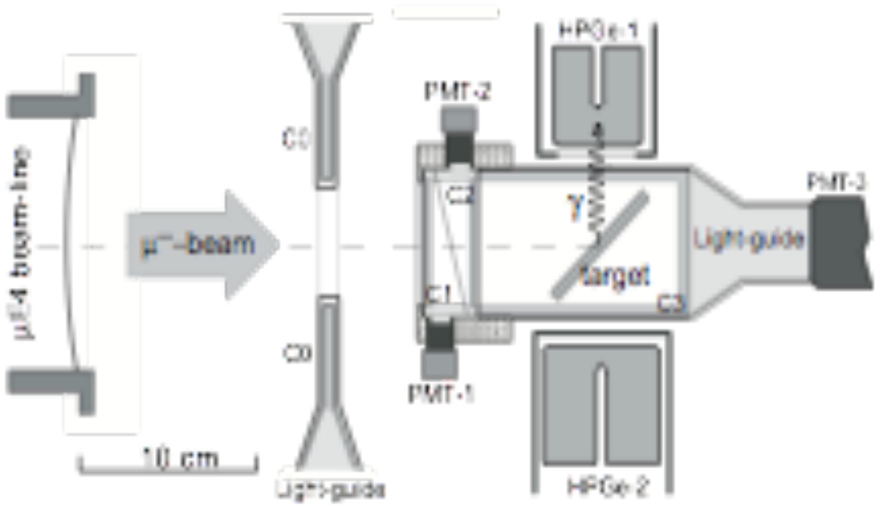


Poptop Det (Runat)

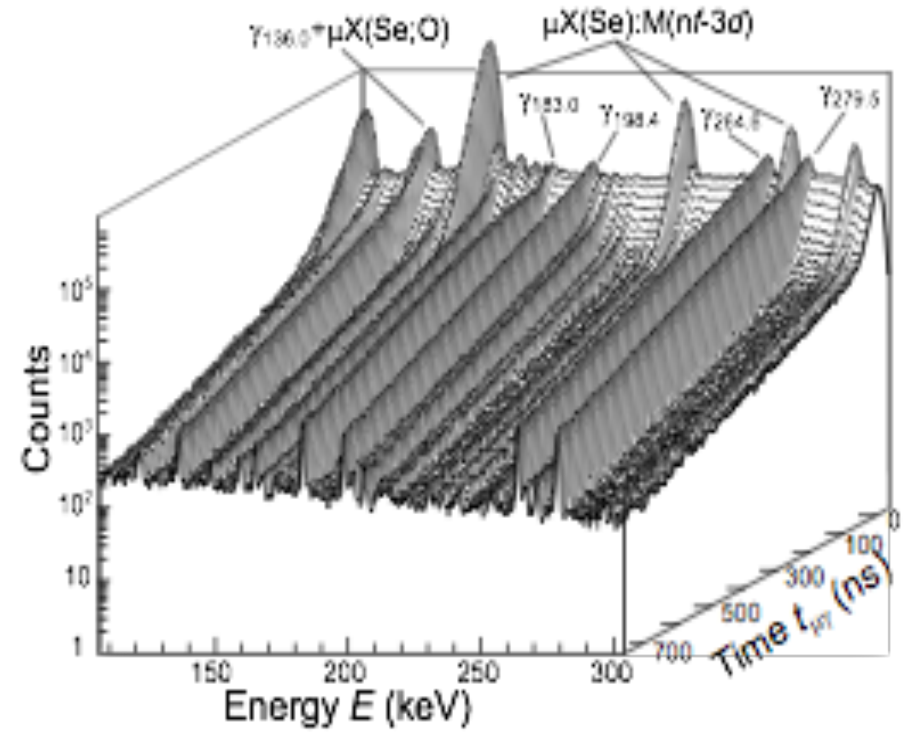


Fukushima Det (RuNat)



