Status and Perspectives of ISTC Projects #2405 and #3266

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Content:

2) Scope of activities and preliminary results of ITEP part of ISTC#2405 (“THICK target”: 1/04/2005-31/03/2007)
3) Scope of activities and first results of the ISTC #3266 (“THIN targets”: 1/09/2006-28/03/2009)
4) Perspectives of further activity on thick target experiments (prolongation of #2405)
5) Perspectives of further activity on thin target irradiations (prolongation of #3266)
6) Other proposal for experiments related to ADS and transmutation

to be presented at ISTC-Contact expert Group on Nuclear Partition and Transmutation related Projects, January 22-23, 2007, Brussels, EU

ISTC#2405: Formal information

- **Project Title: Experimental researches into nuclear-physics characteristics of the materials essential for the processes of weapon plutonium utilization and radioactive waste transmutation**
  - Financing party: USA

- **Duration:** 1/04/2005-31/03/2007
- **Leading Institution: VNIIEF, 607188 Sarov, Russia**

  Participant Institution #1: ITEP, 117218 Moscow, Russia

  Participant Institution #2: MEPhI, 115409 Moscow, Russia
- **Collaborators: Drs. Toshihiko Kawano, Mark Chadwick, Richard E. Prael (Los Alamos National Laboratory**)
- Tasks to be solved by VNIIEF:
  - **A** – manufacture of metal blanket micromodel (MBM) and target micromodel (TMM).
  - **B** – investigation of multiplying and kinetic characteristics of materials that form metal blanket micromodels (MBM) using FKBN-2M facility.
  - **C** – measurement of effective cross-sections of Np, Pu, Am, Cm isotopes fission caused by neutrons of metal blanket micromodel (MBM).
  - **D** – Measurement of fission and neutron radiation capture cross-sections for short-lived odd-odd nuclide of 242gAm near the thermal point.
- **Tasks to be solved by ITEP**
  - **E** – Measurement of the neutron flux characteristics inside and on the surface of 0.8 GeV proton-irradiated Pb TMM.

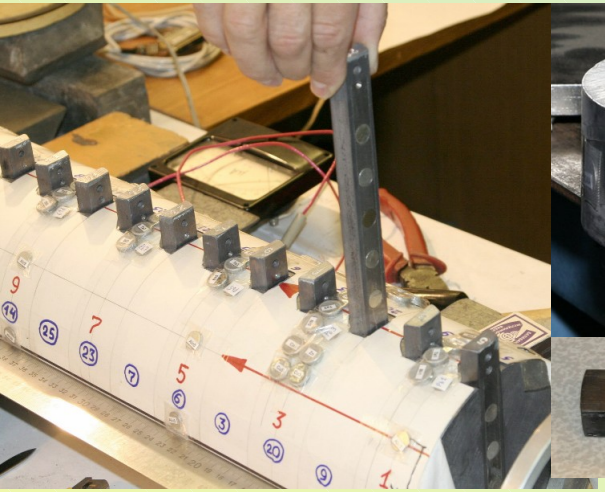
Prolog: the project is an extension of the researches carried out under ISTC Project#1145 (1999-2001, Japan) *Nuclear Physics Investigations Aimed at the Solution of Weapon Plutonium Conversion and Long-Lived Radioactive Wastes Transmutation Problems*

Lead target

irradiated by 0.8GeV protons on 10/06/2006

~6.5·10^{16}p during 18h

Lead target: samples extraction system



Monitoring beam shape

ISTC#2405: Preliminary results review

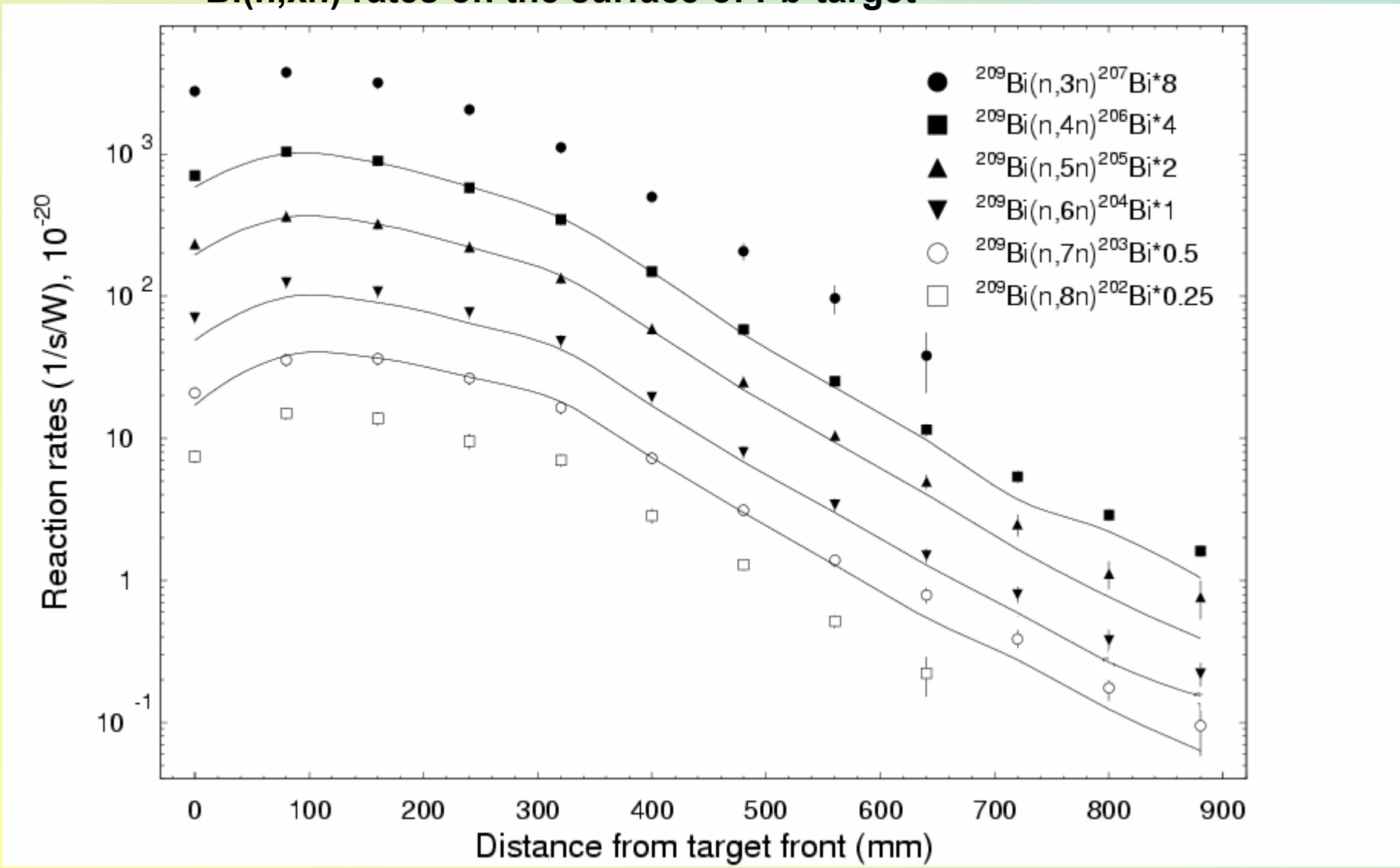
Samples	Number of samples	Number of γ–spectra measured	Number of γ–lines found	Number of Reaction Rates measured
Main samples. Surface: ^{197}Au, ^{209}Bi, ^{nat}Pb, ^{181}Ta, ^{nat}In. Axis: ^{59}Co, ^{nat}Pb Disk#3 surface: ^{59}Co, ^{93}Nb, ^{169}Tm, ^{65}Zn, ^{12}C, ^{19}F, ^{63}Cu, ^{65}Cu	92	663	34227	**1398***
Al on target	114	407	545	218
Al round monitor	36	119	255	-
Al beam monitors	2	7	86	-
TOTAL	**244**	**1196**	**35113**	**1616**

