Joint Institute for Nuclear Research
Dzhelepov Laboratory of Nuclear Problems

Ordinary muon capture studies by means of γ-spectroscopy. Status and futures.

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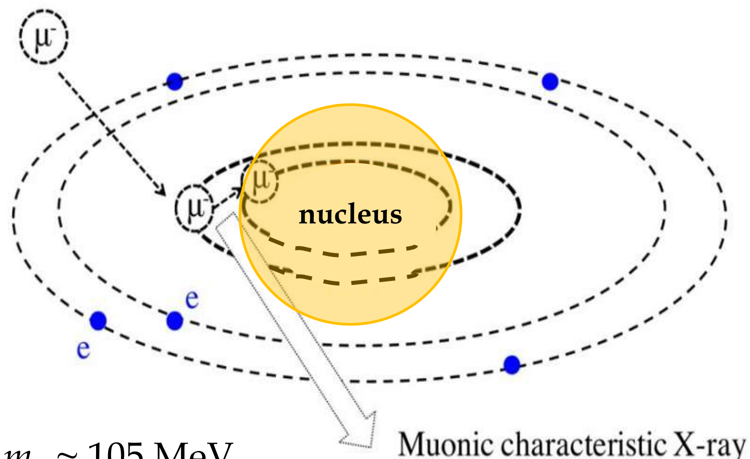
06.02.2020, Dubna

Overview:

- **Ordinary muon capture (OMC)**
- **First Motivation**
  - Nuclear Matrix Elements (NME) for double beta-decay (DBD) processes;
- **Measurement principle (1998-2006)**
  - Short history;
  - Experimental method and results;
- **Pre-conclusions**
- **New Motivation**
  - g_A suppression in NME for DBD;
  - Comparison with theoretical calculations;
  - Japan group and OMC for astroneutrinos;
- **Measurement principle (2018 - ...)**
  - Japan/Malaysia collaboration;
  - muX group collaboration;
  - Detection system, DAQ and first results (2019);
- **Feauters**
- **Conclusion**

Ordinary Muon Capture (OMC)



$m_\mu \sim 105$ MeV

$\mu^- \rightarrow e- + \nu_e + \nu_\mu \qquad \tau_{dec} = 2.2\mu s$

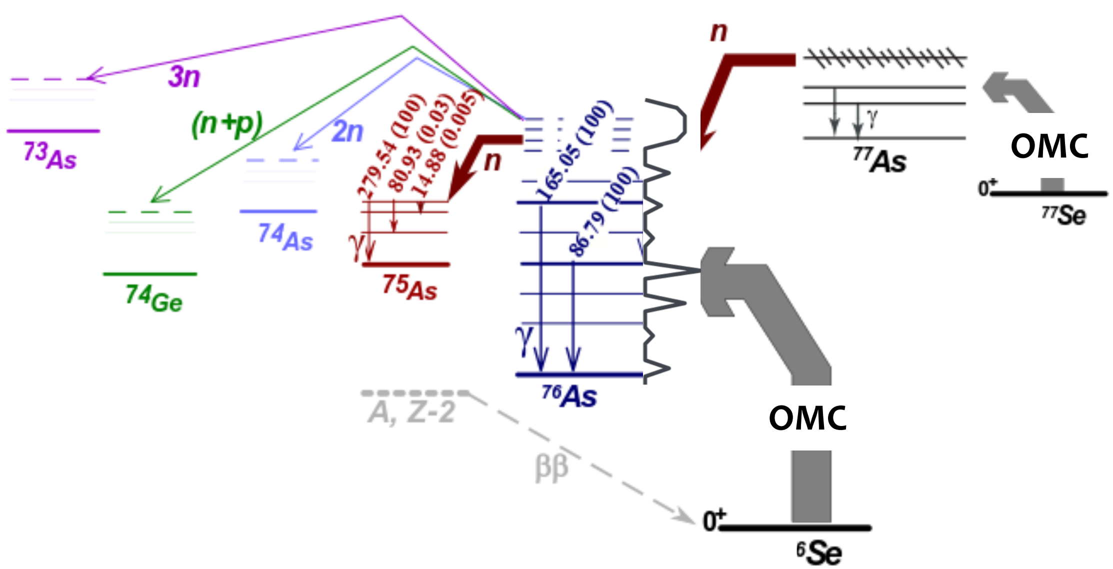
$(A, Z) + \mu^- \rightarrow \; (A, Z\text{-}1)^* + \nu_\mu$

$\rightarrow (A, Z\text{-}1) + \gamma$

$\rightarrow (A\text{-}1, Z\text{-}1) + \gamma + n$

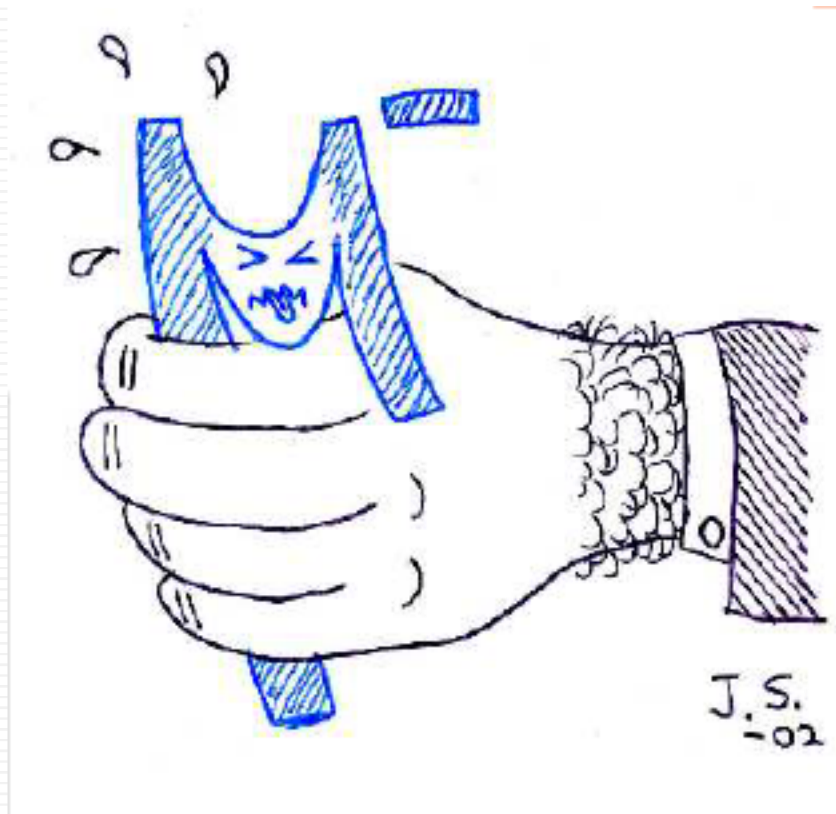
$\rightarrow (A\text{-}2, Z\text{-}1) + \gamma + 2n$

$\rightarrow (A\text{-}1, Z\text{-}2) + \gamma + n + p$



- Muonic cascades (our by-product)
- High momentum transfer (up to 100 MeV) -- High-lying states population
- **Right leg testing for DBD calculations (coupling to charge exchange reactions)**
- g_a – suppression probing -- via capture rates calculations (+ other methods)
- Angular correlations in OMC (Doppler shape of γ-lines)

First Motivation

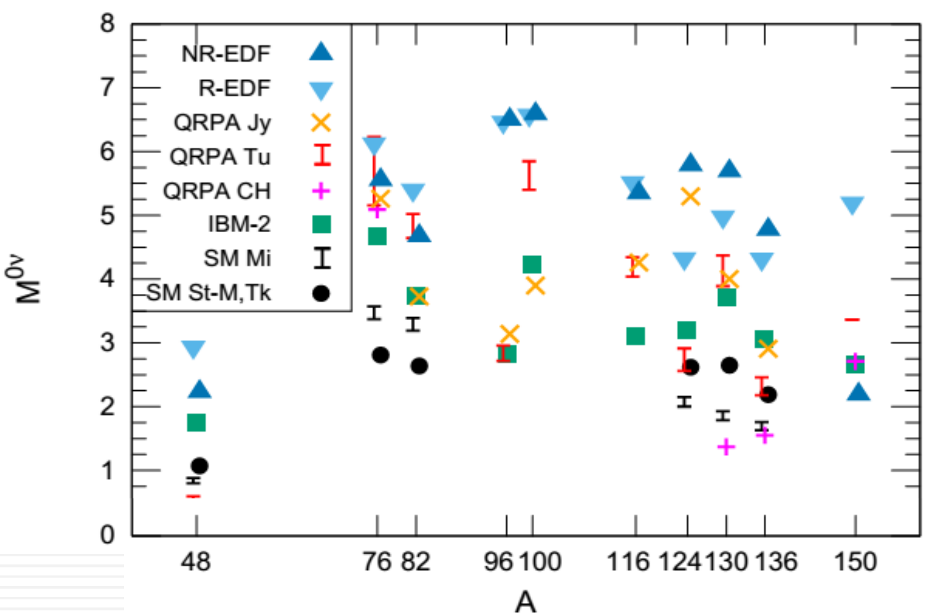


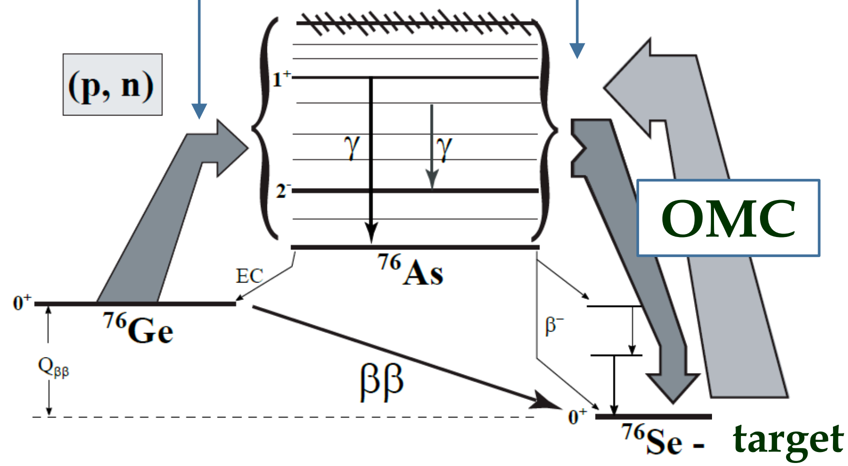
Experimental input for NME calculations

$$\frac{1}{T_{1/2}^{0\nu}} \propto \left|\sum_i U_{ei}^2 m_i\right|^2 G^{0\nu} \left|\langle A,Z+2|S|A,Z\rangle\right|^2$$

$\langle m_{\beta\beta}\rangle$ $M^{0\nu}$

$$\langle A,Z+2|S|A,Z\rangle \propto \sum_n \langle Z+2|\hat{H}|Z+1,n\rangle\langle Z+1,n|\hat{H}|Z\rangle$$



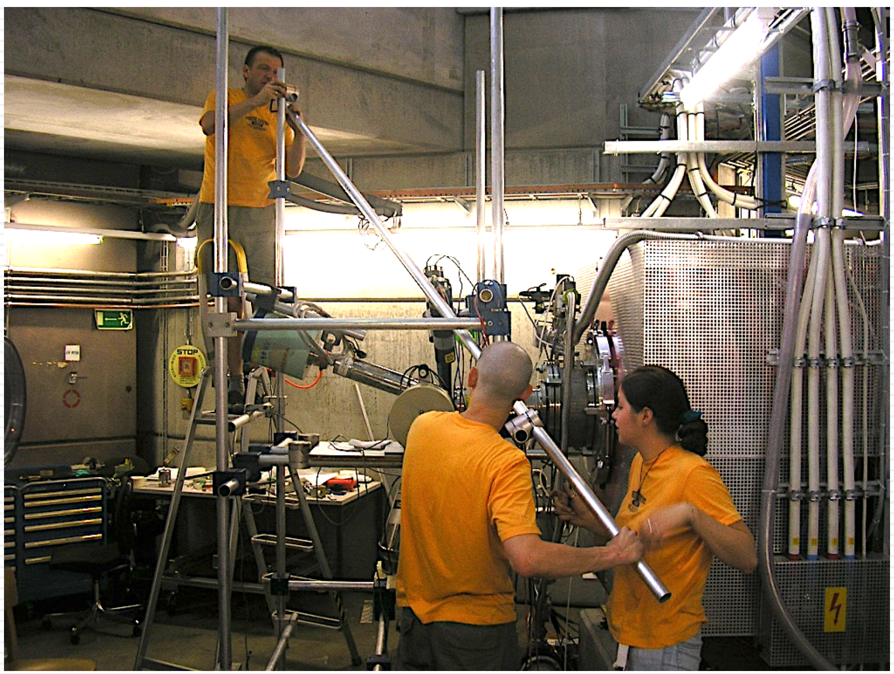


Measurement principle (1998 -2006, PSI)

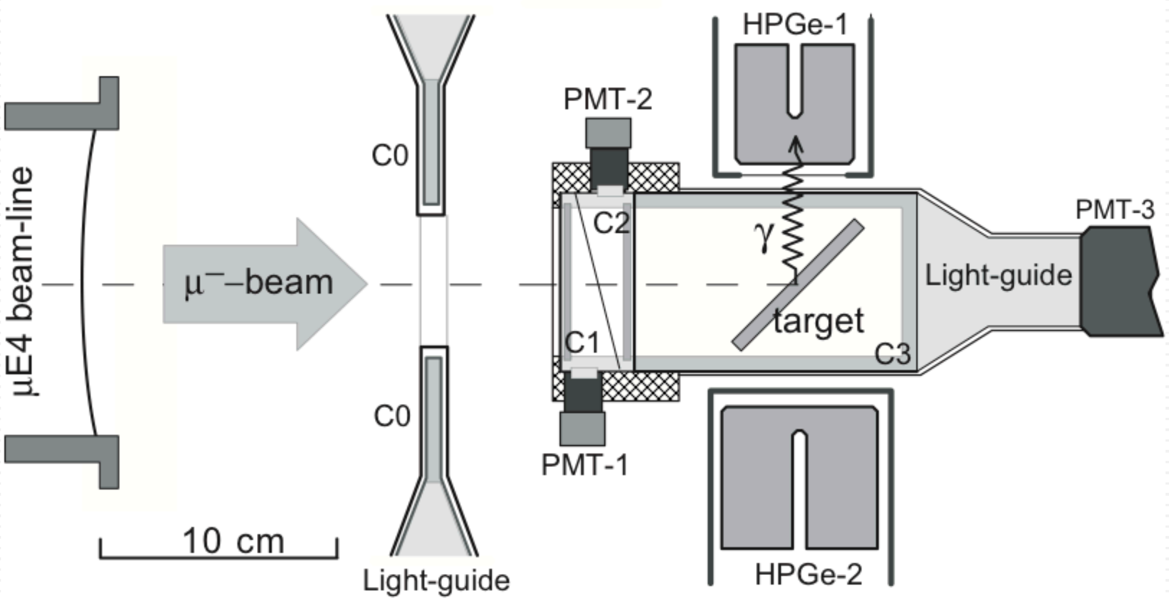

PSI 1998
AC/MC

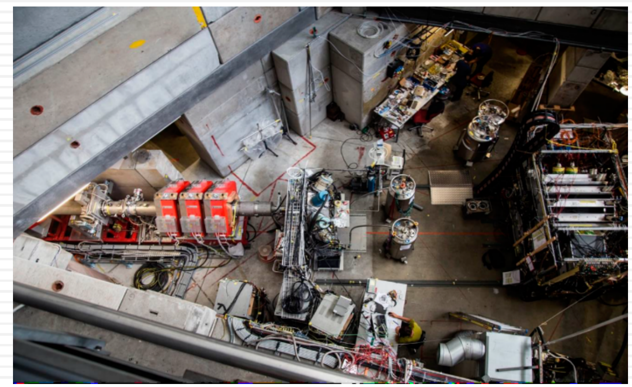
PSI 2006

OMC



Measurement set-up





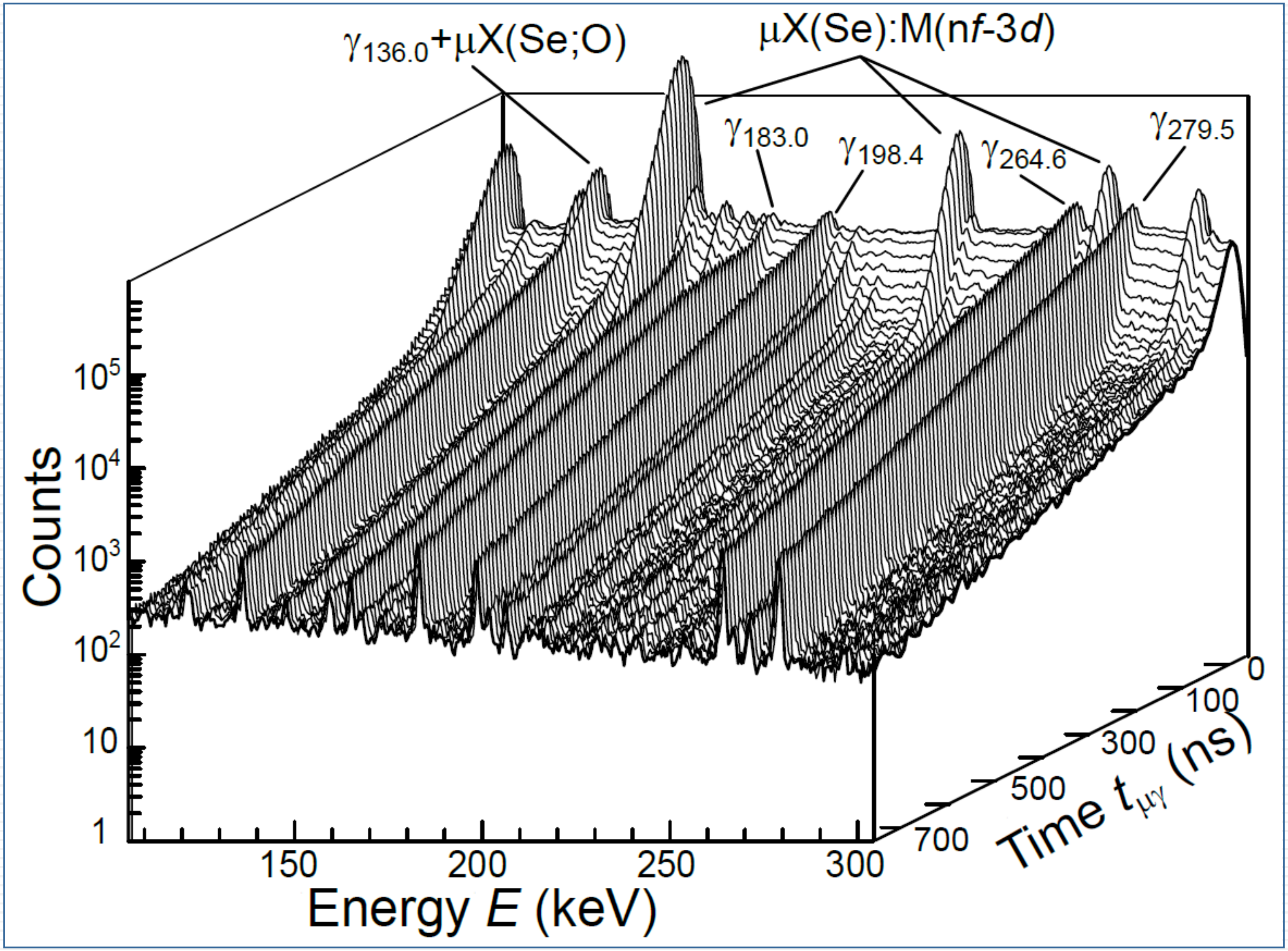
$$\mu_{stop} = \overline{C0} \wedge C1 \wedge C2 \wedge \overline{C3}$$

