Measuring absolute transmission values of the RITU gas-filled separator

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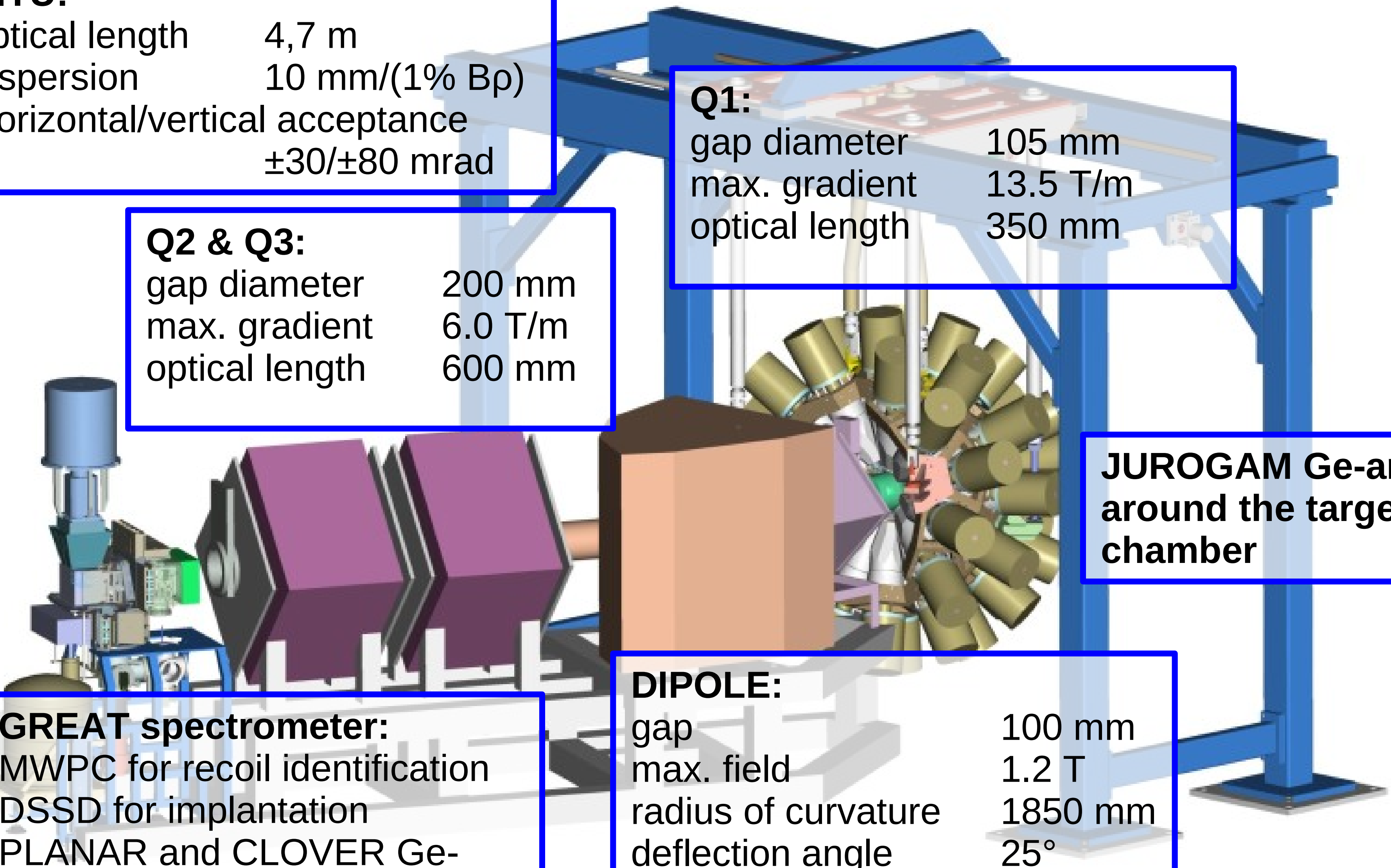
Instrumentation

RITU (QDQQ), Jurogam, Great



RITU:

optical length	4,7 m
dispersion	10 mm/(1% Bρ)
Horizontal/vertical acceptance	±30/±80 mrad

Q1:

gap diameter	105 mm
max. gradient	13.5 T/m
optical length	350 mm

Q2 & Q3:

gap diameter	200 mm
max. gradient	6.0 T/m
optical length	600 mm

JUROGAM Ge-array around the target chamber

GREAT spectrometer:
MWPC for recoil identification
DSSD for implantation
PLANAR and CLOVER Ge-detectors and box detector

