中国科学院近代物理研究所
Institute of Modern Physics, Chinese Academy of Sciences

Discussion on noise match and power match issues of resonant Schottky pickup

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Chinese Academy of Sciences (CAS)

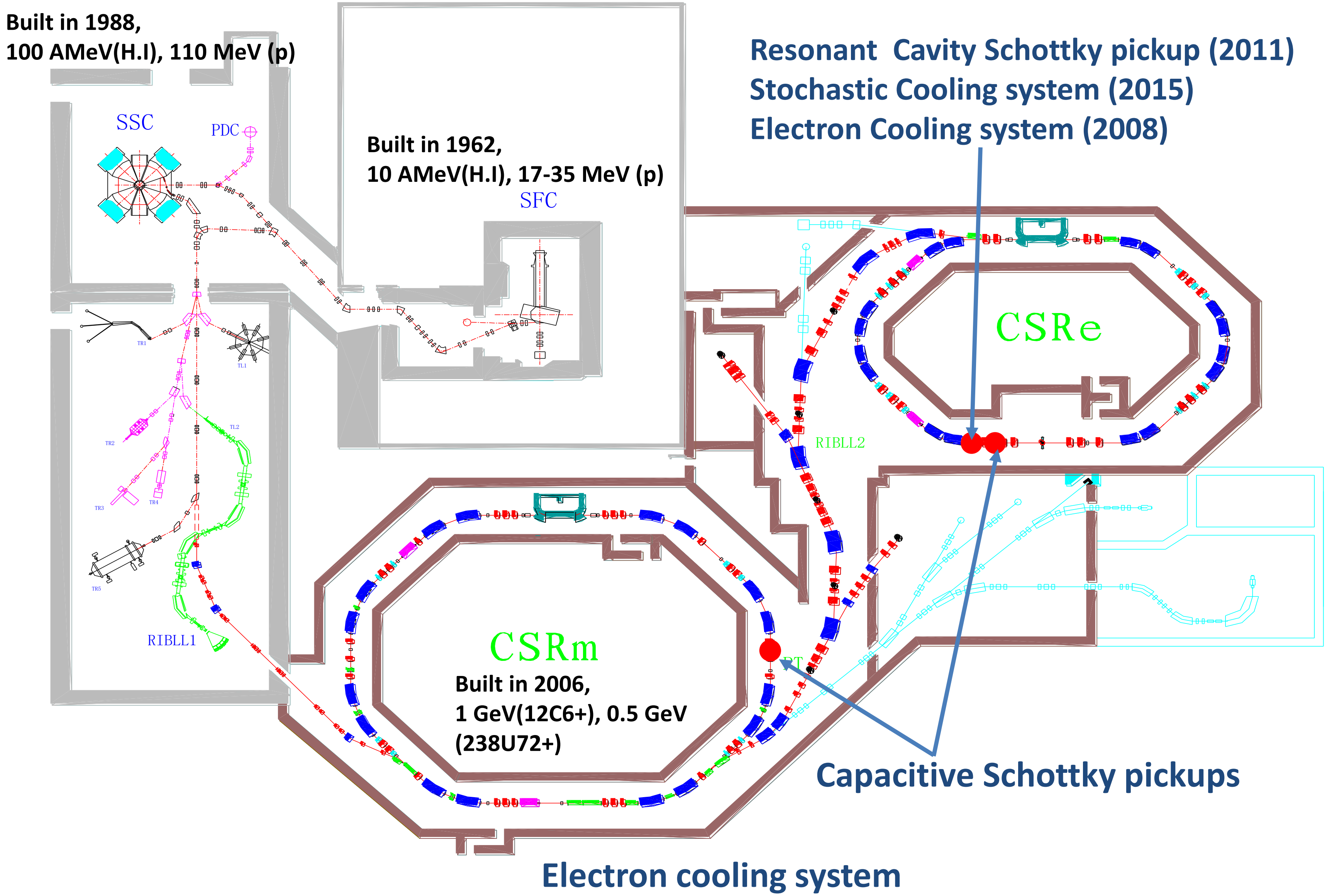
Contents

- Schottky pickups at IMP
- Noise match measurement of the Resonant Schottky pickup

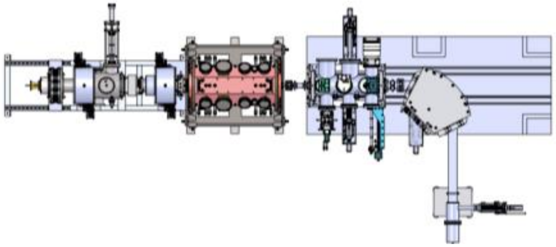
(Many thanks to Fritz Caspers for many useful hints and help on this)

HIRFL-CSR and Schottky pickups

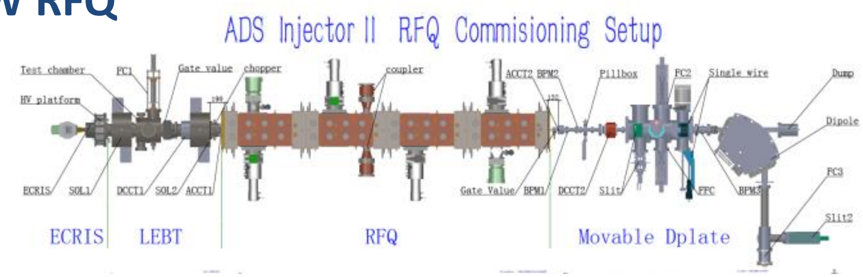
HIRFL-CSR: Heavy-Ion Research Facility with Cooing Storage Ring on Lanzhou,



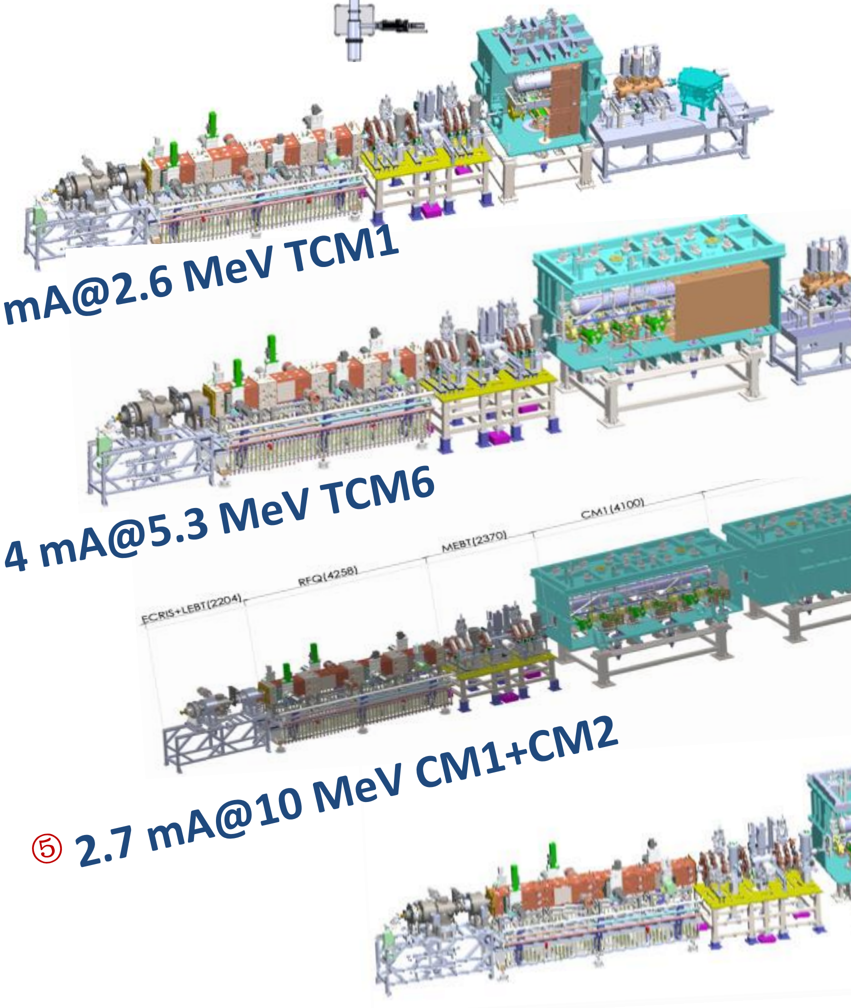
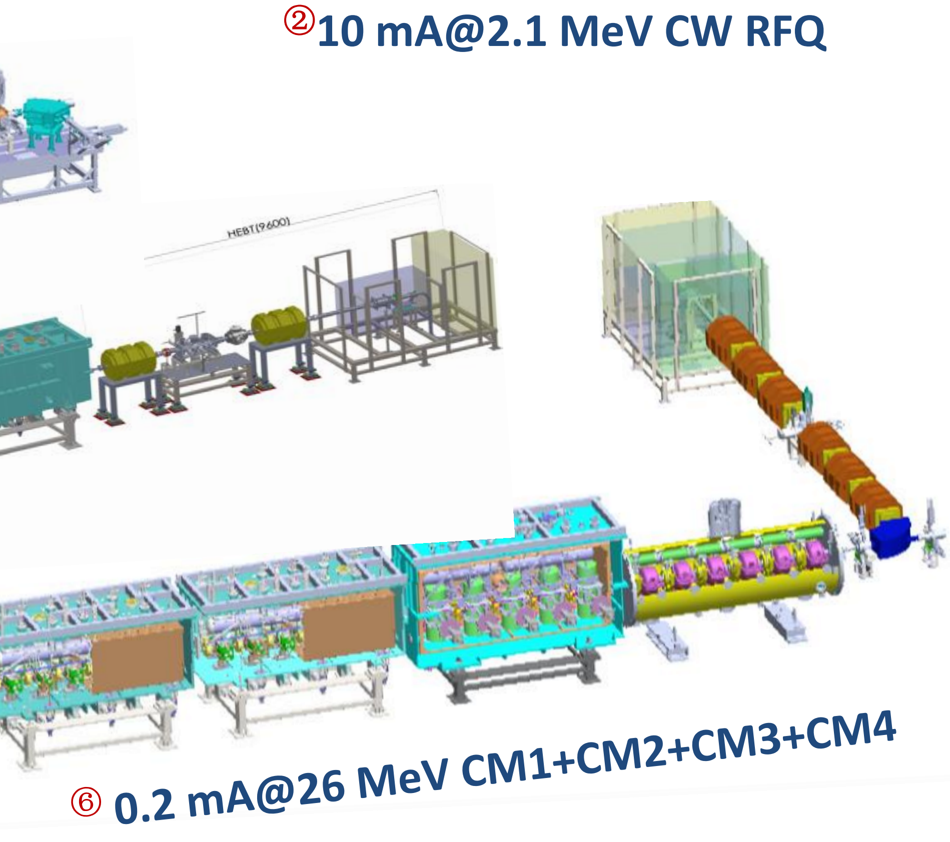
Superconducting Proton LINAC



①7mA@560 keV CW RFQ



②10 mA@2.1 MeV CW RFQ

③ 11 mA@2.6 MeV TCM1

④ 4 mA@5.3 MeV TCM6

⑤ 2.7 mA@10 MeV CM1+CM2

⑥ 0.2 mA@26 MeV CM1+CM2+CM3+CM4

Beam diagnostics in LINAC

LEBT

Wire Scanner	1

MEBT

ACCT	2
Wire Scanner (3 wires)	1
Wire Scanner (H/V)	2
BPM	5
Scraper(H/V)	3
Slit (H/V)	2
Emittance	2
FFC	1
FC(for high currents)	1

Test Cryomodule & Cryomodule 1,2,3

Cold BPM	1
Cold BPM	5
Cold BPM	5
Cold BPM	4

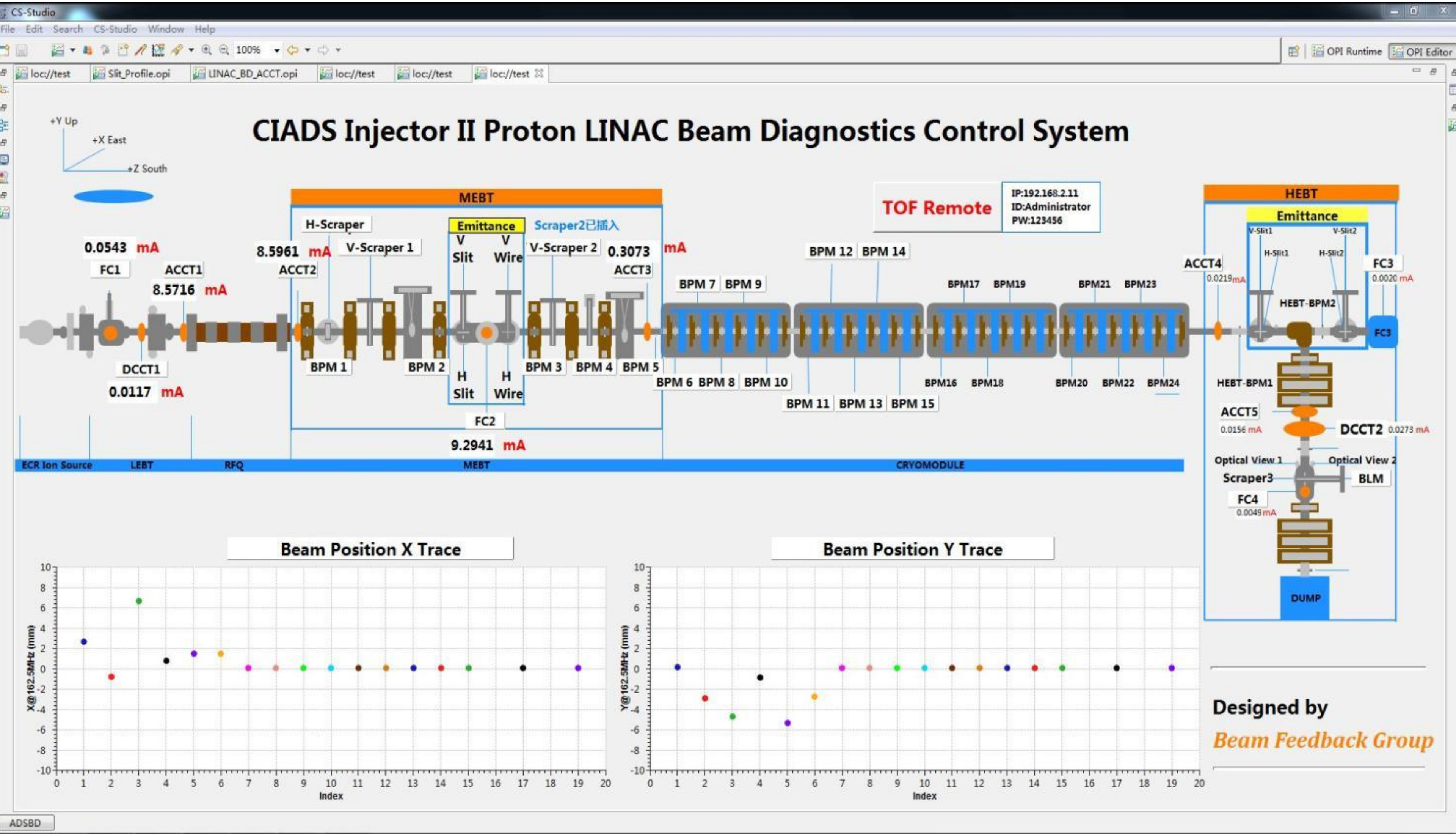
HEBT

ACCT	2
DCCT	1
BPM	4
Slit(H/V)	2
FC	1
Scraper(H)	1
Beam Loss Monitor	1
Momentum Spread	1