Number of μ-stop = (8 – 25) x 10^3 with 20 – 30 MeV/c

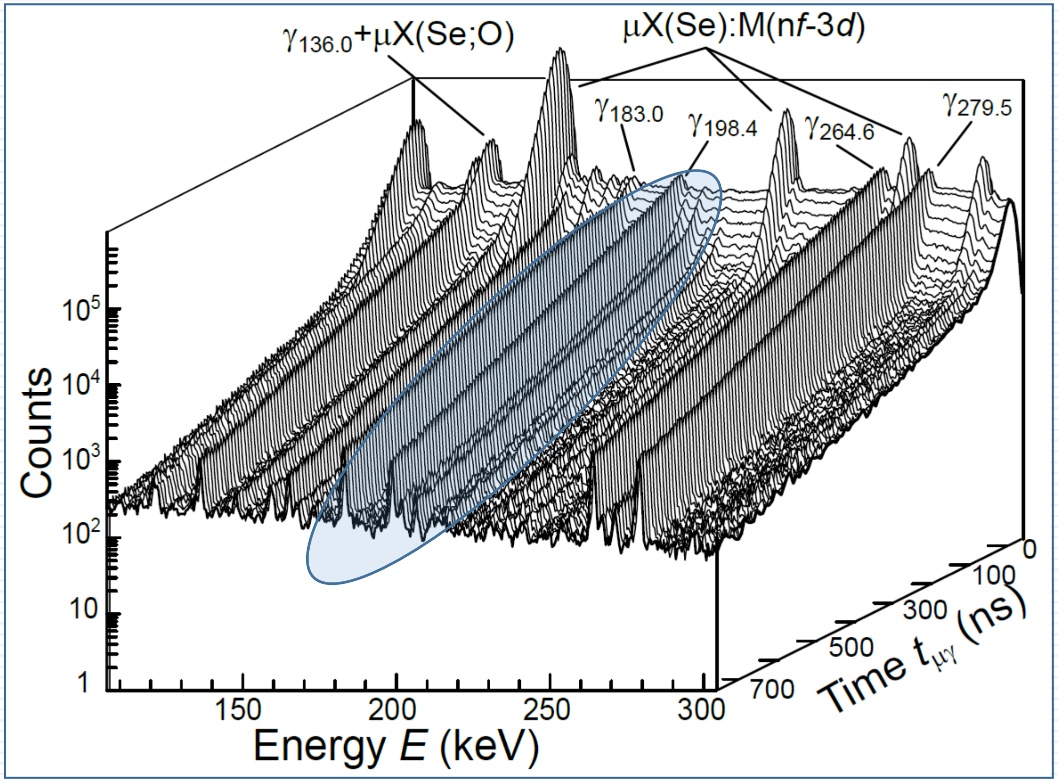
HPGe's: register μX- and γ-radiation, following OMC in the target, and time

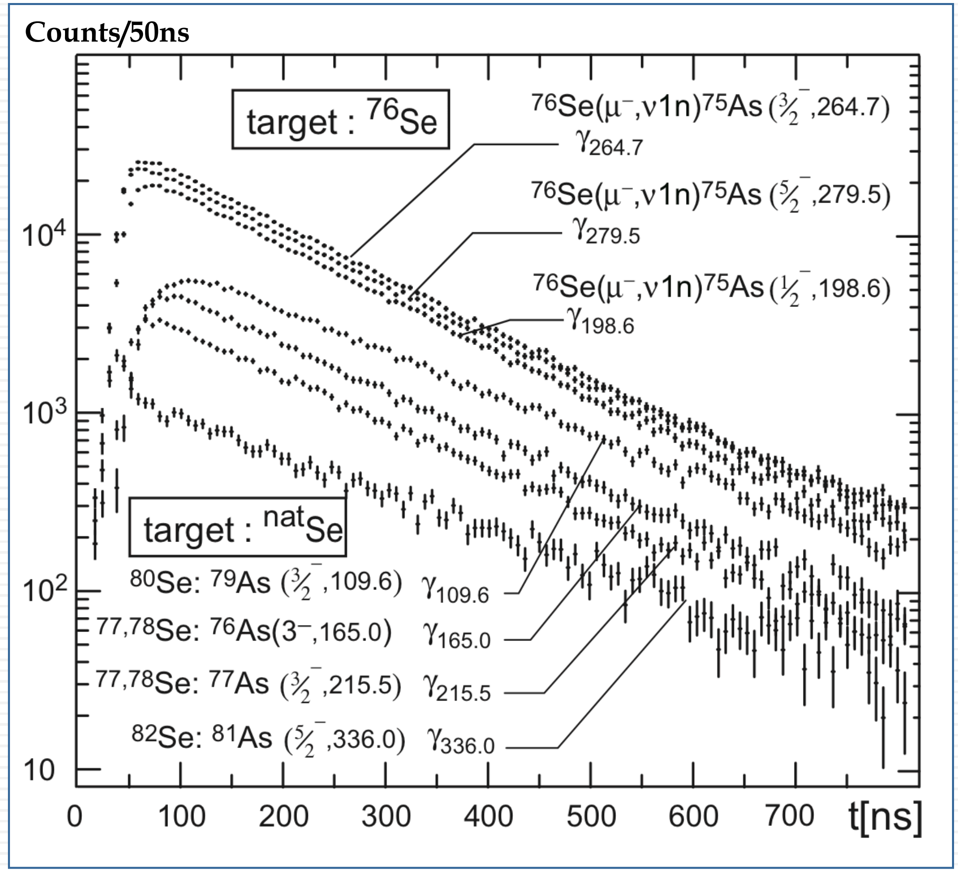
2β-decay	2β-experiments	OMC target	Status
^{76}Ge	GerdaI/II, Majorana Demonstrator, LEGEND	^{76}Se	2004 (PSI)
^{48}Ca	TGV, NEMO3, Candles III	^{48}Ti	2002 (PSI)
^{106}Cd	TGV	^{106}Cd	2004 (PSI)
^{82}Se	NEMO3, SuperNEMO, Lucifer(R&D)	^{82}Kr	2019 (PSI)
^{100}Mo	NEMO3, AMoRE(R&D), LUMINEU(R&D), CUPID-0 Mo	^{100}Ru	--
^{116}Cd	NEMO3, Cobra	^{116}Sn	--
^{150}Nd	SuperNEMO, DCBA(R&D)	^{150}Sm	2006 (PSI)
^{136}Xe	nEXO, KamLAND2-Zen, NEXT, DARWIN, PandaX-III	^{136}Ba	2020 (PSI)
^{130}Te	Cuore 0/Cuore, SNO+	^{130}Xe	2019 (PSI)

(*E*, *t*) distribution of the correlated events following μ-capture in ^{76}Se target



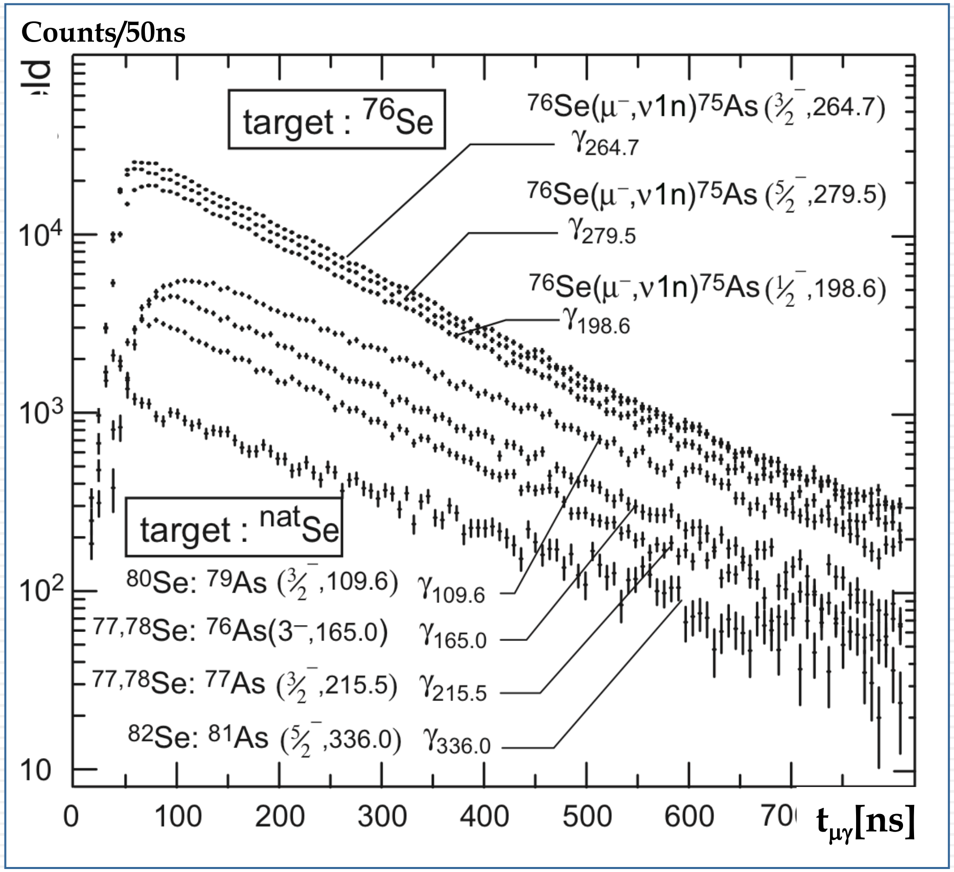
(*E*, *t*) distribution of the correlated events following μ-capture in ^{76}Se target





Time evolution of the intensities of the strongest γ-lines following OMC in ^{76}Se (top) и ^{nat}Se (bottom).

Total μ-capture rates in different isotopes of Se



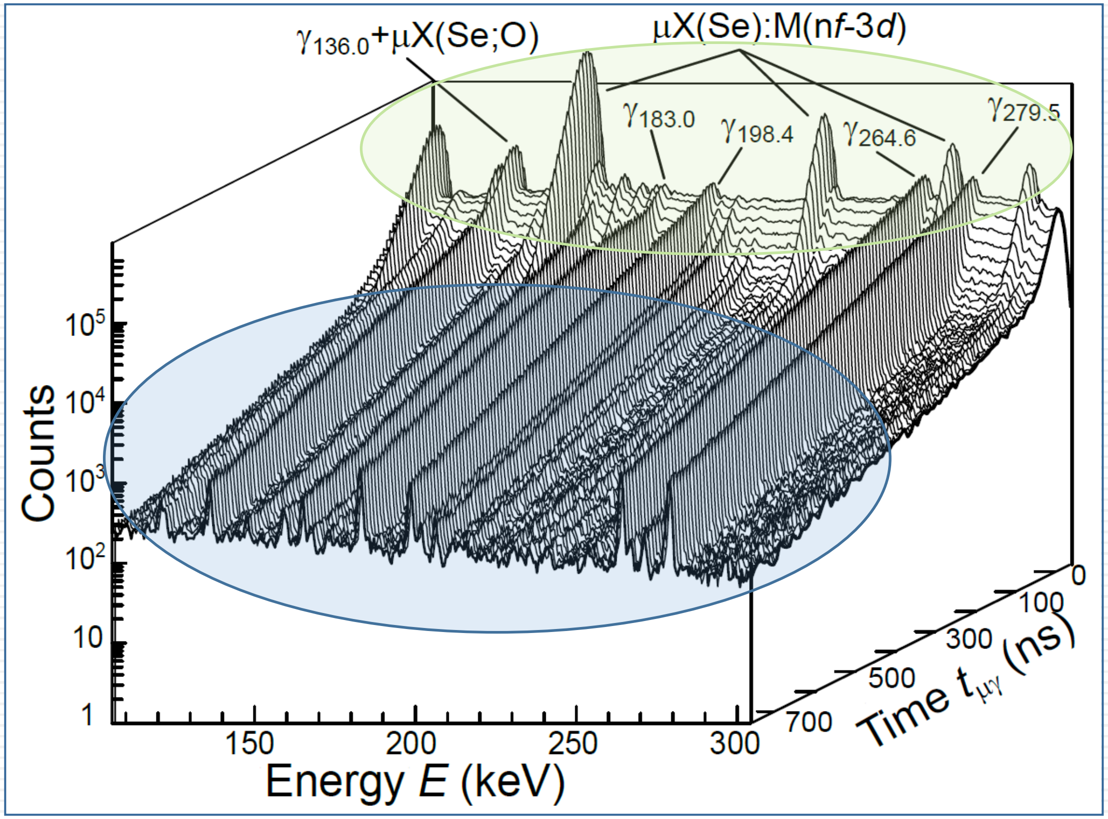
Time evolution of the intensities of the strongest γ-lines following OMC in ^{76}Se (top) и ^{nat}Se (bottom) (A.

