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# Cold test stands

# for cryogenic beam vacuum Qualification

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FCC week, Washington 25.03.2015

- Motivations

- **Historical tour: measurements made at BINP for SSC and LHS cold beam vacuum**

- **What we have to know else**

- **Parameters of perspective SR beam lines at BINP for vacuum cold stands**

- **SEY measurements in presence of strong magnetic field**

# FCC energy scale

| | |
|---|---|
| **1E14 eV** | **FCC hh** |
| **1E4 eV** | **Synchrotron radiation,**<br>**Electrons in e-clouds** |
| **1 eV** | **Binding energy of atoms in molecules** |
| **1E-2 eV** | **Condensation energy of hydrogen** |
| 2E-4 eV | T=2K, High field superconducting magnets |

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# Initial surface condition after pumping at RT down to 1e-4 ÷ 1e-5 Torr :

**30 ÷ 100 ML of**

- Chemically bound: MxOy, Mx(OH)y, Mx(HOC3)y, carbon clusters
- Physically adsorbed: H2O, organics

SR provoke dissociation of the molecules.

Note 1: Evaporating 0.1% of 1ML cause gas density increase on 100 time more of acceptable level!

Note 2: Life time of Physically adsorbed molecules on a surface can by evaluated from Frenkel equation:

$$\tau \approx 10^{-13} \exp \frac{E_b}{kT}$$

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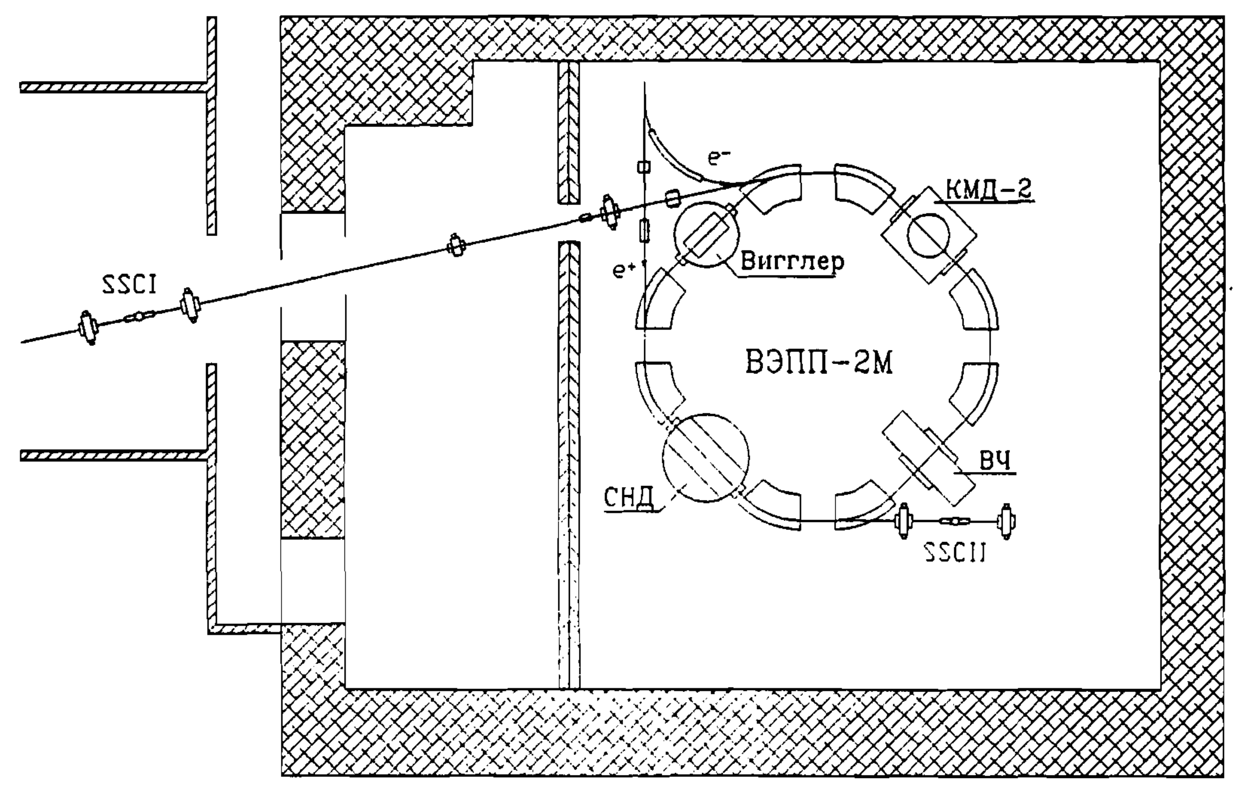
# First SR beam lines at BINP for cold vacuum tests



Ec = 20 ÷ 500 eV (SSC – 300 eV, LHC – 46 eV,

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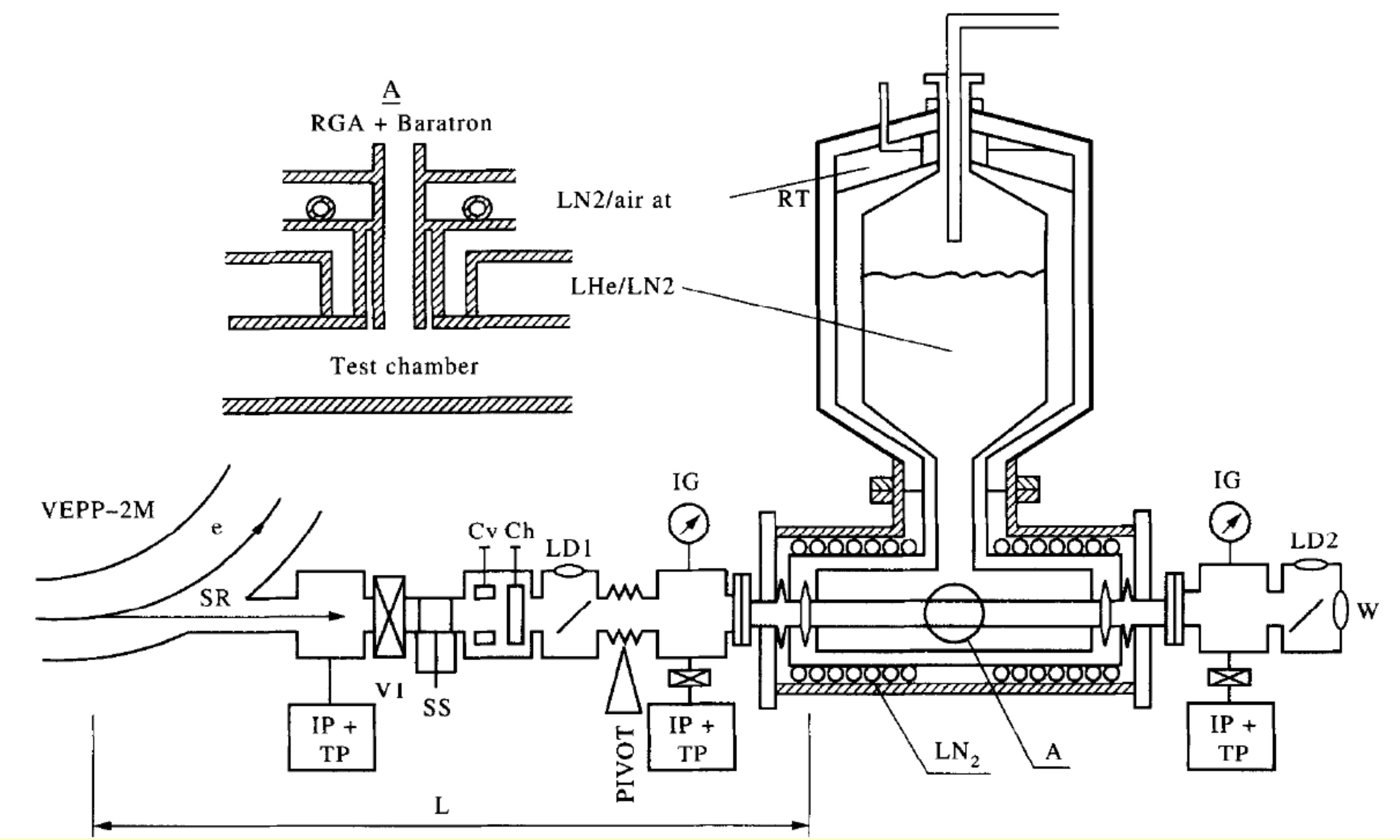
# *Stand for testing of prototype chambers for SSC cold beam vacuum*