* - except Pb samples

The results are to become a good benchmark task for IAEA Coordinated Research Project (CRP) on “Analytical and Experimental Benchmark Analyses of Accelerator Driven Systems”

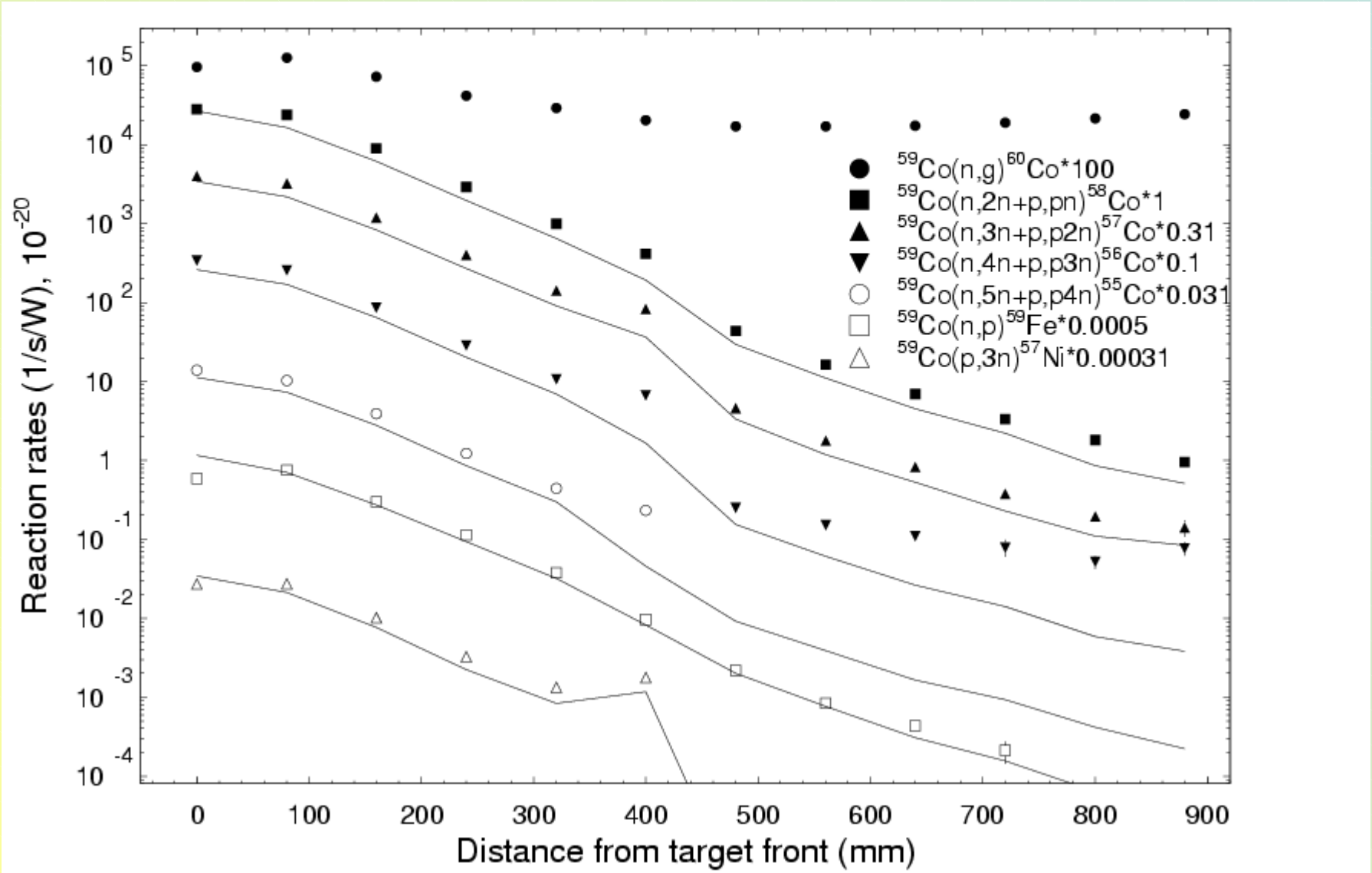
ISTC#2405: Preliminary results examples

^{209}Bi(n,xn) rates on the surface of Pb-target



ISTC#2405: Preliminary results examples

^{59}Co(n,xn; p,xn) rates on the axis of Pb-target



ISTC#3266: Formal information

Title: *Experimental and theoretical study of the residual nuclide production in 40-2600 MeV proton-irradiated thin targets of ADS structure materials*

Dates: Approved for funding in October 2005. Expected duration *2nd quarter 2006 – 3rd(or 4th) quarter 2008*

Financing party: *EU*

Collaborators

- SCK-CEN (***Hamid Ait Abderrahim, Edouard Malambu, Thierry Aoust***)
- Royal Institute of Technology (***Waclaw Gudowsky***)
- Universitat Hannover / Zentrum fur Strahlenschutz und Radioekologie (ZSR) (***Rolf Michel***)
- CEA / DSM / DAPNIA/CEN Saclay / Service de Physique Nucleaire (***Sylvie Leray***)
- Forschungszentrum Karlsruhe Technik und Umwelt / Institut fuer Reaktorsicherheit (***Cornelis H.M. Broeders***)
- Los Alamos National Laboratory / Nuclear Physics Group (T-16) (***Eric Pitcher, Stepan Mashnik***)
- Oak Ridge National Laboratory (***Phillip D. Ferguson***)
- JAERI / Nuclear Data Center (***Tokio Fukahori***)
- Georgia Institute of Technology / The Nuclear & Radiological Engineering & Health Physics Program of the George W. Woodruff School of Mechanical Engineering (***Nolan E. Hertel***)
- + *OECF/NEA* (***Enrico Sartori***)

Prolog: the project is an extension of the researches carried out under:

- ISTC Project#17 (1994-1996, USA)*Feasibility study of the basic technologies for weapon plutonium conversion and for long-lived radioactive waste transmutation*
- ISTC #839 (1997-1998; 1999-2000, Japan, EU, Norway) *Experimental and Theoretical Study of the Residual Product Nuclide Yields in Thin Targets Irradiated with 100-2600 MeV Protons*
- *ISTC # 2002 (2002-2004, EU): Experimental and theoretical studies of the yields of residual product nuclei produced in thin Pb and Bi targets irradiated by 40-2600 MeV protons*

Brief info available via http://tech-db.istc.ru/ISTC/sc.nsf/html/projects.htm?open&id=3266

ISTC Project #3266

List of irradiation runs for beta-active nuclide production measurements.