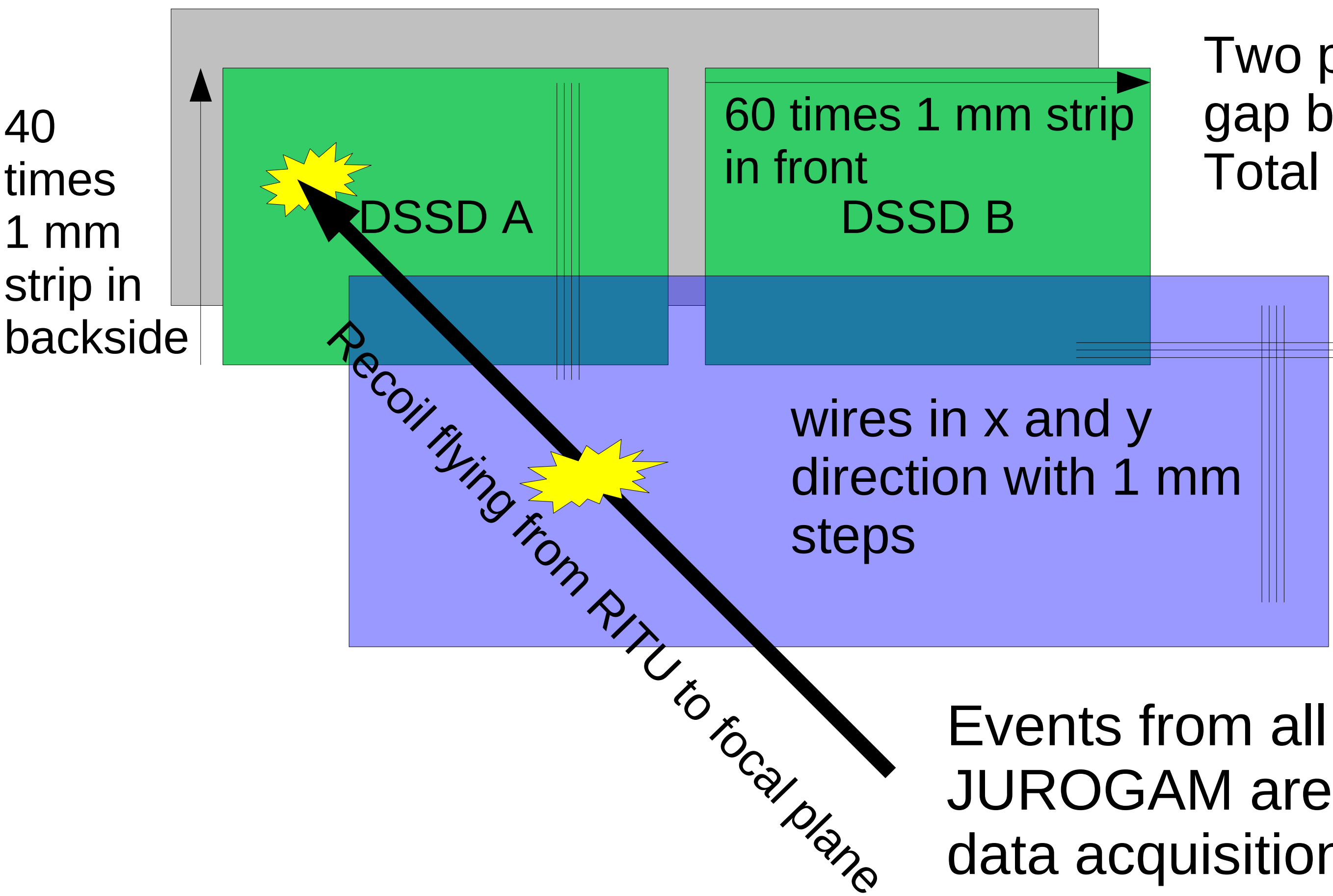
DIPOLE:

gap	100 mm
max. field	1.2 T
radius of curvature	1850 mm
deflection angle	25°
entrance/exit angles	0/-25°

Instrumentation

Focal plane setup: MWPC, DSSD, Planar, ...

PLANAR GE-detector for low-energy gamma-particles. It can be used for vetoing punch-through protons and alphas. Planar was not important in these transmission studies



Two parallel **DSSD**s with 5 mm gap between.
Total size 125 x 40 mm^2

MWPC for identifying particles flying from RITU to DSSD. In principle, position resolution is 1 mm in horizontal and vertical direction.

Events from all detectors including JUROGAM are collected via triggerless data acquisition and a timestamp from 10 MHz clock is assigned to every event.

Reactions

Beam	Elab [MeV]	Target	Pressure [mbar]	Thicknes s [ug/cm2]	Combound	Main evap. ch	Evap. Residue
40 Ar	170	150 SmF	0.2 – 1.6	250	190 Hg	4n	186 Hg
		144 SmF	0.6	402	184 Hg	2n	182 Hg
						p2n	181 Au
		150 Sm	0.6	400	190 Hg	4n	186 Hg
		170 Er	0.6	500	210 Rn	4n	206 Rn
						5n	205 Rn
		120 Sn	0.6	500	160 Er	4n	156 Er
						5n	155 Er
84 Kr	336	90 Zr	0.7	500	174 Os	2n	172 Os
		92 Mo	0.7	600	176 Pt	2n	174 Pt
		nat Mo	variable				
20 Ne	95	168 Er	0.2 – 0.8	500	188 Pt	4n	184 Pt
		169 Tm	0.3	420	189 Au	4n	185 Au
		169 Tm	0.3	670	189	4n	185 Au

Well known nuclei in a same mass region were populated in fusion reactions with very different beam and target mass ratios (different asymmetry).