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# H2 dynamic pressure vs photon dose

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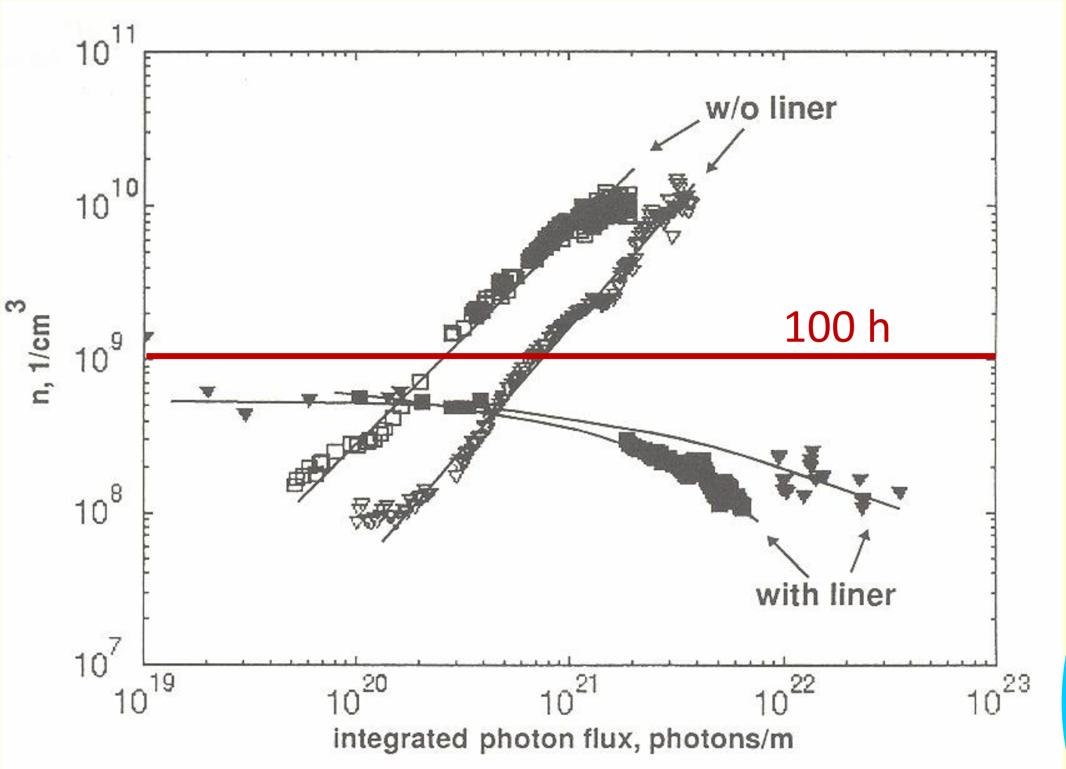