Targets	Proton energies (MeV)										
	40	70	100	150	250	400	600	800	1200	1600	2600
^{56}Fe +	x	x	x	x	x	x	x	x	x	x	o
^{nat}Cr	x	x	x	x	x	x	x	x	x	x	x
^{nat}Ni	x	x	x	x	x	x	x	x	x	x	x
^{93}Nb	x	x	x	x	x	x	x	x	x	x	o
^{181}Ta	x	x	x	x	x	x	x	x	x	x	x
^{nat}W	x	x	x	x	x	x	x	x	x	x	o

o – the irradiations were made under the ISTC Project#839.

+ Additionally, ^{56}Fe will be irradiated by 300, 500, 750, 1000 and 1500 MeV proton

to be compared with recent GSI measurements!

List of irradiation runs for alpha-active nuclide (^{148}Gd) production measurements.

Targets	Proton energies (MeV)			
	600	800	1600	2600
^{181}Ta	x	x	x	x
^{nat}W	x	x	x	x

Isotopic composition of the targets

Isotope	Number of samples	Isotopic composition, %
^{56}Fe	15	^{54}Fe-0.3, ^{56}Fe-99.5±0.1, ^{57}Fe-0.2, ^{58}Fe-<0.05.
^{nat}Cr	11	^{50}Cr-4.345 , ^{52}Cr-83.789 , ^{53}Cr-9.501, ^{54}Cr-2.365 .
^{nat}Ni	11	^{58}Ni-68.077, ^{60}Ni-26.223, ^{61}Ni-1.140, ^{62}Ni-3.634, ^{64}Ni-0.926
^{93}Nb	10	^{93}Nb > 99.9
^{181}Ta	15	^{180}Ta-0.012, ^{181}Ta-99,988.
^{nat}W	14	^{180}W-0.12, ^{182}W-26.50, ^{183}W-14.31, ^{184}W-30.64, ^{186}W – 28.43.

Accelerator time requirements:

68 short (~0.7h) irradiations

8 long (~20h) irradiations

~130h accelerator time

For comparison:

ISTC#2002 took **37h** acc.time

(disregarding time for accelerator preparation and beam adjustment)

ISTC#3266 scope of activities

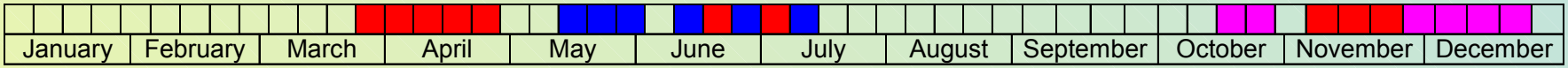
Scope of activities: the similar as in ISTC#2002 + alpha measurements !
(irradiation, alpha-spectra measurements, spectral analysis, ^{148}Gd CRS determination)

- *Manufacture of samples (1-4 quarters) - 76 samples (68 – for beta, 8 – for alpha measurements)*
- Adjusting of the additional detector for gamma-measurement (1-2 *quarters*)
- *Calibration of spectrometers; stability tests (1-10 quarters)*
- *Irradiation of experimental samples (1-8 quarters)*
- *Gamma-spectrometry of the samples (1-9 quarters) (68 samples)*
- *Processing of gamma-spectra (1-9 quarters)*
- *Identification of gamma-lines and determination of radioactive residual nuclide yields (1-10 quarters)*
- Pre-starting procedure to operate the alpha detector (1-4 quarters)
- Alpha-spectrometry of the W and Ta samples (5-8 quarters) (8 samples)
- Processing of the alpha-spectra, determination of the ^{148}Gd yield (9-10 quarters)
- *Theoretical simulations by different codes (1-9 quarters): LAHET (we are still trying get MCNPX from RSICC), CEM03 (LANL), LAQGSM(LANL), INCL4 (from CEA-Sacley), INCL5 (SCK), CASCADE-2004 (Jaipur Univer., BARC), CASCADO, LAHETO.*
- *Updating the models and codes on the basis of the new experimental data obtained under the Project (3-10 quarters)*
- *Sending the experimental results to the Worldwide Network of Nuclear Data Centers via Center for Nuclear Structure and Reaction Data (Russia) (8-10 quarters)*
- *Preparation of technical reports (5, 6, 9, 10 quarters)*

ISTC #3266 Irradiation schedule

ITEP U10 accelerator complex is being intensively modified to provide heavy ion beams. So, unlike previous years, in 2006 just 10 of 22 accelerator weeks are planed for protons.

Planed schedule for ITEP U-10 accelerator runs for 2006 year:



Protons
^{12}C ions
^{27}Al ions

Therefore, the previous schedule mode of irradiations used under ISTC#839&2002 cannot be applied further.

→ **We need <u>additional Ge-detector</u> (Canberra) to double the rate of irradiations (at least 12 targets during 1 accelerator run which last about a month).**

For comparison: during ISTC#2002 average rate of irradiations was 5-7 irradiation per 1 acc.run, irradiations being uniformly time distributed during a run

→ **We need to have manufactured samples (and 2nd detector) by the end of March**

However,

ISTC regulations do not allow spending money before a project signing!

Moreover, we cannot even make an order of the detector!

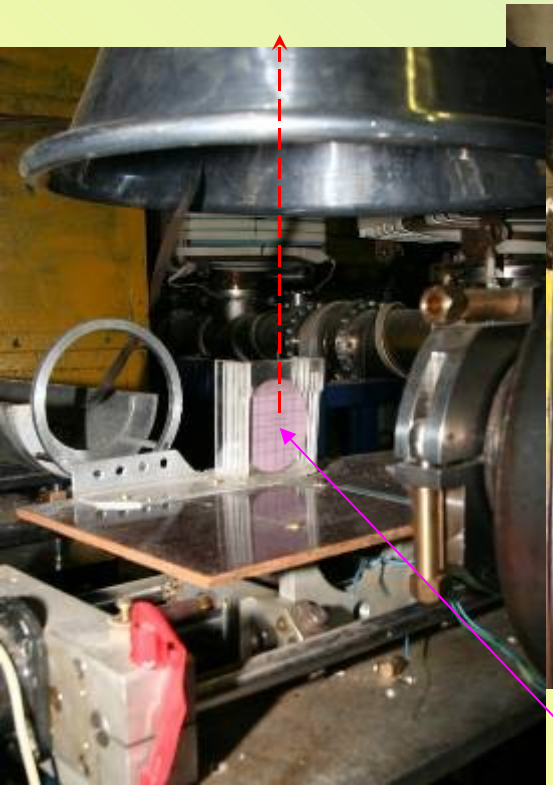
So,

First quarter of the Project will be partially "lost" to purchase Ge-detector probably leading to some delay of the project results.