Movable Diagnostics Bench

ACCT	1
DCCT	1
BPM	3
Wire Scanner (H/V)	2
Slit(H/V)	2
FFC	1
FC	1
Momentum Spread	1
Pillbox cavity schottky	1

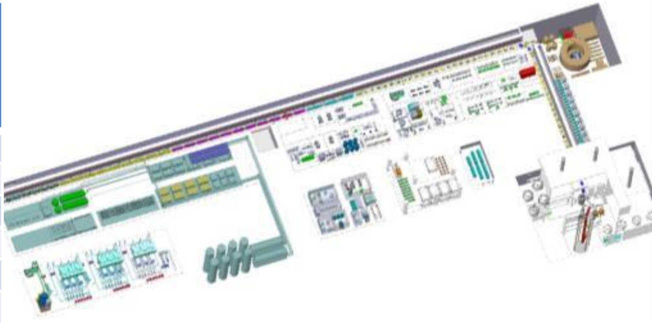
Beam diagnostics Interface



Future facility

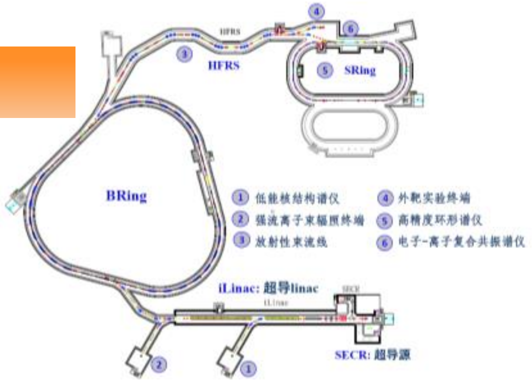
- **CiADS Beam Diagnostics: proton\ 10 mA @ 250 MeV**

Type	LEBT	MEBT	HWR 010	HWR 019	Spoke 042	Ellipse 062	Ellipse 082	HEBT
ACCT	1	2	1	1	1	1		2
DCCT	1	1	-	-	-	-		1
BPM	-	7	12	12	9	22	6	15
Emittance	-	2			1	1	1	2
High Power FC	2	1	-	1	1	1	1	2
Bunch Shape Monitor		1			-	-	-	1
Wire Scanner	-	1	1	1	1	1	1	1
Beam Loss Monitor		1						1

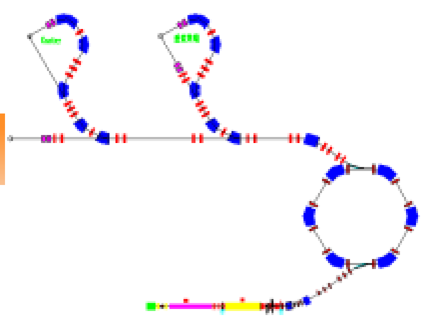


- **HIAF-iLINAC Beam Diagnostics: heavy ion\ 2 emA @ 17 MeV/u**

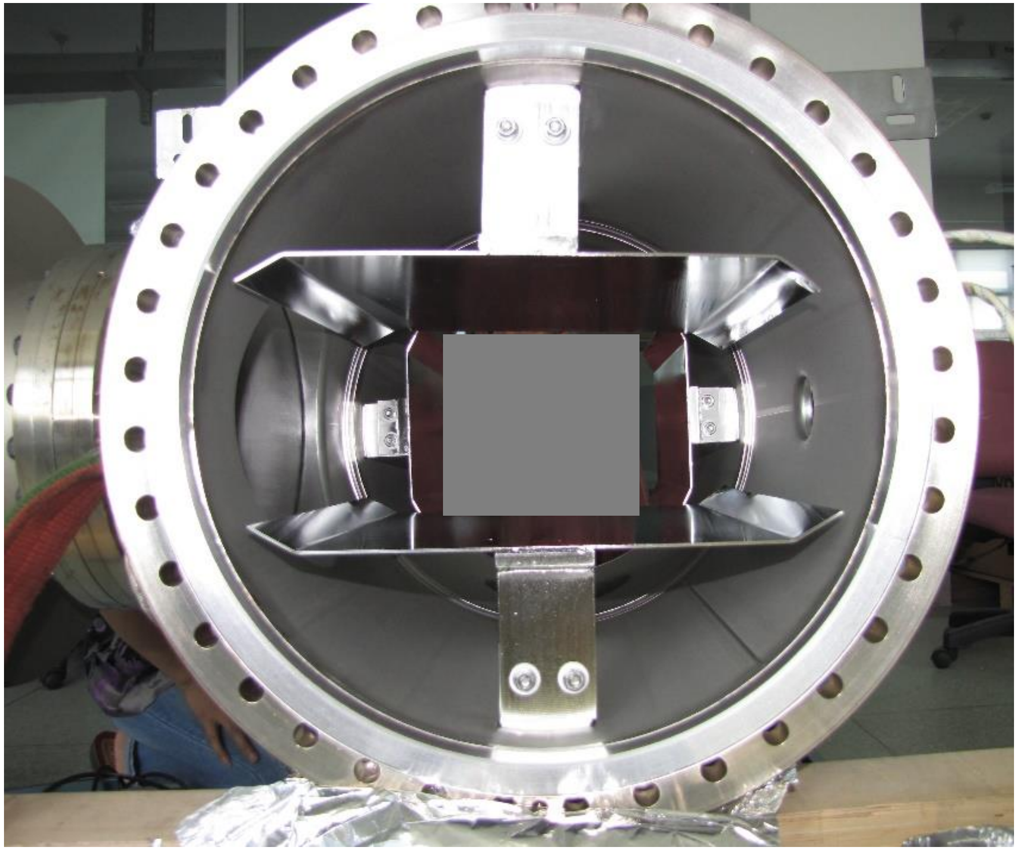
	MEBT	QWR 047	1.6 MeV	HWR 010	5.3 MeV	HWR 015	17 MeV
ACCT	2						1
BPM	5	15		15		12	
Scrapper	3						1
ES	1		1		1		1
FC	1						1
BSM	1		1		1		1
BLM			1		1		1



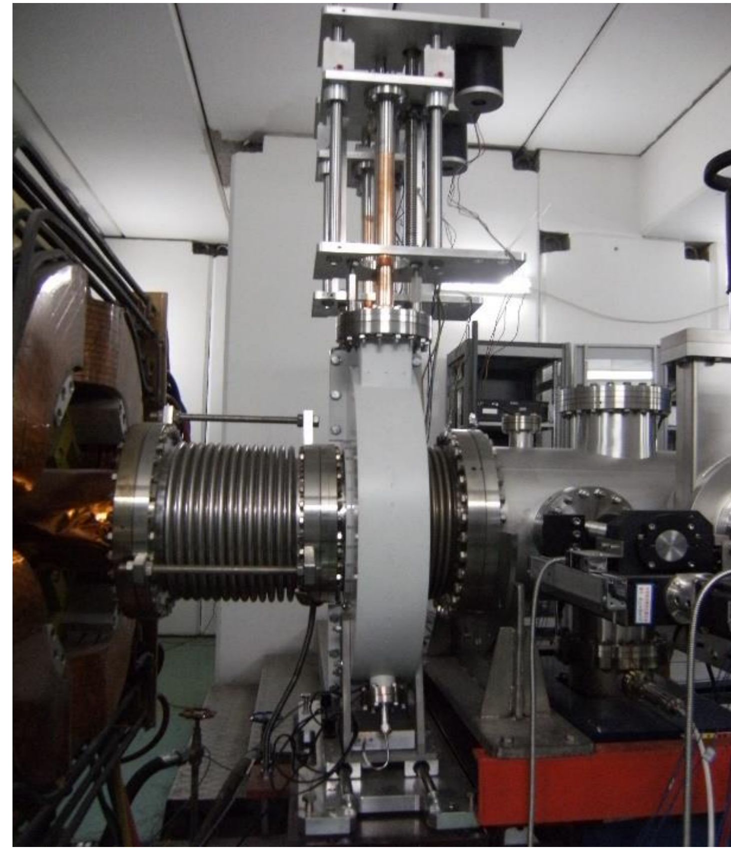
- **Proton Therapy Facility-LINAC Beam Diagnostics : proton\ 2 mA @ 7 MeV**



Schottky pickups at IMP



Capacitive pickup

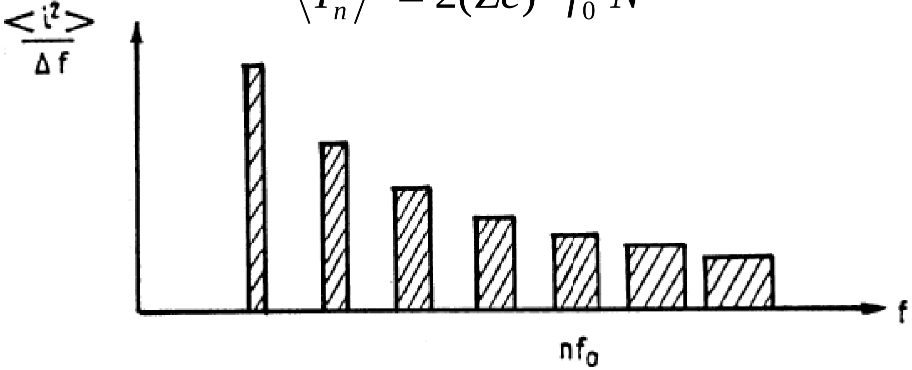


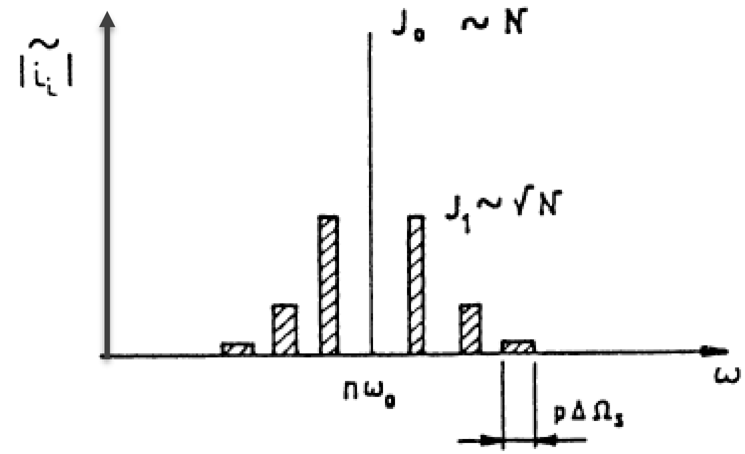
Resonant cavity
Collaborated with GSI

M. Bregman,, et al., Phys. Lett. 78B (1978) 174
ICE ring, antipron, 128 MHz

Longitudinal Schottky Signals

$$\langle I_n \rangle^2 = 2(Ze)^2 f_0^2 N$$



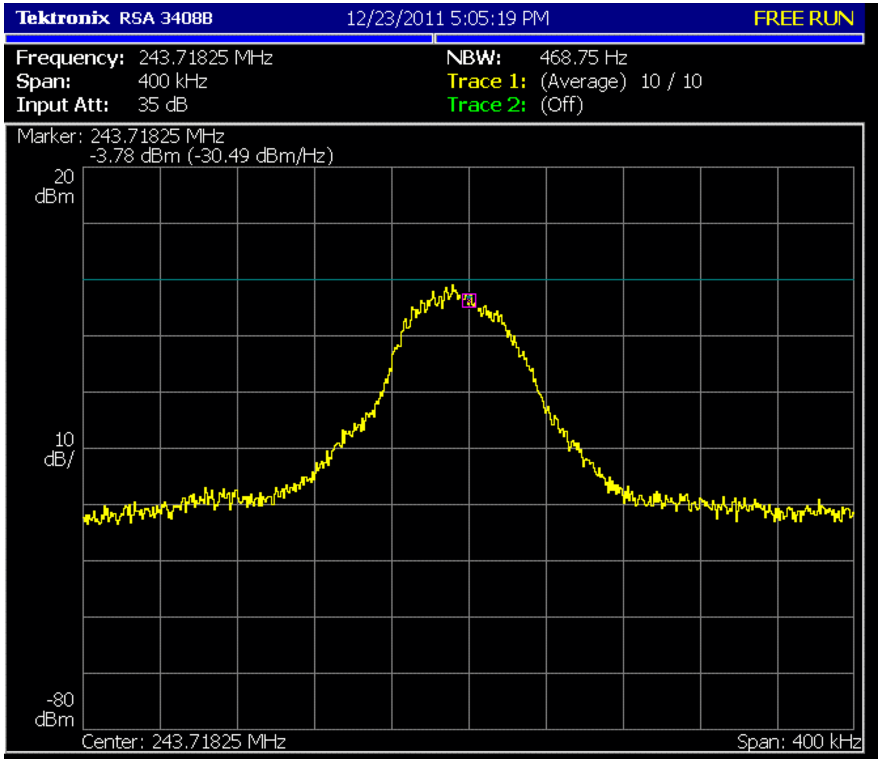


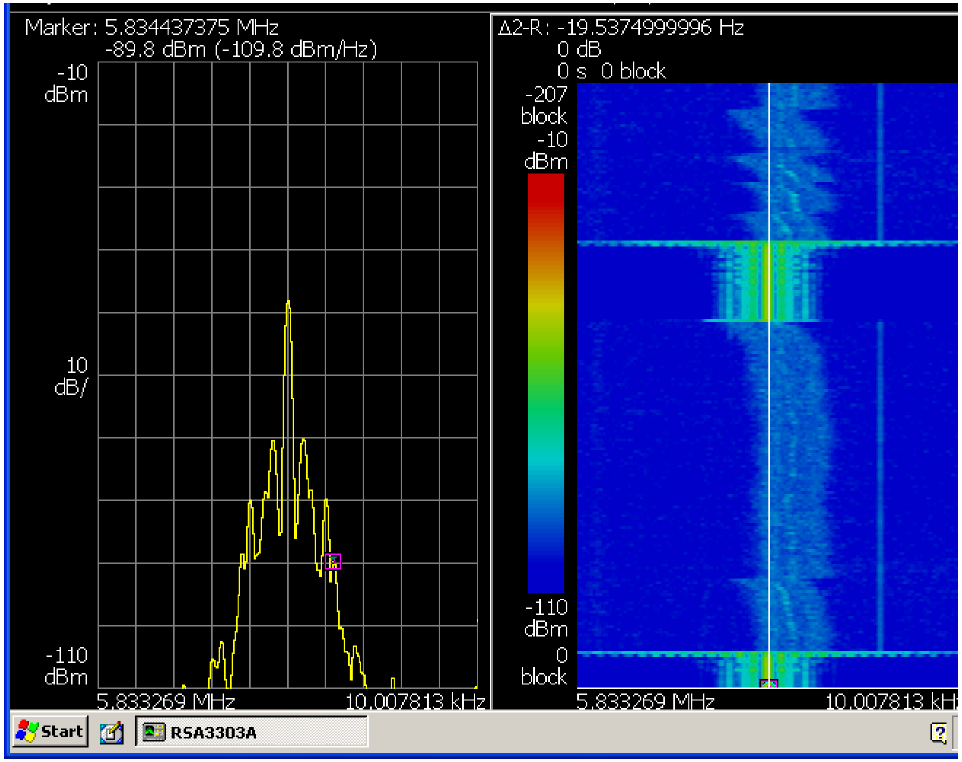
Schottky noise and beam transfer function diagnostics. D. Boussard