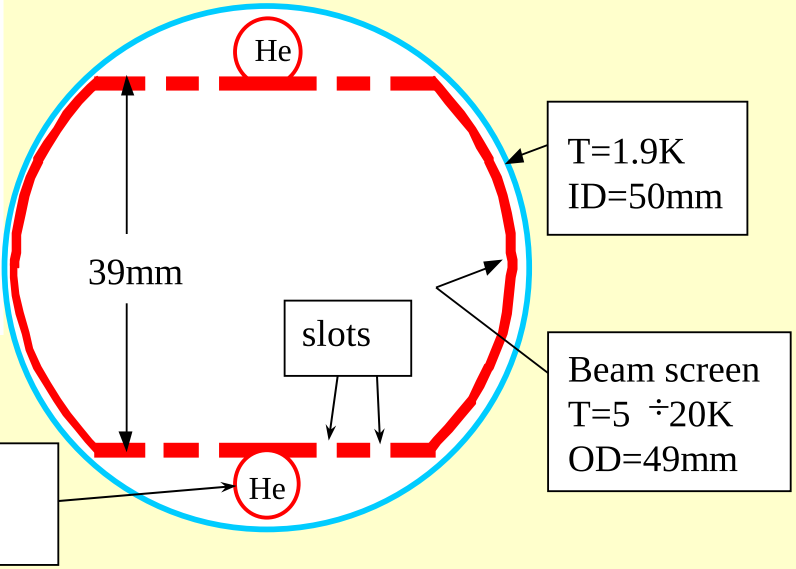

T=1.9K
ID=50mm

Beam screen
T=5 ÷20K
OD=49mm

Cooling
tubes

## Long term prognosis for CO, CO2, O2 ?

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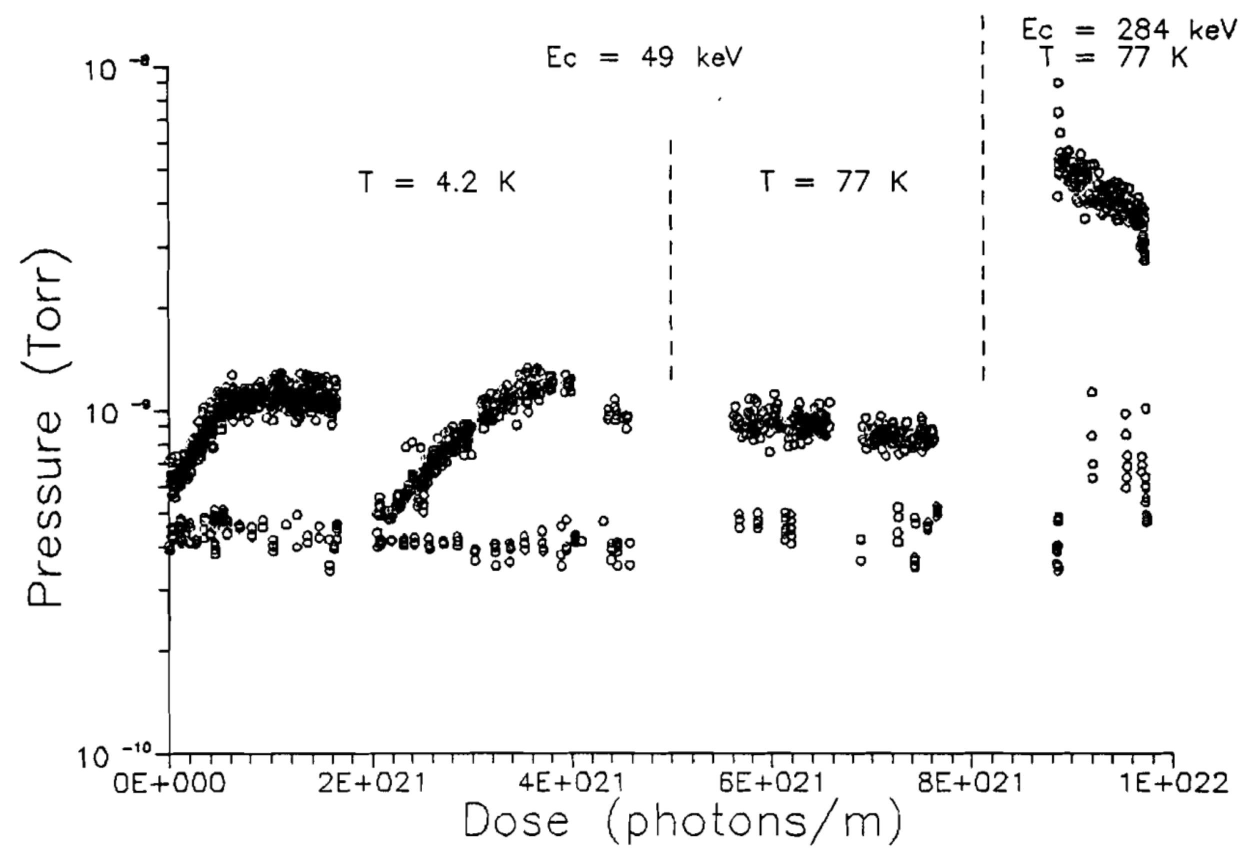
# One of prototype chamber with beam screen for **LHC** cold beam vacuum



Long term prognosis for CO, CO2, O2 ?

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# One of first prototype chamber with beam screen for **LHC** cold beam vacuum

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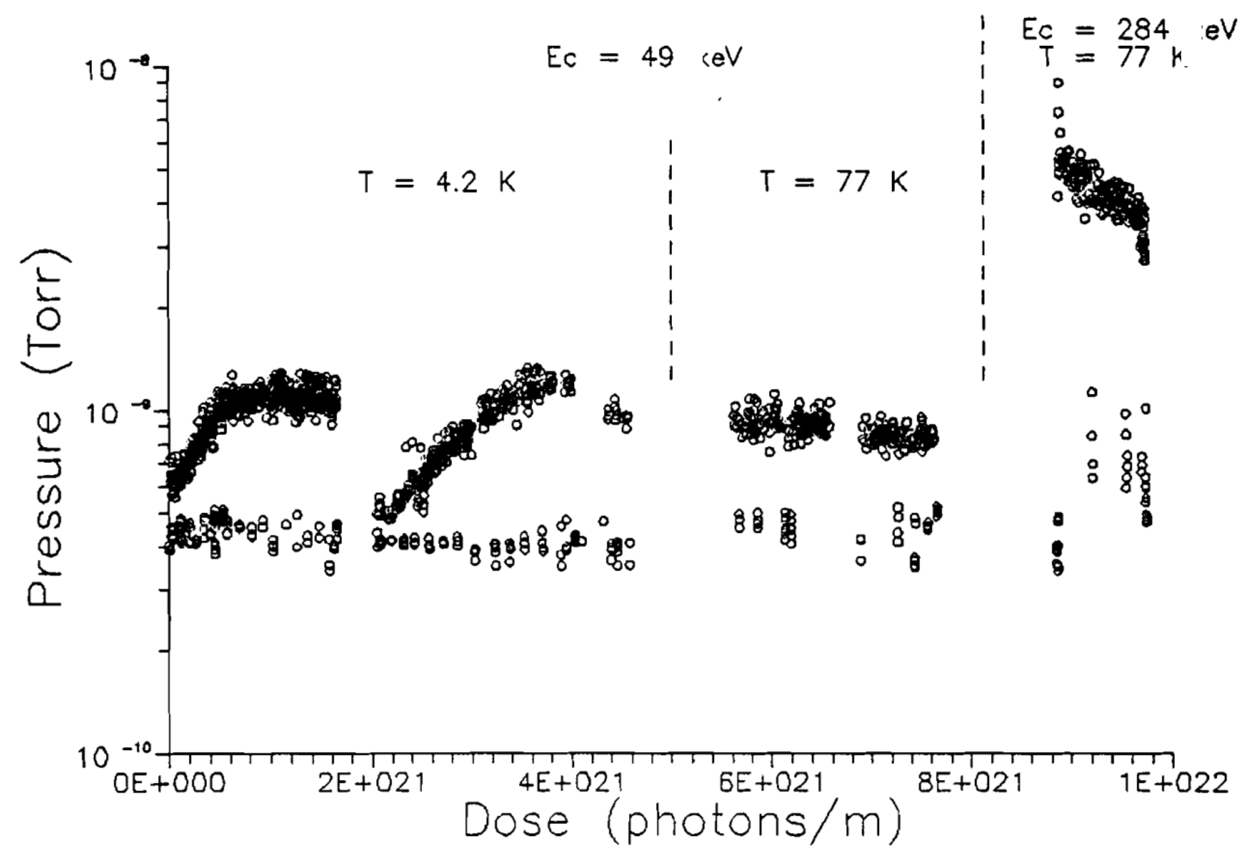

Long term prognosis for CO, CO2, O2 ?