ISTC#3266: First results

Fast sample extraction system mounted

Irradiated samples are pulled from magnetic hall to outside via strings inside flexible tube.
→ reduction of time gap between irradiation end and start of γ-measurements.
→ reduction of minimal half lives of the products measured: $^{53}Fe(T_{½}=8.5m)$, $^{38}K(T_{½}=7.6m)$, $^{29}Al(T_{½}=6.6m)$, ^{52}V $(T_{½}=3.7m)$.



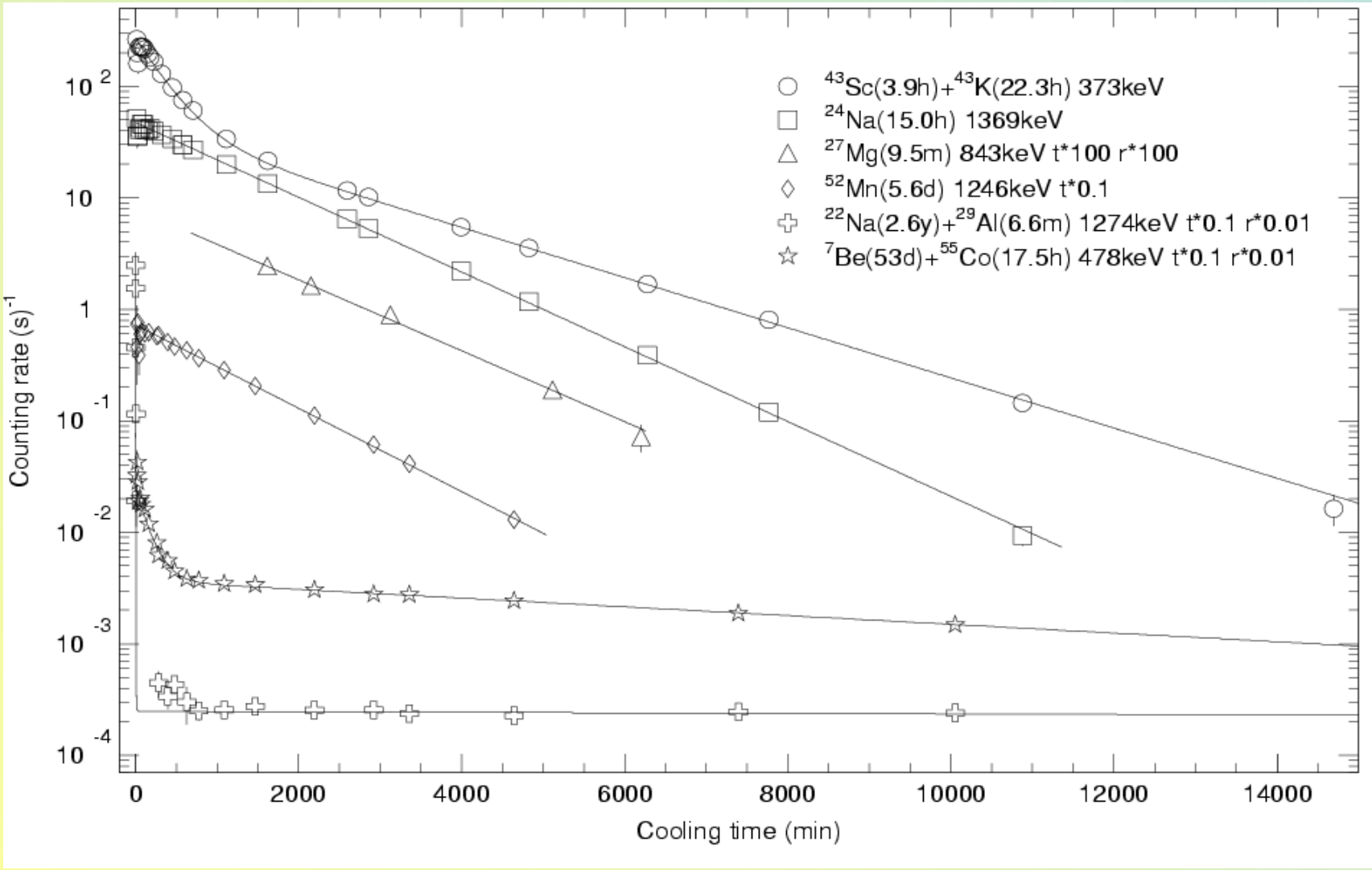
Sample location during irradiation

ISTC#3266: First results

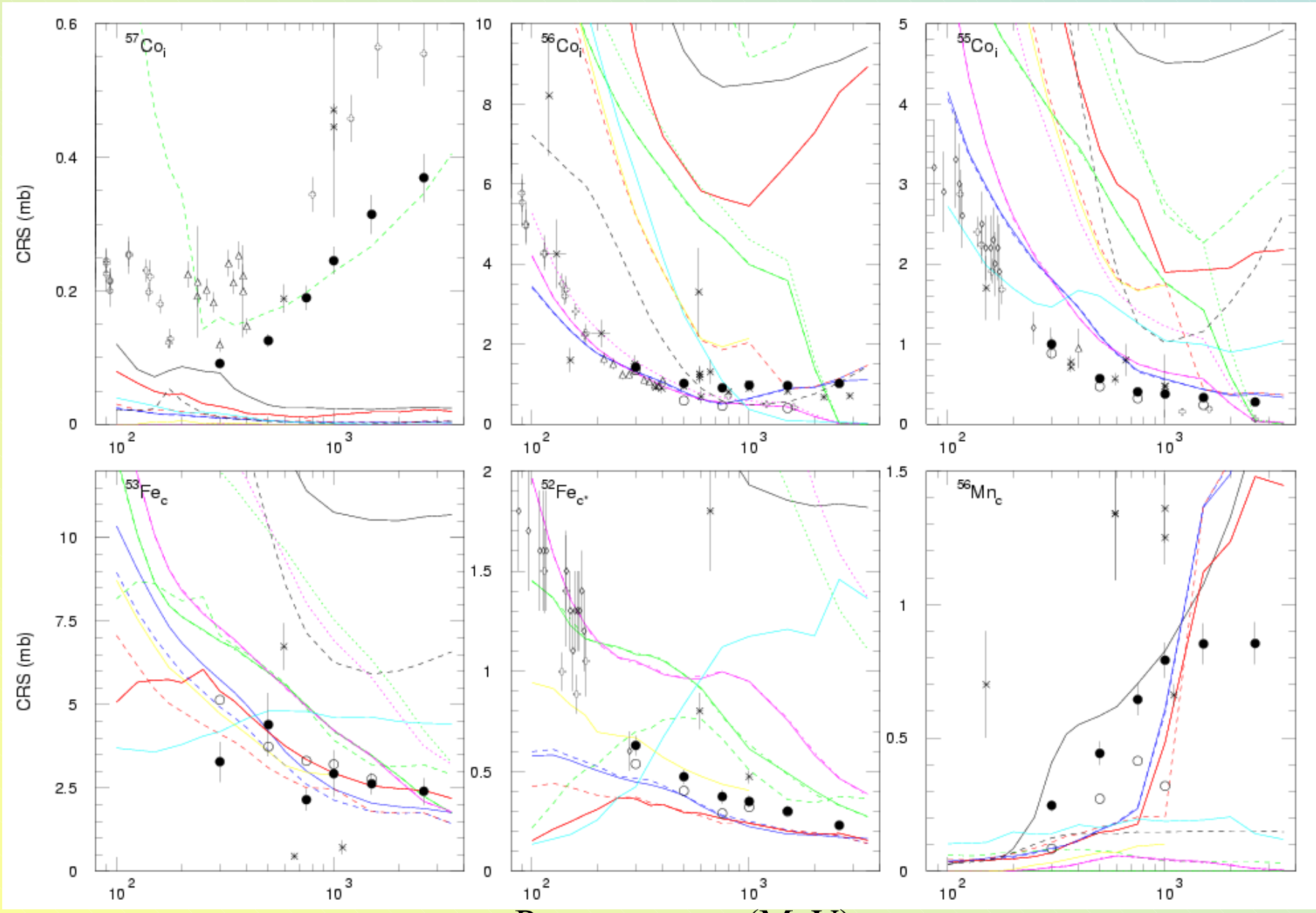
- 11 samples were standard irradiated
- 2 pairs of samples (Ta and W) were irradiated with high proton flux (~10^{16} p/cm^2, 0.8 and 1.6GeV) to measure α-active ^{148}Gd