- **For coasting beam, total current per band is proportional to √N due to its incoherent distribution, power spectrum density P(*f*) in Δ*f*, P(*f*)=$Z_t(I_n^2/\Delta f)$**

- **For bunched beam, there is a modulation in time of the particles' passage through PU, spectrum splits into several lines due to synchrotron oscillation**

Longitudinal Schottky Signals



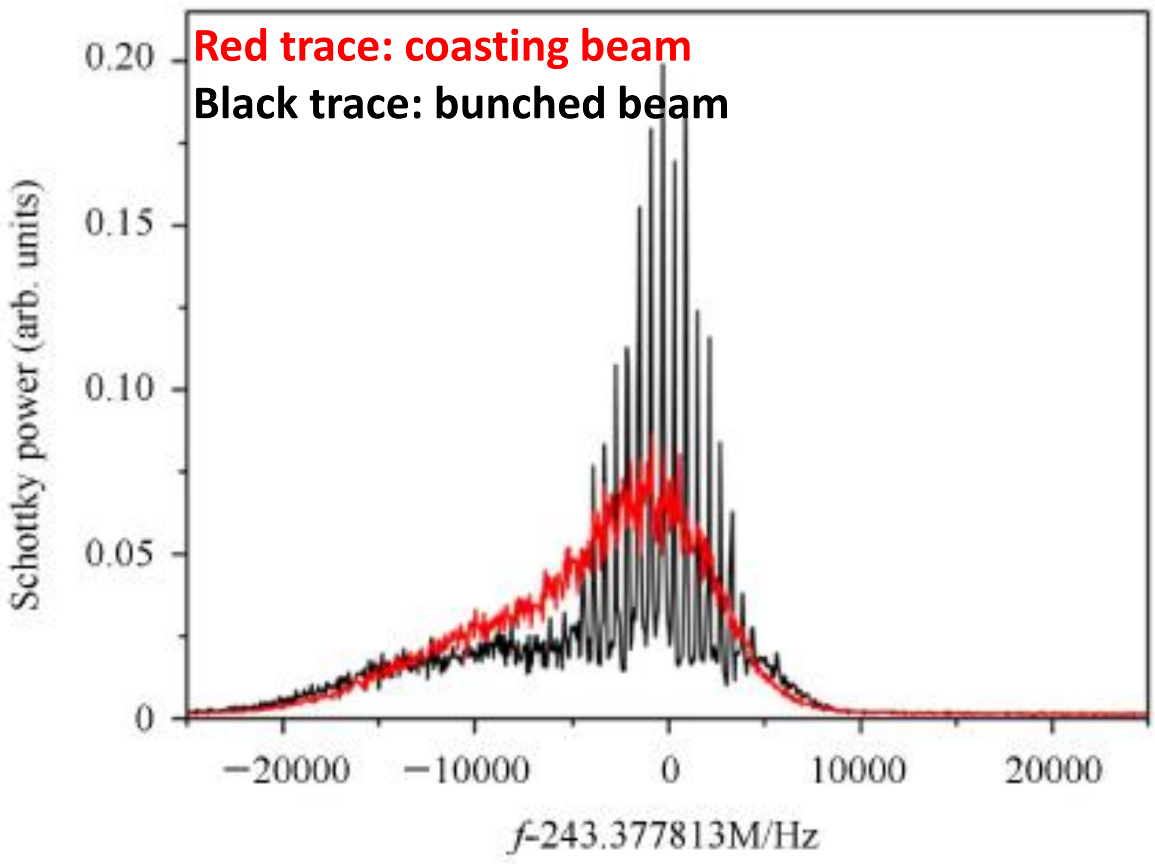


Schottky signals observation in our ring

Longitudinal Schottky Signals

- **For small N with random phase, insufficient S/N.**

Nuclear mass and lifetime measurement, even one particle detection

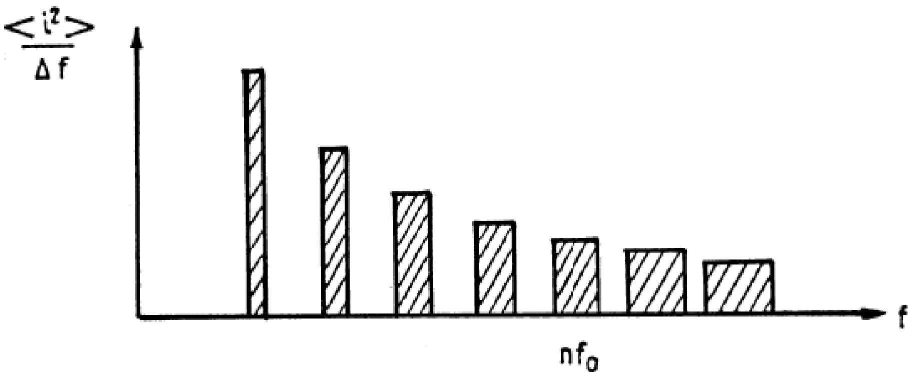


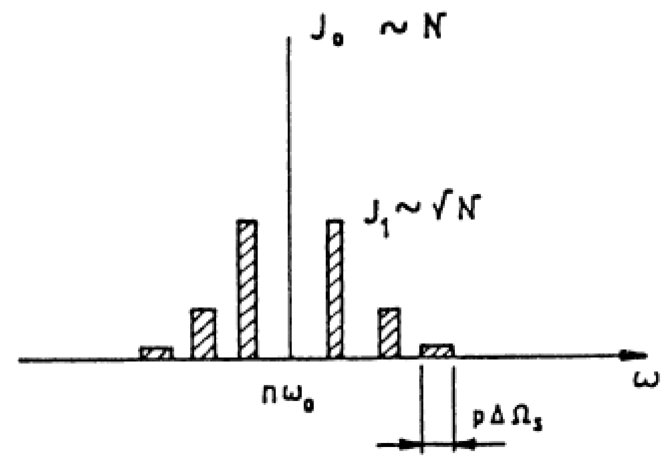
Same particle number

Resonant Schottky pickup

- **Output power of the resonant Schottky cavity PU**

$$P_p = (Ze)^2 f_0^2 N \frac{R_s}{Q} Q_L$$





Shottky noise and beam transfer function diagnostics. D. Boussard

Resonant Schottky pickup

For mass measurement of unstable exotic nuclei or their isomeric states, the observation time is needed to get a certain required line separation.

- Transient spectrum of an excitation current after K passages of a single particle

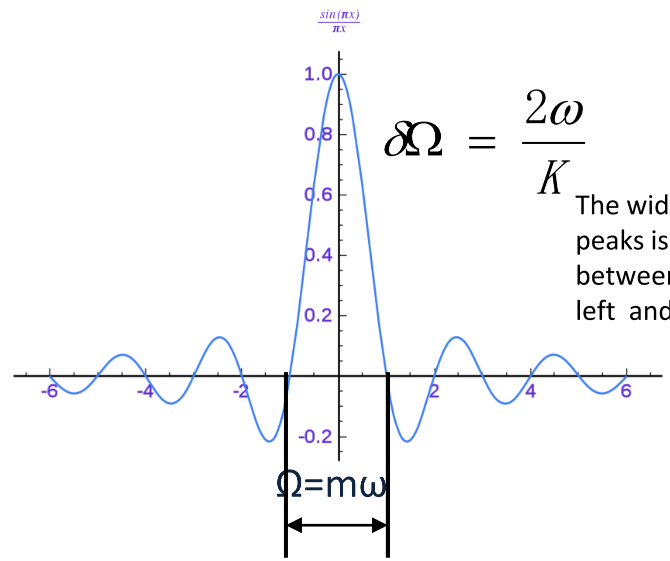
$$I_K(t) = Ze\sum_{k=0}^{K-1}\delta(t - kT)$$

- Fourier transform of this current is peaked at the revolution harmonics Ω=mω with sidelobes.

$$\tilde{I}_K(\Omega) = Ze\frac{\sin(K\Omega T/2)}{\sin(\Omega T/2)}e^{i(K-1)\Omega T/2}$$

- Different nuclear species separated by δω

$$\frac{\delta\omega}{\omega} = \eta\frac{\delta(\beta\gamma)}{\beta\gamma} - \alpha_p\frac{\delta(m/q)}{m/q}$$



$$\delta\Omega = \frac{2\omega}{K}$$

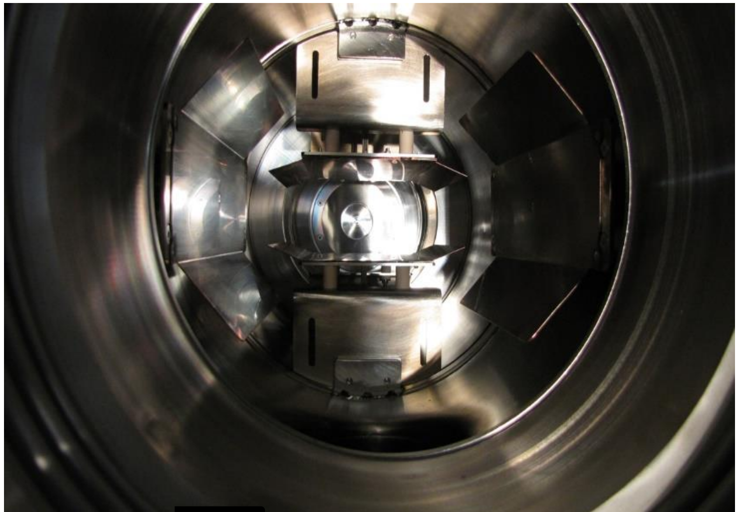
The width of central peaks is the distance between the first left and right zeroes

- To separate the different nuclear species at m^th harmonic, δΩ<mδω

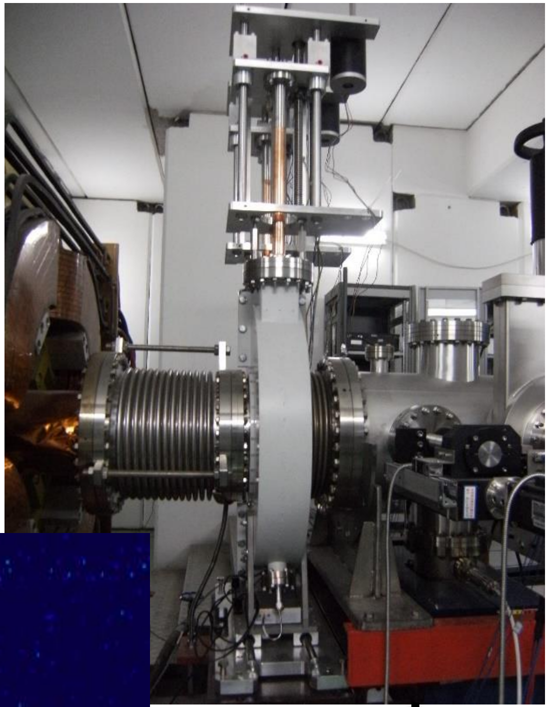
$$\frac{2}{mK} < \frac{\delta\omega}{\omega}, m\uparrow, K\downarrow$$ high observation harmonics *m* lead to short measurement times

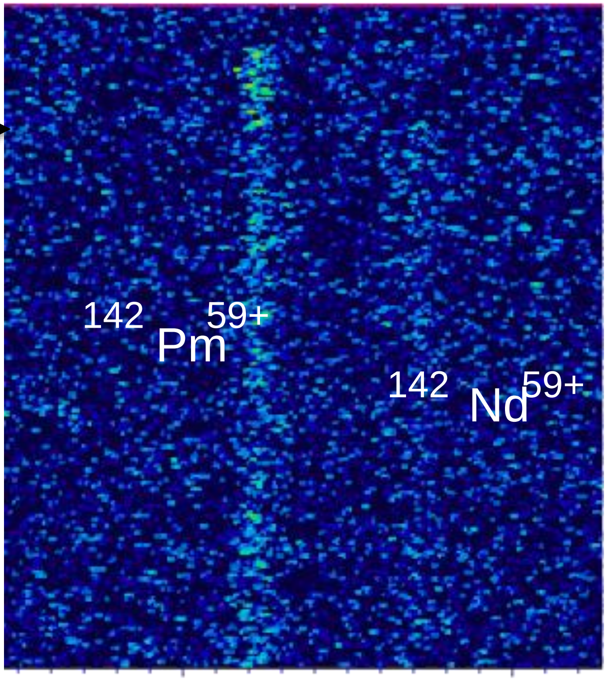
■ F.Nolden, NIM A 659(2011) 69-77

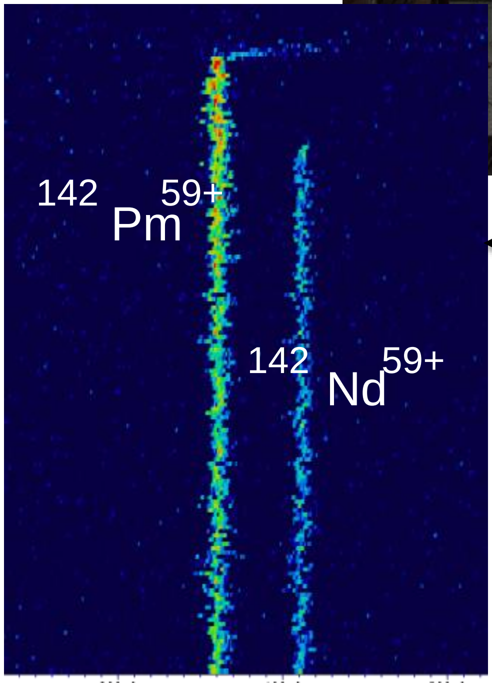
S/N between two pickups at GSI



- The same decay: improvement by a factor of about 100



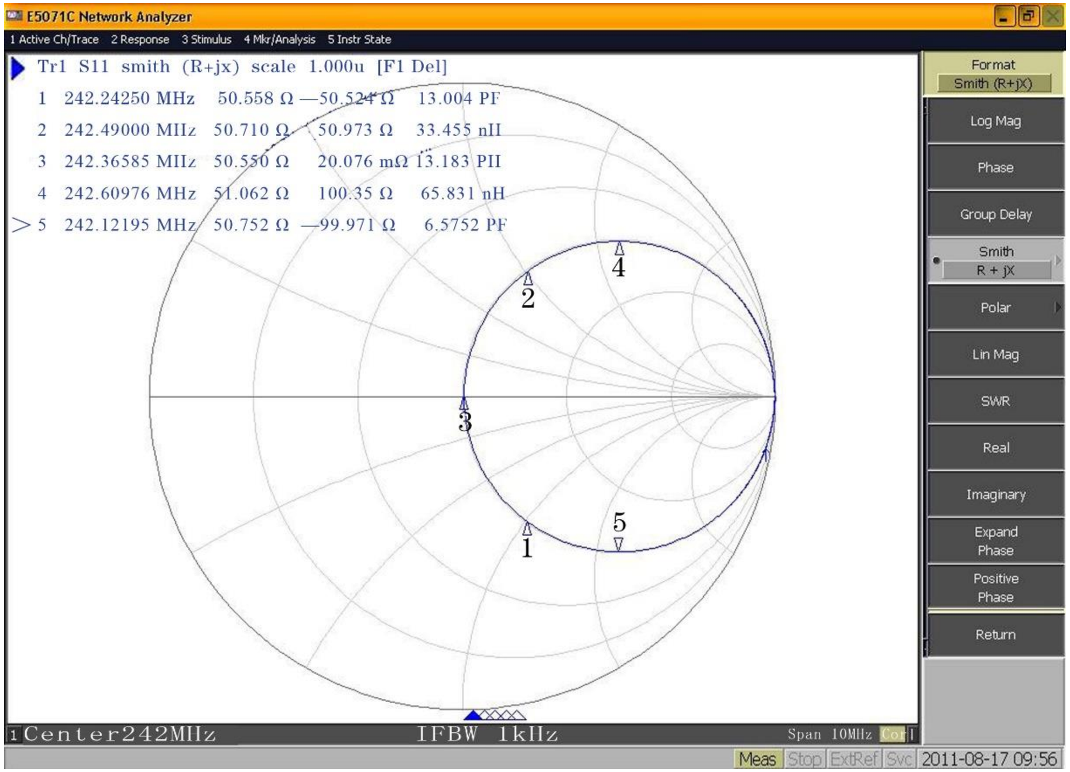




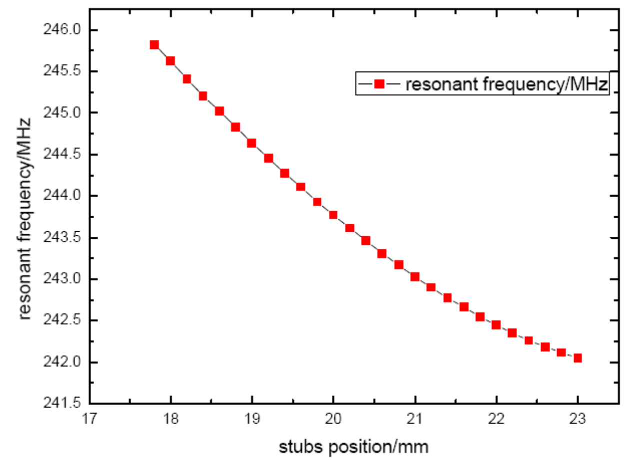
Old Schottky Pickup (1992)
30^{th} harmonic