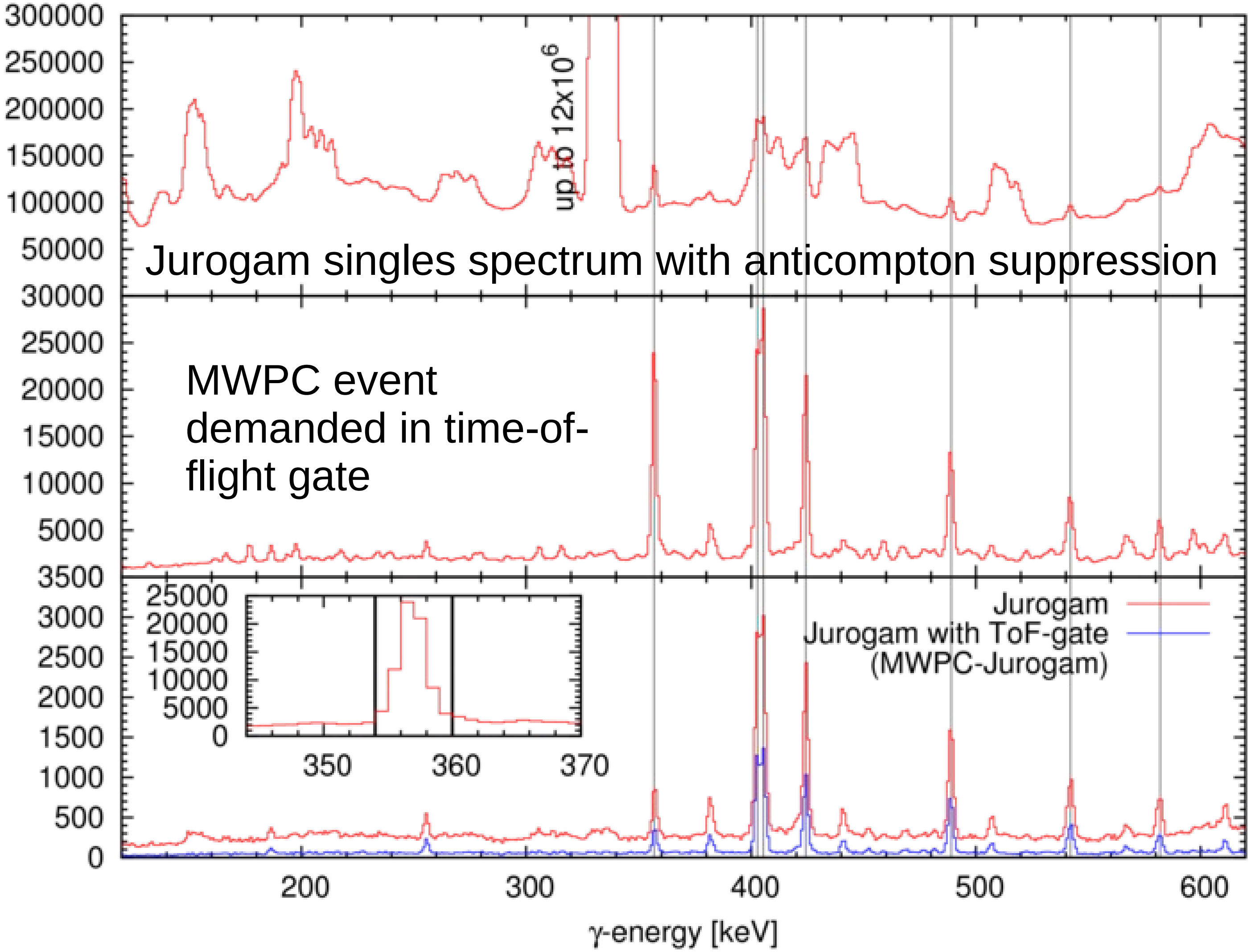
Principle of measuring transmission

Overall view

- Simple idea: using Ge-array to count how many interesting isotopes produced in the target and count how many of them is seen in a time window at the focal plane. Transmission is then ratio between these numbers.
- For each target:
  - Identifying the main evaporation channel(s) from mwpc-gated singles and gamma-gamma spectra
  - Tighting the time-of-flight gates
  - Selecting usable gamma-gamma pairs
- For different parameter (pressure, beam stop, ...)
  - Fitting gamma-gamma peaks and calculating a weighted average of those → absolute transmission
  - Fitting position distributions seen by DSSD and time-of-flight distributions (using sum of all gamma-gamma gates)
  - Correcting transmission with the center of horizontal distribution and detector dead times

Principle of measuring transmission

Prompt gamma spectra: singles, gated, gamma-gamma



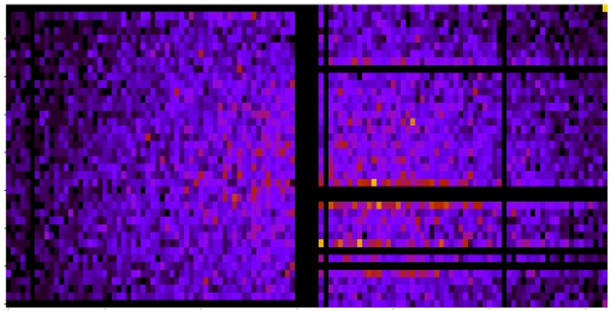
In the reaction ^{40}Ar+^{150}SmF the gamma energies of ^{186}Hg are difficult to see from the total **Jurogam singles** spectrum.

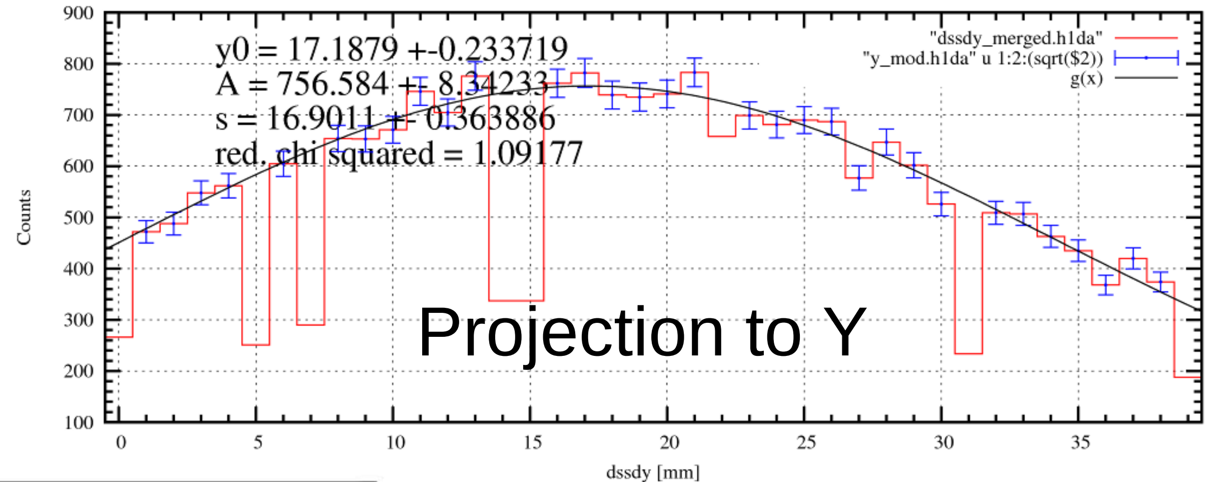
Demanding an event in the **MWPC** cleans spectra remarkably.

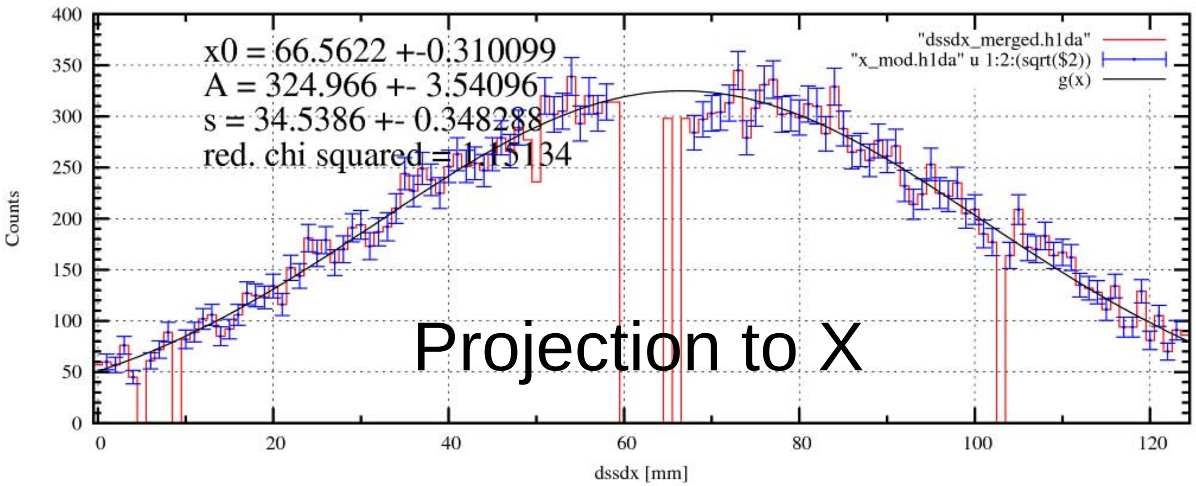
Gamma-gamma coincidences are needed to extract a transmission.