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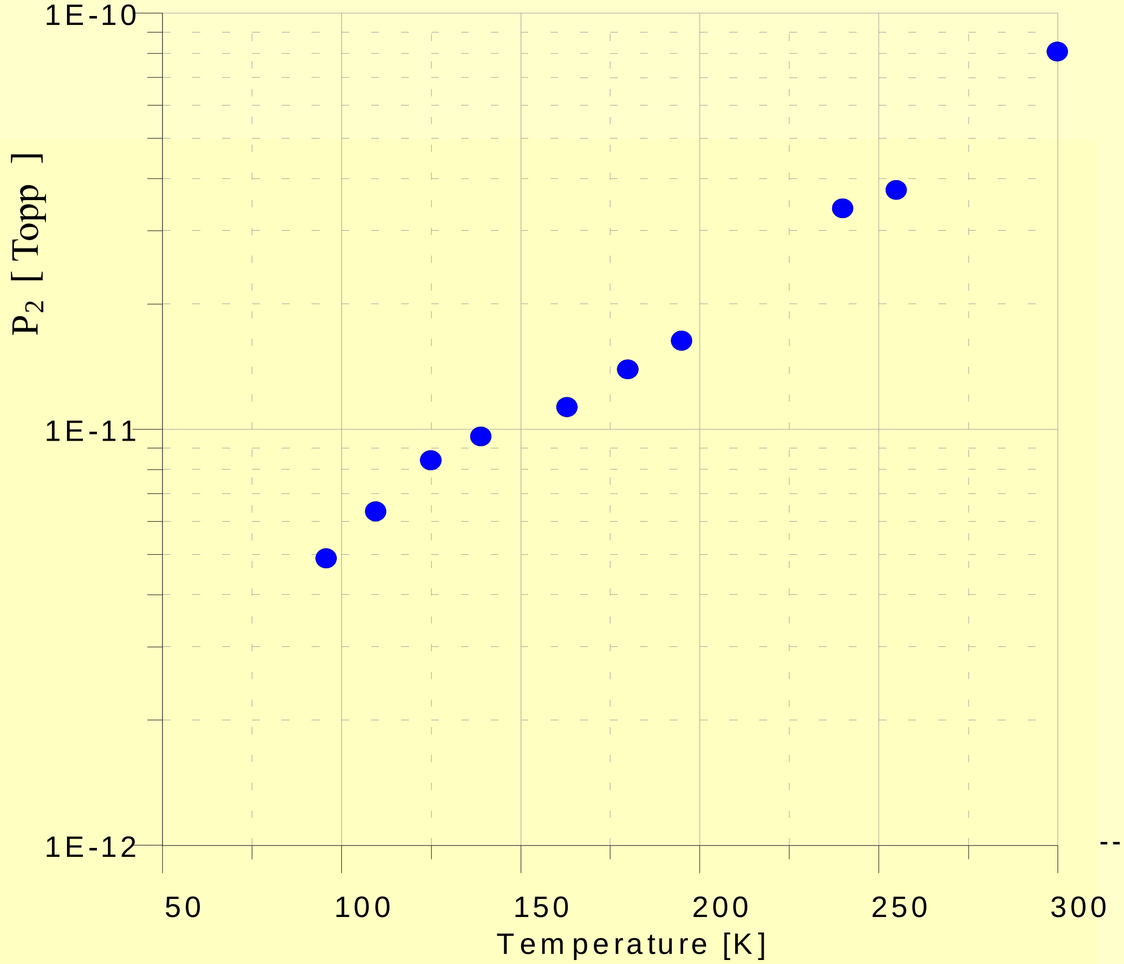
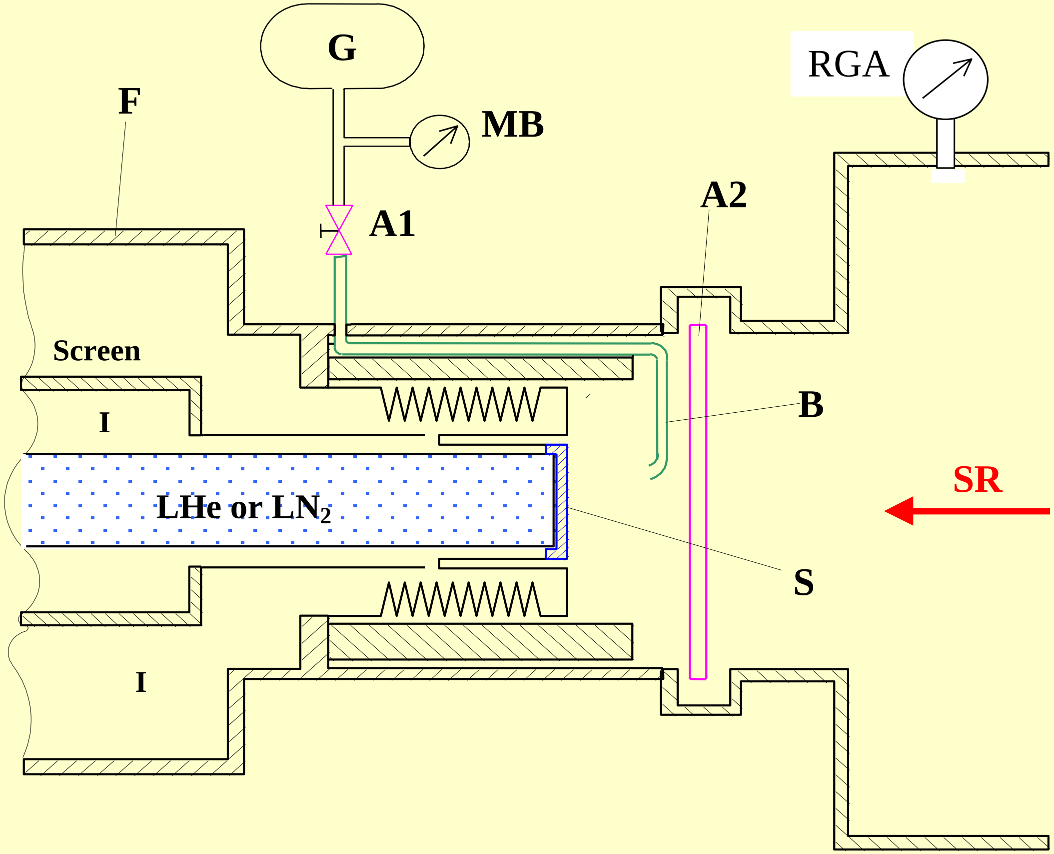
# Dynamic pressure of H2 vs temperature inside simple tube with **TiZrV** getter film.