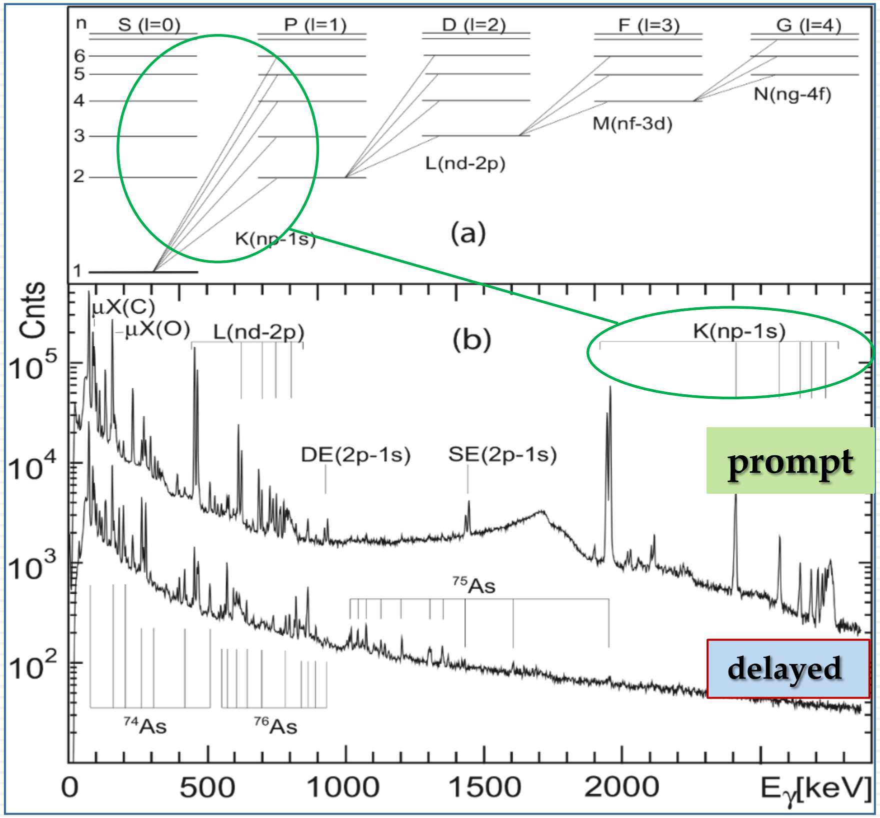
Target	Daugh. Nuclei	E_i^{γ} [keV]	τ [ns]	$\langle\lambda_{cap}\rangle$ [10^6 c^{-1}]
^{76}Se (A	^{75}As	198.6	148.4(7)	
		279.5	148.6(5)	
			<148.48(10)>	6.300(4)
^{nat}Se (A				
$^{(77)}$Se	^{76}As	164.7	163.5(20)	5.68(7)
$^{(78)}$Se	^{77}As	215.5	165.9(19)	5.59(7)
$^{(80)}$Se	^{79}As	109.7	185.5(27)	4.96(7)
$^{(82)}$Se	^{81}As	336.0	208.2(68)	4.37(14)
^{nat}Se (B			163.5(10)	5.681(37)

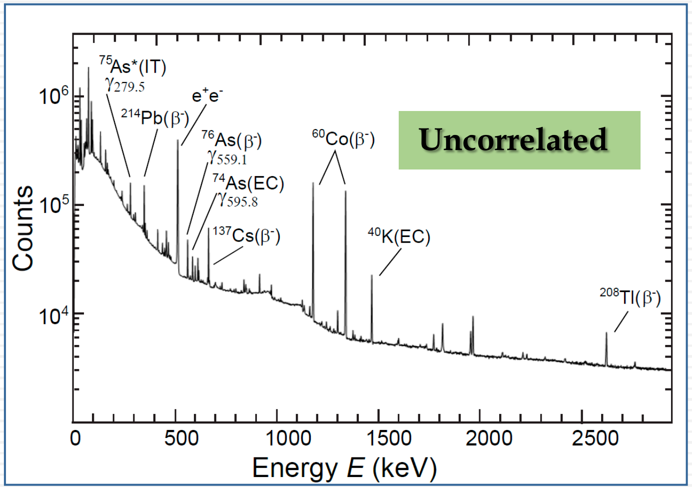
A) D. Zinatulina, V. Egorov et al. // Phys. Rev. C 99(2019)024327

B) T. Suzuki, D.F. Measday // Phys. Rev. C 35(1987)2212

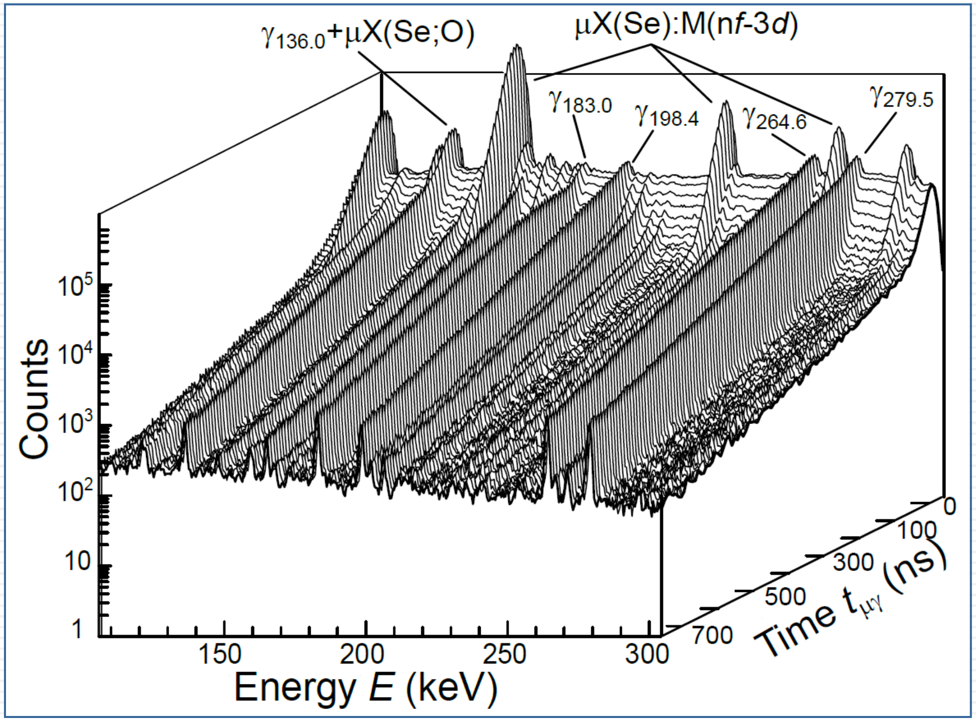
Energy spectra in OMC

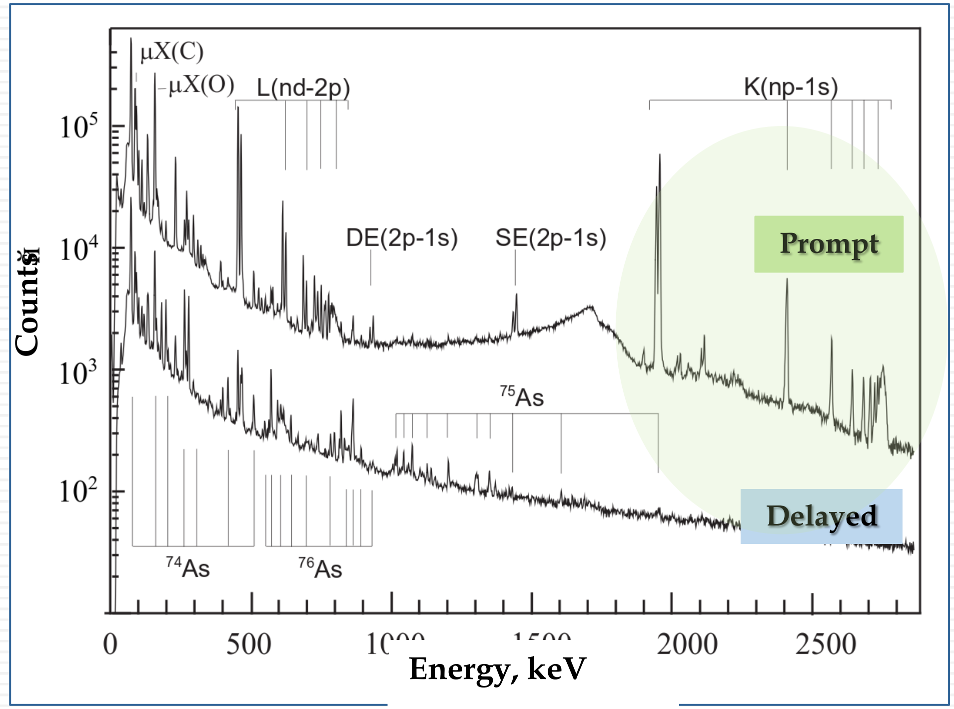


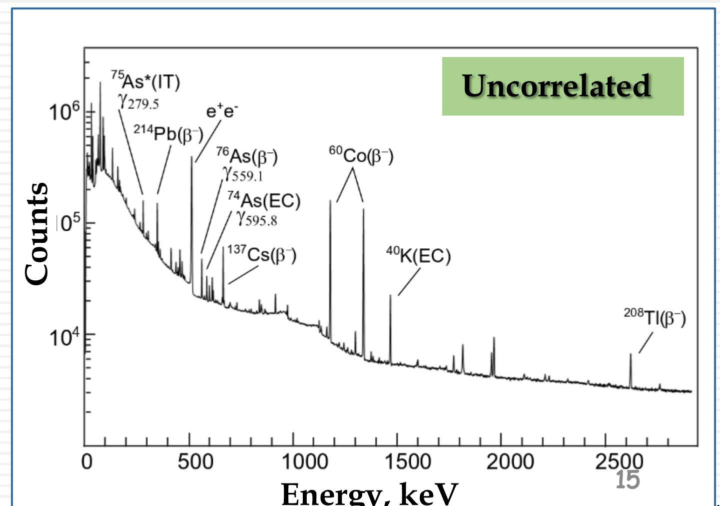




Energy spectra in OMC

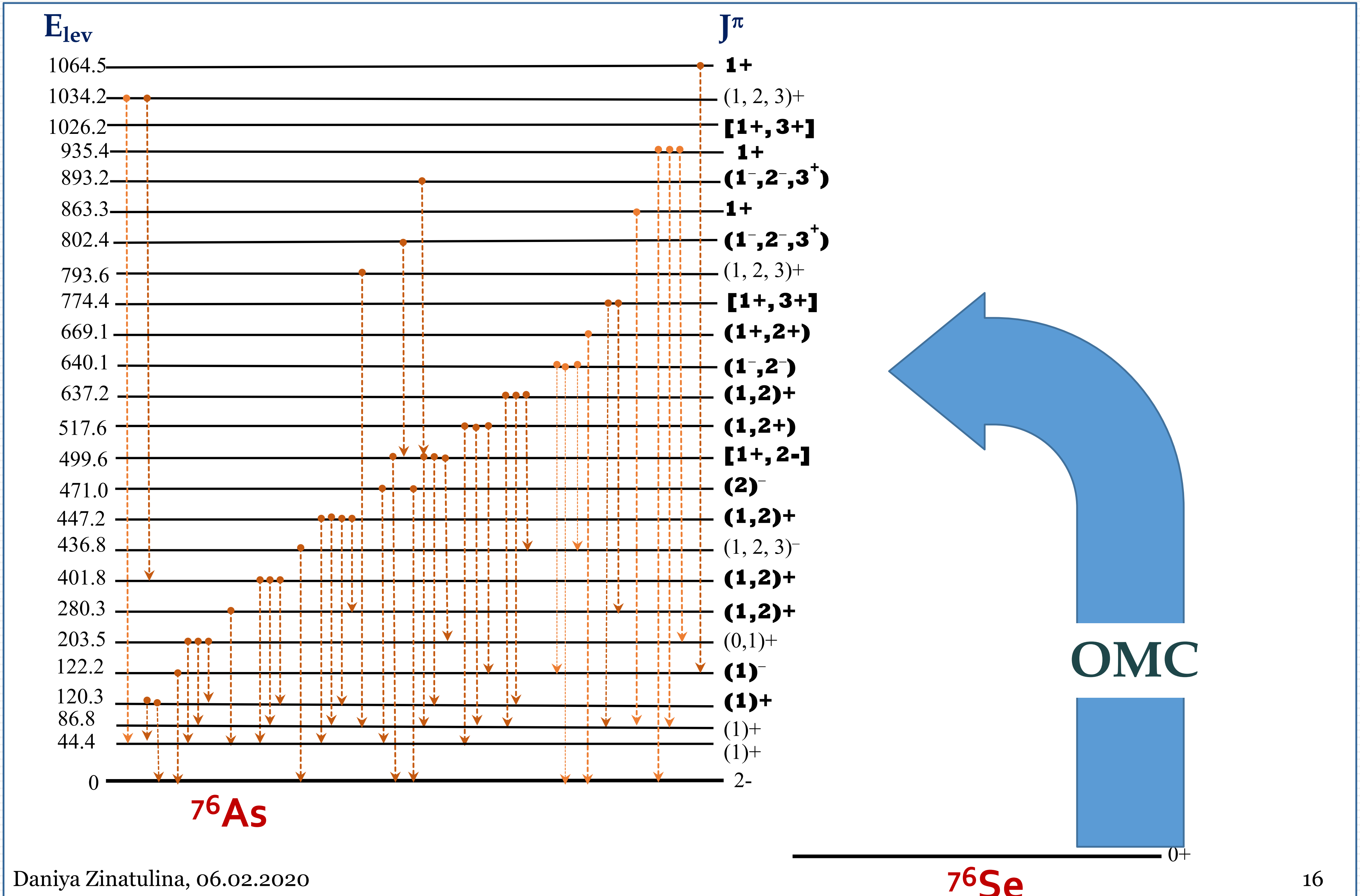




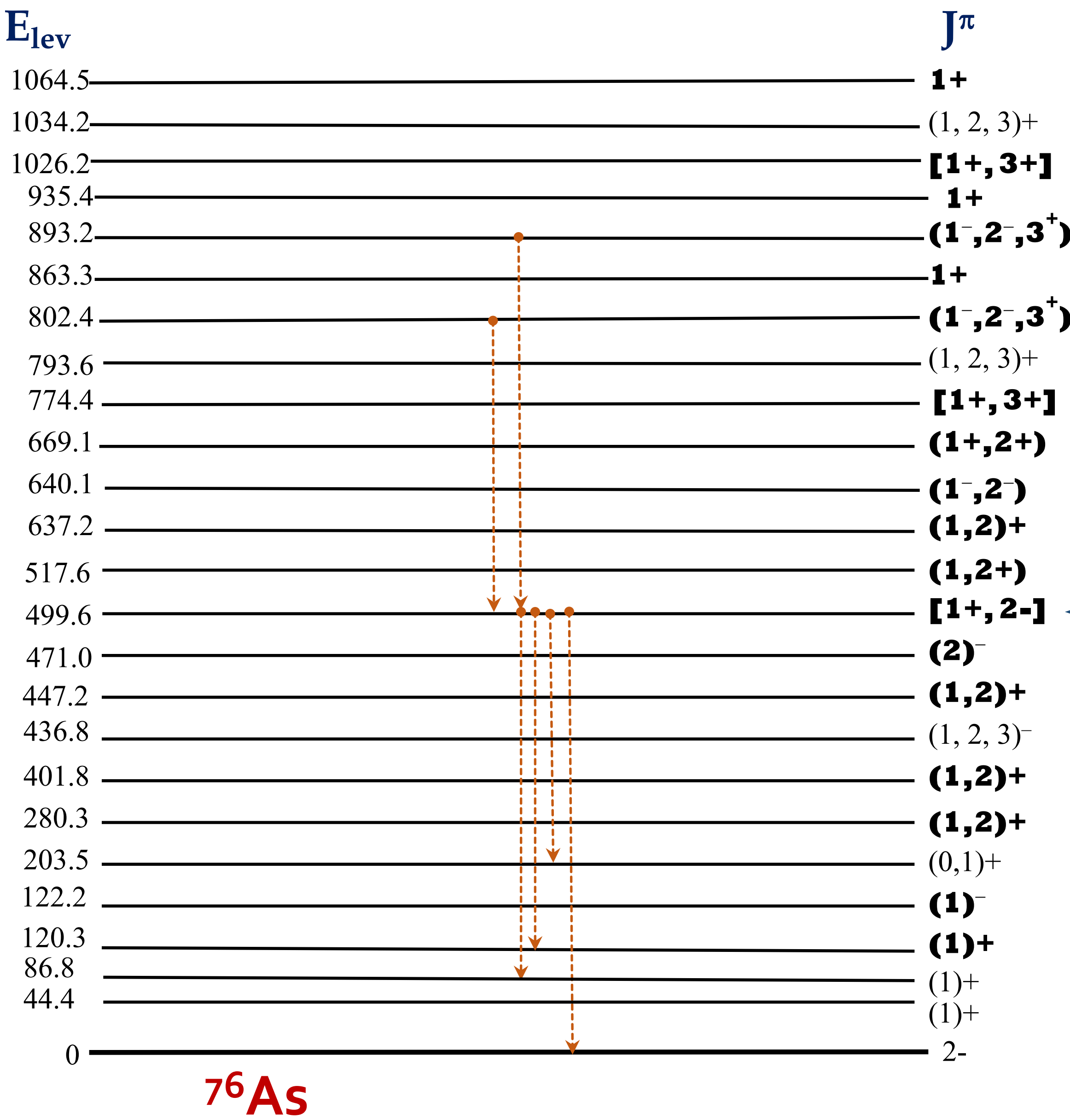


- $t_{\mu\gamma}$ = 0-50 ns: μX-cascades (**Prompt** spectra) – normalization, identification, composition of the surrounded materials and target itself;
- $t_{\mu\gamma}$ = 50-700 ns: γ-radiation following OMC (**Delayed** spectra) – partial μ-capture rates – strength function of the right side;
- T >> $t_{\mu\gamma}$: background radiation (**Uncorrelated** spectra) – calibration of the det-s, identification, yields of short-lived RI during exposure