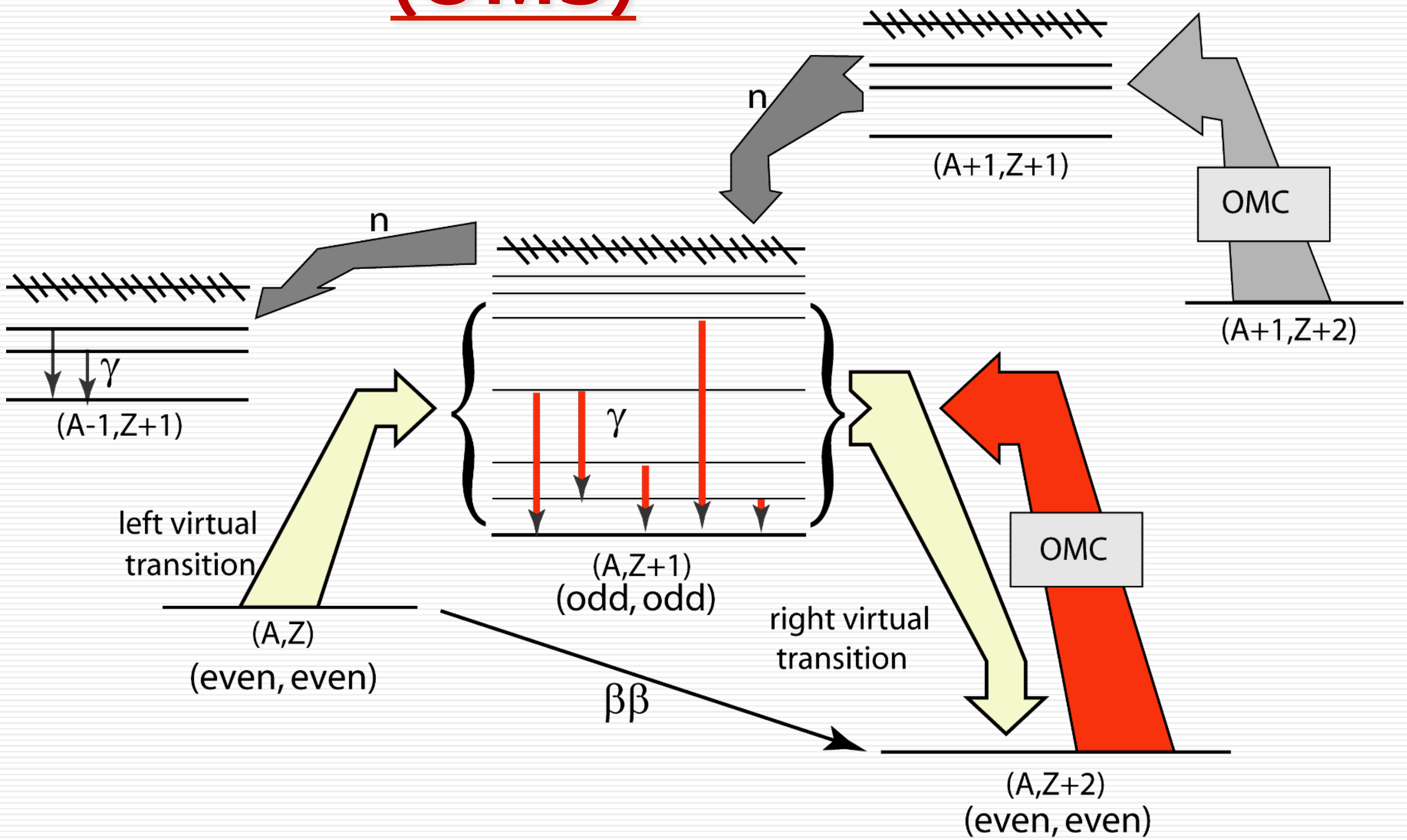


target	enr-ment	composition	element mass	thickness mg/cm^2
^{82}Kr	99.9%	Kr gas	1.0 l (1 atm.)	37.3
^{nat}Kr	–	Kr gas	1.0 l (1 atm.)	37.3
^{130}Xe	99.9%	Xe gas	1.0 l (1 atm.)	37.3
^{nat}Xe	–	Xe gas	1.0 l (1 atm.)	37.3
^{24}Mg	99.89%	MgO powder	1.0 g	250



[1] D. Zinatulina et al. Phys. Rev. C 99 (2019) 024327.