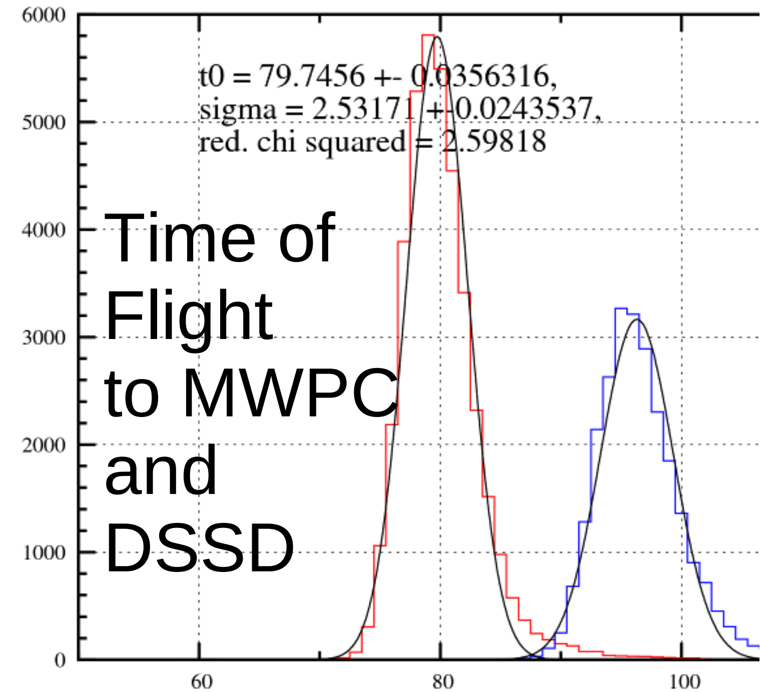
Principle of measuring transmission

Using gamma-gamma coincidences to get image sizes and ToF





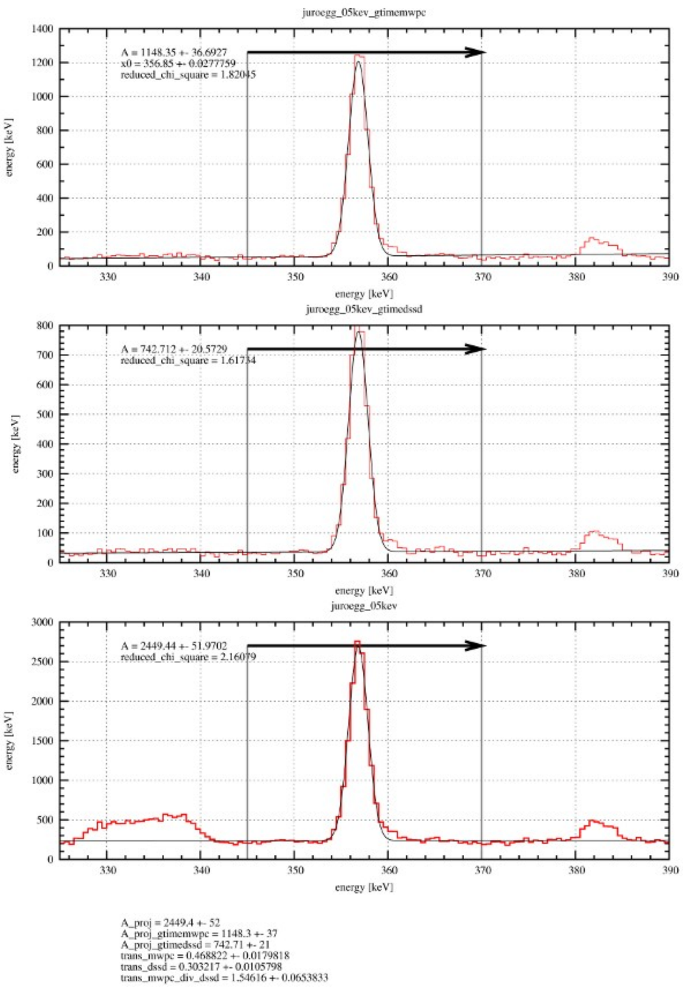




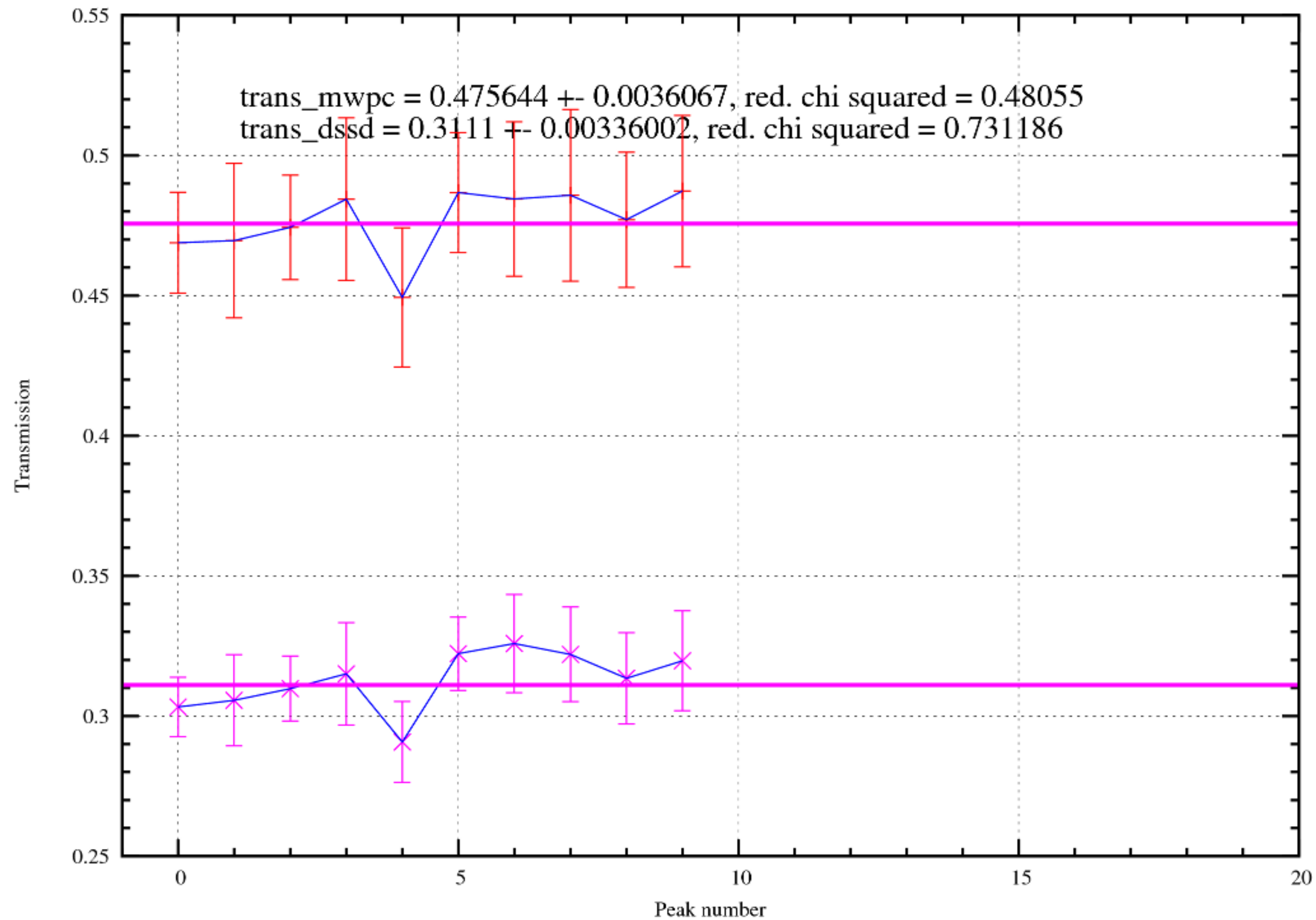
A center of the recoil distribution is needed to correct a transmission and magnetic rigidity values.