New resonator Cavity (2010)
124^{th} harmonic

Resonant Schottky pickup

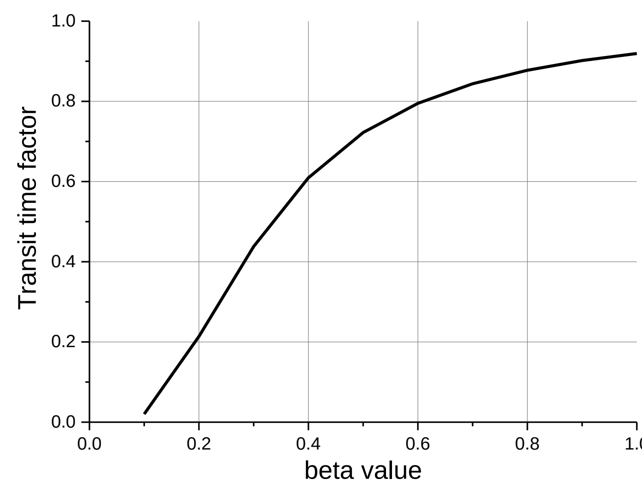


Resonant frequency & piston position



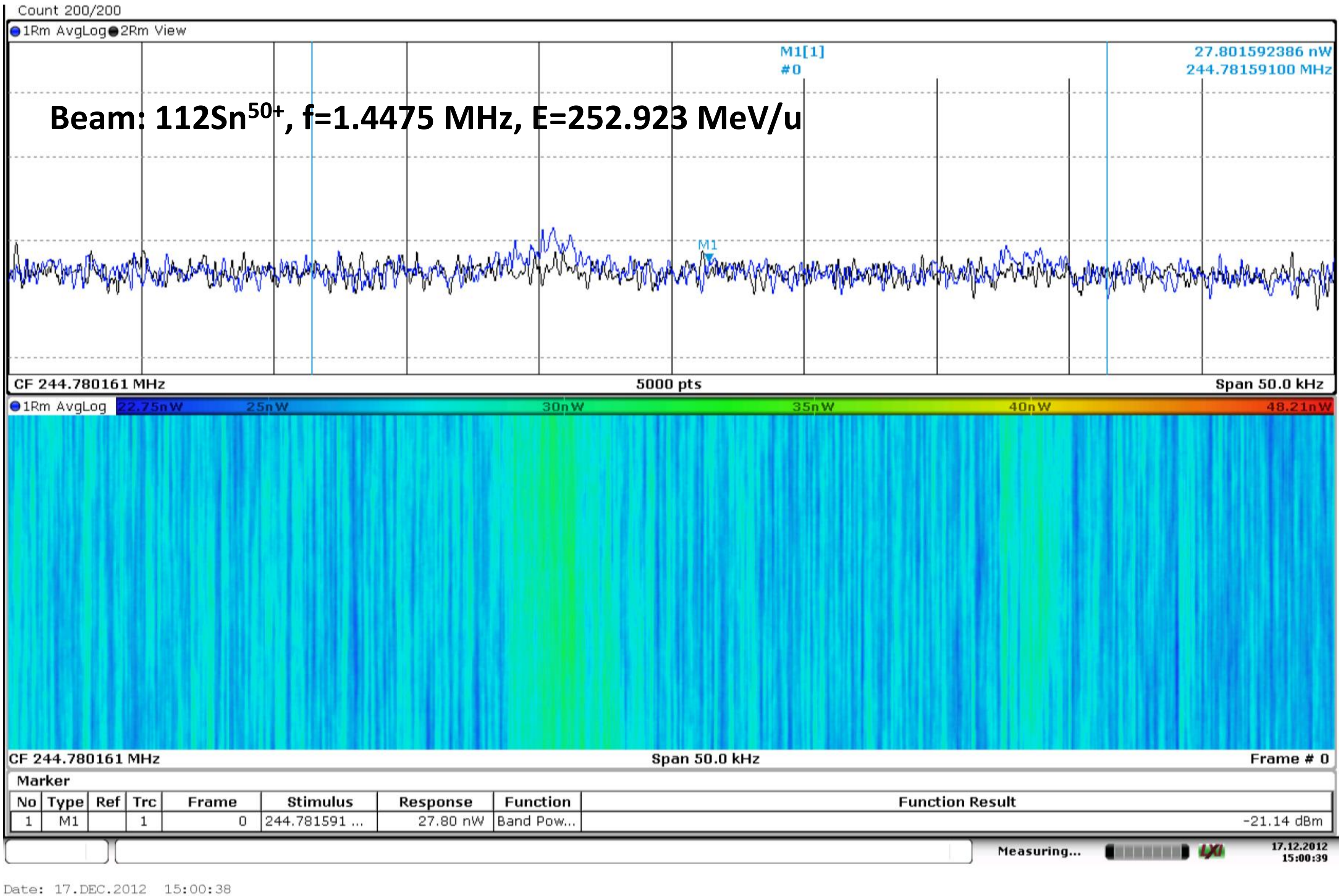
Frequency (MHz)	244 ± 2
Q	979
Q_L	497
R/Q (ohm)	Simulated: 51.8
	Measured: 48.1

Transit time factor & beta values



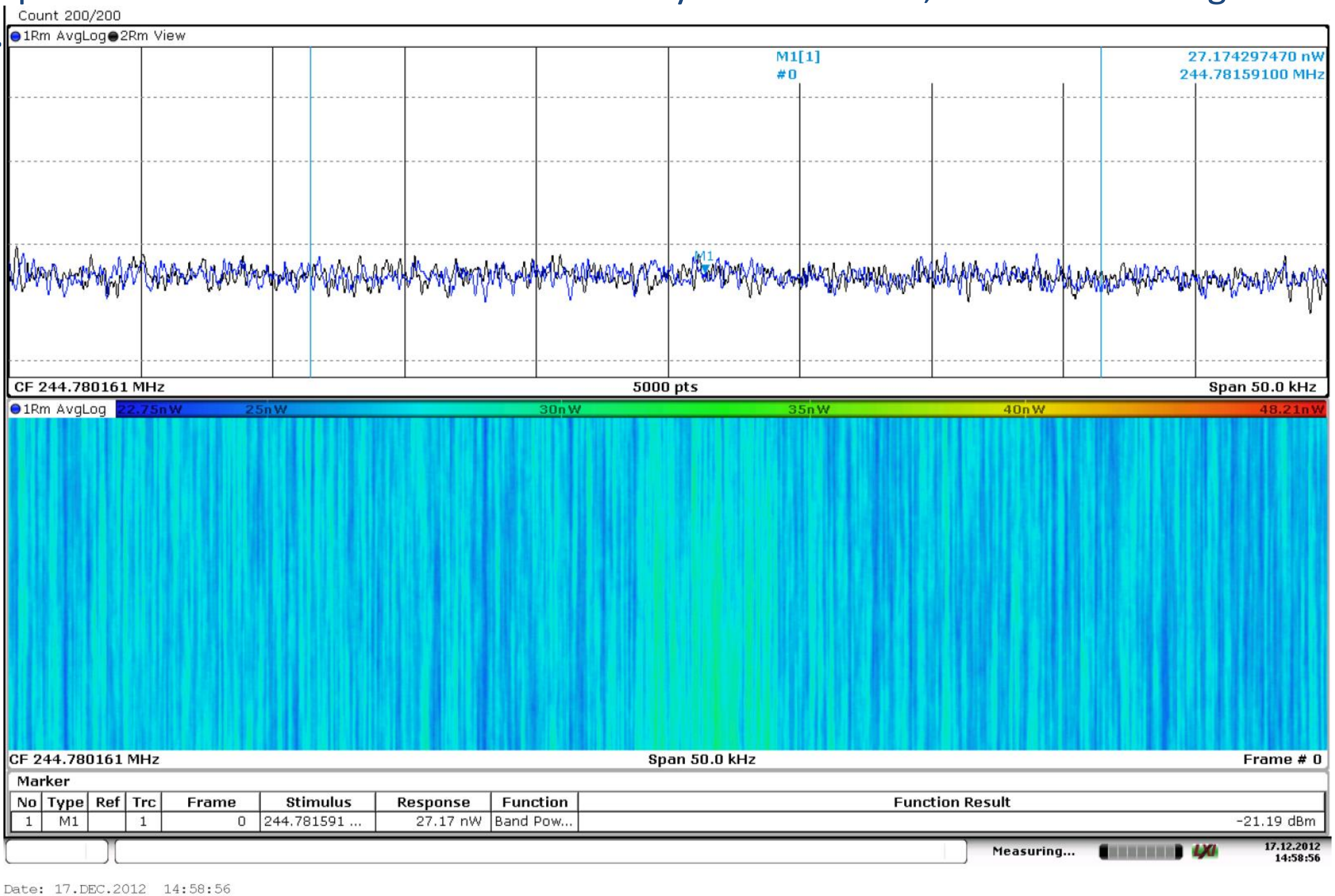
Resonant Schottky pickup for one particle detection

Beam: 112Sn^{50+}, f=1.4475 MHz, E=252.923 MeV/u

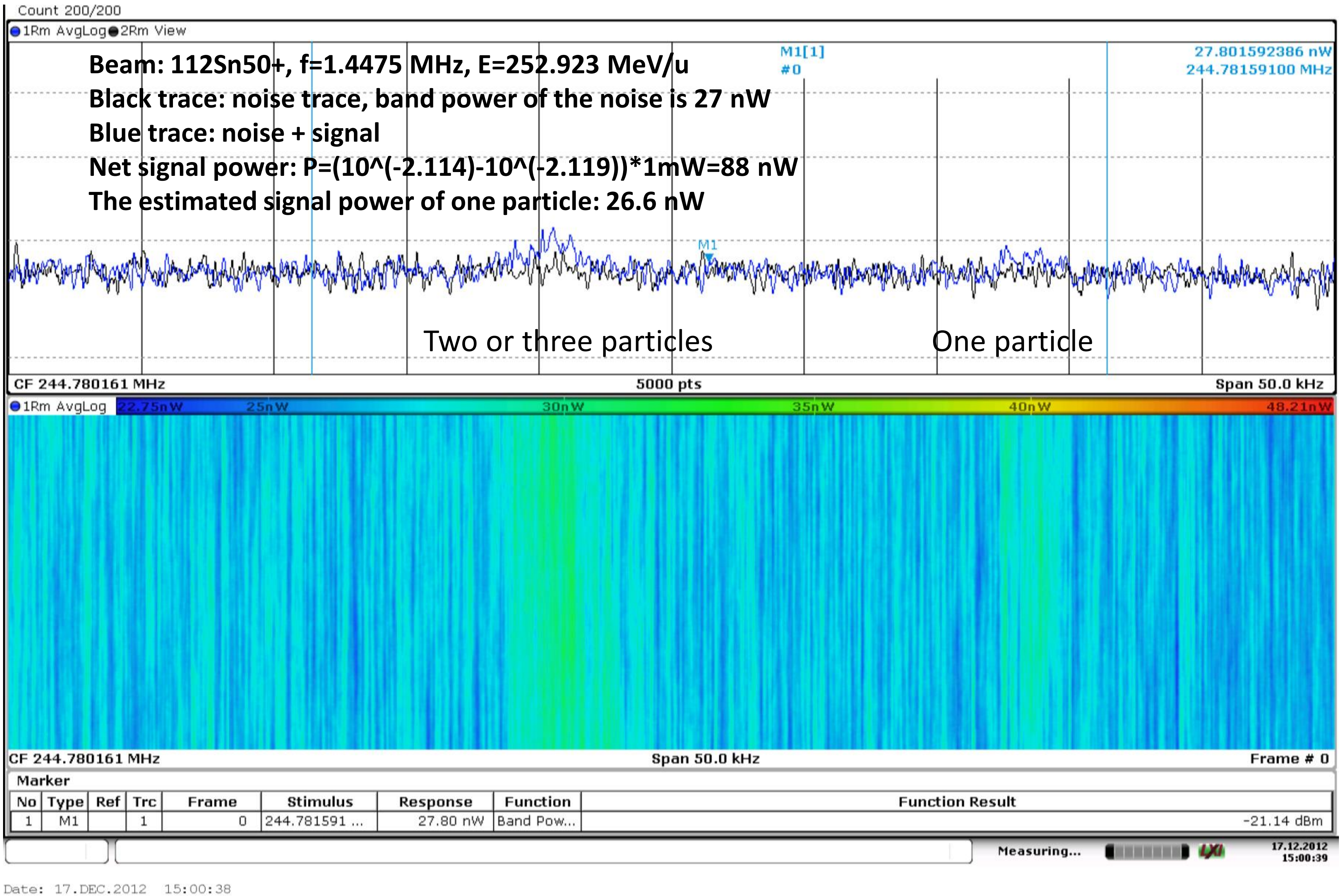


Resonant Schottky pickup-one particle detection

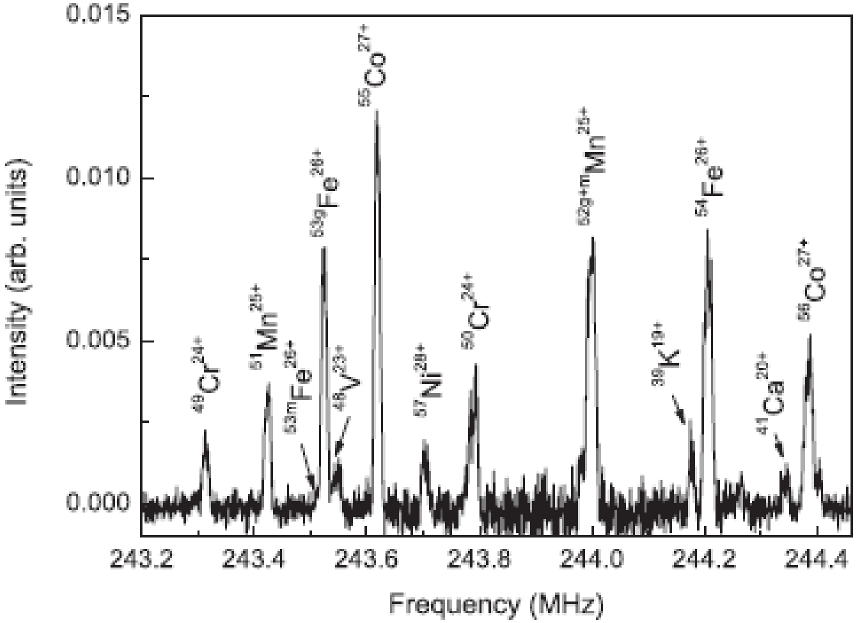
To perform this detection, the intensity of injected beam to CSRe was slowly decreased until sometimes there was signal on the resonant cavity and sometimes there was nothing except noise. The experimental condition was confirmed by TOF detector, which can recognize single particle well.