Partial μ-capture probabilities to ^{76}As



Partial μ-capture probabilities to ^{76}As

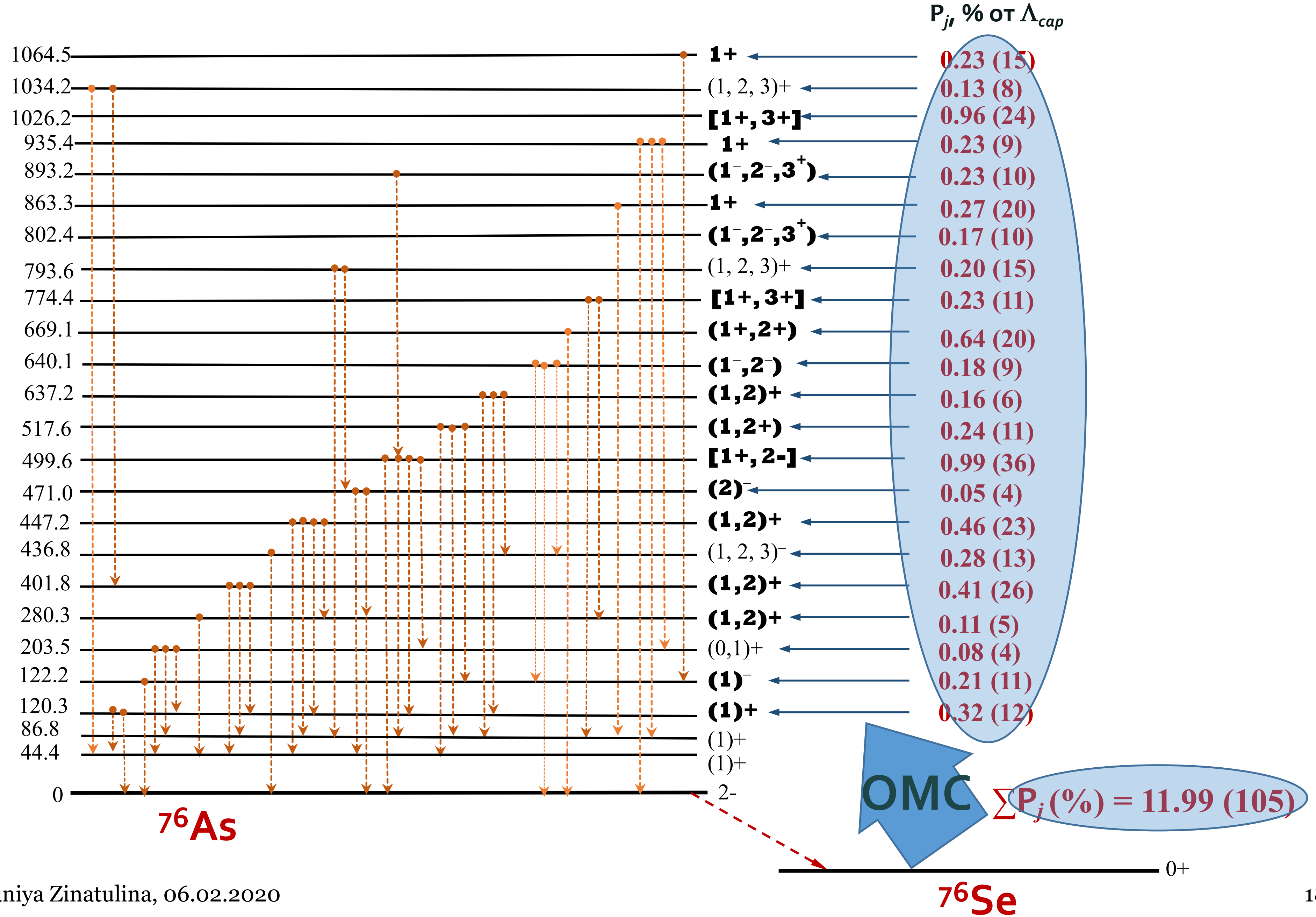


$$Y_j^{\mu} = \frac{\sum I_{i\downarrow}^{\gamma} - \sum I_i^{\gamma\downarrow}}{\varepsilon \sum_n I(K_n)}$$

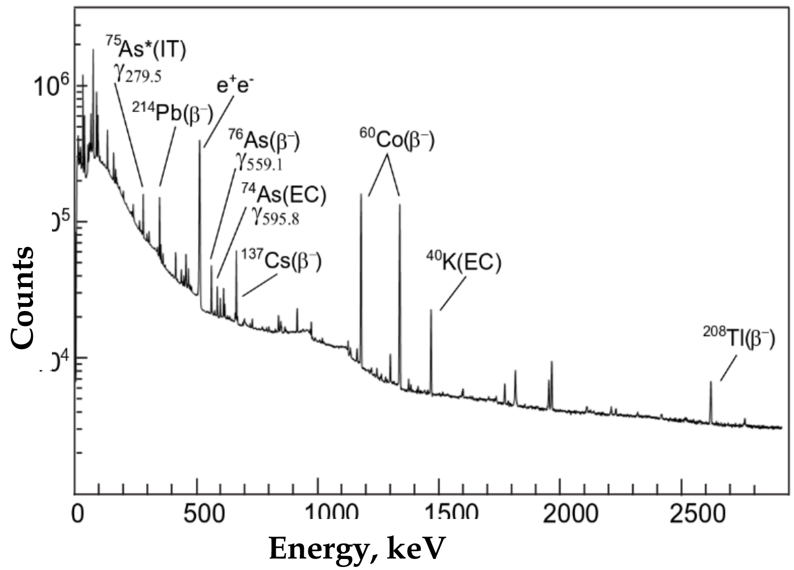
$$P_j^{\mu}[\%] = \frac{\lambda_{part}}{\lambda_{cap}} \cdot 100\% = \frac{Y_j^{\mu}\lambda_{tot}}{\lambda_{cap}} \cdot 100\%$$

^{76}Se

Partial μ-capture probabilities to ^{76}As



Results measured with U-spectra in ^{76}Se and ^{150}Sm

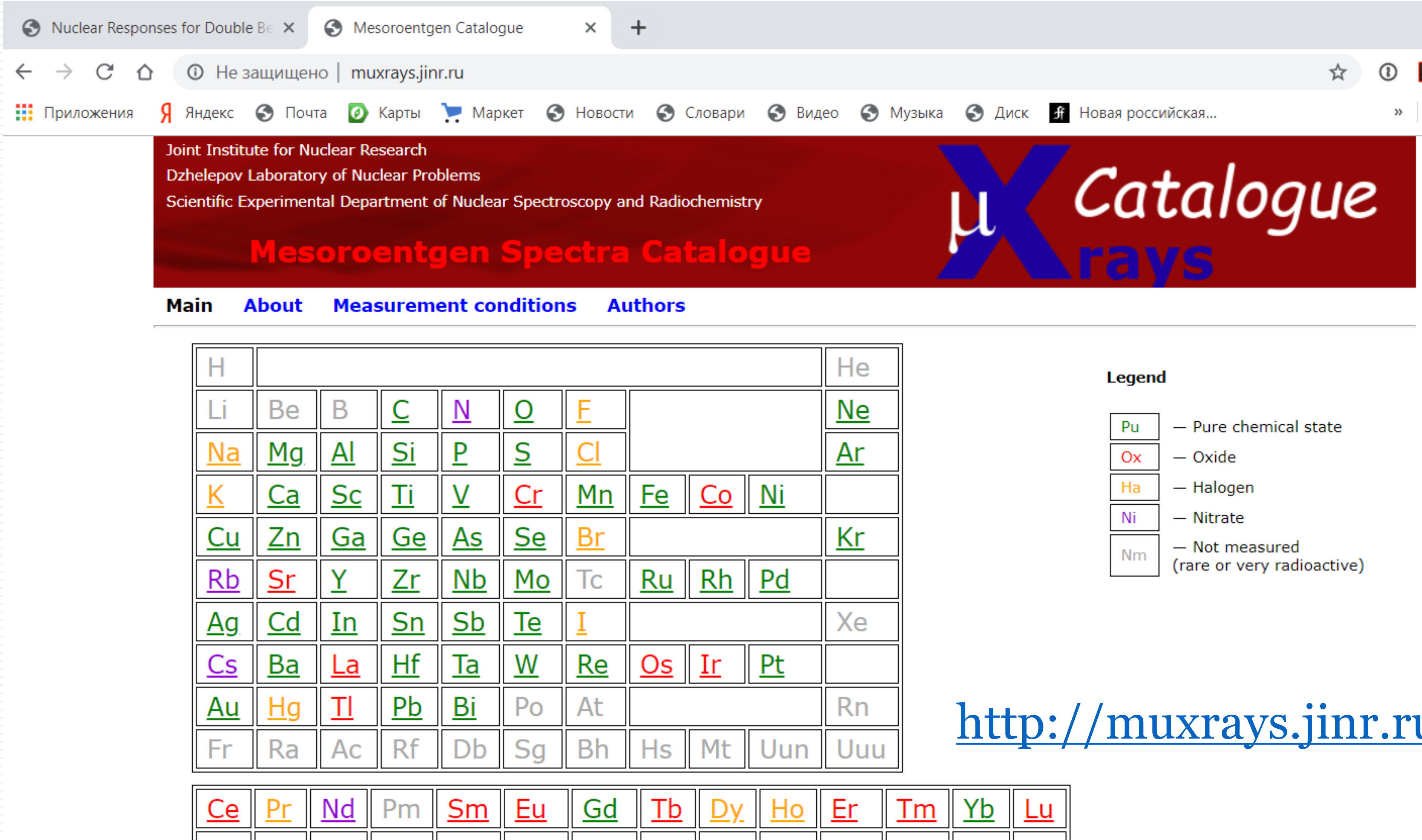


Background radiation (**Uncorrelated** spectra) –

- calibration of the det-s,
- identification,
- yields of short-lived RI during exposure

Isotope	Decay type	$T_{1/2}$	$\lambda_{cap}(xn)$ $(10^6\ s^{-1})$	P_{cap}
^{76}As	β^-	26.3 h	0.86(3)	13.65(255)
^{75m}As	IT	17.6 ms	0.41(7)	6.5(11)
^{75}As	stable		unmeasured	
^{74}As	β^-, EC	17.8 d	1.1(2)	17.5(32)
^{73}As	EC	80.3 d	unmeasured	
^{72}As	β^+	26 h	0.15(3)	2.4(5)
^{71}As	β^+	65.3 h	0.061(18)	0.96(28)
^{75m}Ge	IT	48 s	0.047(13)	0.75(21)
^{75}Ge	β^-	82.8 min	0.054(2)	0.86(3)
^{71m}Ge	IT	20 ms	0.020(3)	0.32(5)
^{74}Ga	β^-	8.1 min	0.026(6)	0.40(9)
^{72}Ga	β^-	14.1 h	0.026(7)	0.40(11)
				$\sum$=43.7(43)
^{150}Pm	β^-	2.68 h	1.45(11)	12.3(9)
^{149m}Pm	IT	35 μs	1.80(31)	15.3(26)
^{149}Pm	β^-	53.1 h	2.93(60)	24.9(51)
^{148}Pm	β^-	5.37 d	0.77(26)	6.6(22)
^{148m}Pm	IT	41.3 d	0.10(2)	0.85(17)
^{148m}Pm	β^-	41.3 d	0.21(6)	1.79(51)
^{149}Nd	β^-	1.73 h	0.78(35)	6.6(29)
^{148}Nd	stable		unmeasured	
				$\sum$=68.3(69)

Muonic X-rays Catalogue

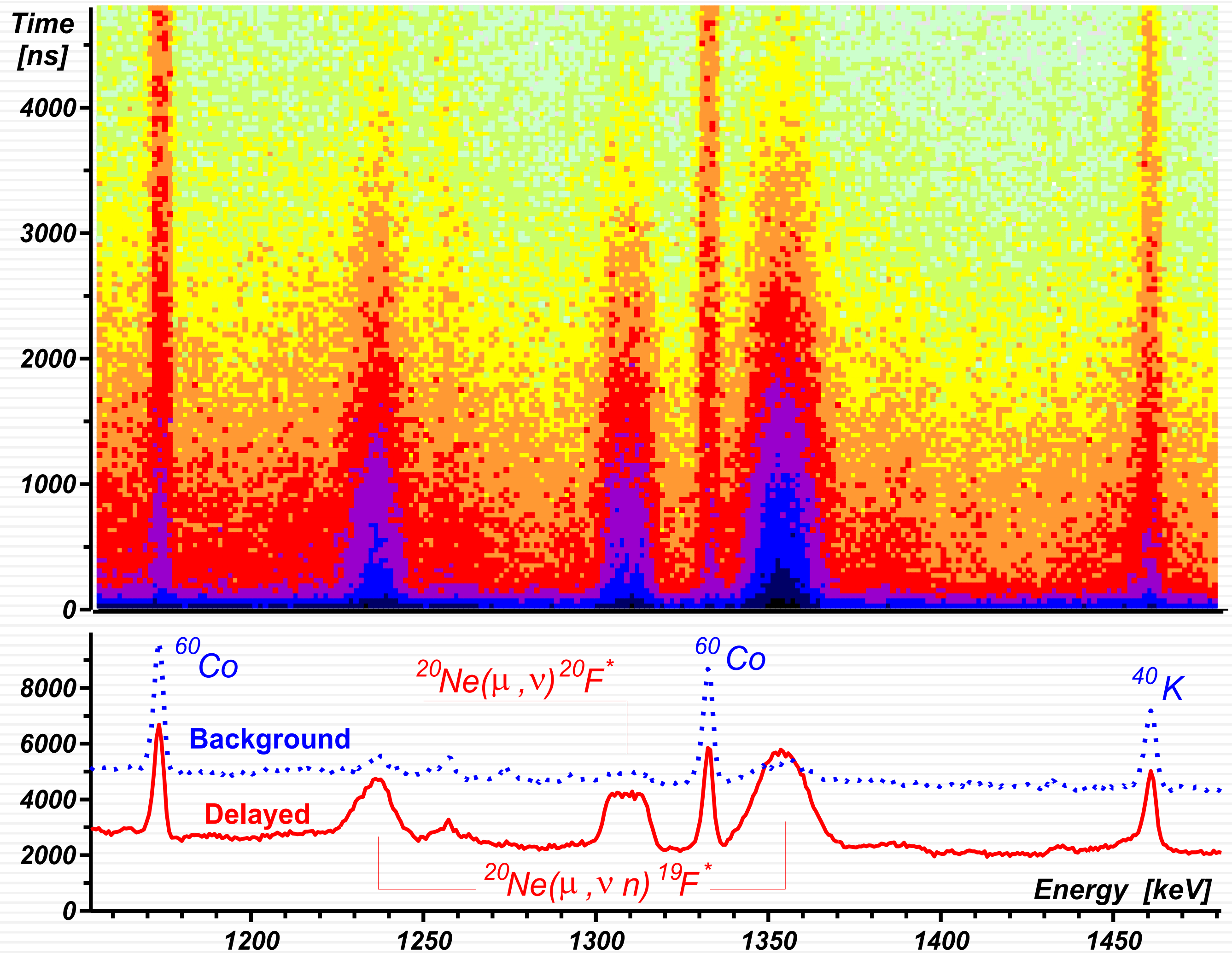


http://muxrays.jinr.ru/

More than 75 chemical elements, PSI, μE1 и μE4 (The information from the μX-ray spectra catalogue is important! (It helps us to identify γ-lines, background, and gives correct selection of the targets and construction materials for different experiments with muons)

Angular correlations with n in OMC (Doppler shape of γ-lines)

^{20}Ne, ^{12}C and ^{16}O were investigated for that purpose



Pre-Conclusions:

- **OMC presently seems to be a bit off the main stream of physics**

  But: it can provide important information about the high-q component of the weak nuclear response, i.e. it is relevant for the neutrinoless double beta decay

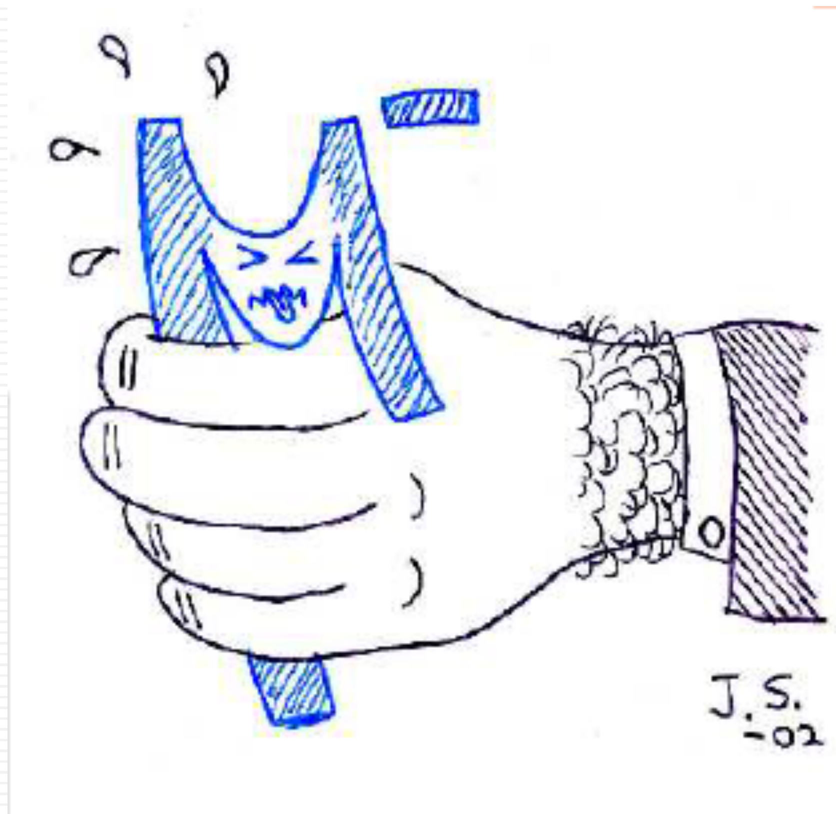
- **Several targets (^{48}Ti, ^{76}Se, ^{82}Kr, ^{106}Cd, ^{150}Sm) have been studied by our group for the double beta decay (^{48}Ca, ^{76}Ge, ^{82}Se ^{106}Cd, ^{150}Nd).** Total and Partial capture rates were extracted and a substantial strength of the μ-capture was found to reside in the low-energy region -- especially in the case of heavy systems.