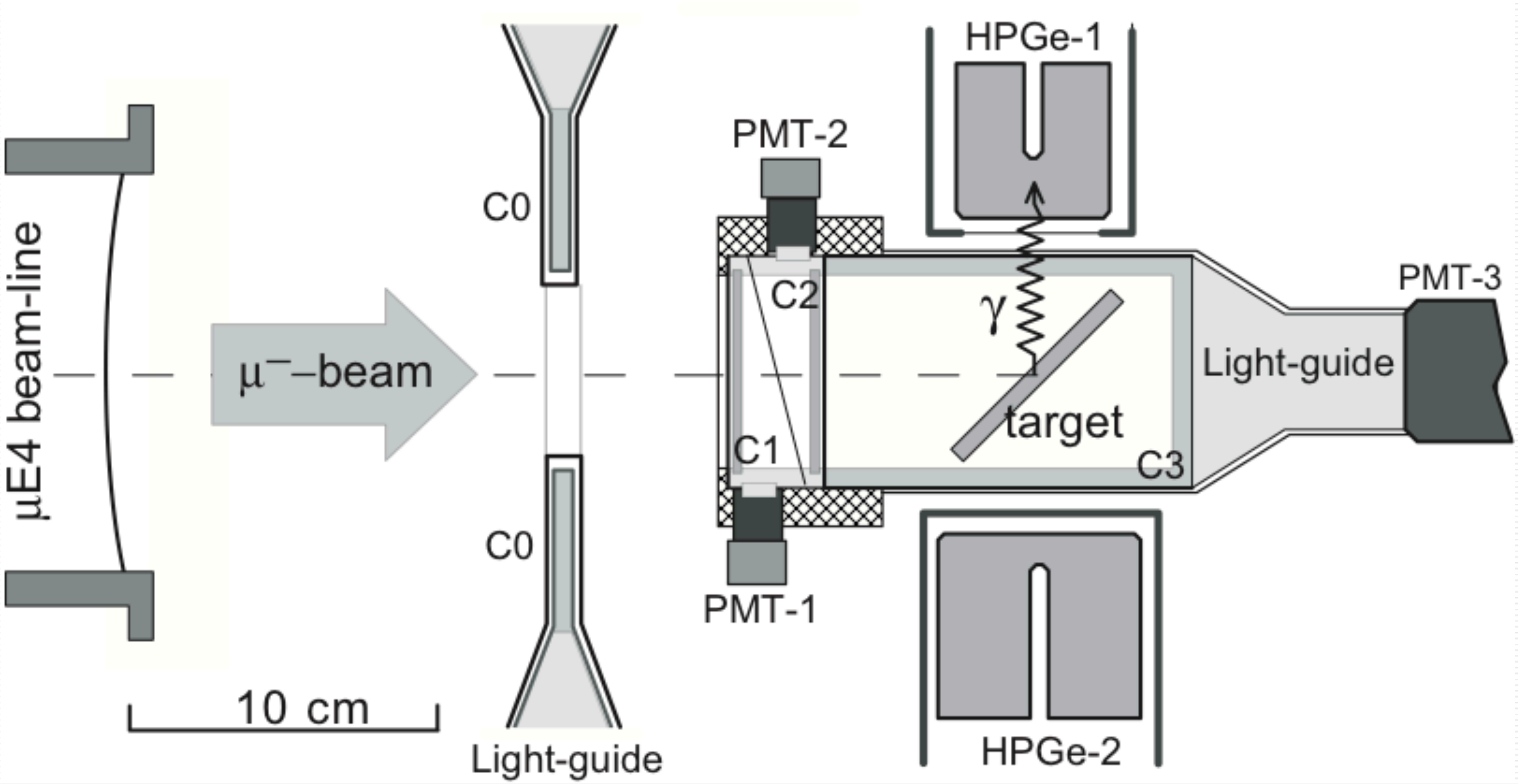
Обычный мюонный захват (ОМЗ)



ОМЗ **(0n):** $\mu^- + (A, Z) \rightarrow (A, Z\text{-}1)^* + \nu_\mu \rightarrow (A, Z\text{-}1) + \gamma$, $m_\mu \sim 100$ MeV

2β-распад	2β-эксперименты	Мишени ОМЗ	Статус
^{76}Ge	GerdaI/II, Majorana Demonstrator	^{76}Se	2004 (PSI)
^{48}Ca	TGV, NEMO3, Candles III	^{48}Ti	2002 (PSI)
^{106}Cd	TGV	^{106}Cd	2004 (PSI)
^{82}Se	NEMO3, SuperNEMO, Lucifer(R&D)	^{82}Kr	2006 (PSI)
^{100}Mo	NEMO3, AMoRE(R&D), LUMINEU(R&D)	^{100}Ru	2018 (RCNP)
^{116}Cd	NEMO3, Cobra	^{116}Sn	2002
^{150}Nd	SuperNEMO, DCBA(R&D)	^{150}Sm	2002, 2006
^{136}Xe	EXO200, Kamland-Zen, NEXT	^{136}Ba	2019 (RCNP)
^{130}Te	Cuore 0/Cuore, SNO+	^{130}Xe	2019 (PSI)?