Principle of measuring transmission

Fitting all usable gamma-gamma pairs

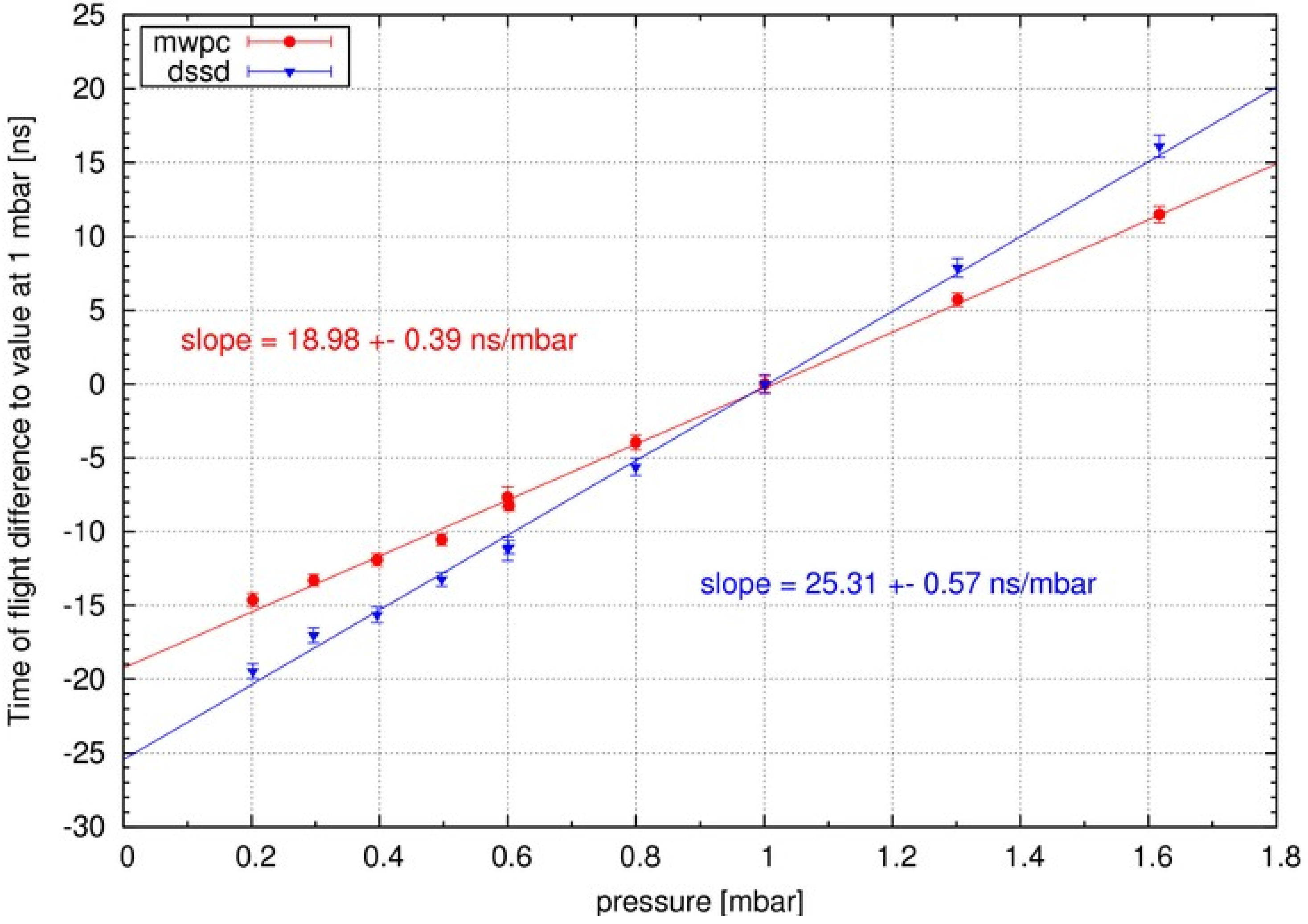


The intensities of multiple gamma-gamma peaks were fitted for each datafile and the transmission value was taken as weighted average of those.