  All results have been published in 9 different journals also the main article with methods is - > D. Zinatulina et al. **Phys. Rev. C 99 (2019)024327**
  PhD thesis of D.Zinatulina

- By-product: Electronic catalogue of muonic X-rays have been made (muxrays.jinr.ru)

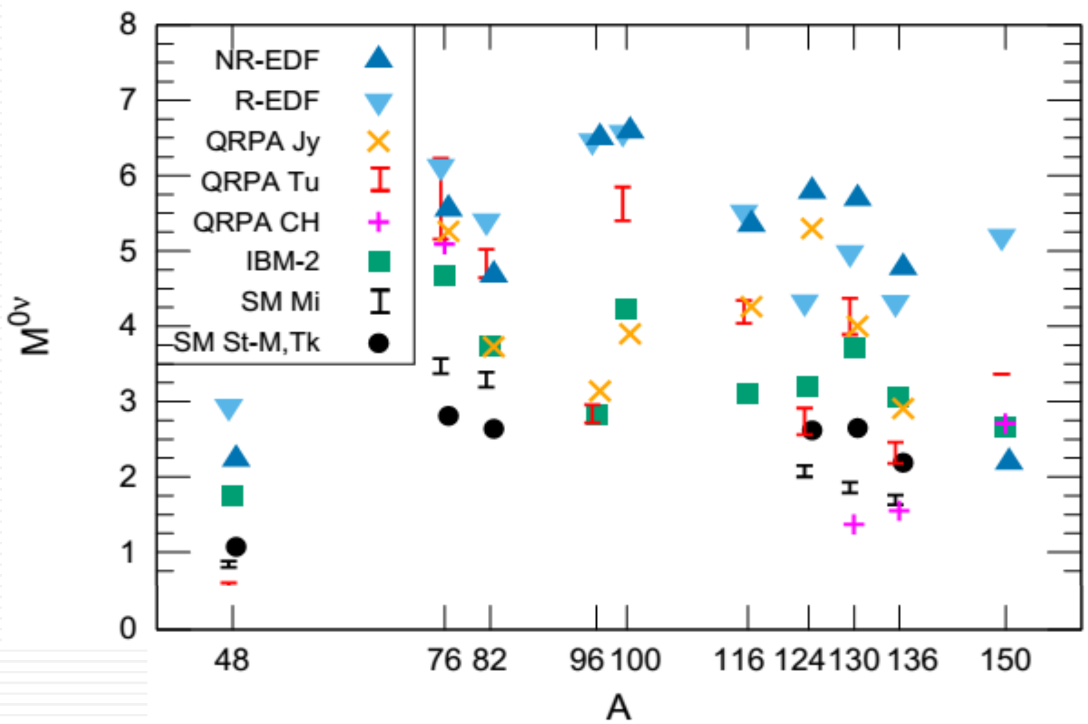
- **Angular correlations for ^{20}Ne, ^{16}O and ^{12}C have been investigated (g_p/g_A, PCAC)**

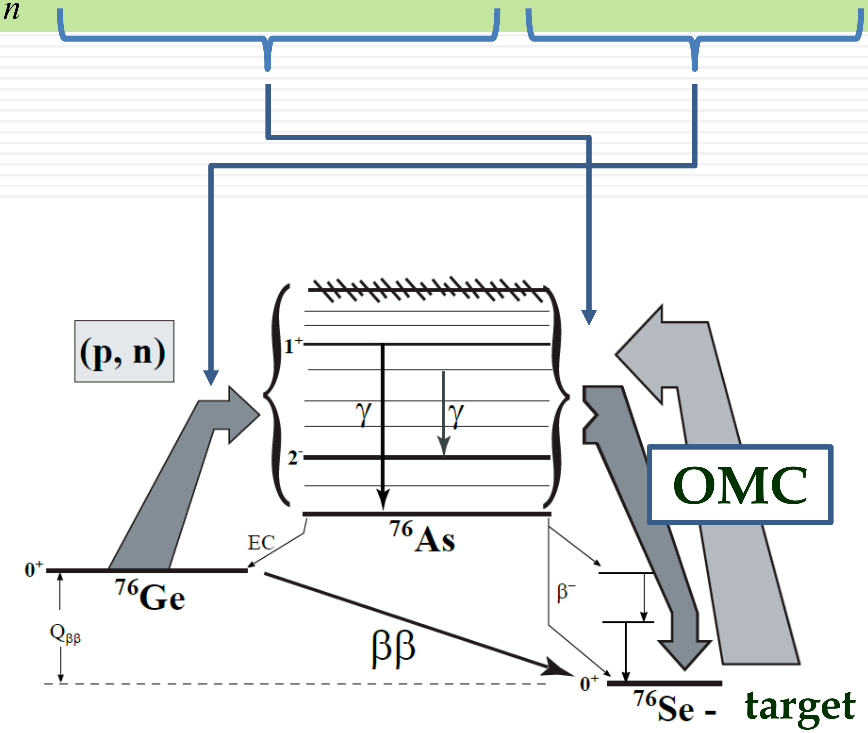
New Motivation



Experimental input for NME calculations

$$\langle A,Z+2|S|A,Z\rangle \propto \sum_n \langle Z+2|\hat{H}|Z+1,n\rangle \langle Z+1,n|\hat{H}|Z\rangle$$





APPEC-2019, Recommendation 6: *The computation of nuclear matrix elements is challenging and currently is affected by an uncertainty which is typically quantified in a factor of 2-3… An enhanced effort is required and a stronger interactions between the particle physics and nuclear community would be highly beneficial. Dedicated experiments may be required.*

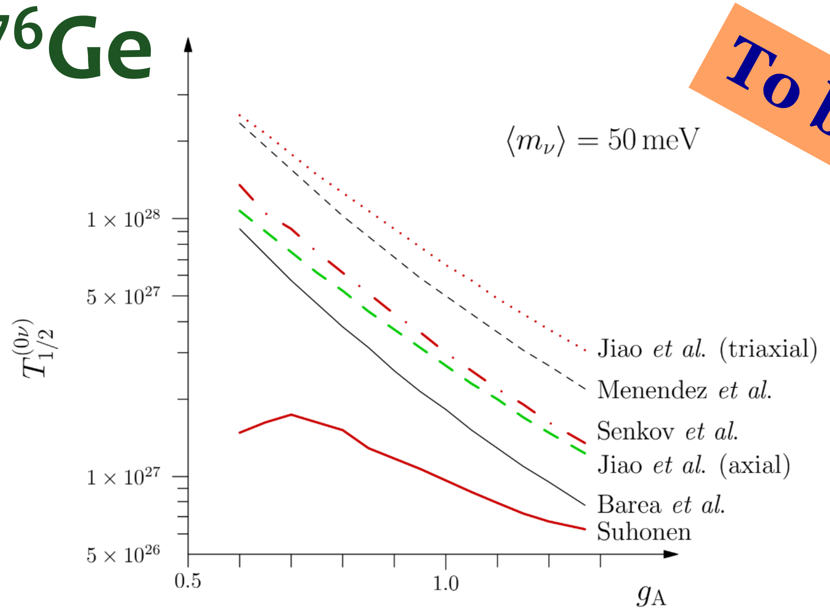
g_A – suppression probing -- via capture rates calculations

To be, or not to be, that is the quenching…

$$|\mathrm{NME}_{0\nu}|^2 \cong \left|M^{0\nu}_{GTGT}\right|^2 = \left(g_{a,0\nu}\right)^4 \left|\Sigma_{J^\pi}\left(\langle 0_f^+|O^{0\nu}_{GTGT}|0_i^+\rangle\right)\right|^2$$

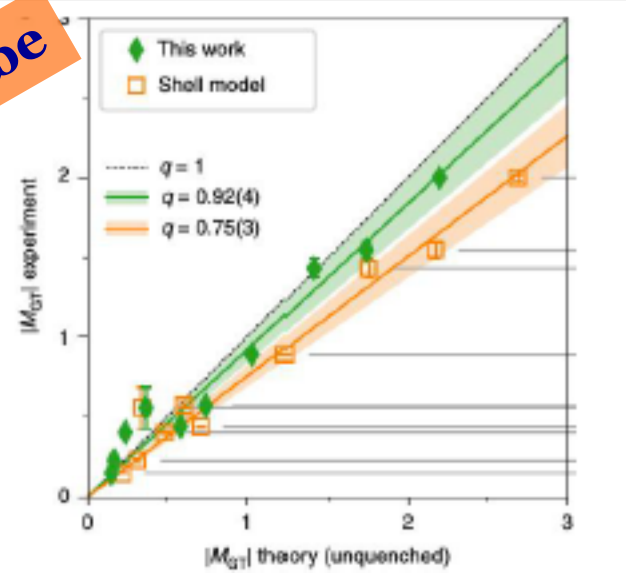
^{76}Ge

To be



Jiao et al.: **Phys.Rev. C 96** (2017)054310 (GCM+ISM)
Menendez et al.: **Nucl. Phys.** A818 (2009) 139 (ISM)
Senkov et al.: **Phys. Rev. C 93** (2016) 044334 (ISM)
Barea et al.: **Phys.Rev. C 91** (2015)034304 (IBM-2)
Suhonen: **Phys.Rev. C 96** (2017)055501 (pnQRPA)

or not to be

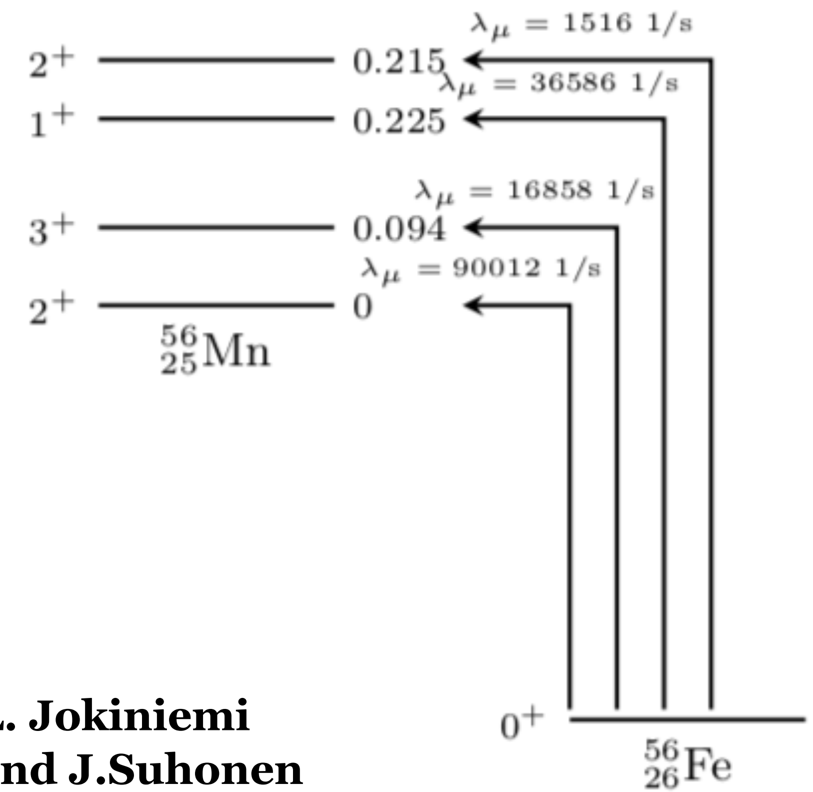


Gysbers et al. Nature Phys. 15 428 (2019)

Ab initio calculations including
meson-exchange currents
do not need any "quenching"

Testing shell model calculations (^{56}Fe, ^{24}Mg, ^{32}S)

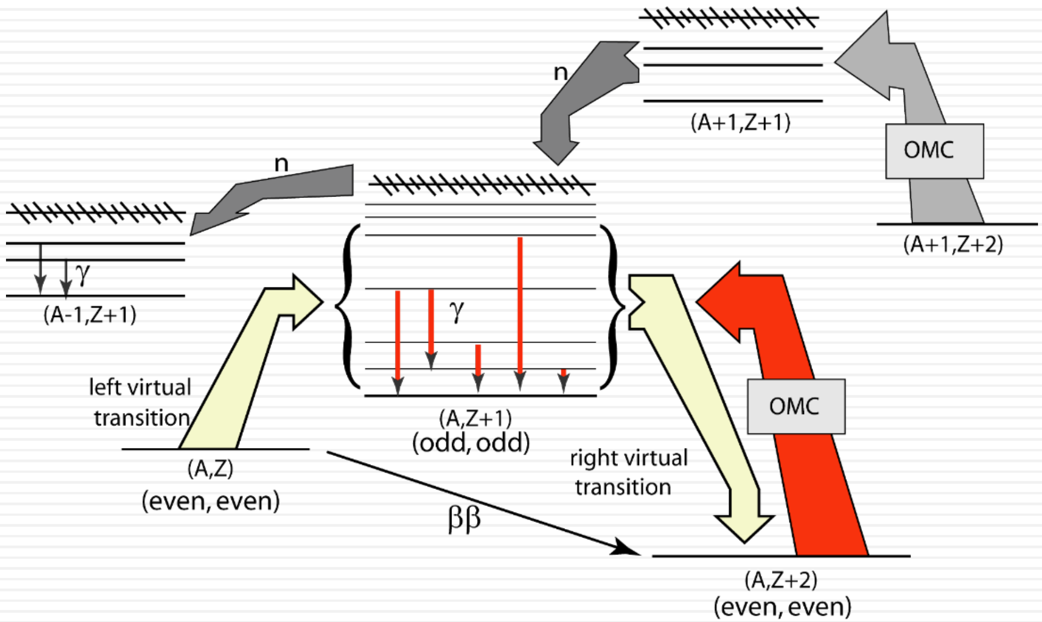
- The level scheme of light nuclei is very well known
- Experiment vs. theory
- Optimization for DBD candidates
- Testing g_A quenching



L. Jokiniemi and J.Suhonen

$$\lambda_\mu \approx C(q_i) \sum_{\kappa u} |g_V M_V(\kappa, u) + g_A M_A(\kappa, u) + g_P M_P(\kappa, u)|^2$$

Comparison experimental OMC results with theoretical calculations



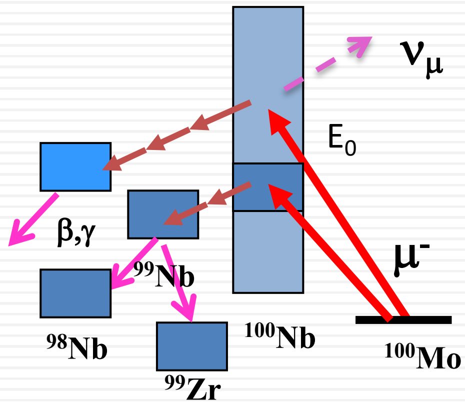
OMC in ^{76}Se

J^{π}	OMC rate (1/s) Exp.(A	pnQRPA (B
0^+	5120	414
1^+	218 240	236 595
1^-	31 360	28 991
2^+	120 960	114 016
2^-	145 920 + g.s.	177 802
3^+	60 160	55 355
3^-	53 120	34 836
4^+	-	2797
4^-	30 080	23 897

A) **D. Zinatulina, V. Egorov et al. // Phys. Rev. C 99 (2019) 024327**

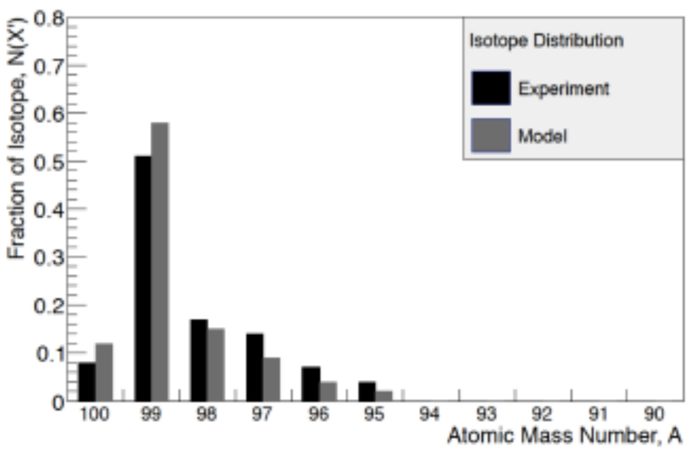
B) **L. Jokiniemi, J. Suhonen // Phys. Rev. C 100 (2019) 014619**

Comparison experimental OMC results with theoretical calculations

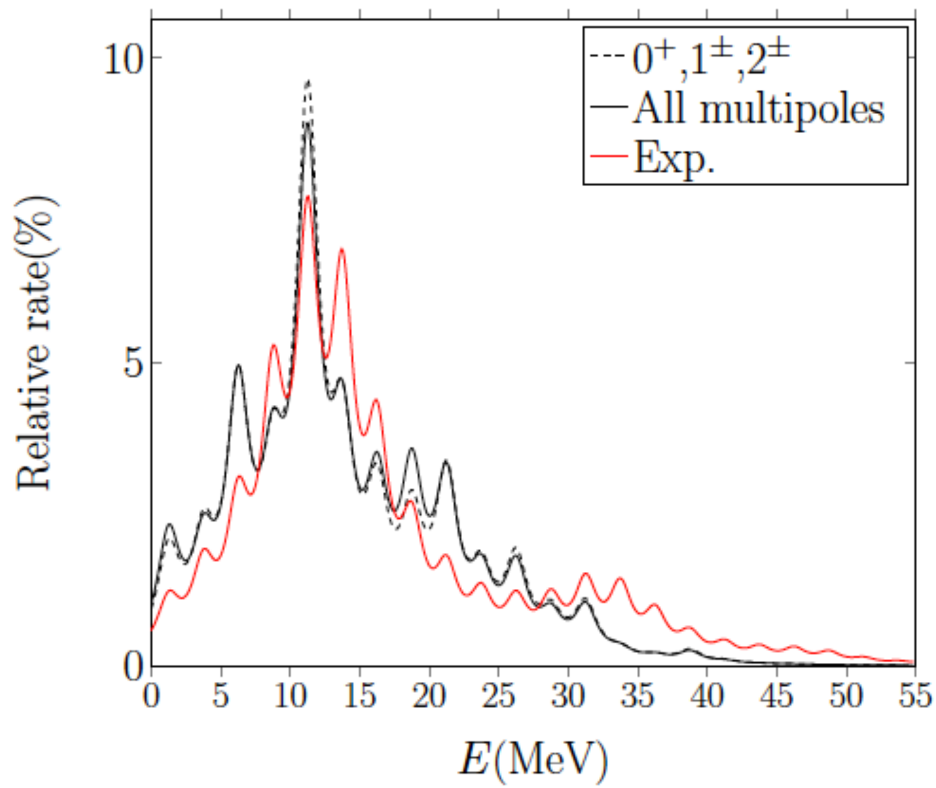


OMC in ^{100}Mo

Calculation by proton and neutron emission model provides initial capture strength ^{100}Nb after muon capture



Population of RI $^{100-x}$Nb isotopes after muon capture on ^{100}Mo.