Экспериментальная установка (PSI)

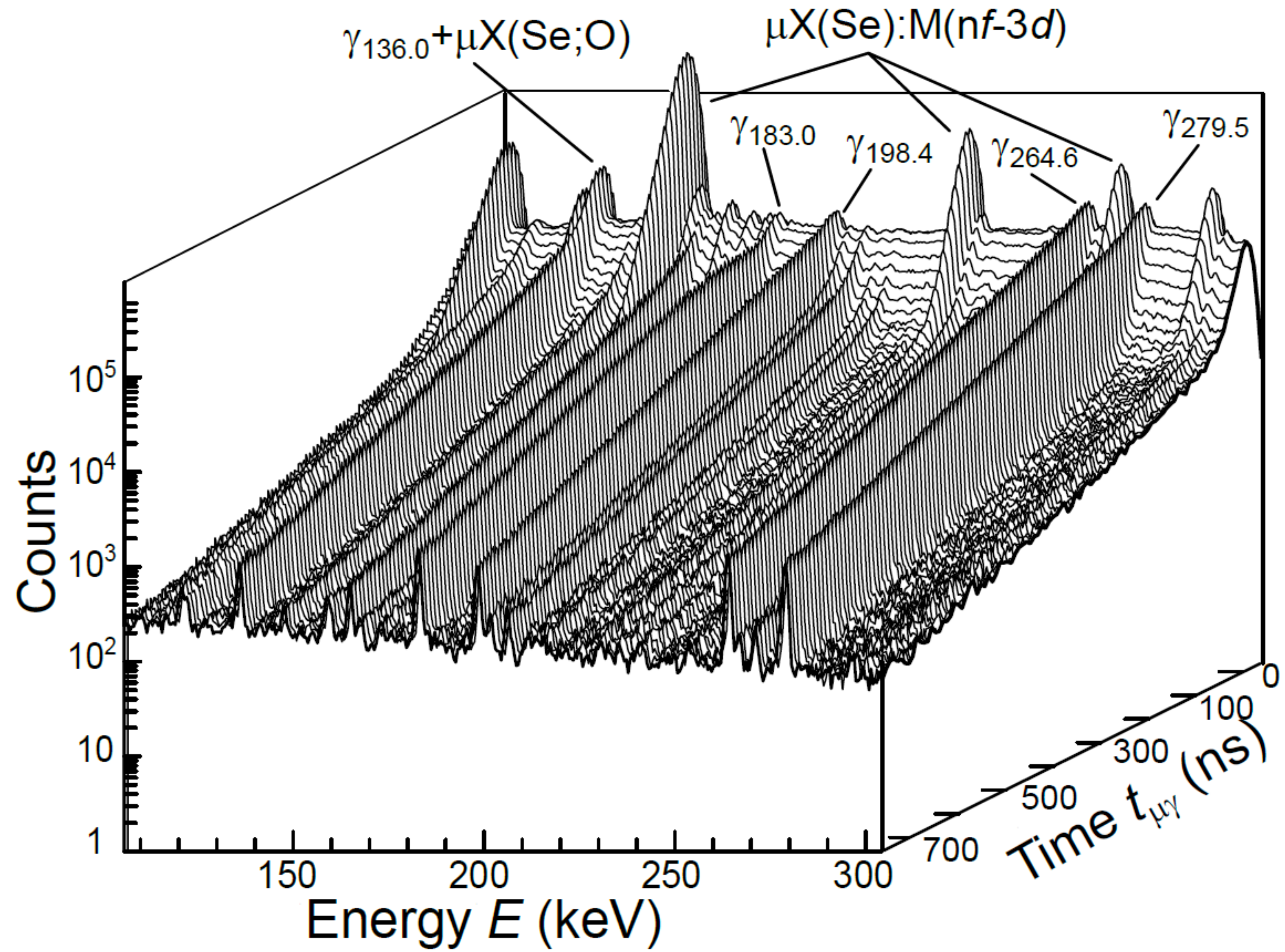


$$\mu_{stop} = \overline{C0} \wedge C1 \wedge