Target	Proton energy	Number of γ–spectra measured	Number of γ–lines found	Number of CRS of radioactive nuclides determined
^{56}Fe	300	42	2631	33
^{56}Fe	500	40	2743	33
^{56}Fe	750	35	2457	38
^{56}Fe	1000	31	2358	38
^{56}Fe	1500	32	2434	38
^{56}Fe	2600	26	1620	in process
^{nat}Cr	2600	22	1245	in process
^{58}Ni	2600	25	1815	in process
^{93}Nb	2600	25	3890	in process
^{181}Ta	2600	24	6442	in process
^{nat}W	2600	26	6830	in process
Al-monitors (20 units)		151	2097	
Total		**479**	**36562**	**180**

ISTC #3266: First results

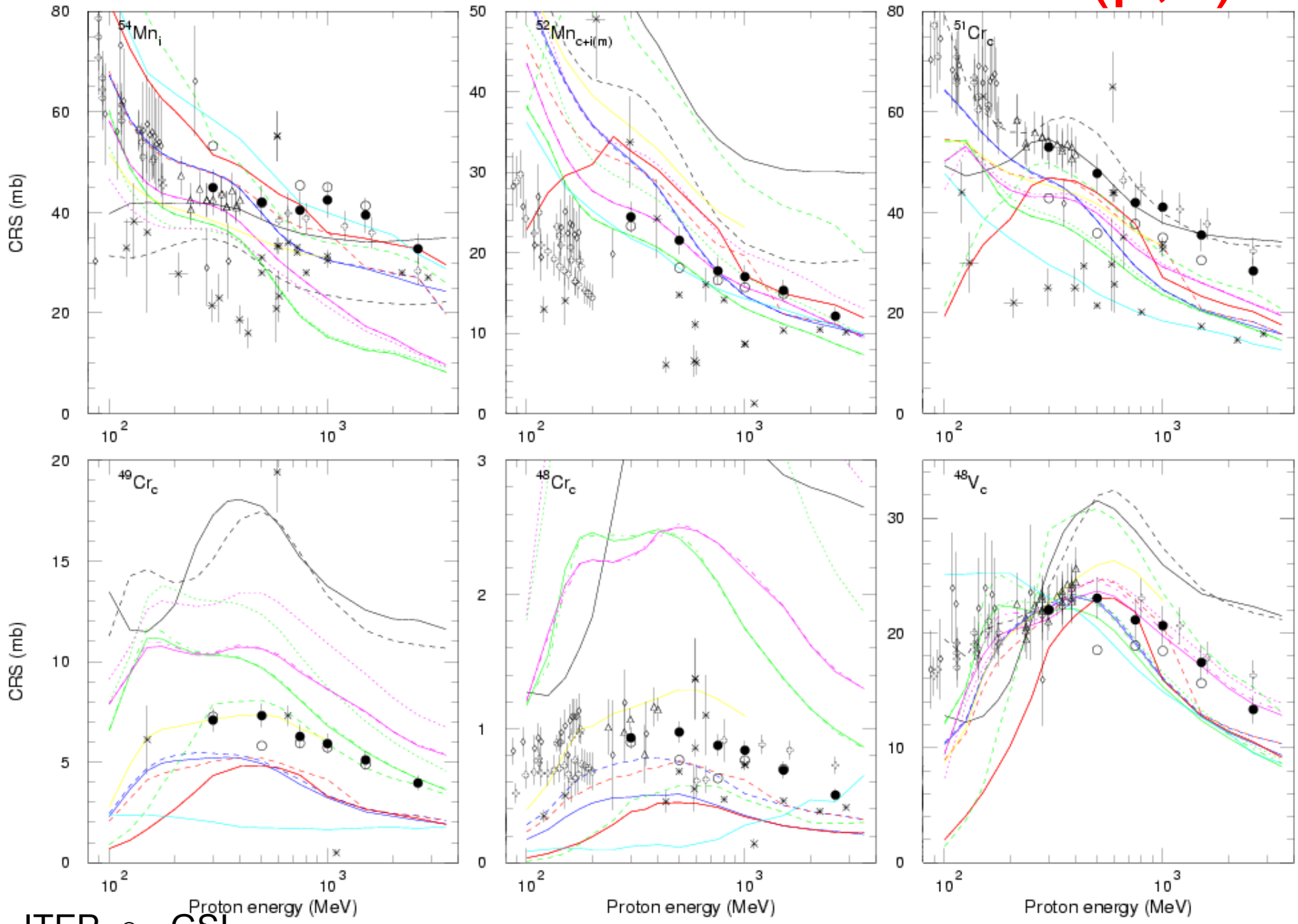


ISTC #3266: First results – ^{56}Fe(p,x)



● - ITEP, ○ - GSI

ISTC #3266: First results – ^{56}Fe(p,x)