Comparison of the measured and computed relative OMC capture rates for the OMC on ^{100}Mo. Two theoretical distributions are shown, the total one and the one containing the main contributing multipolarities.

Distribution of initial strength can provide the final nuclei isotope population (**PRC 97(2018) 014617 (J-PARC 2014)**)

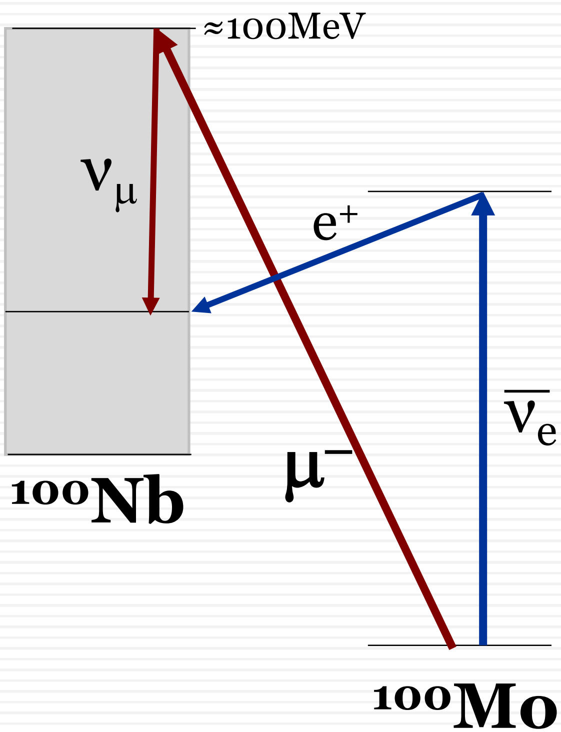
L. Jokiniemi, J. Suhonen, H. Ejiri, and I.H. Hashim, Phys. Lett. B 794 (2019) 143

Astrophysics with ^{100}Mo

- Astro neutrino (including solar and supernovae neutrino study) observation provides evidences for neutrino matter oscillation, nuclear fusion reaction in sun and as tools for probing the supernovae (SN) explosion process

- It was proposed to measure SN antineutrinos on ^{100}Mo (MOON) [1, 2]

- OMC in ^{100}Mo will give experimental input for theoretical calculations of this process



$^{100}Mo(\bar{\nu}_e, e^+)^{100}Nb$ **(SN)**

$^{100}Mo(\mu^-, e^+)^{100}Nb$ **(OMC)**

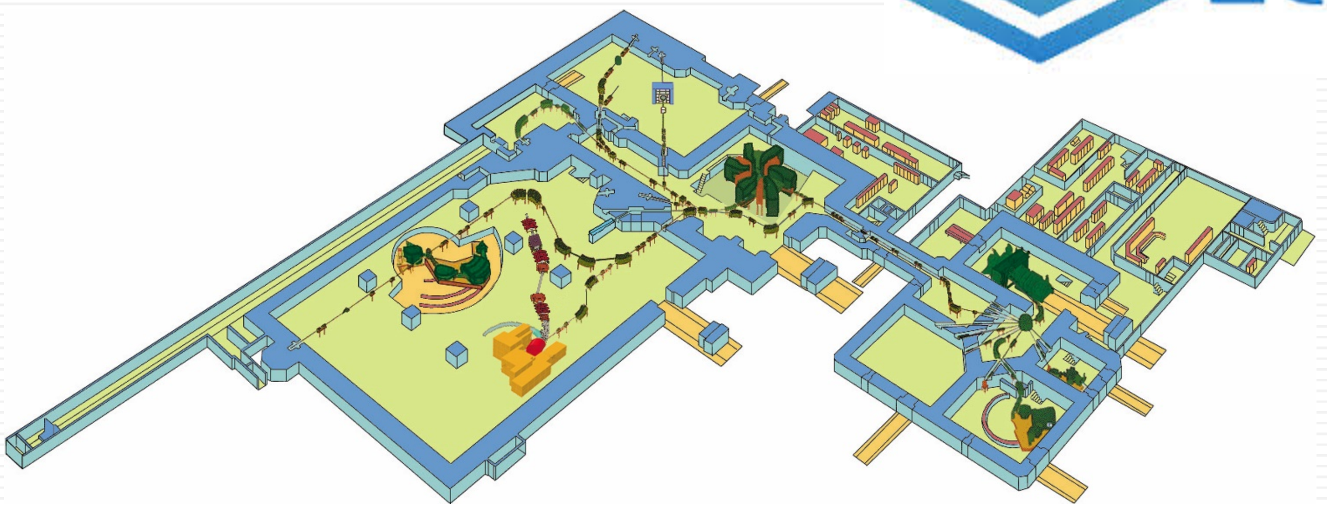
[1] H.Ejiri, J.Suhonen, K.Zuber. // Phys. Rep 797 (2019) 1 – 102

[2] H.Ejiri, J.Engel, N. Kudomi // PLB 530 (2002) 27-32

Measurement principle (2018 - ...)

Accelerator at RCNP and E489 experiment

RCNP

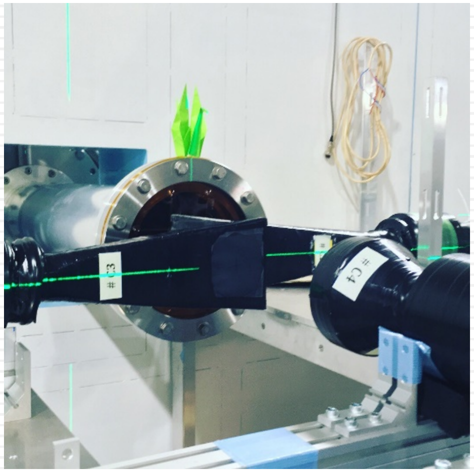


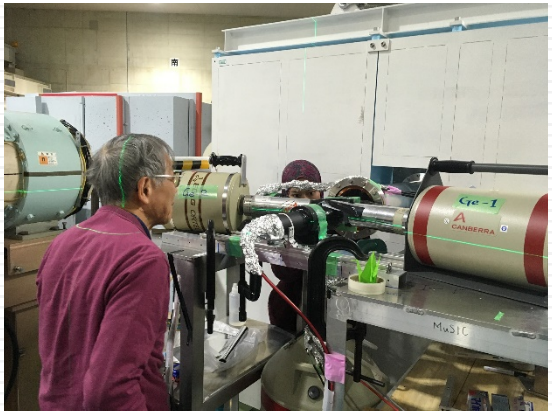
BEAM LINE: MuSIC

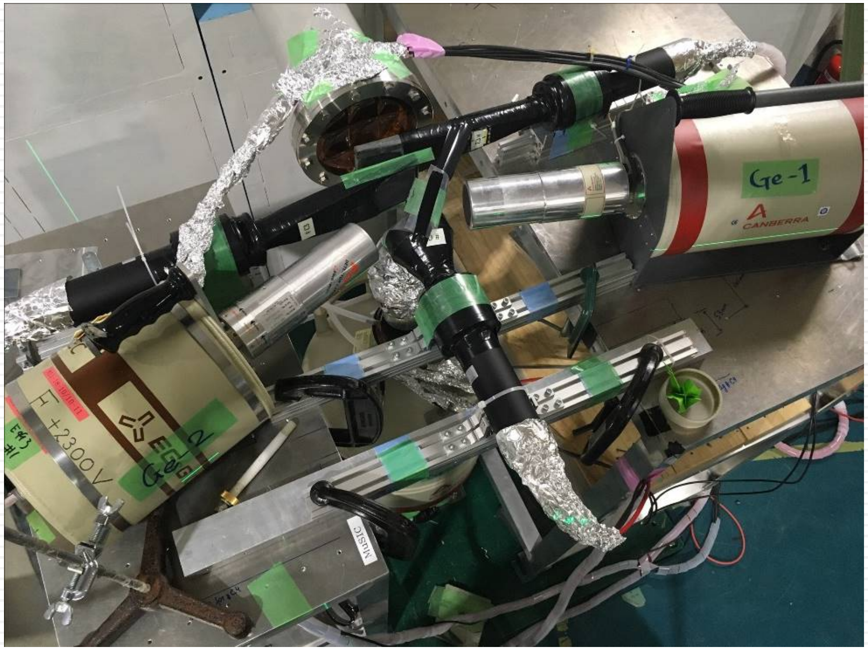
BEAM REQUIREMENTS:

Type of particle	proton
Beam energy	400 MeV
Beam intensity	1 μA
Type of particle	muon
Muon momentum	50 MeV/c
Beam intensity	1 μA

E489 experiment (February 2018y.)







E489 collaboration:

I.H. Hashim [1], D .Zinatulina[3],
H. Ejiri[2], A.Sato[2], M. Shirchenko[3], S.A.Hamzah[1], F.Othman[2], K.Ninomiya[2], T.Shima[2], K. Takahisa[2], D.Tomono[2], Y.Kawashima[2] and V. Egorov[3]

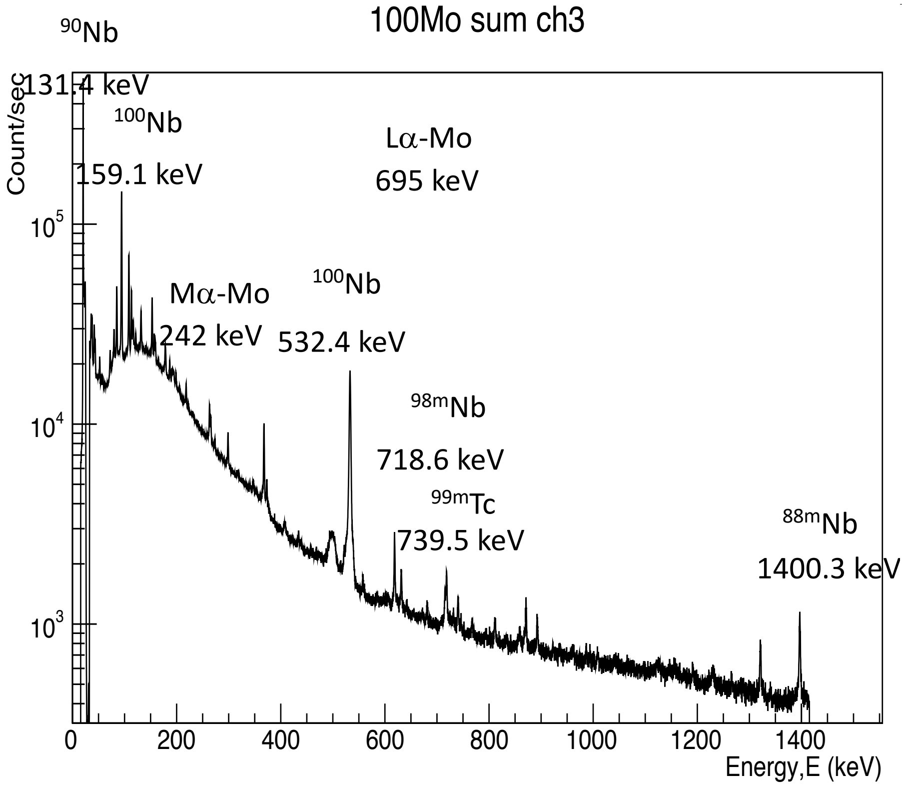
[1]Department of Physics, Universiti Teknologi Malaysia, Johor Bahru, Malaysia.
[2]Research Center on Nuclear Physics, Osaka University, Ibaraki, Osaka, Japan
[3]Joint Institute for Nuclear Research, Dubna, Russia.

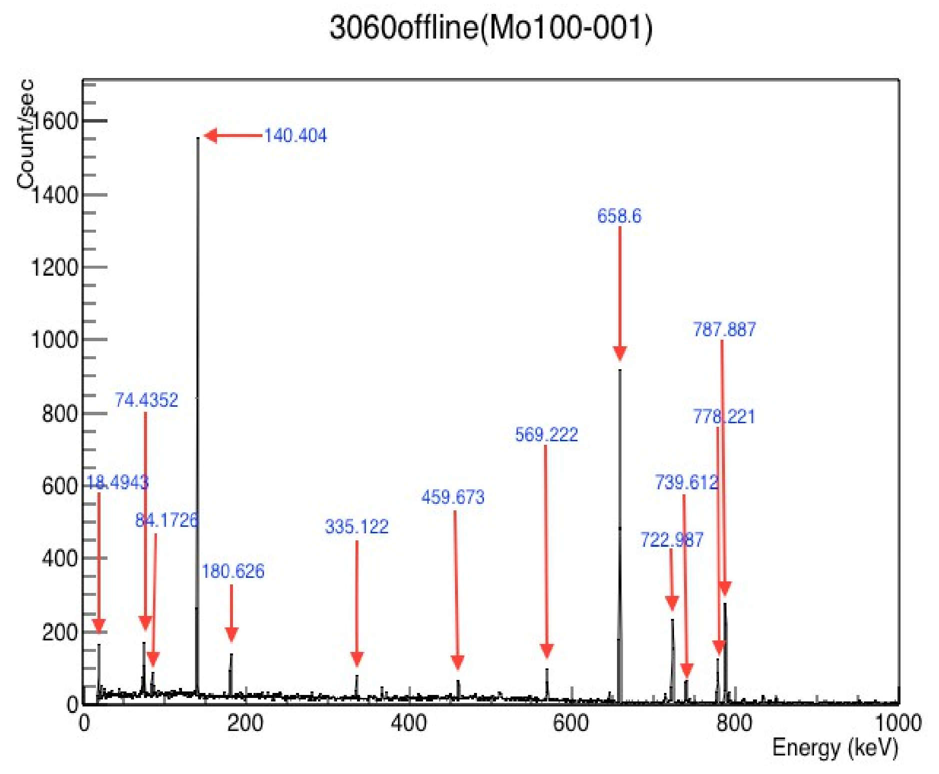
E489 experiment (February 2018y.)