C2 \wedge \overline{C3}$$

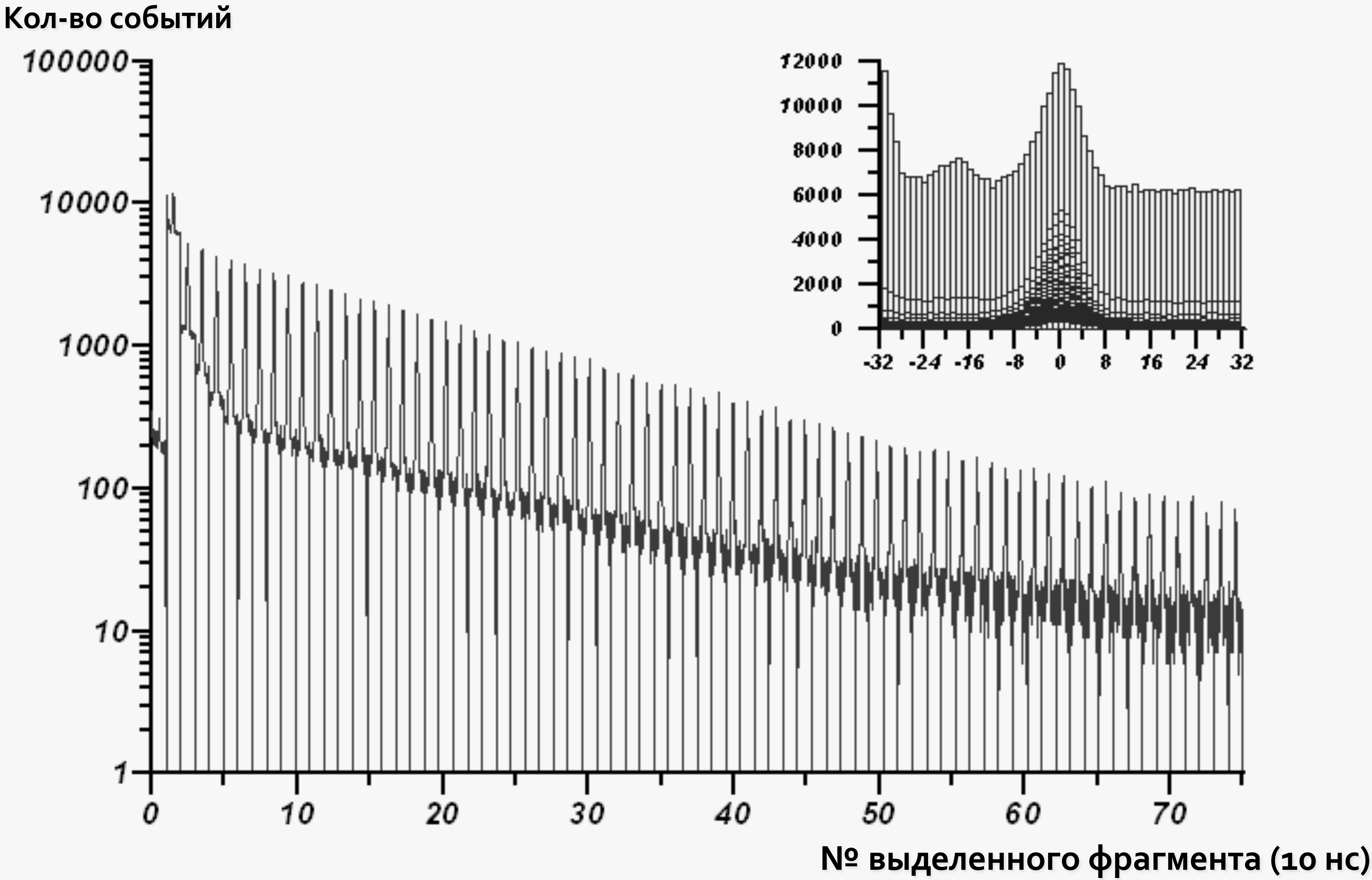
Количество μ-stop = (8 – 25) x 10³ с 20 – 30 MeB/c