Details of reaction $^{40}Ar+^{150}SmF$

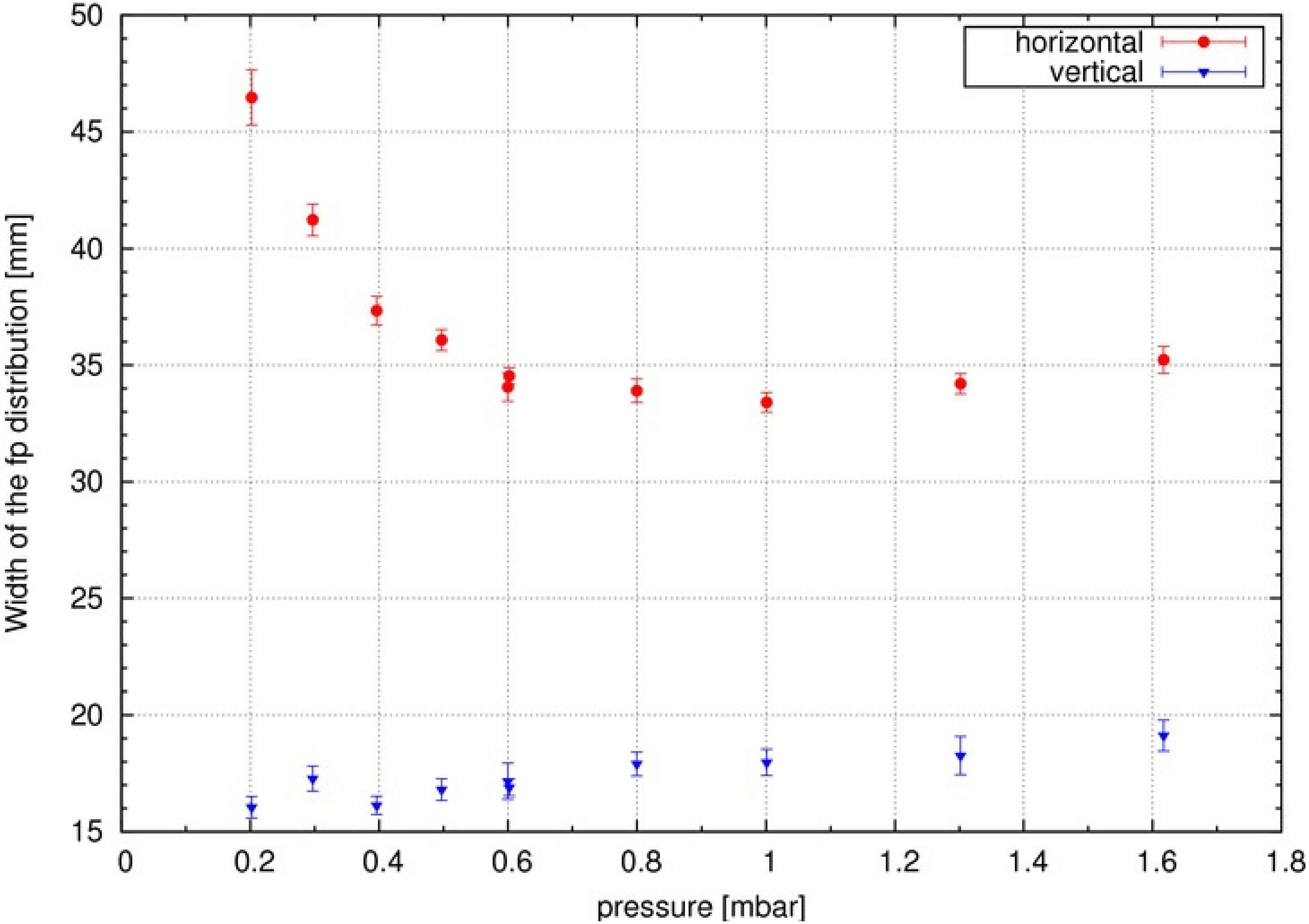
Time of Flight through RITU in function of He-pressure



The time of flights are directly proportional to gas-pressure which corresponds to constant energy loss dE/dx.