OMC in ^{100}Mo/^{nat}Mo и ^{100}Ru/^{nat}Ru

•Total capture rates

•Prompt и Delayed (off-line) Gamma





The analyses are under progress

µX collaboration and JINR group

Addendum to proposal R-16-01.1 ("Muon capture on double beta decay nuclei of ^{130}Xe, ^{82}Kr and ^{24}Mg to study neutrino nuclear responses")


A. Adamczak[1], A. Antognini[2,3], N. Berger[4], T. Cocolios[5], R. Dressler[2], C. Du¨llmann[4], R. Eichler[2], P. Indelicato[6], K. Jungmann[7], K. Kirch[2,3], A. Knecht[2], J. Krauth[4], J. Nuber[2], A. Papa[2], R. Pohl[4], M. Pospelov[8,9], E. Rapisarda[2], D. Renisch[4], P. Reiter[10], N. Ritjoho[2,3], S. Roccia[11], N. Severijns[5], A. Skawran[2,3], S. Vogiatzi[2], F. Wauters[4], and L. Willmann[7]

[1]Institute of Nuclear Physics, Polish Academy of Sciences, Krakow, Poland

[2]Paul Scherrer Institut, Villigen, Switzerland

[3]ETH Zu¨rich, Switzerland [4]University of Mainz, Germany [5]KU Leuven, Belgium

[6]LKB Paris, France

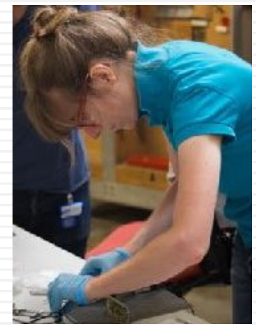
[7]University of Groningen, The Netherlands

[8]University of Victoria, Canada

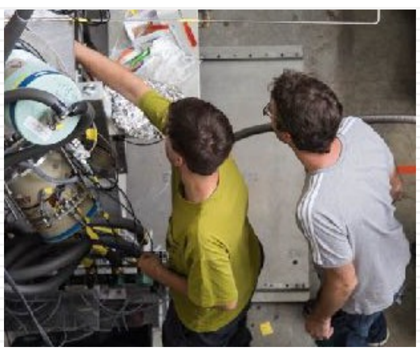
[9]Perimeter Institute, Waterloo, Canada

[10]Institut fu¨r Kernphysik, Universita¨t zu Ko¨ln, Germany

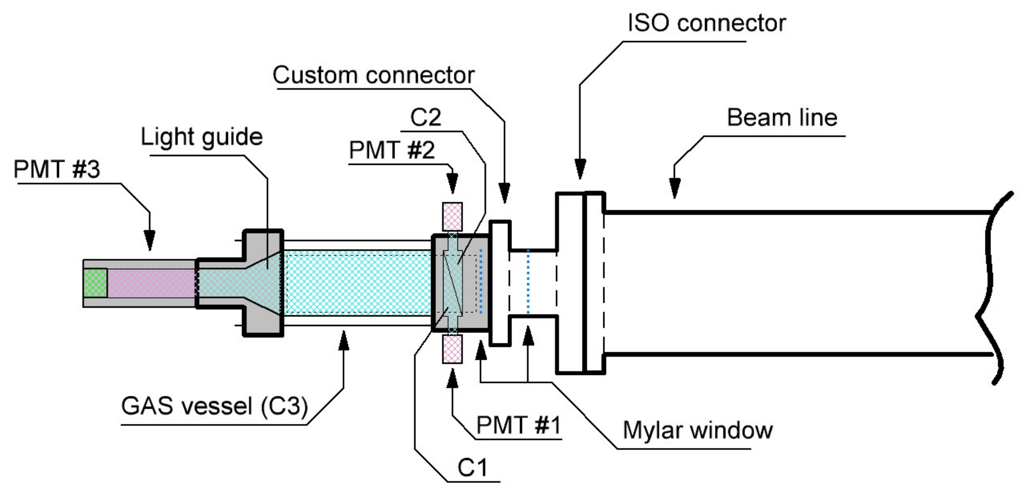
[11]CSNSM, Universit´e Paris Sud, CNRS/IN2P3, Orsay Campus, France

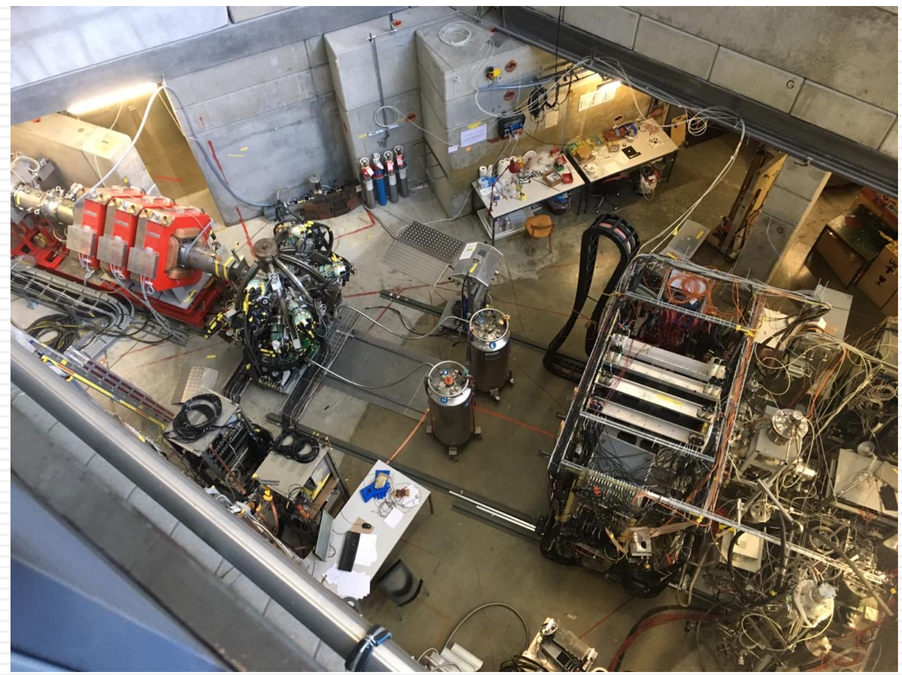






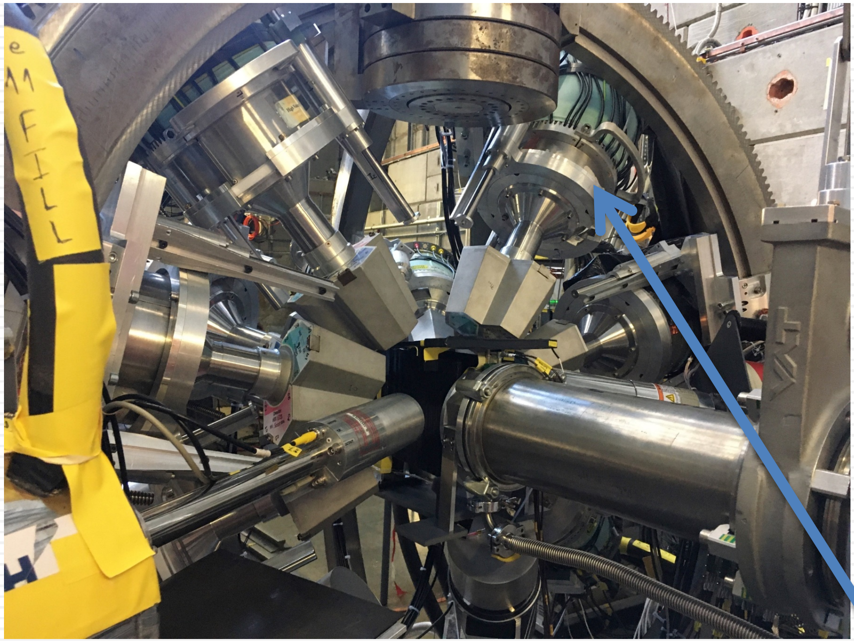
Measurements in 2019

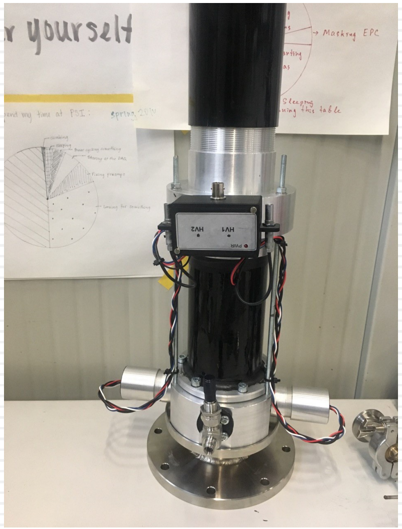


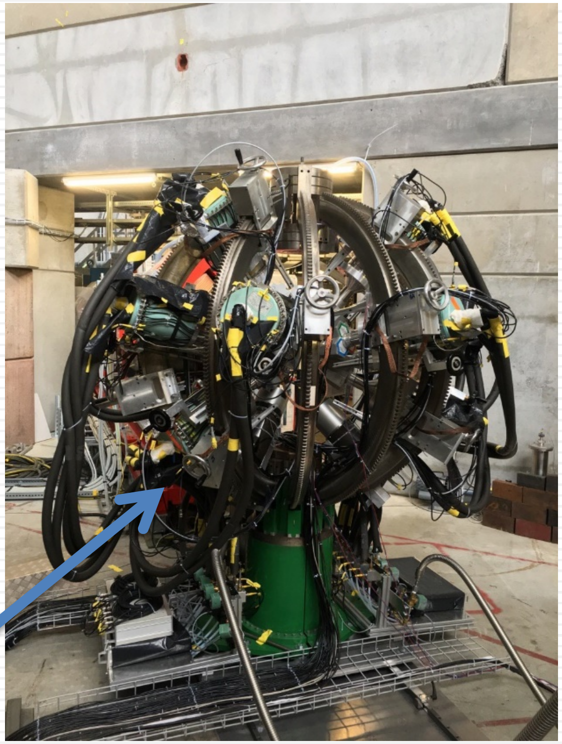


0ν2β-decay	0ν2β-Exper-ts	OMC targets	Quant-ty
^{82}Se	**NEMO3, SuperNEMO, Lucifer(R&D)**	**^{82}Kr (99.9%)**	**1 l (1.7 atm.)**
^{130}Te	**Cuore 0/Cuore, SNO+**	**^{130}Xe (99.9%)**	**1 l (1.7 atm.)**
---	**Testing shell model for NME**	**^{24}Mg (99.85%)**	**2 g**

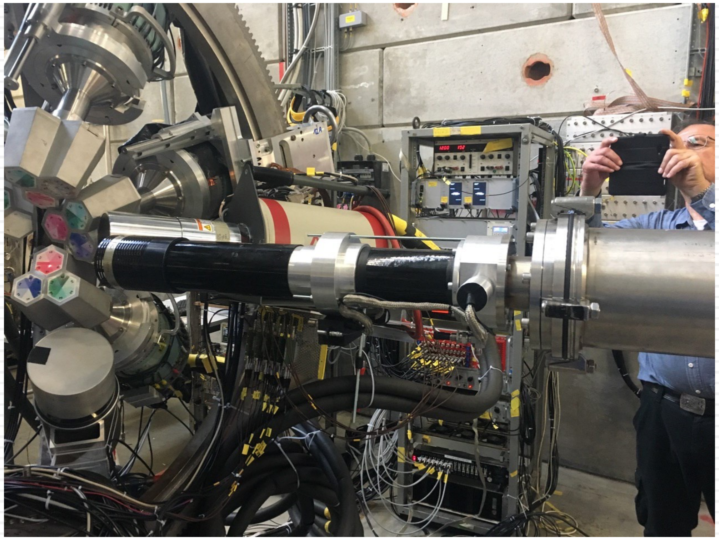
Measurements in 2019

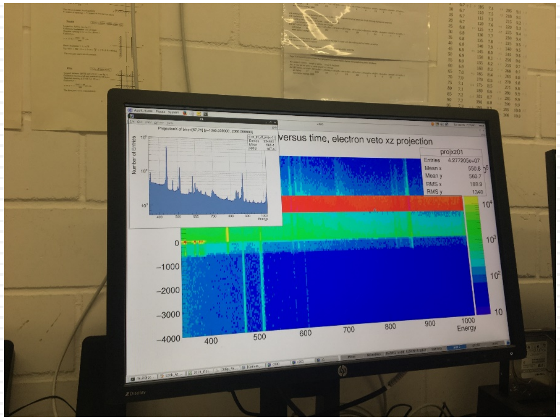






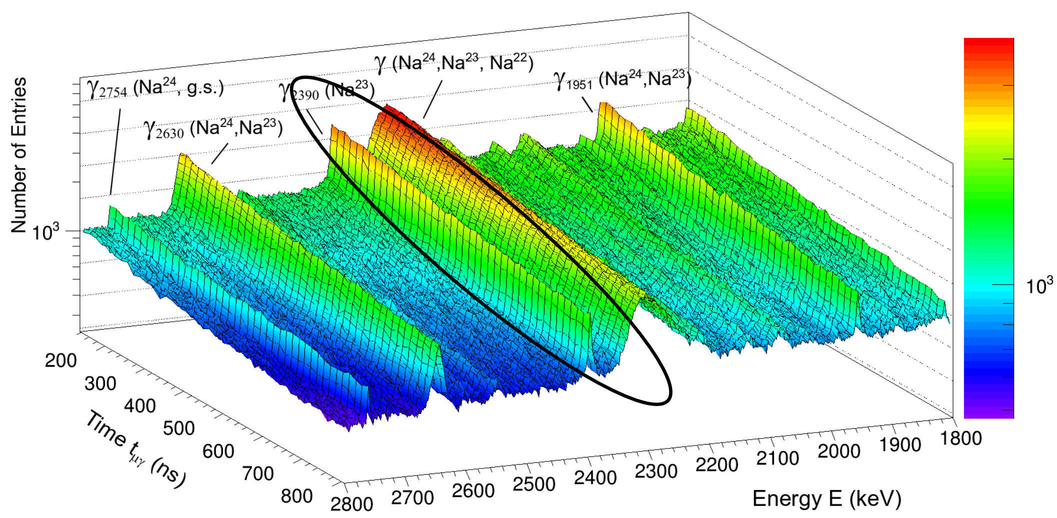
«Miniball» HPGe detectors array

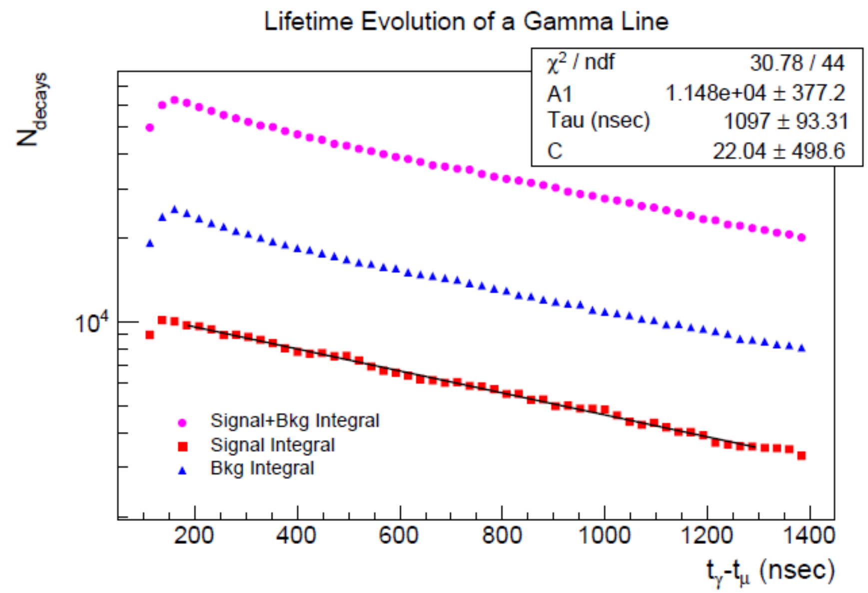




DAQ: 3 digitizers@250 MHz
MIDAS DAQ
MIDAS slow control
Online analysis
Data backup

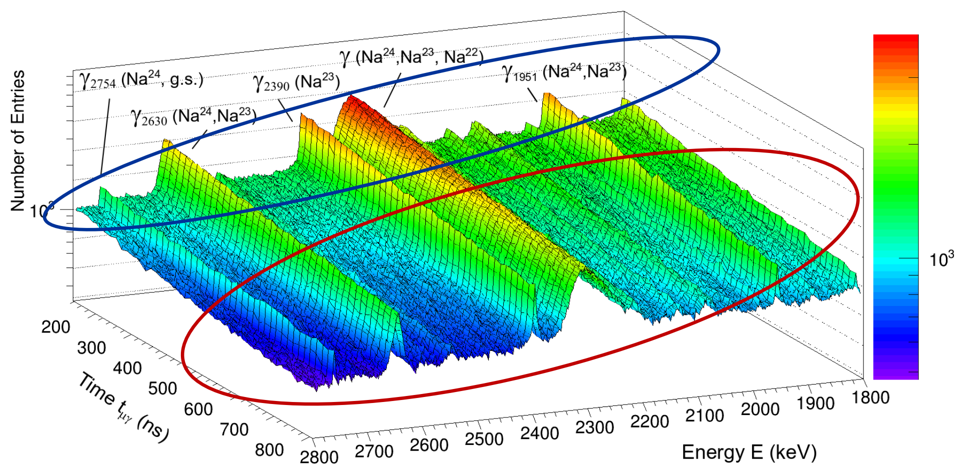
Preliminary 2019 results: *(E, t)* distribution of the correlated events following μ-capture in ^{24}Mg target

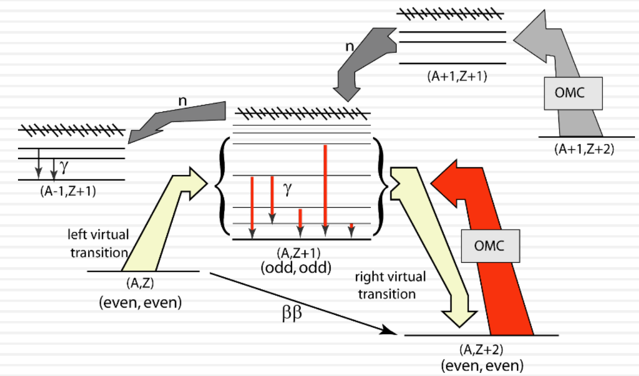


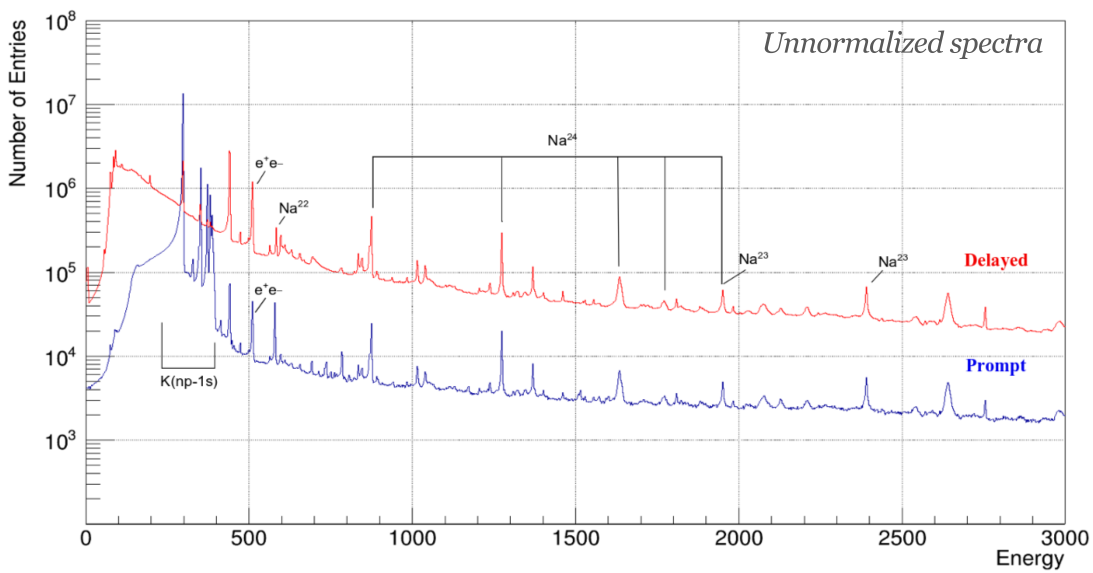


Time evolution of the 2390.6 keV γ-line, following OMC in ^{24}Mg.