***SR photon flux 4E10 ph/s,  Ec=4.5 keV***

# Installation for investigation photo-desorption of condensed gases



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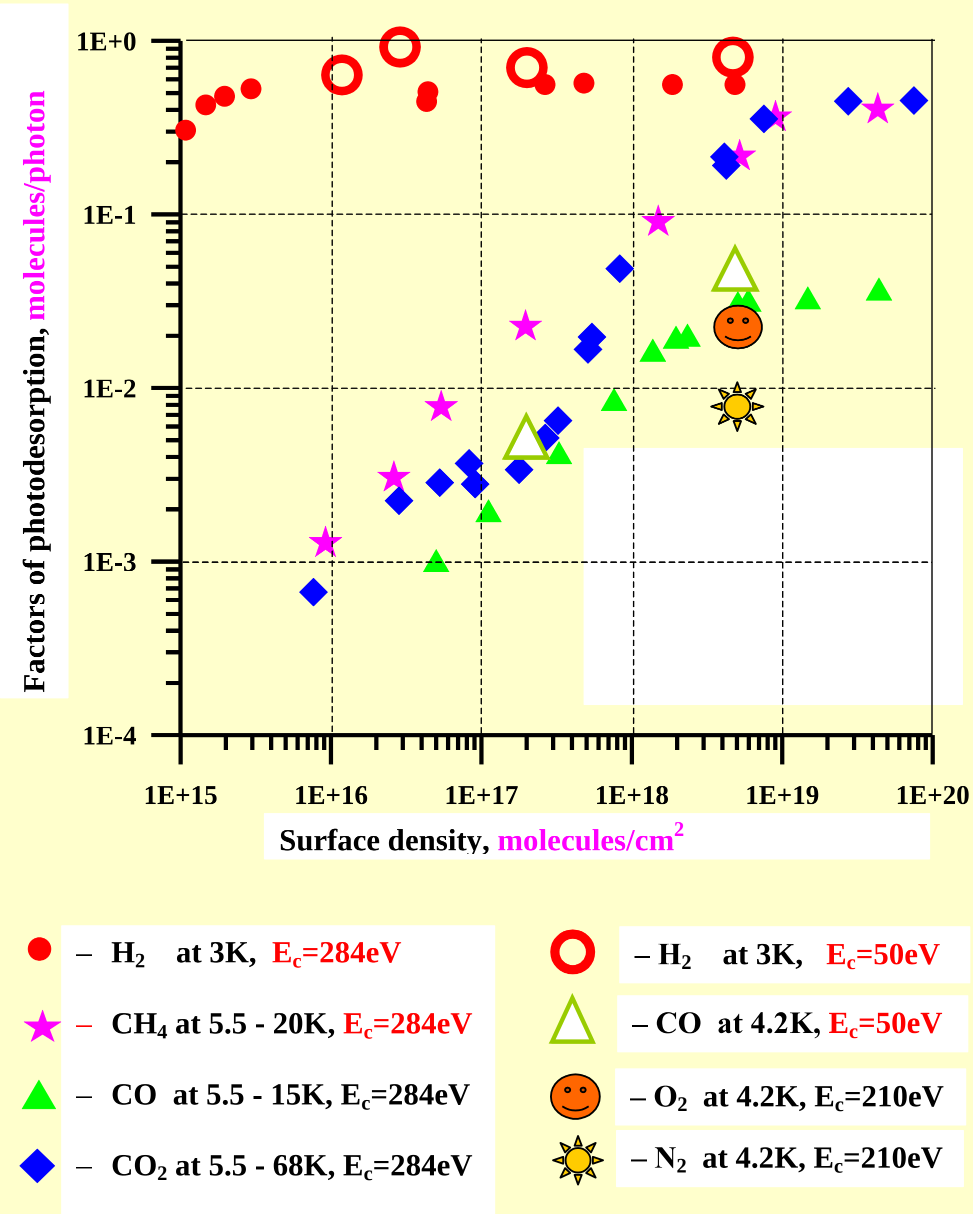
# Photo-desorption of condensed gases



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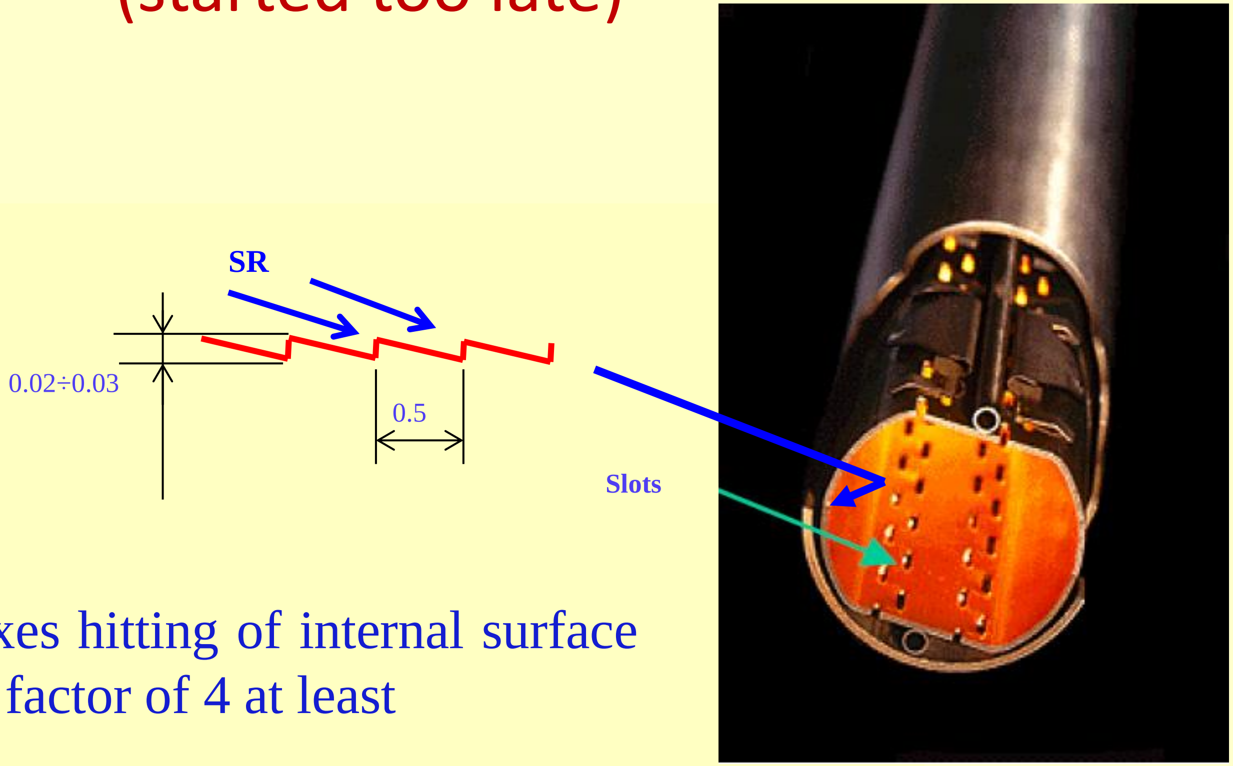
# Electron cloud consideration (started too late)