Details of reaction $^{40}Ar+^{150}SmF$

Image size in function of pressure

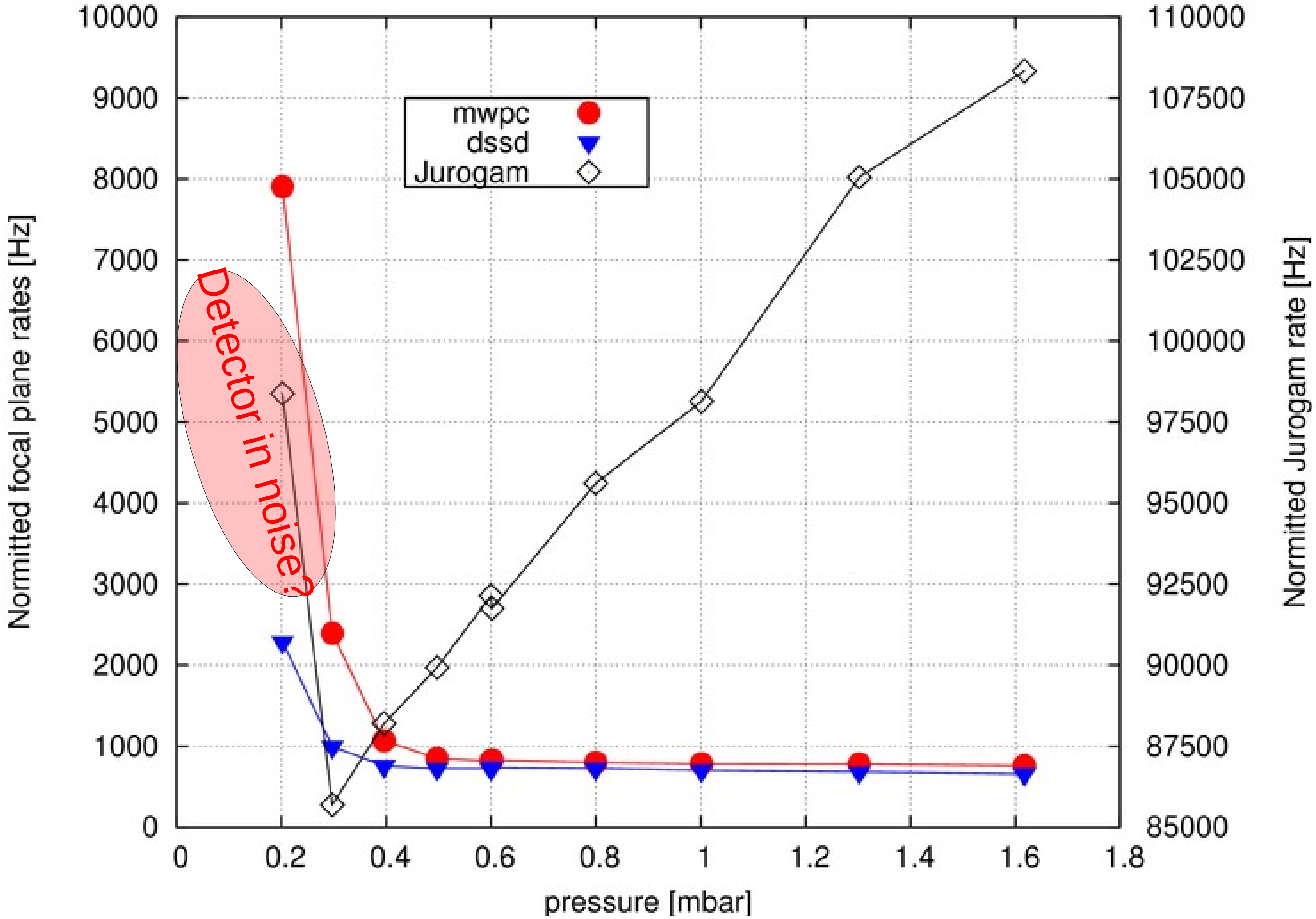


The horizontal width of the image at the DSSD behaves smoothly in function of pressure and it has a minimum around 1 mbar.

The width of the image in the vertical direction seems to increase linearly with increasing pressure due to multiple scattering in gas.

Details of reaction $^{40}Ar+^{150}SmF$

Detector rates in function of pressure

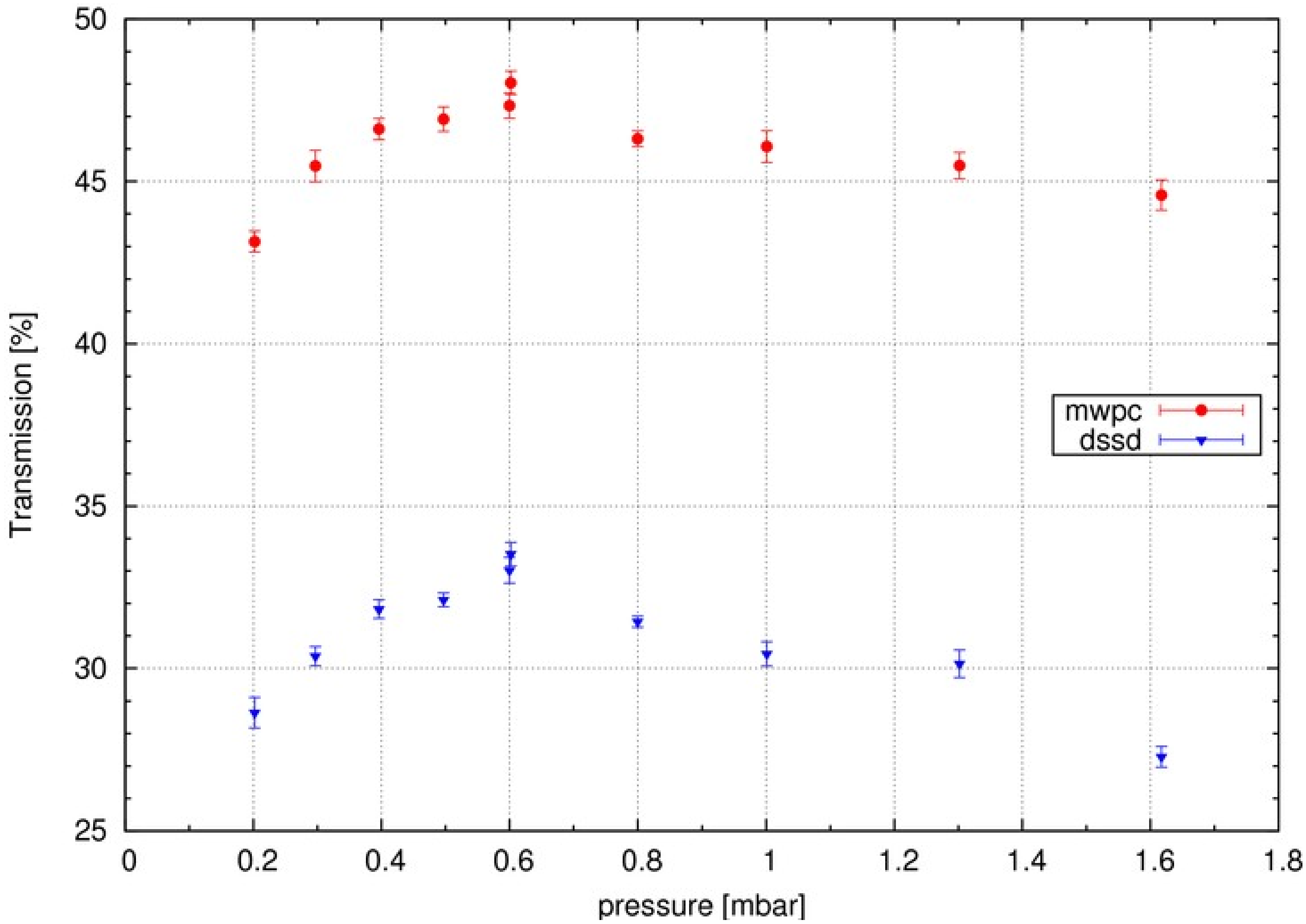


When the pressure is decreased the amount of scattered beam reaching the focal plane is increased dramatically.

In the Jurogam-array the counting rates are increasing linearly with increasing pressure due to reactions with beam and He.