<u>Preliminary 2019 results:</u> *(E, t)* distribution of the correlated events following μ-capture in ^{24}Mg target







- $t_{\mu\gamma}$ = 0-50 ns: μX-cascades (**Prompt** spectra) – normalization, identification, composition of the surrounded materials and target itself;
- $t_{\mu\gamma}$ = 50-700 ns: γ-radiation following OMC (**Delayed** spectra) – partial m-capture rates – strength function of the right side;
- T >> $t_{\mu\gamma}$: background radiation (**Uncorrelated** spectra) – calibration of the det-s, identification, yields of short-lived RI during exposure

Recent status:

2β-decay	2β-experiments	OMC target	Status
^{76}Ge	GerdaI/II, Majorana Demonstrator, LEGEND	^{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	2019 (PSI)
^{100}Mo	NEMO3, AMoRE(R&D), LUMINEU(R&D), CUPID-0 Mo	^{100}Ru	--
^{116}Cd	NEMO3, Cobra	^{116}Sn	--
^{150}Nd	SuperNEMO, DCBA(R&D)	^{150}Sm	2006 (PSI)
^{136}Xe	nEXO, KamLAND2-Zen, NEXT, DARWIN, PandaX-III	^{136}Ba	2020 (PSI)
^{130}Te	Cuore 0/Cuore, SNO+	^{130}Xe	2019 (PSI)

Features

Proposal for BVR 51

OMC4DBD: ordinary muon capture as a probe of properties of double beta decay processes

V. Brudanin[1], L. Baudis[2], V. Belov[1], T. Comellato[3], T. Cocolios[4], H. Ejiri[5], M. Fomina[1], I.H. Hashim[6], K.Gusev[1,3], L. Jokiniemi[7], S. Kazartsev[1,8], A. Knecht[9], F. Othman[6], I. Ostrovskiy[10], N.Rumyantseva[1], M. Schwarz[3], S.Schönert [3], M. Shirchenko[1], E. Shevchik[1], Yu. Shitov[1],J. Suhonen[7], S.M. Vogiatzi[9,11], C. Wiesinger[3], I. Zhitnikov[1], and D. Zinatulina[1]

[1]Joint Institute for Nuclear Research, Dubna, Russia.
[2]Physik-Institut, University of Zurich, Zurich, Switzerland
[3]Technische Universität München, Garching, Germany.
[4]KU Leuven, Institute for Nuclear and Radiation Physics, Leuven, Belgium
[5]Research Center on Nuclear Physics, Osaka University, Ibaraki, Osaka, Japan
[6]Department of Physics, Universiti Teknologi Malaysia, Johor Bahru, Malaysia.
[7]Department of Physics, University of Jyväskylä, Jyväskylä, Finland.
[8]Voronezh State University, Voronezh, Russia.
[9]Paul Scherrer Institut, Villigen, Switzerland.
[10]Department of Physics and Astronomy, University of Alabama, Tuscaloosa, AL, USA
[11]ETH Zurich, Switzerland

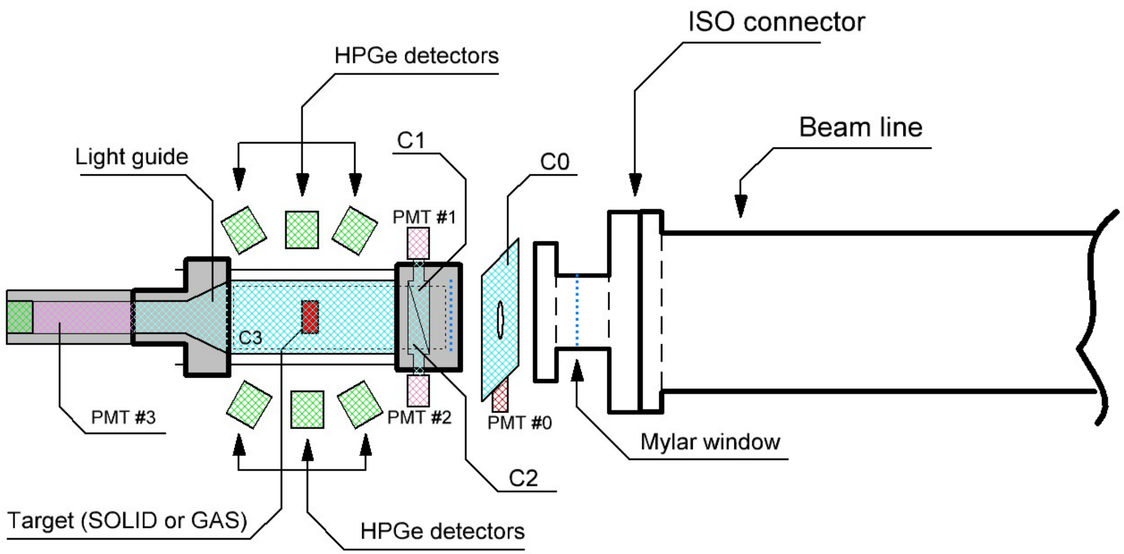
Daniya Zinatulina **Open Users Meeting BV51, 28.02.2020**

Targets:

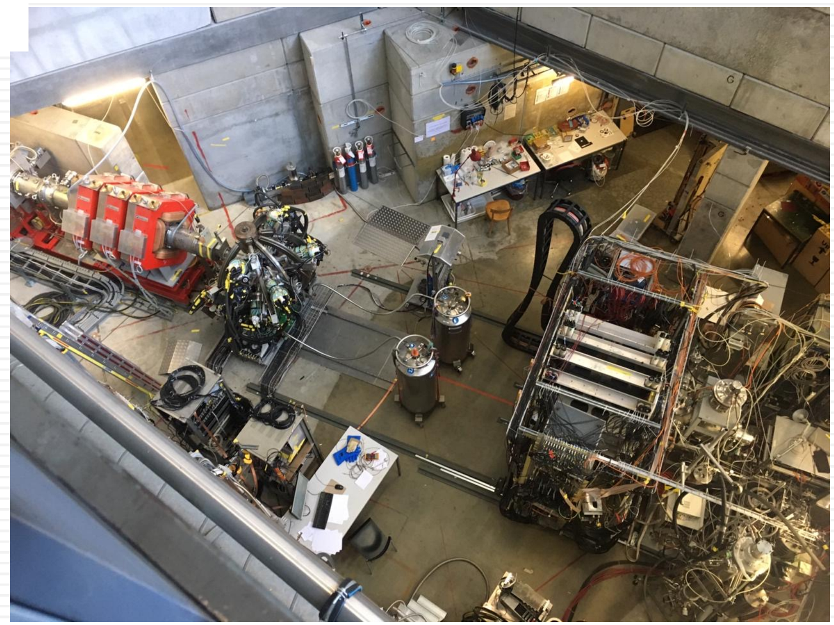
- The present project is extended to DBD nuclei in the atomic mass number region between 70 to 140;

Target	Enrichment	Main purpose	Year
^{136}Ba	95.27 %	Partial cap.rates for NME for DBD	2020
^{nat}Ba	--	Identification for enriched Ba	2020
^{100}Mo	99.8 %	Astroneutrinos	2020 - 2021
^{96}Mo	99.78 %	Partial cap.rates for NME for DBD	2021
^{nat}Mo	--	Identification for enriched Mo	2021
^{76}Se	99.7 %	Partial cap.rates for NME for DBD	2020 - 2021
^{40}Ca	99.81 %	g_A testing with SM	2022
^{56}Fe	99.9 %	g_A testing with SM	2022
^{32}S	99.95 %	g_A testing with SM	2022

Proposed measurements in 2020



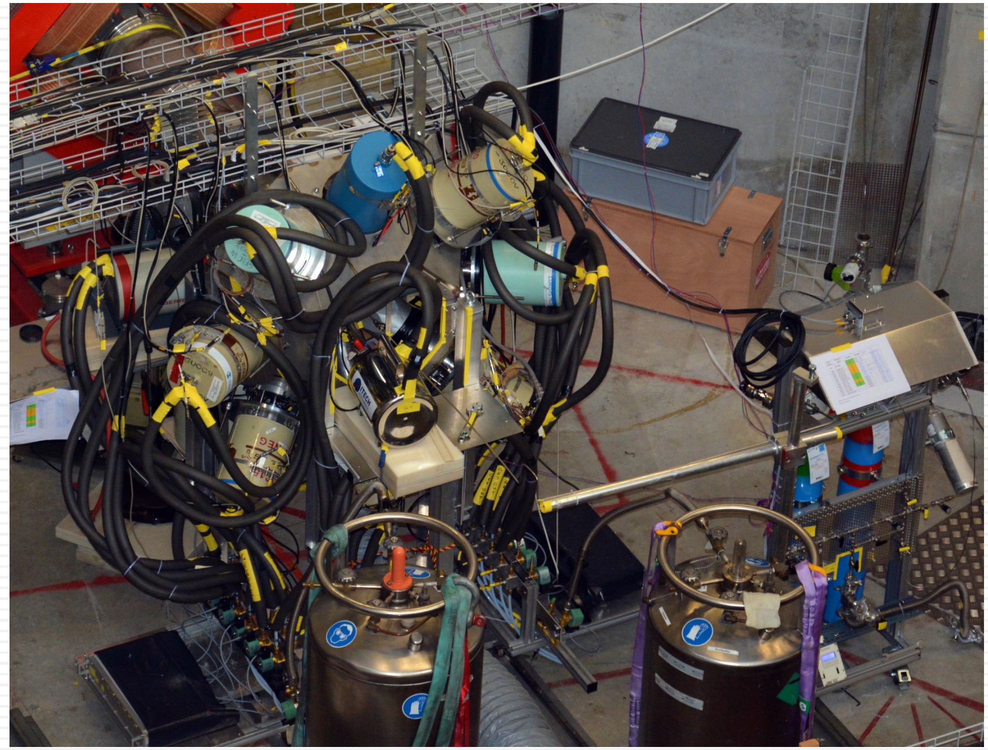
0ν2β-decay	0ν2β-Exper-ts	OMC targets	Quant-ty
^{136}Xe	nEXO, KamLAND2-Zen, NEXT, DARWIN, PandaX-III	^{136}Ba (95.27%)	2 g
---	---	^{nat}Ba	2 g



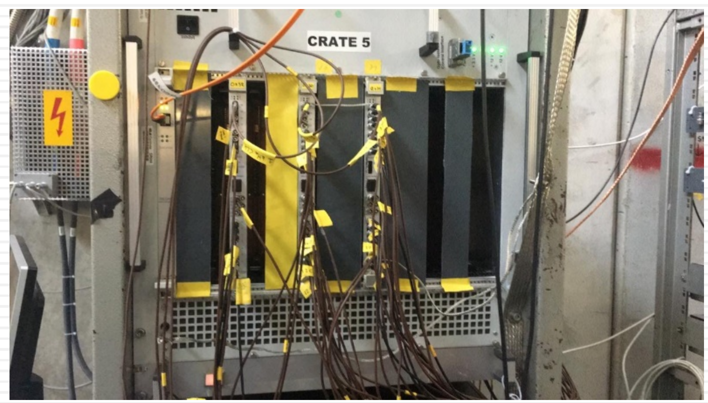
Detection system and DAQ

PAUL SCHERRER INSTITUT

- **Set of 8 HPGe detectors :**
  3 n-type (250 cm^3
  and low-region (PSI) + 1 from JINR)
  2 p-type BEGe det's (TUM)
  2 p-type inverted-coaxial
  (TUM+JINR)
  1 low-region det. (UZH)
- **C0** (aperture defining veto counter)
- **C1-C2** (pass-through counters)
- **C3** (cup-like counter)



- **DAQ:** 2 digitizers@250 MHz
  MIDAS DAQ
  MIDAS slow control
  Online analysis
  Data backup



Beam Schedule 2020

PSI 590 MeV Program 2020

Last update: Jan 29th, 2020, S. Ritt <stefan.ritt@psi.ch>					May				June				July				August					September				October				November					December			
http://www.psi.ch/ltp/FacilitiesEN/schedule_2020.pdf				**Week number**	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48	49	50	51	52
		PSP	**PSI Contact**	**Availability**																																		
PiM3	MuSR (GPS&LTF)		Amato	Amato (coord.)																																		
PiE3	MuSR high field		Scheuermann	Scheuermann (coord.)																																		
MuE1	MuSR (GPD)		Amato	Amato (coord.)																																		
MuE4	MuSR (LEM)		Prokscha	Prokscha (coord.)																																		
PiE1-1	MuSR (Dolly)		Amato	Amato (coord.)																																		
	PSEC-Micromegas		Antognini	Sohl																																		
	RPC counters		Antognini	Bencivenni																																		
	MuEDM		Schmidt-Wellenbur	Schmidt-Wellenburg																																		
PiE1-2	R-20-01.1	5203.85800.012	Knecht	Zinatulina																																		
	R-08-01.3 Musun	5203.32030.004	Knecht	Kravchenko																																		
	MIXE		Amato	Amato/Knecht																																		
	Muonium		Knecht	Soter																																		
	uRWELL		Knecht	Poli Lener																																		
PiE5	R-99-05.2 MEG	5203.32030.001	Ritt	Mori					provisional																	provisional												
	R-12-03.1 Mu3E	5203.32030.002	Ritt	Schoening																												provisional						
	Praktikum	5203.85800.012	Meier	Grab																																		
UCN	R-05-03.1 n2EDM		Schmidt-Wellenbur	Schmidt-Wellenburg																																		
	Mirror-Neutron		Schmidt-Wellenbur	Ayres																																		
PiM1	R-12-03.1 Mu3E	5203.32030.002	Ritt	Schoening																																		
	R-12-01.2 MUSE	5203.32030.006	Reggiani/Ritt	Gilman																																		
	Praktikum	5203.85800.012	Meier	Steinkamp																																		
	CMS Diamond Detectors	5203.85800.012	Meier	Hits																																		
	PIMice	5203.85800.012	Reggiani	Desorgher																																		
	HVMAPS	5203.85800.012	Meier	Fritsch																																		
	RADEM (PIF)	5203.85800.012	Hajdas	Hajdas																																		
	TIMESPOT	5203.85800.012	Papa	Cardini																																		
	COMET/NA62	5203.85800.012	Papa	Nishiguchi																																		
	TOTEM	5203.85800.012	Papa	Garcia																																		
	RadMap	5203.85800.012	Meier	Losekamm																																		
	PAD-Micromegas	5203.85800.012	Meier	Camerlingo																																		
				Spin-rotator																																		
				Start (Monday)	04.05.17	11.05.17	18.05.17	25.05.17	01.06.17	08.06.17	15.06.17	22.06.17	29.06.17	06.07.17	13.07.17	20.07.17	27.07.17	03.08.17	10.08.17	17.08.17	24.08.17	31.08.17	07.09.17	14.09.17	21.09.17	28.09.17	05.10.17	12.10.17	19.10.17	26.10.17	02.11.17	09.11.17	16.11.17	23.11.17	30.11.17	07.12.17	14.12.17	21.12.17
				End (Sunday)	10.05.17	17.05.17	24.05.17	31.05.17	07.06.17	14.06.17	21.06.17	28.06.17	05.07.17	12.07.17	19.07.17	26.07.17	02.08.17	09.08.17	16.08.17	23.08.17	30.08.17	06.09.17	13.09.17	20.09.17	27.09.17	04.10.17	11.10.17	18.10.17	25.10.17	01.11.17	08.11.17	15.11.17	22.11.17	29.11.17	06.12.17	13.12.17	20.12.17	27.12.17

Conclusions:

- OMC is the sensitive tool to probe properties of DBD process. It is based on mature experimental technique successfully developed during many years, which demonstrates satisfactory agreement between experimental and theoretical data;

- The unique information obtained at OMC will provide a significant experimental contribution to the theory of ββ decay and astropartical physics researches. In particular, it will help improve NME calculations for DBD. Leading ββ decay theorists have shown serious interest in obtaining this new experimental information;

- An intensive multi-year PSI beam research program was proposed;

- As a by-product -- the muonic X-rays spectra will be added to Mesoroentgen electronic catalogue (muxrays.jinr.ru)