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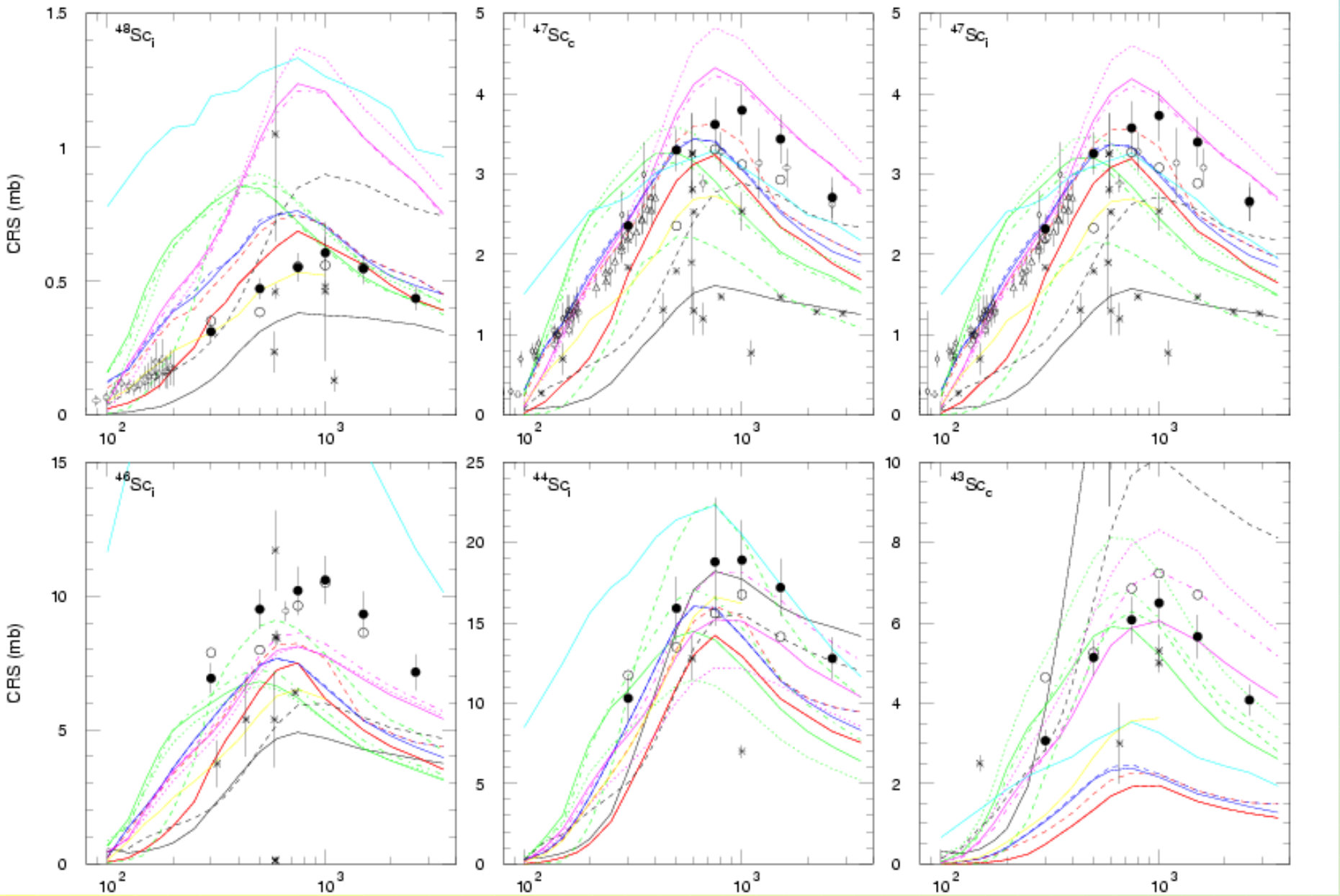
ISTC #3266: First results – ^{56}Fe(p,x)



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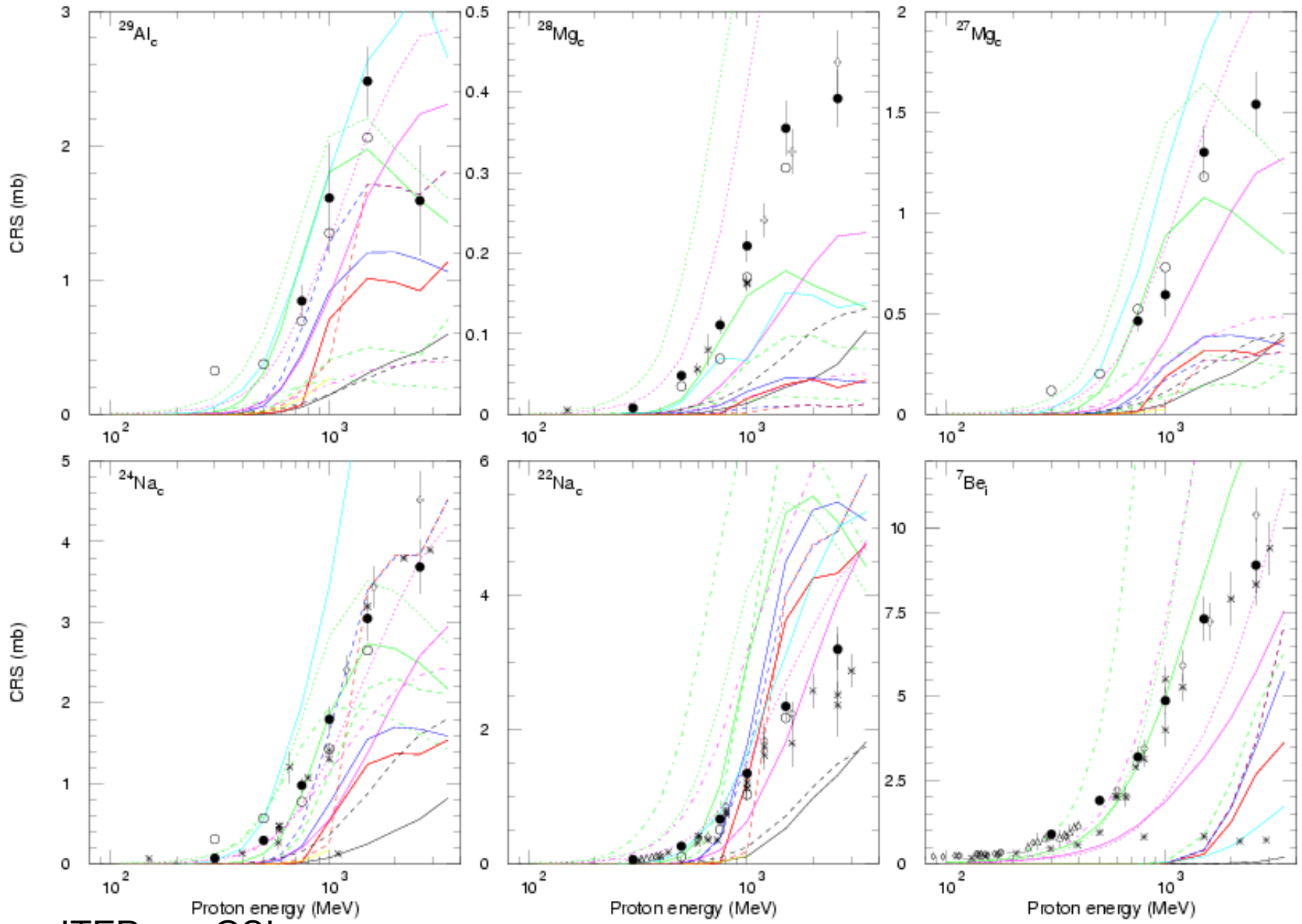
ISTC #3266: First results – ^{56}Fe(p,x)



● - ITEP, ○ - GSI

ISTC #3266: First results – ^{56}Fe(p,x)

Designation on pictures:

INCL/MCNPX (solid) BRIEFF (dashed)

CEM03.01 (solid) CEM2k/MCNPX (dashed) CEM03.G1 (dotted) CEM03.S1 (dashed-dotted)

BERTINI (MCNPX - solid, LAHET - dashed)

ISABEL (MCNPX - solid, LAHET - dashed)

LAQGSM03.01 (solid) LAQGSM03.G1(dotted) LAQGSM03.S1(dashed-dotted)

CASCADE-2004

LAHETO

● ITEP (This work)

○ GSI (C.Villagrasa-Canton, Ph.D. thesis(2003))

✚ ZSR (R. Michel et al.)