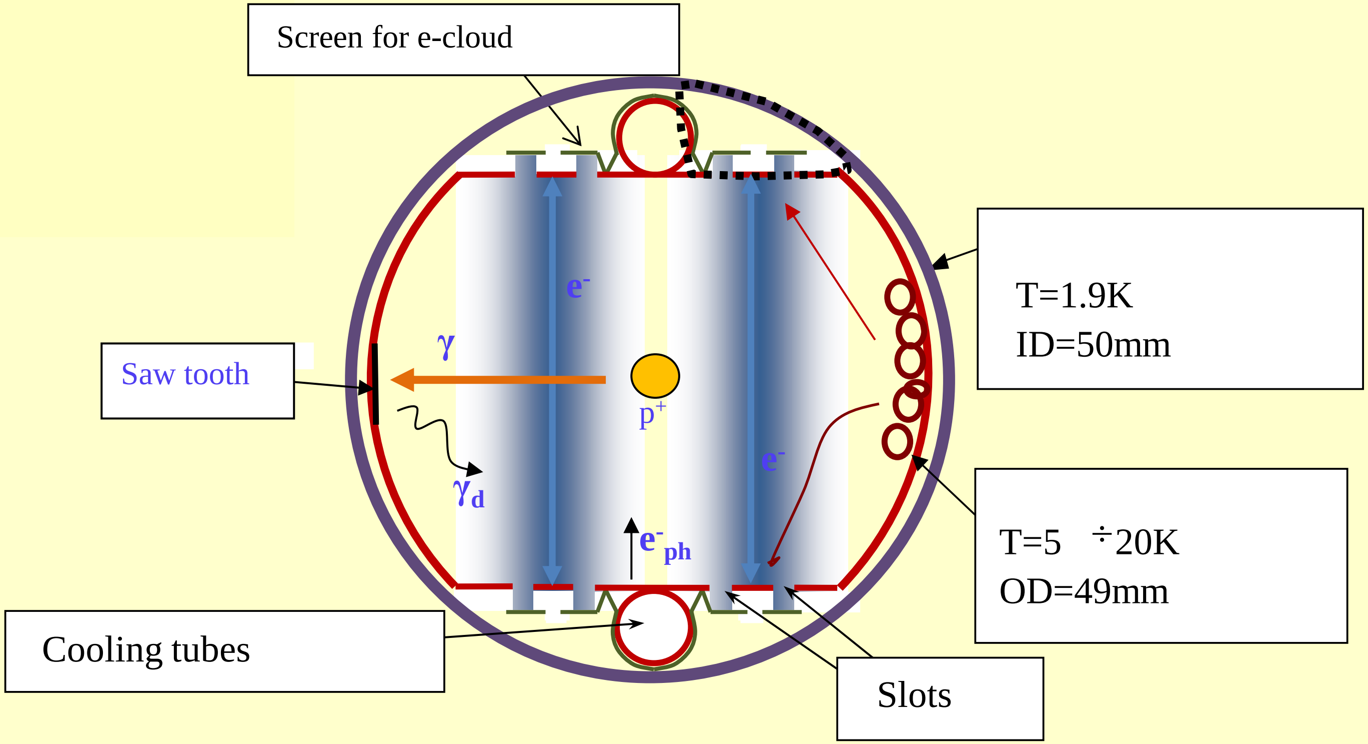


Indirect photon fluxes hitting of internal surface was decreased by a factor of 4 at least

Two benefits:

1. Decreasing of photoelectrons contribution in e-clouds from roughly 20% to 5%
2. Mitigation of recycling of condensed molecules: helps for surface conditioning

# Electron cloud consideration



Screen for e-cloud

Saw tooth

T=1.9K
ID=50mm

T=5 ÷20K
OD=49mm

Cooling tubes

Slots

$$k(SEY=1.3)=\frac{q_e(CO)}{q'_{ph}(CO)}\approx\frac{(1-a)I_e\frac{1}{42}(30\div300)\eta_0}{a\cdot0.24\cdot(1-a)\cdot\dot{\Gamma}\eta'}\approx0.14\div1.4$$

A thermo-cycling might be needed

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# What we have to investigate by testing of FCC cold beam chamber prototypes:

First stage

- Dynamic pressure in presence of SR (Ec up to 4.5 keV) in temperature range 40 ÷ 80K. Transparency of BS.
- Possible pressure raise during thermo-cycling after accumulating a photon dose. Definition suitable temperature range
- Azimuthal distribution of photoelectrons
- Specular SR reflecting, distribution of diffusely scattered photons
- SEY of cold surface in presence of strong magnetic field (up to 13T)

Add at second stage

- SEY *in situ*
- XPS (Auger) *in situ (surface element analysis)*
- *Ion desorption under SR*

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# Parameters of available and potentially available SR beam lines for vacuum investigations at BINP

| Parameter | BEP | | VEPP-3 | | NISSI | | | |
|---|---|---|---|---|---|---|---|---|
| | | | | | Normal dipole | | Super-bend | |
| | min | max | min | max | min | max | min | max |
| **E [GeV]** | 0,2 | 0,9 | 0,3 | 2 | 0,4 | 2 | 0,4 | 2 |
| **SR critical energy [keV]** | 0,014 | 1,3 | 0,016 | 5 | 0,028 | 3,5 | 0,13 | 16 |
| **SR incident angle [mrad]** | 10 (5) | | 10 | | 10 | | 10 | |
| **SR flax on testing chamber [ph/m/s]** | 3E16 (1,5E15) | 4E17 (2E17) | 1,6E15 | 3E16 | 3E16 | 3E17 | 2,7E16 | 2E17 |
| **SR max power on testing chamber [W/m]** | 30 (15) | | 7,7 | | 58 | | 160 | |
| **Sample chamber possible length [m]** | 1 (in 2015)<br>2 (in 2016) | | 1,5 | | 3 | | 3 | |
| **Available [year]** | from 2015 | | 2015 ÷ 2017 | | from 2020 | | from 2020 | |

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# SEY at magnetic field

## Set-up for RT experiments

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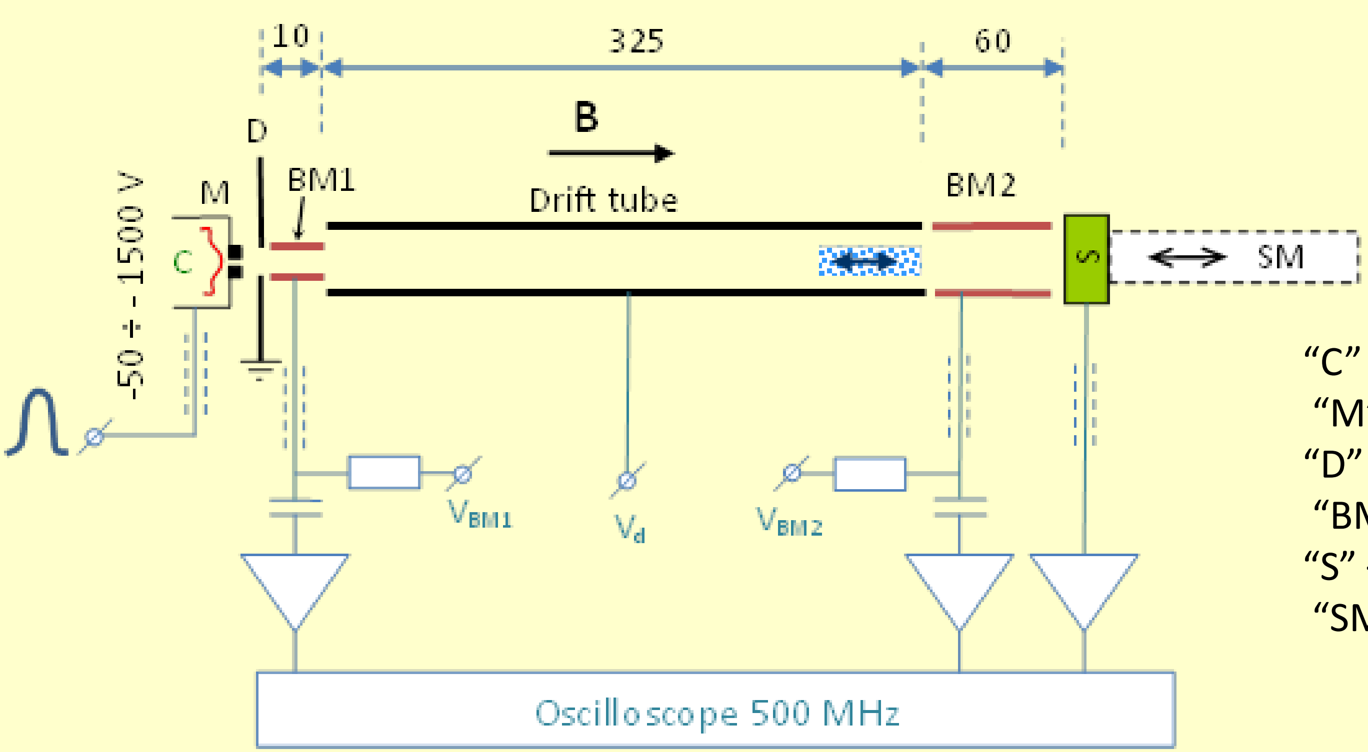