Details of reaction $^{40}Ar+^{150}SmF$

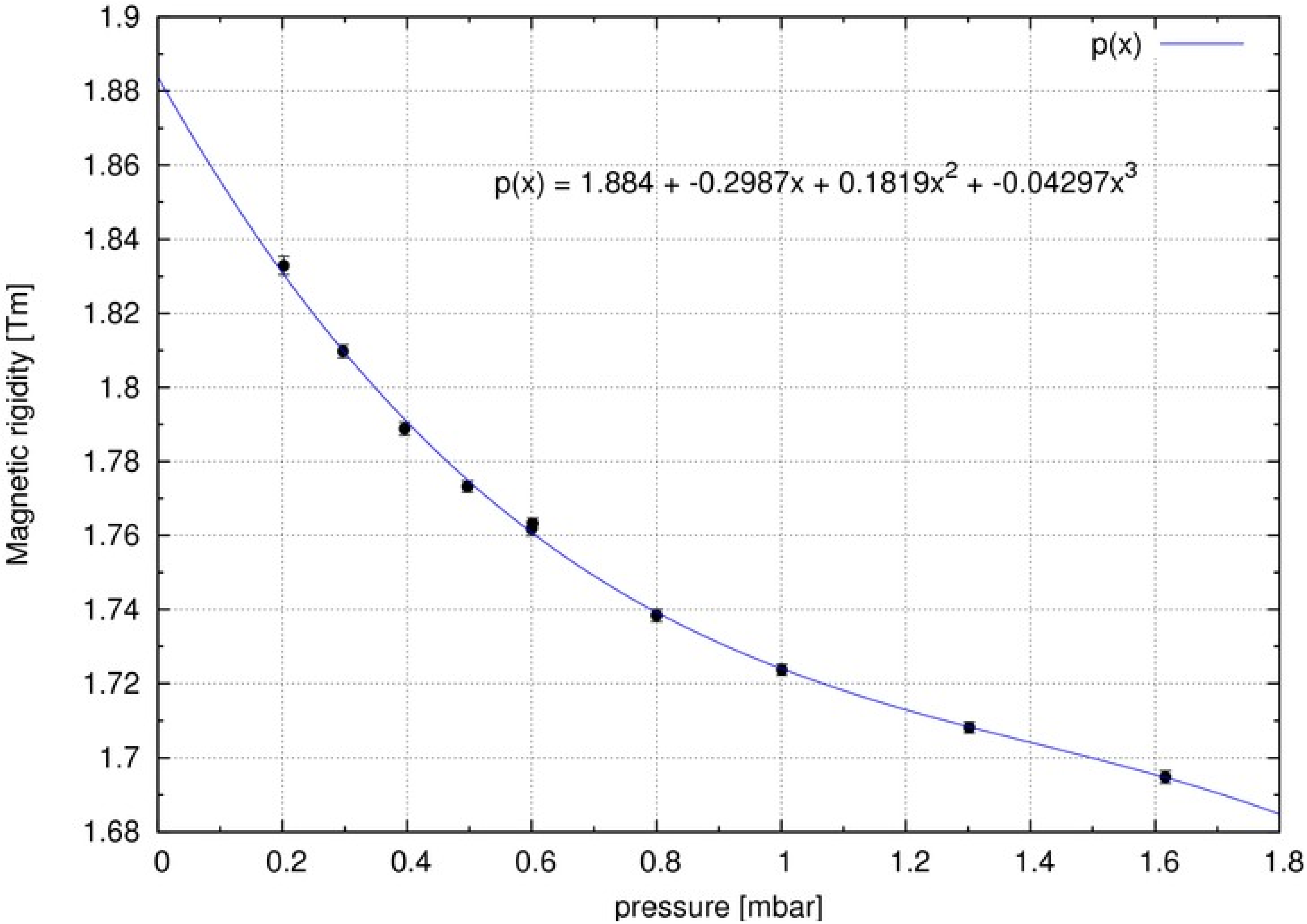
Transmission through RITU in function of pressure



Transmission to both detectors, MWPC and DSSD behaves similarly. Both have the maximum value around 0.6 mbar.

Details of reaction ^{40}Ar+^{150}SmF

Magnetic rigidity, Bρ, in function of pressure



A magnetic rigidity decreases smoothly with increasing pressure.

The calculated RITU dispersion 10mm/(1% in rigidity) and the center of horizontal distribution at DSSD were used to correct rigidity values.

Results

Beam	Elab [MeV]	Target	Pressure [mbar]	Thickness [ug/cm2]	Combound	Main evap. ch	Evap. Residue	Angular cone of the recoil [mrad]	Transmission to MWPC [%]	Transmission to DSSD [%]	Rigidity [Tm]	x sigma [mm]	y sigma [mm]	
40 Ar	170	150 SmF	0.2 – 1.6	250	190 Hg	4n	186 Hg	36,06	**47.3(4)**	**33.0(4)**	1.762(2)	34.1(7)	17.2(8)	with pressu
		144 SmF	0.6	402	184 Hg	2n	182 Hg	36,24	**45.9(11)**	**31.6(9)**	1.721(2)	35.5(8)	15.3(8)	
						p2n	181 Au	42,52	**31.3(7)**	**21.9(6)**	1.746(3)	36.4(12)	21(3)	
		150 Sm	0.6	400	190 Hg	4n	186 Hg	41,73	**64.8(6)**	**47.5(4)**	1.760(2)	34.4(5)	15.4(4)	
		170 Er	0.6	500	210 Rn	4n	206 Rn	49,2	**24.9(6)**	**16.1(4)**	1.742(2)	35.0(7)	18.6(11)	
						5n	205 Rn	54,2	**15.4(4)**	**9.2(5)**	-	-	-	
		120 Sn	0.6	500	160 Er	4n	156 Er	43,86	**47.8(3)**	**37.0(2)**	1.515(2)	34.9(3)	13.65(9)	
						5n	155 Er	46,67	**47.4(2)**	**36.2(2)**	1.507(2)	35.0(3)	13.7(2)	
84 Kr	336	90 Zr	0.7	500	174 Os	2n	172 Os	17,89	**77.1(10)**	**71.5(11)**	1.376(2)	39.9(7)	4.74(10)	
		92 Mo	0.7	600	176 Pt	2n	174 Pt	18,87	**57(4)**	**48(5)**	1.418(4)	33(2)	5.4(2)	
		nat Mo	variable					0	**?**	**?**				
20 Ne	95	168 Er	0.2 – 0.8	500	188 Pt	4n	184 Pt	122,1	**7.7(3)**	***nothing***				
		169 Tm	0.3	420	189 Au	4n	185 Au	0	**?**	***nothing***				
		169 Tm	0.3	670	189	4n	185 Au	0	**?**	***nothing***				

Transmission to DSSD is always lower compared to transmission to MWPC because the MWPC detector is little larger and some recoils hit the wires inside MWPC. There is also a narrow supporting bar in other MWPC window.

It can be seen that reaction asymmetry affects strongly to transmission as expected. The calculated angular cone correlates with transmission (evaporations were simulated at the centers of the targets, cone is combined from the evaporation process and from scattering in the target).

Symmetric reaction gives the best transmission values, but an additional beam stopper must be used inside dipole to reduce scattered beam component.

Thank you