△ (Th. Schiekel et al.)

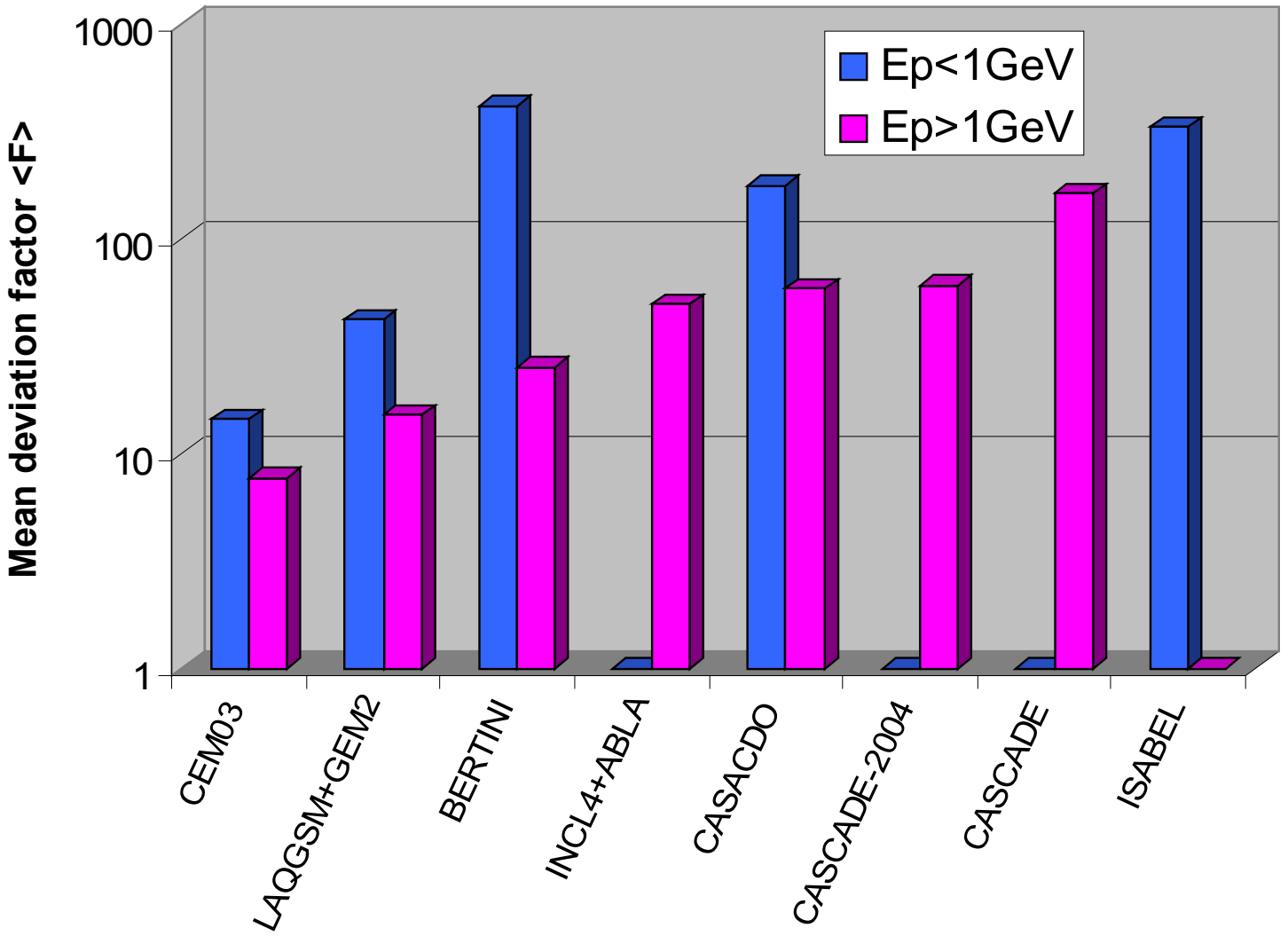
◊ (M. Fassbender et al.)