"C" – thermo-cathode
"M" – modulator
"D" – diaphragm
"BM1, BM2" – beam monitors
"S" – sample
"SM" – sample manipulator

| Element (from left to right) | ID [mm] | Length [mm] | Gap with right element [mm] |
|---|---|---|---|
| C | - | - | 0.25 |
| M | 0.5 | 2 | 3 |
| D | 4.5 | 1 | 1 |
| BM1 | 4 | 10 | 0 |
| Drift tube | 7 | 325 | 1 |
| BM2 | 7 | 59 | 2 ÷ 3 (to sample) |

### Parameters

- -Energy of primarily electrons: 50 ÷ 1500 eV
- -Primarily beam pulse current: up to 200 µA
- -Primarily electron beam pulse duration: 1 ÷ 10 ns.
- -Beam diameter: ~ 1.5 mm
- -Maximum magnetic field: 0.05 T
- -BM1, Drift tube, BM2 bias: -600 ÷ +600 V

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# First experimental results

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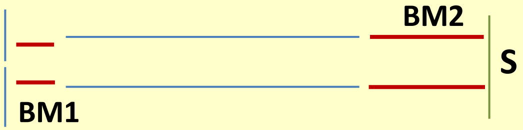
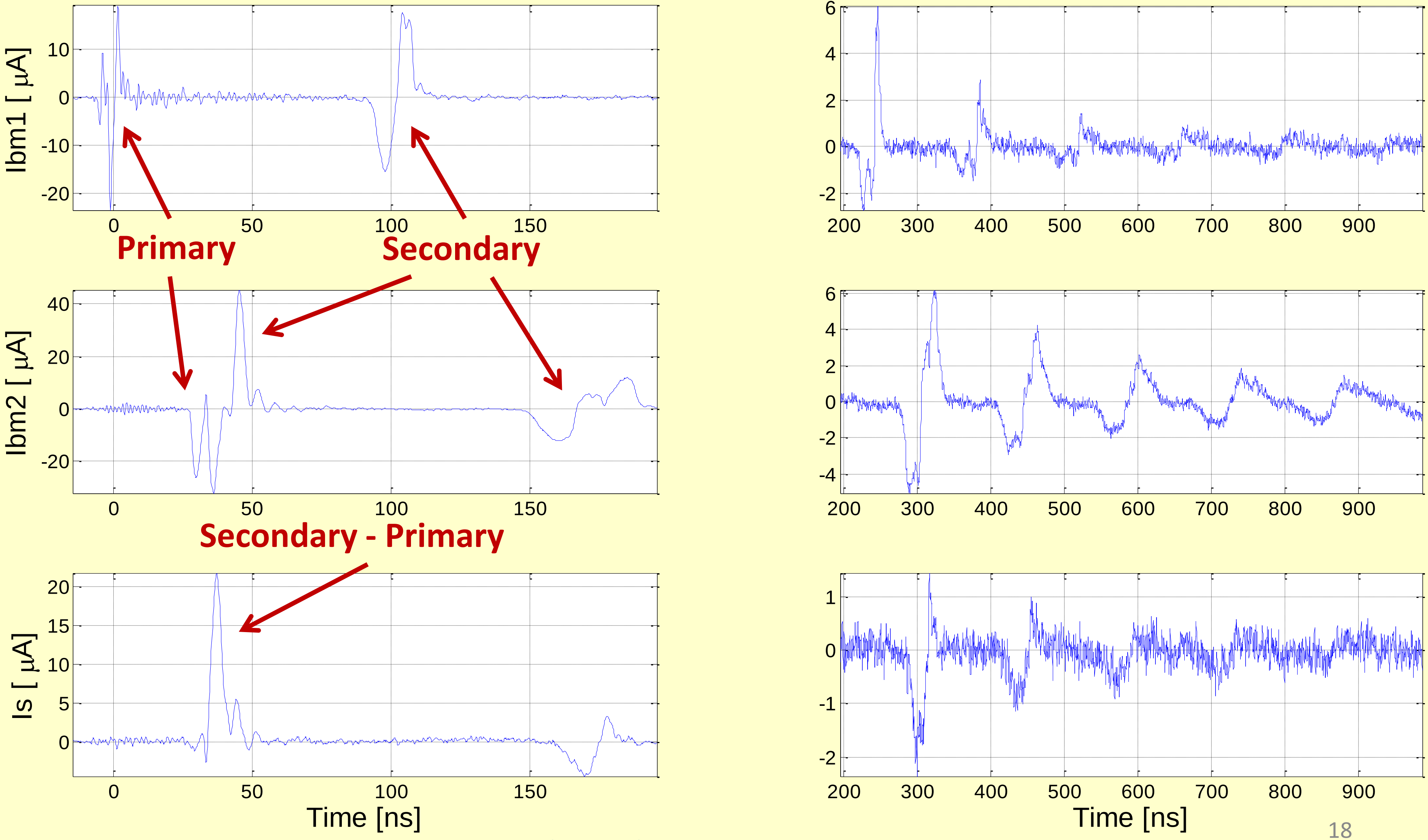


Cu acetone cleaning. P=4E-8 mbar

Uc=-300V, Ubm1=Udrift=Ubm2=+100V, Us=0, Pulse=[3ns, 4.5V]