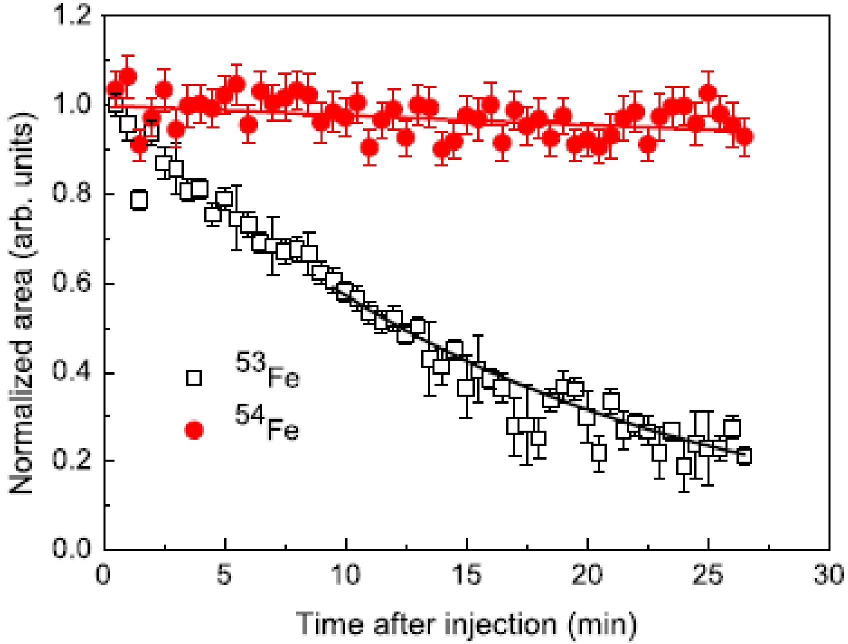


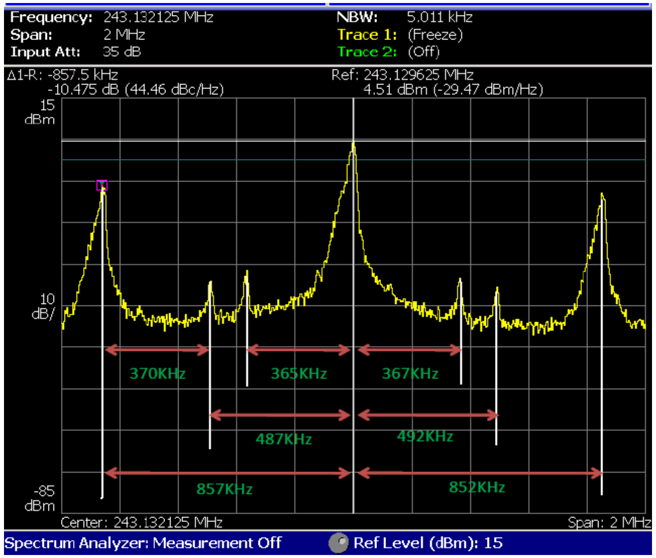
Resonant Schottky pickup-one particle detection

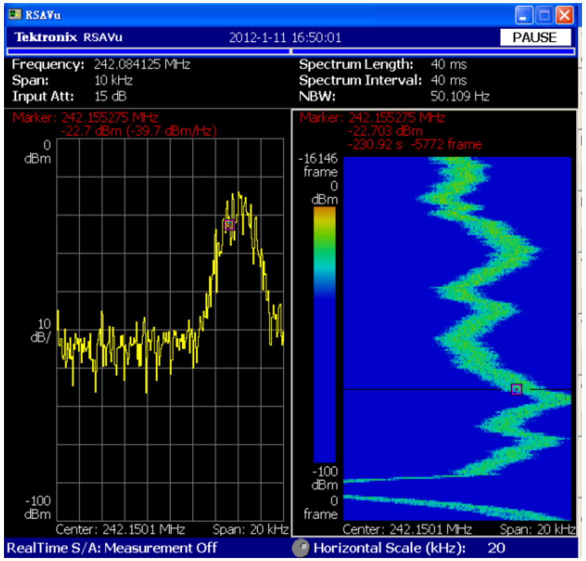


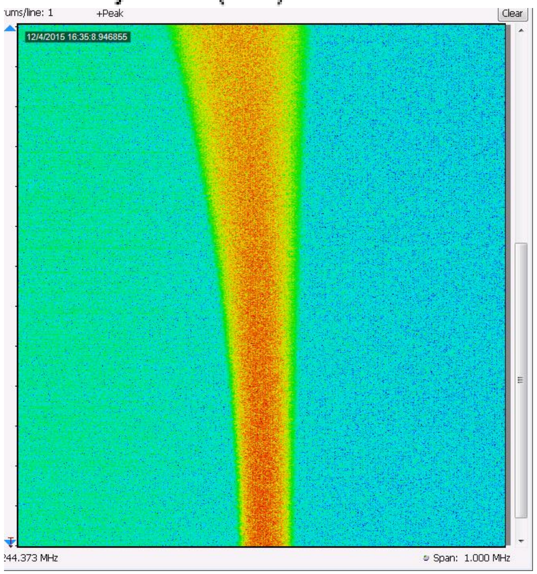
Resonant Schottky pickup performance at IMP







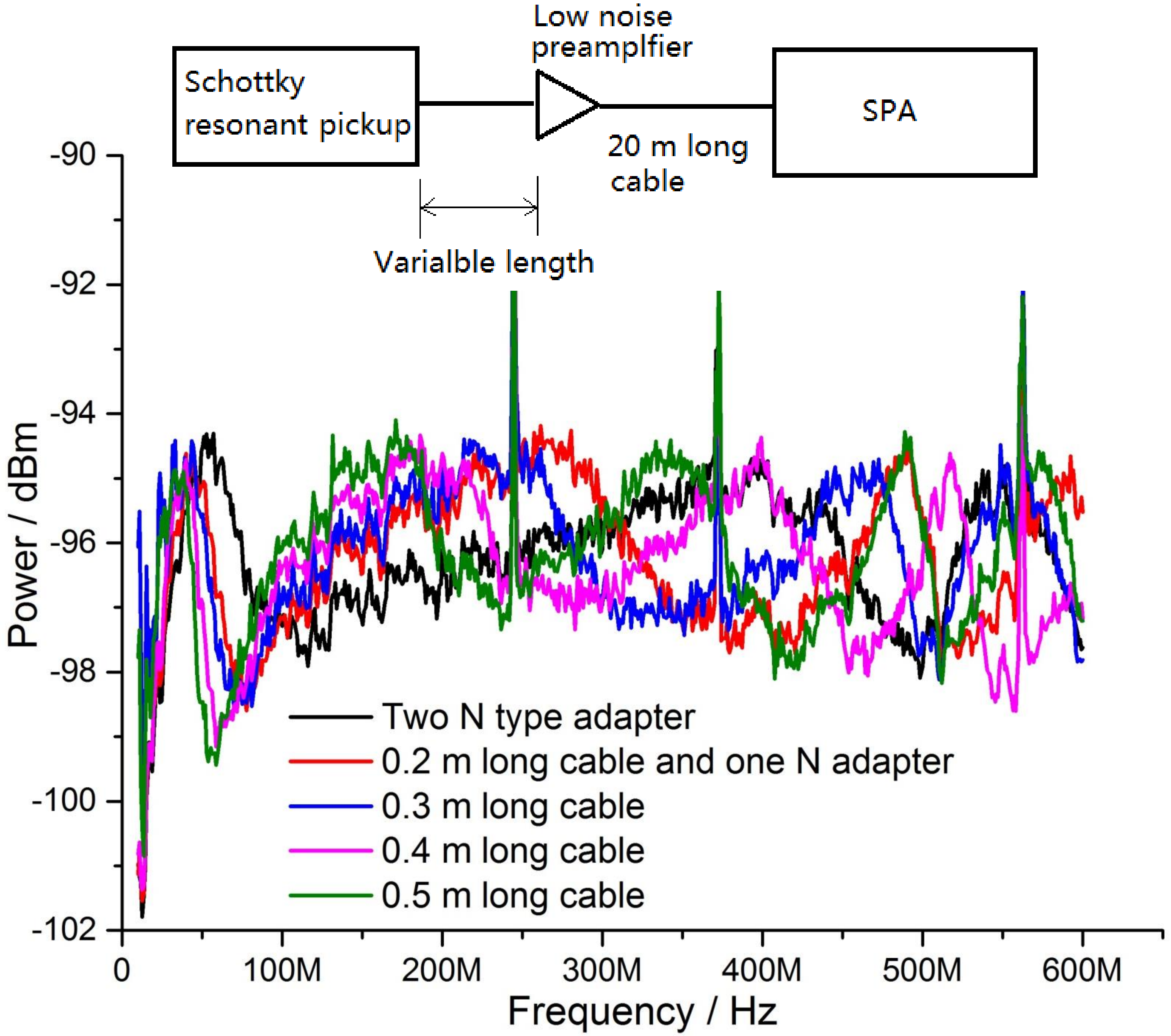




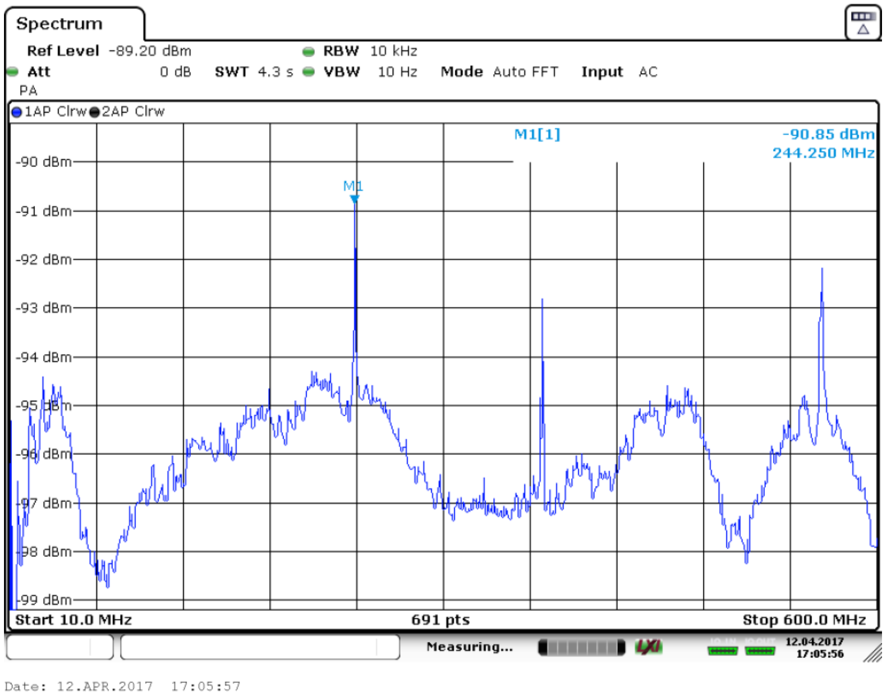
Contents

- Schottky pickups at IMP
- Noise match measurement of the Resonant Schottky pickup

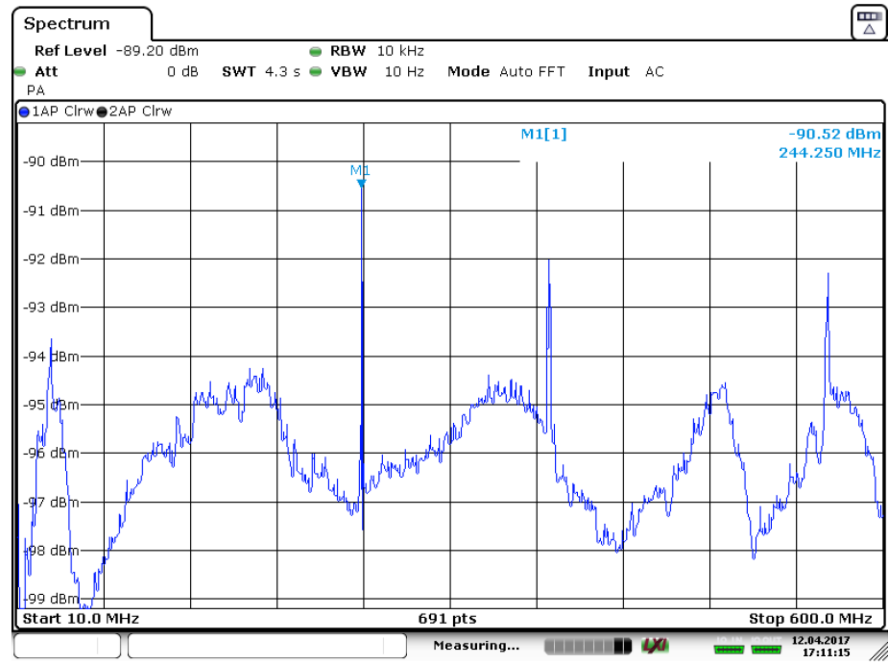
Noise spectrum from Resonant Schottky pickup