✳ Others

Mean squared deviation factors <F> for ^{56}Fe(p,x) products predictions

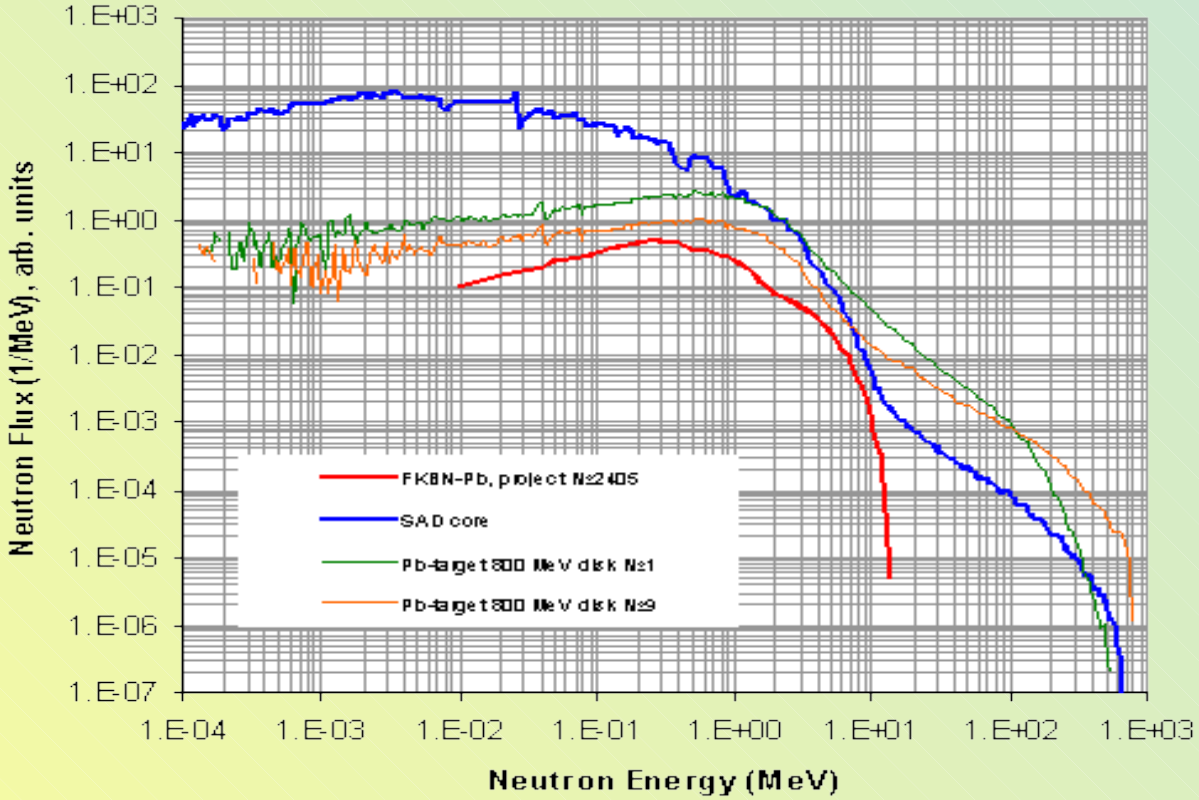
Code/Model	Product mass (A), Proton energy (MeV)												All energies, All products
	300		500		750		1000		1500		2600		
	A<30	A>30	A<30	A>30	A<30	A>30	A<30	A>30	A<30	A>30	A<30	A>30	
MCNPX/INCL	233	4.66	2159	3.18	51.5	3.08	38.1	3.08	26.1	3.29	12.1	3.46	**7.07**
MCNPX/CEM2k	--	2.68	12.6	2.48	21.13	2.56	7.83	2.72	4.87	2.87	4.02	3.14	**3.50**
MCNPX/BERTINI	1035	2.21	26.1	2.26	50.5	2.73	13.8	2.85	4.93	3.16	3.35	3.19	**4.35**
MCNPX/ISABEL	--	3.71	256	2.82	49.1	2.99	17.1	2.62	5.99	2.83	4.02	2.99	**4.21**
LAHET/BERTINI	542	2.23	36.1	2.26	6.98	2.66	16.5	3.15	7.34	3.37	5.69	3.14	**4.02**
LAHET/ISABEL	--	2.75	147	2.59	44.6	3.00	15.4	3.43	7.34	3.37	5.69	3.14	**4.60**
CEM03.01	13.0	1.83	2.23	1.88	1.32	1.88	1.49	1.92	1.58	2.05	1.72	3.17	**2.26**
CEM03.G1	2.82	2.58	2.55	2.59	2.42	2.60	2.15	2.33	1.67	2.31	1.57	3.10	**2.51**
CEM03.S1	3.35	2.15	4.35	2.32	4.21	2.68	4.94	2.94	6.19	3.25	6.98	4.35	**3.34**
LAQGSM03.01	45.3	2.09	8.05	1.94	3.15	2.02	2.43	2.09	1.98	2.19	1.46	3.74	**2.87**
LAQGSM03.G1	2.43	4.10	2.09	2.46	1.73	2.76	1.66	2.76	1.50	2.89	1.60	4.22	**2.95**
LAQGSM03.S1	4.64	2.67	3.87	2.41	3.75	2.67	3.89	2.67	4.17	2.66	3.59	4.13	**3.06**
CASCADE-2004	4.69	2.59	2.22	2.84	12.4	3.14	8.00	3.72	4.55	5.43	3.04	6.48	**4.30**
LAHETO	--	3.90	178.3	2.42	22.8	2.82	38.9	3.24	--	--	--	--	**5.02**
BRIEFF 1.5.3a	85.2	3.37	42.22	3.37	23.0	3.54	22.0	3.67	23.6	3.81	17.8	3.76	**6.11**

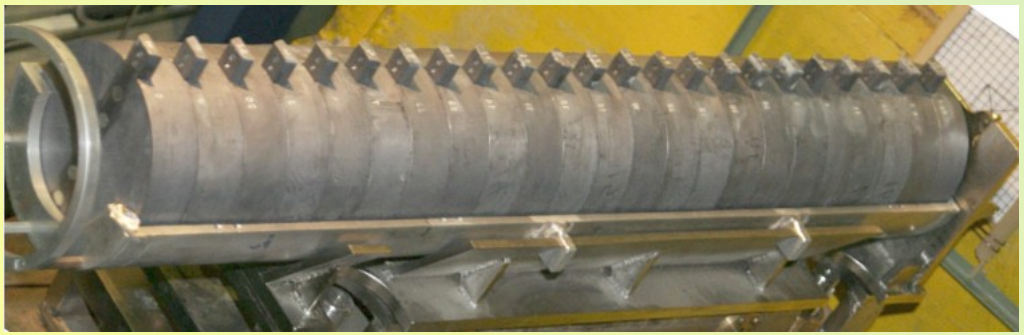
Mean squared deviation factor <F> for products with A below 30



Perspectives of further works (#2405)

Comparison of neutron spectra in ADS (SAD), Pb-target, FKBN





1st proposal:
Meaurement (n,f) rates of:

^{235}U(basis)
^{237}Np,
^{238}Pu, ^{239}Pu, ^{240}Pu,
^{241}Pu, ^{242}Pu, ^{244}Pu,
^{241}Am, ^{242m}Am,
^{243}Am,
^{243}Cm, ^{244}Cm,
^{245}Cm, ^{246}Cm,
^{247}Cm, ^{248}Cm, ^{238}U,
^{238}U(n,γ),
Mixed compositions (MOX emulation)

2nd proposal:
Measurement of Pb-target activation

Perspectives of thin target works (#3266)

Targets	Energy (MeV)										
	40	70	100	150	250	400	600	800	1200	1600	2600
Mo	X	X	X	X	X	X	X	X	X	X	X
Zr	X	X	X	X	X	X	X	X	X	X	X
Ti	X	X	X	X	X	X	X	X	X	X	X
Th, U?	X	X	X	X	X	X	X	X	X	X	X

Mo – structure, fuel lattice, fission product,
Zr – fuel lattice, “nuclear model” (A. Koning’s recommendation)
Ti – target window
Th, U – fuel
Pb&Bi - target

List of targets should be coordinated with priority list of high energy nuclear data requirements to be included in FP7 P&T program (2007-2011)

Th-cycle ADS related works

- **Studies on energetic nucleons interaction with thorium**. Application to protection of enriched uranium against proliferation and terrorism by means of uranium isotopic denaturing.

  Measurements at different proton energies:
  - Measurement of activation reaction rates inside and on the surface of the Th-disks in the target assembly,
  - Measurement of residual nuclei production cross sections in thin Th-foils induced by protons
  - Neutron yield and spectrum from extended thorium targets
- **Studies on thorium fuel cycle for ADS and conventional thermal reactors**

  Measurements of Th-Pu-MA oxide fuel parameters:
  - ^{233}U breeding rate
  - ^{231}Pa and ^{232}U production rate
  - Pu and MA burn-up rates

Summary

	THIN targets	THICK targets	Other research lines (fuel cycle, …)
Projects	#839-0, #839 (1997-2001) #2002 (2002-2004) #3266 (2006-2009)	#1145 (1999-2001) #2405 (2005-2007)	#017 (1994-1996)
Results by Jan07	More than 10000 CRS's measured and published in IAEA and OECD web sites. Data are used for: 3)designs 4)physics models verification	More than 2500 reaction rates measured. Data are used for activation excitation functions verification	
Perspectives	Mo, Ti, Zr, Th&U?	1)Pb-target activation. 2)Actinide(n,f) CRS in ADS-spectrum	Th-cycle in ADS

The new proposals should be linked with FP7 P&T program (2007-2011).
Direct contacts with FP7 key executives would be useful.