PSI, 2006

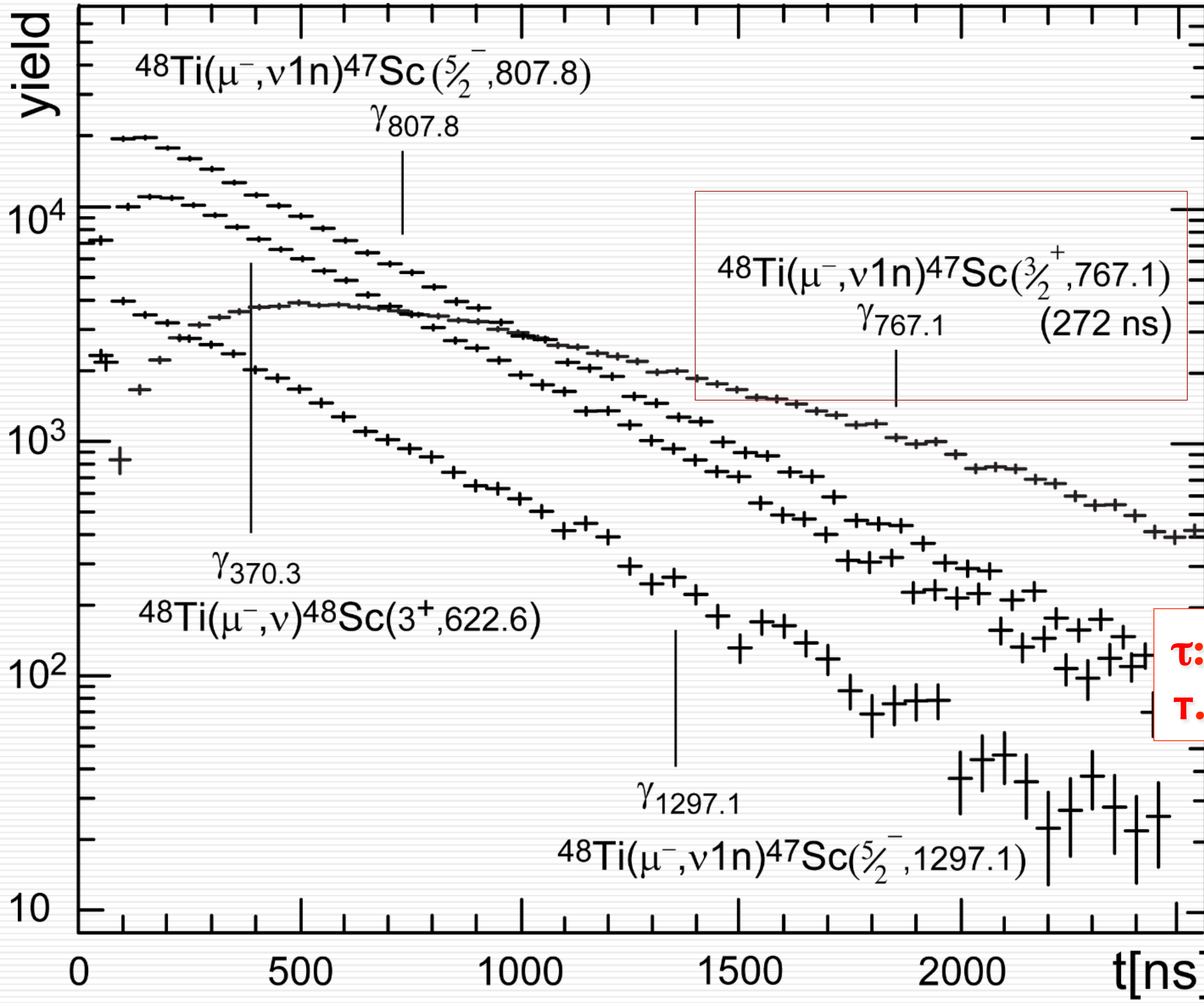
(E, t) распределение при μ-захвате в мишени ^{76}Se



Метод временной эволюции γ-линии



Полные скорости m-захвата в ^{48}Ti



τ: 361.1 нс

т.е., λ_{cap} = 2.32 μc^{-1}