Noise spectrum from Resonant Schottky pickup

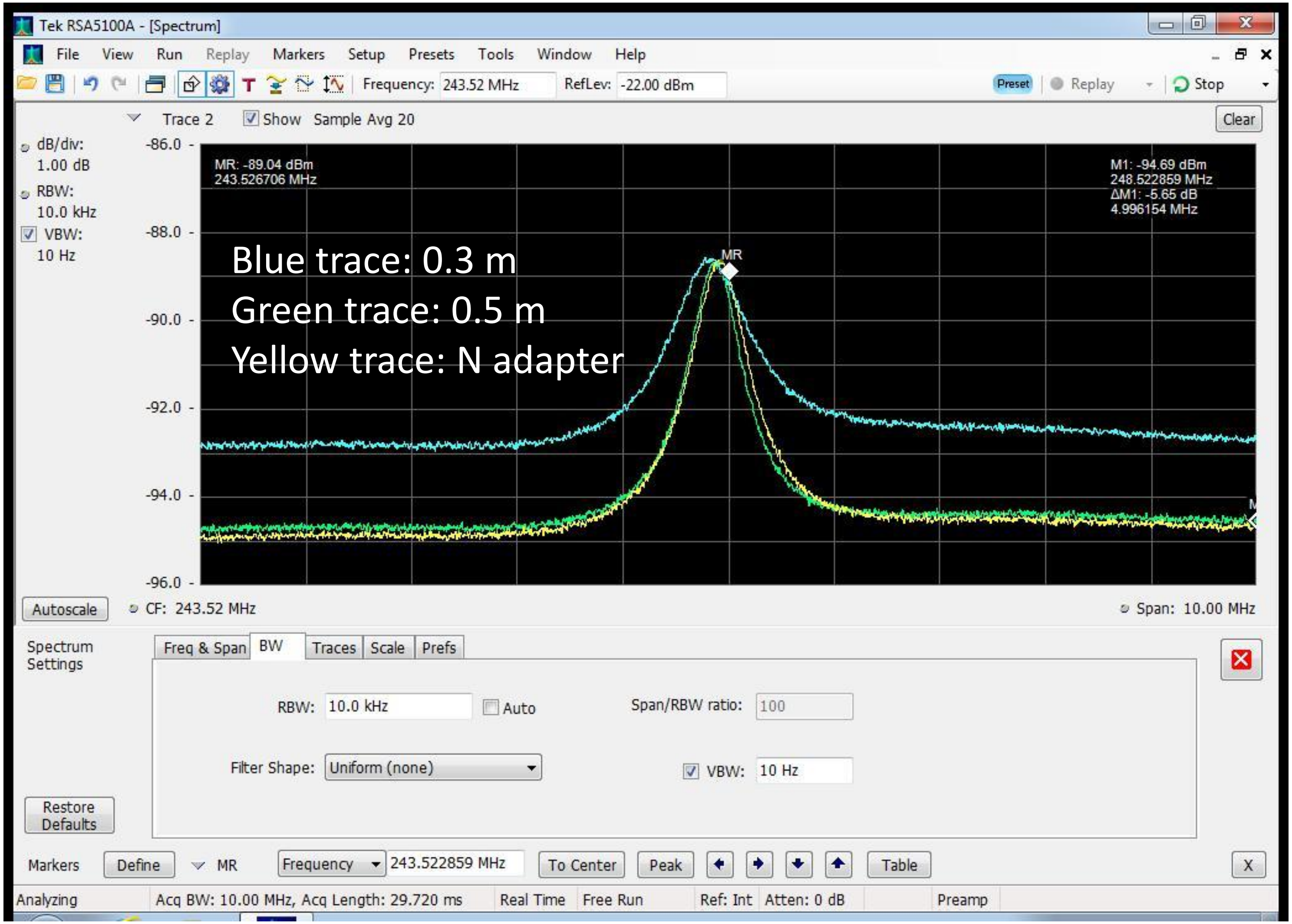


Noise Spectrum - 0.3 m long cable



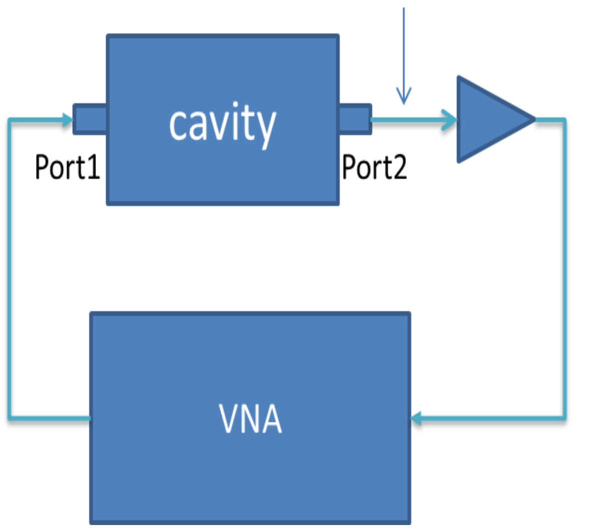
Noise Spectrum - 0.5 m long cable

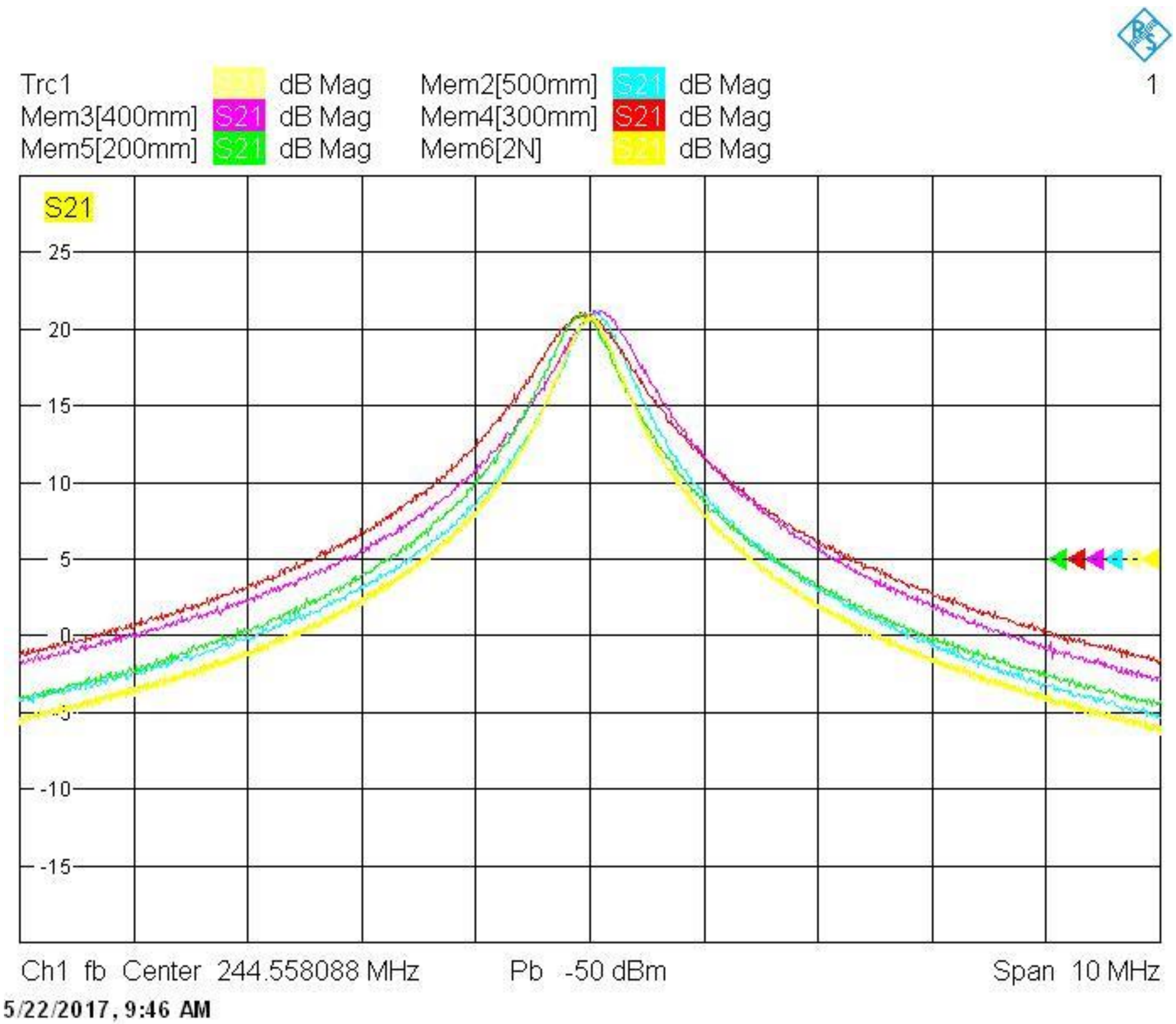
Noise spectrum from Resonant Schottky pickup



S21 measurement of the Resonant Schottky pickup

Variable length, 2 N connectors,
0.3 m, 0.4 m, 0.5 m

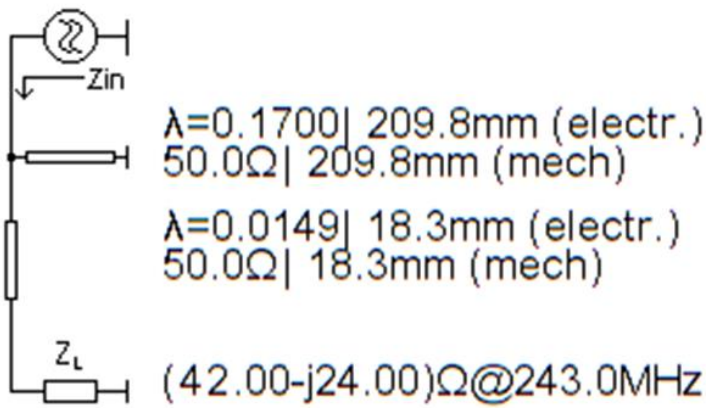


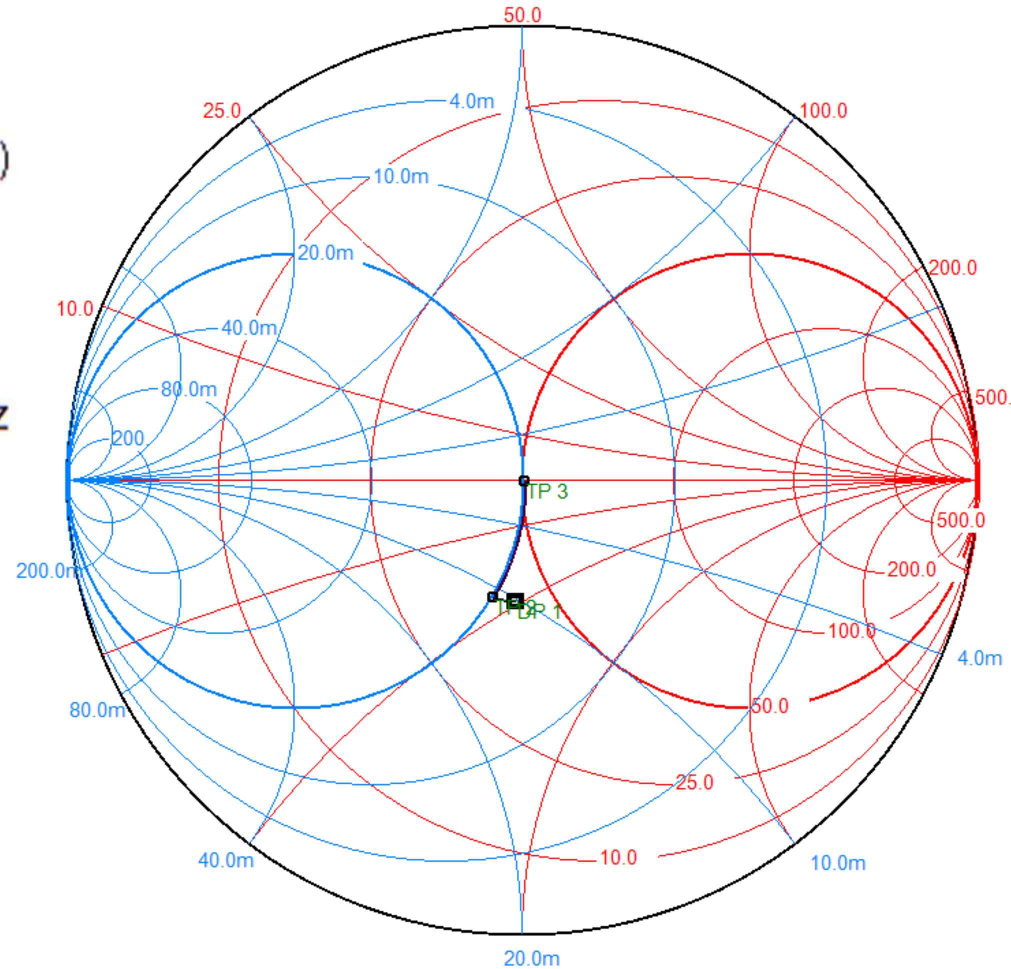


The resonant frequency is shifted.
The loaded Q is changed.

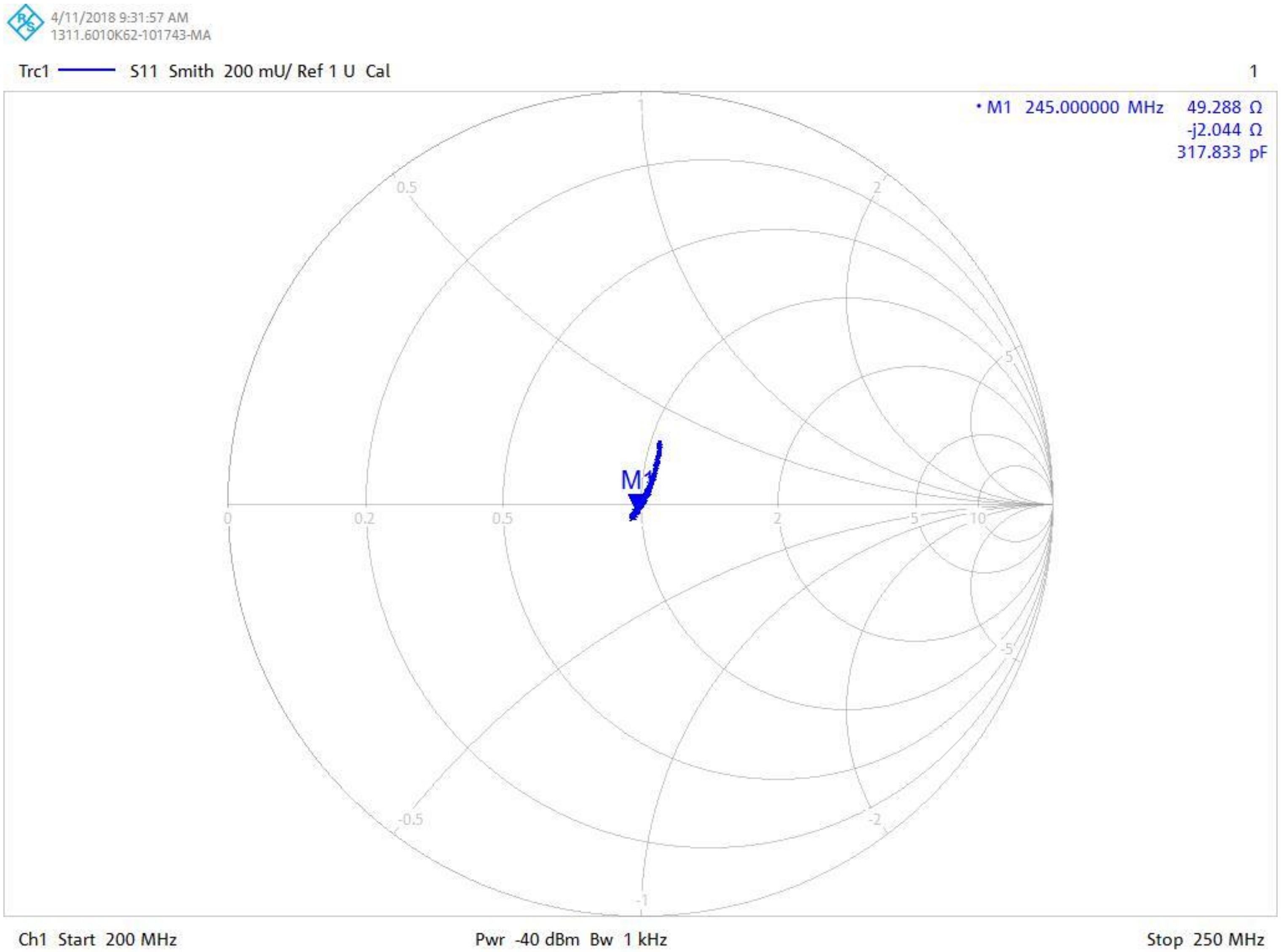
S11 of the preamplifier

Impedance match circuit to the preamplifier



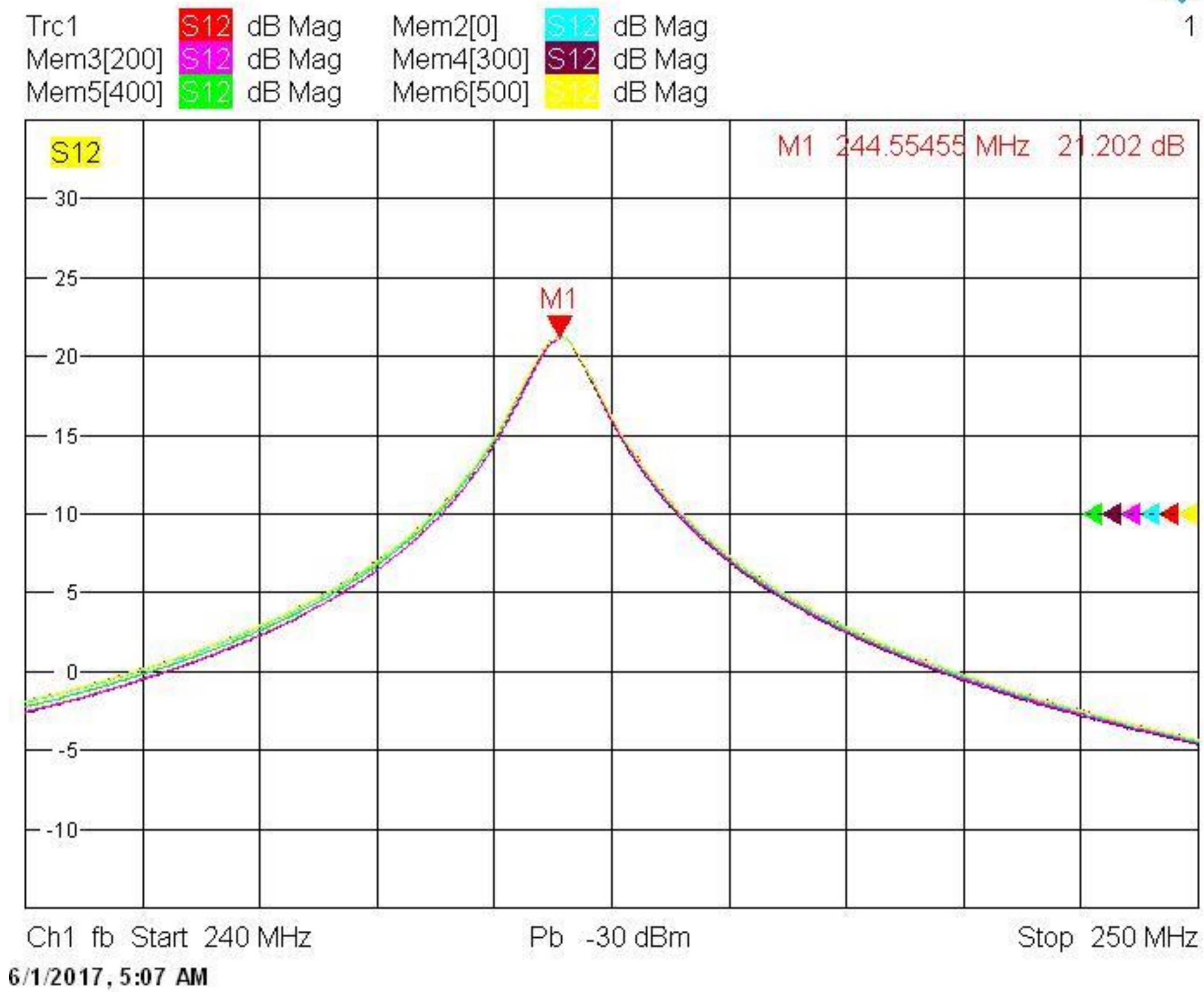


S11 of the preamplifier - after impedance match



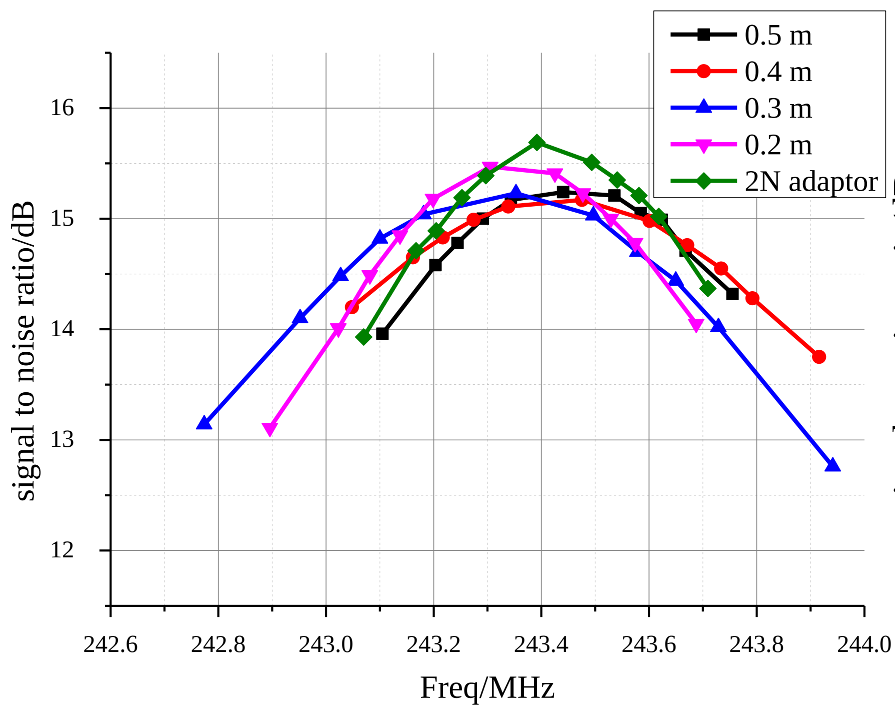
S21 measurement of the Resonant Schottky pickup

With impedance match, the resonant frequency and Q value are independent to the cable length

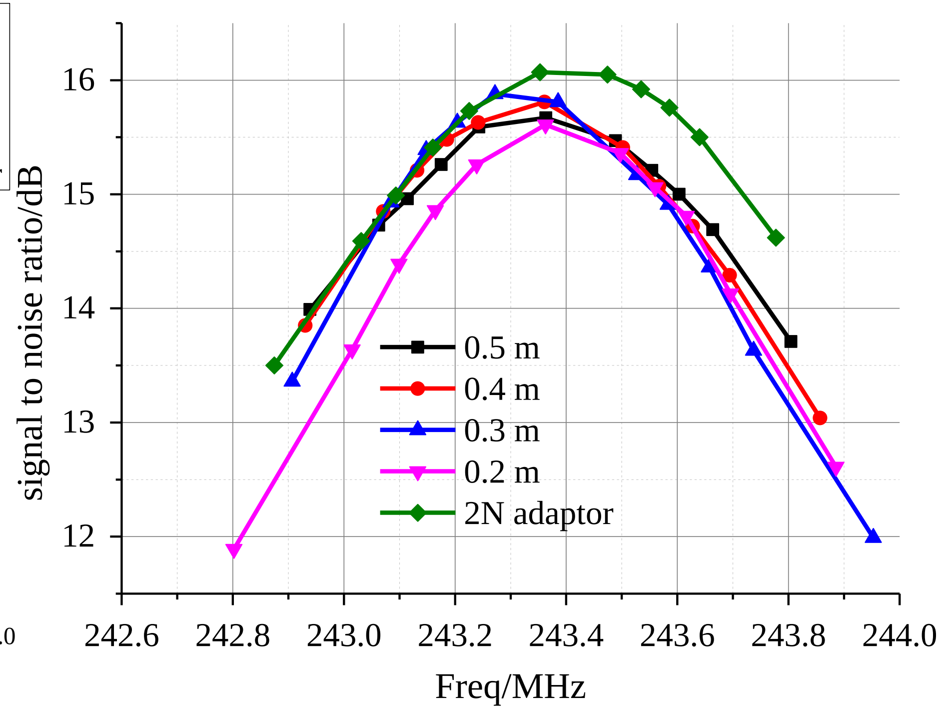


S/N measurement for Resonant Schottky pickup

Variable length, N connector,
0.2 m, 0.3 m, 0.4 m, 0.5 m

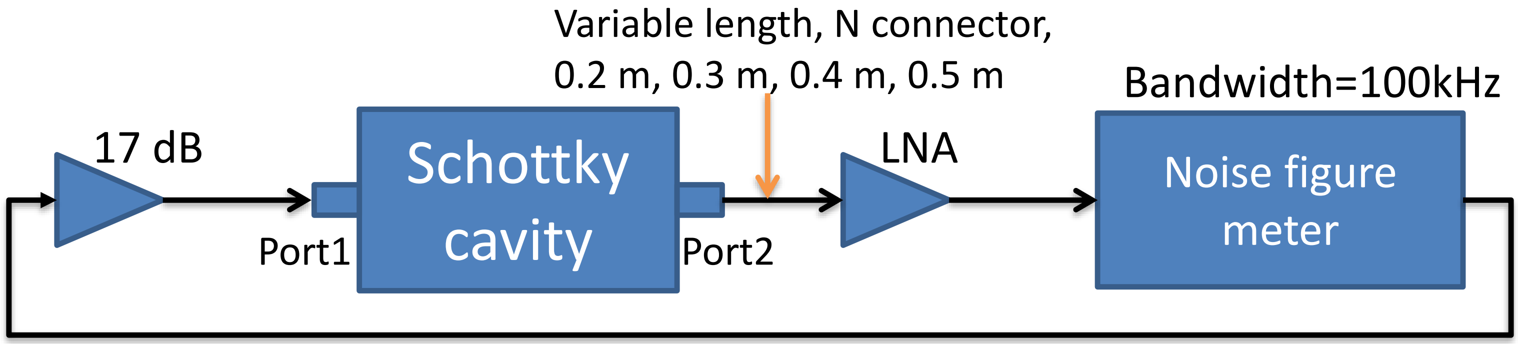


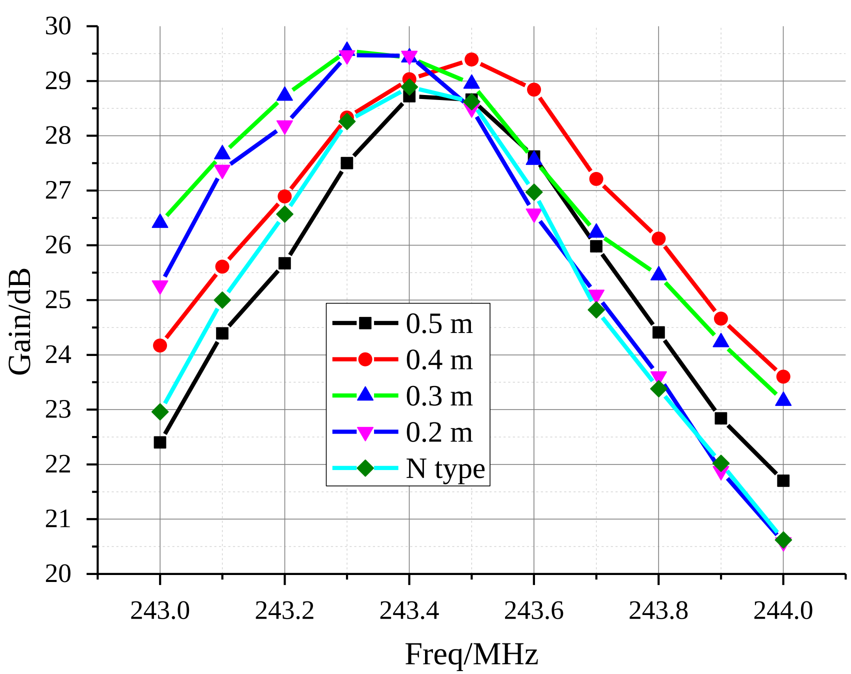
Without impedance match to the preamplifier



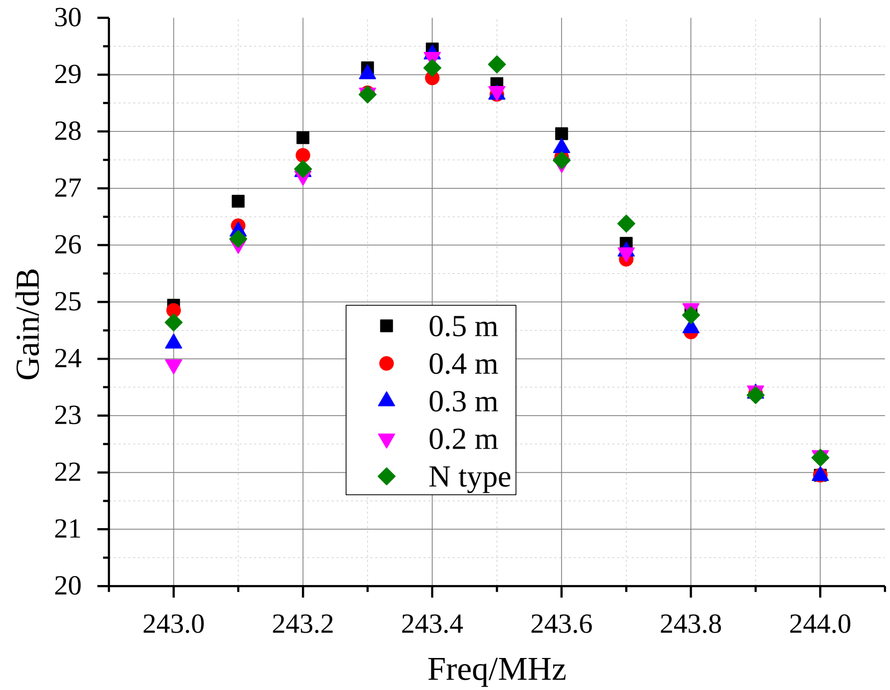
With impedance match to the preamplifier

Gain measurement with a noise figure meter



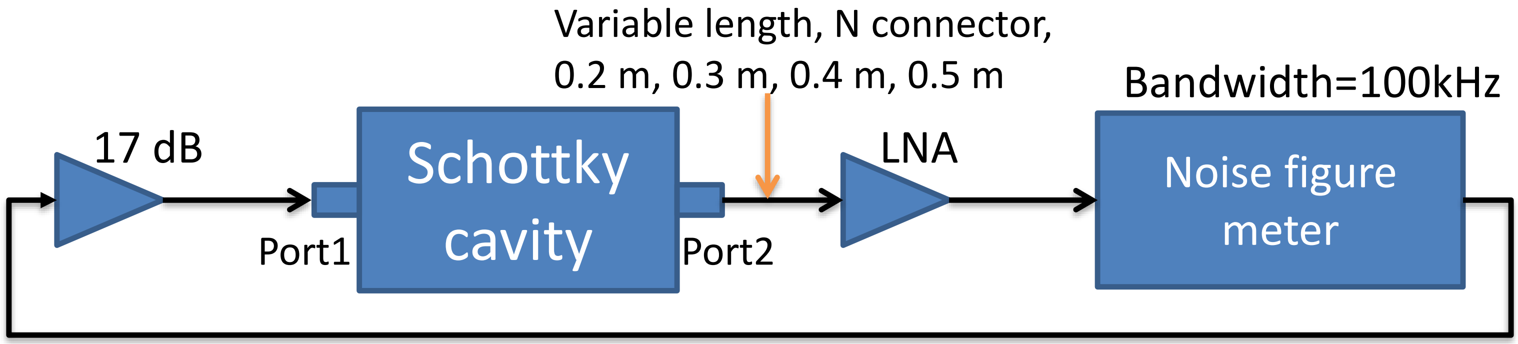


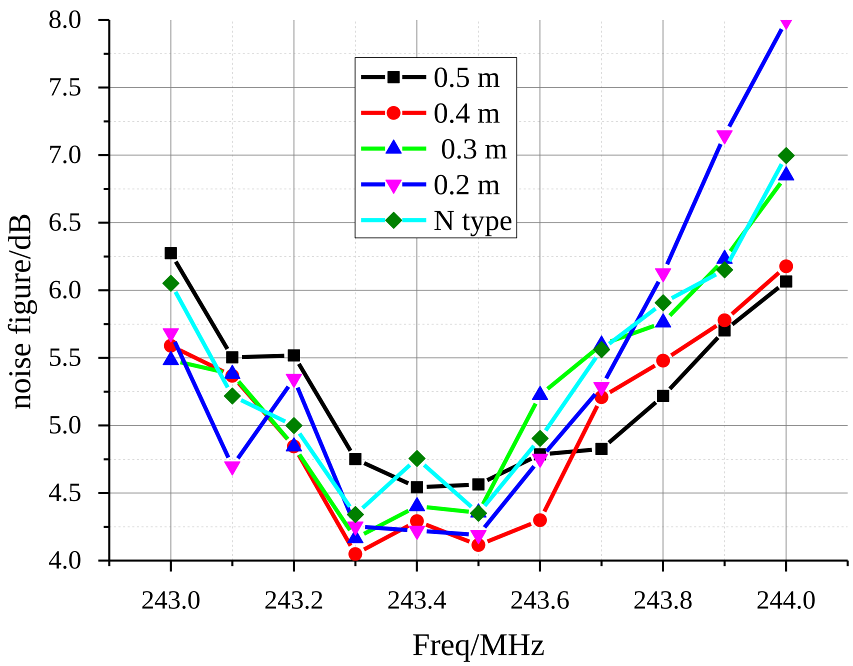
Without impedance match to the preamplifier



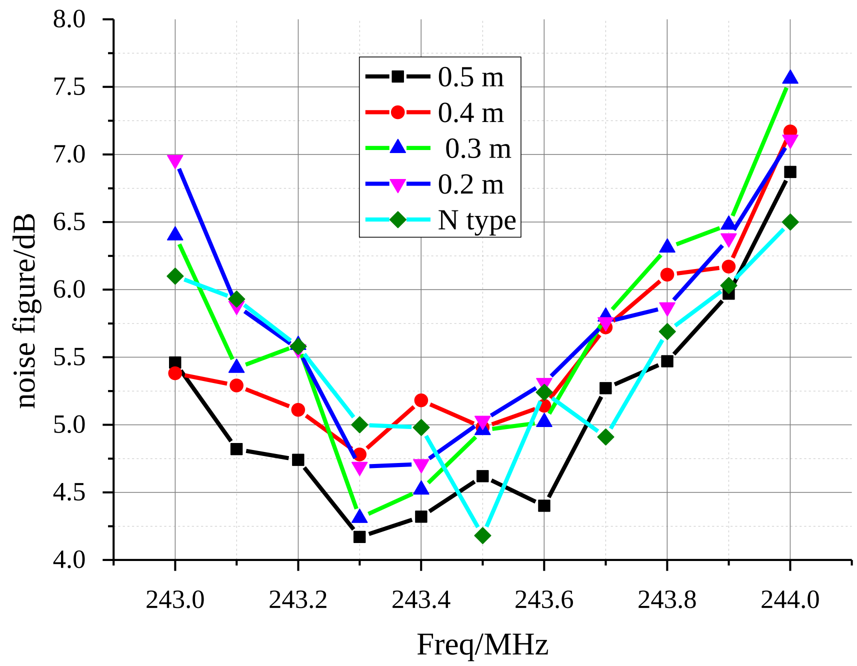
With impedance match to the preamplifier

NF measurement with a noise figure meter





Without impedance match to the preamplifier



With impedance match to the preamplifier

Conclusions

- The length of the transmission line between cavity and preamp has a significant impact on the loaded Q value of the cavity due to rather strong mismatch of the input of the LNA.
- To have a defined Q value and optimum power transfer, we did the impedance matching.
- With impedance match circuit, the loaded Q are independent of the cable lengths.
- But different cable lengths yield different S/N ratios.
- To have a compromise between the noise match and power match, we need to do further work.

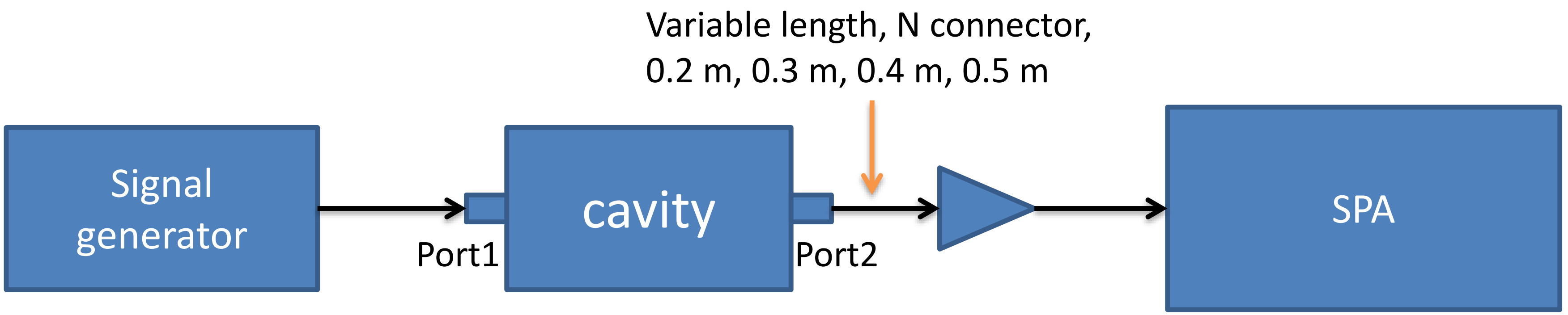
Great thanks to:

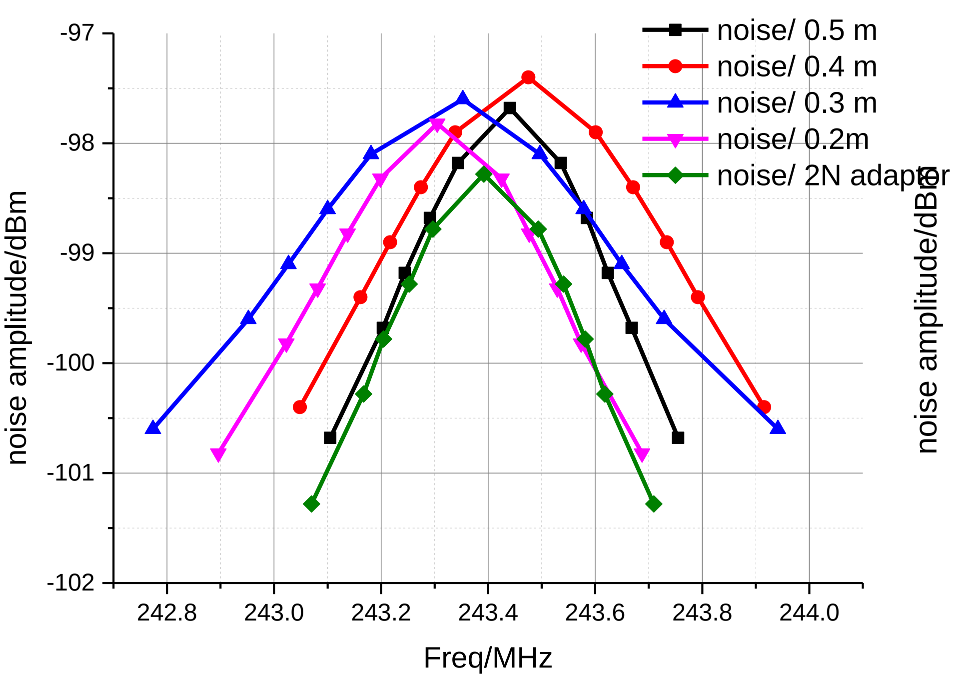
- **Rhodri Jones, Peter Fork, Madeleine Catin, ……**
- **ARIES**

Thanks for your attention.

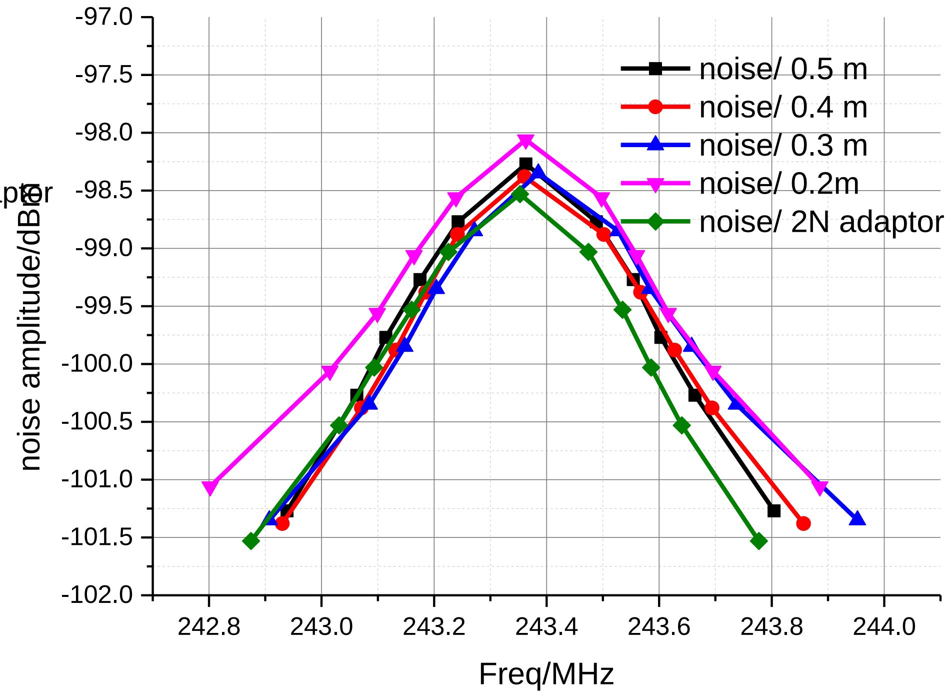
Welcome to your comments

Noise measurement for Resonant Schottky pickup





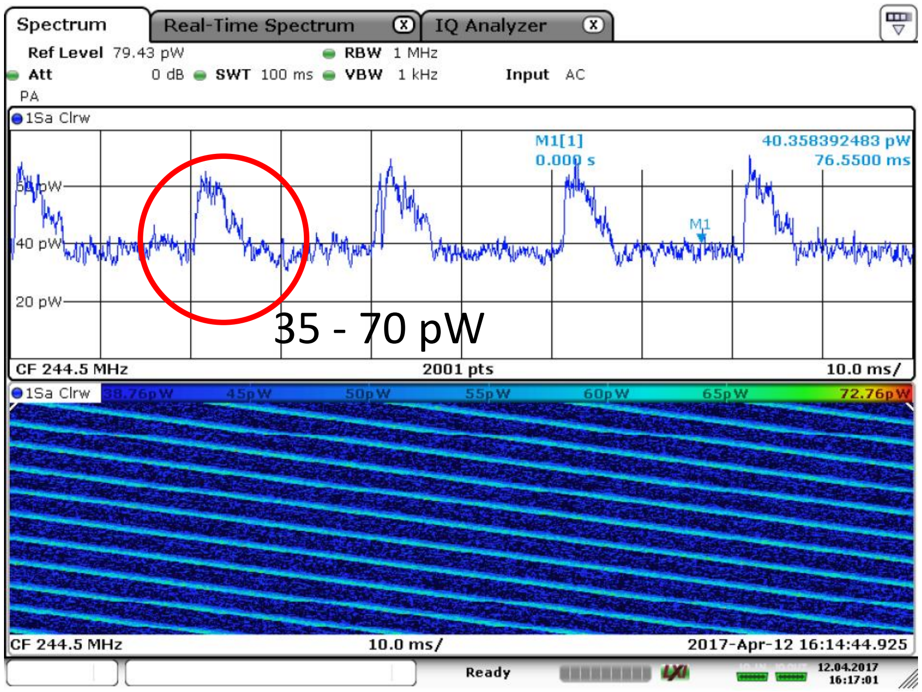
Without impedance match to the preamplifier



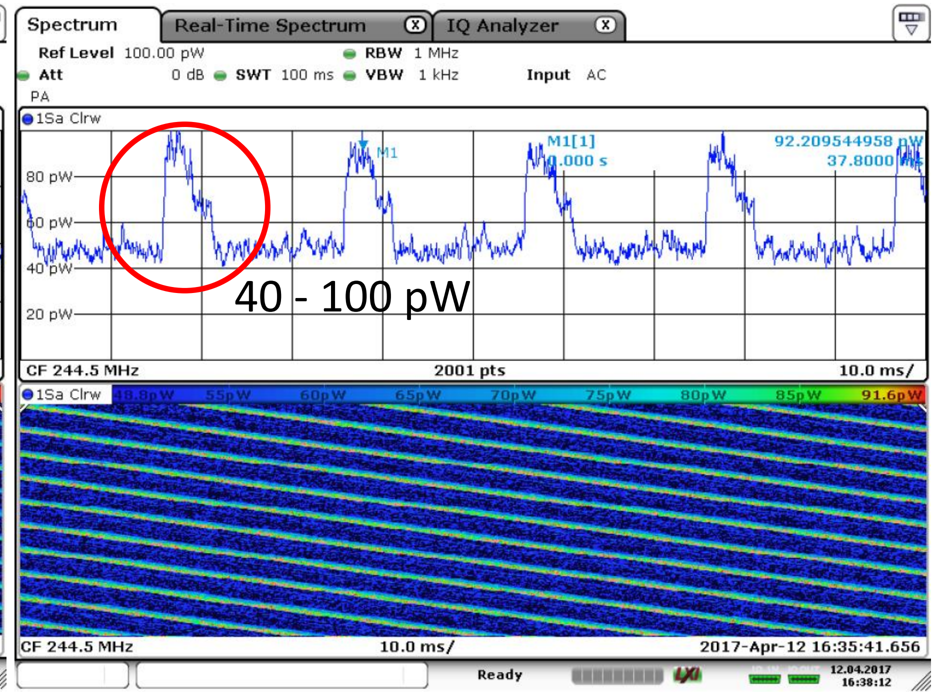
With impedance match to the preamplifier

Noise spectrum from Resonant Schottky pickup

50 Hz noise observation from the Schottky pickup with different cable length



Noise Spectrum – 0.5 m long cable



Noise Spectrum – 0.3 m long cable