**Primary**

**Secondary**

**Secondary - Primary**

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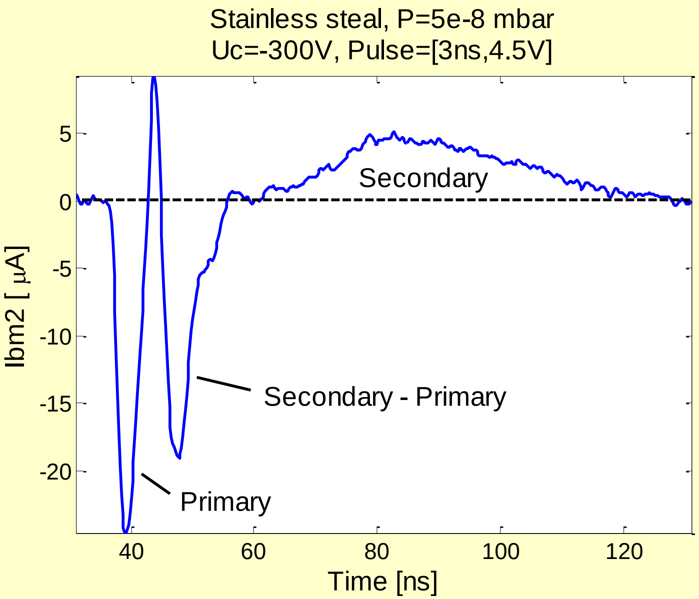
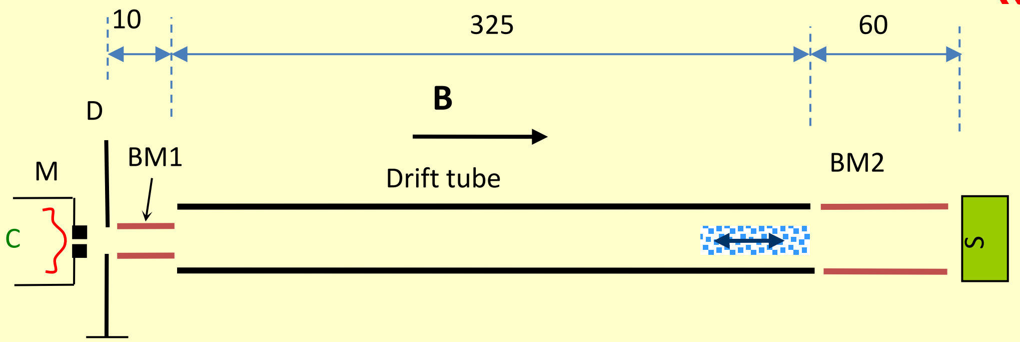
# First experimental results. **SEY**



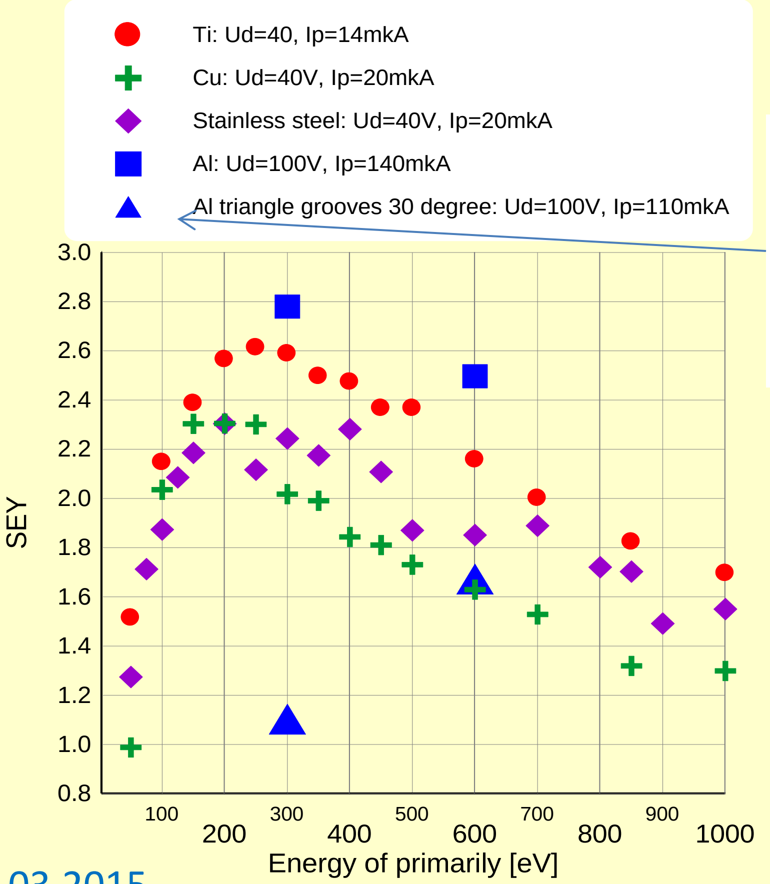


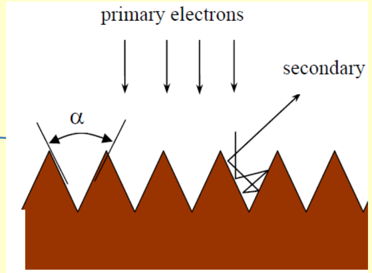
$$SEY = \frac{Q_P + \Delta Q}{Q_P}$$

$$Q_P = -\underset{\text{over first negative pulse}}{\int} I_{BM2}(t)dt$$

$$\Delta Q = \underset{\text{over first interaction}}{\int} I_s(t)dt$$

$$Q_{S\_BM2} = \underset{\text{over first positive pulse}}{\int} I_{BM2}(t)dt$$





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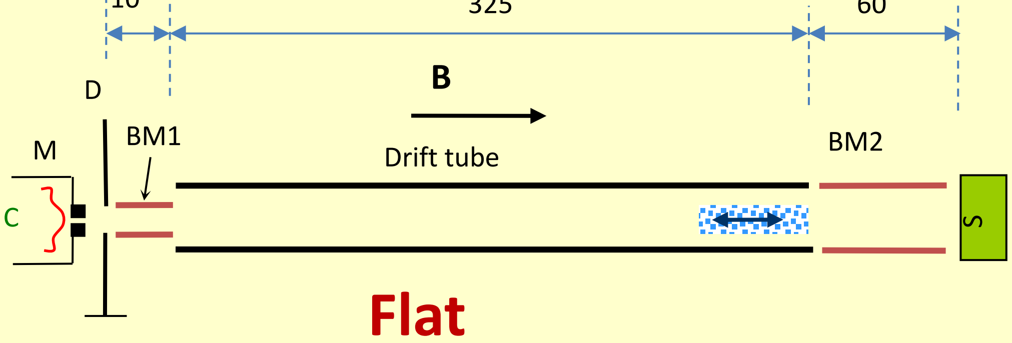
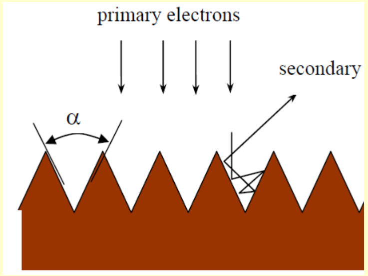
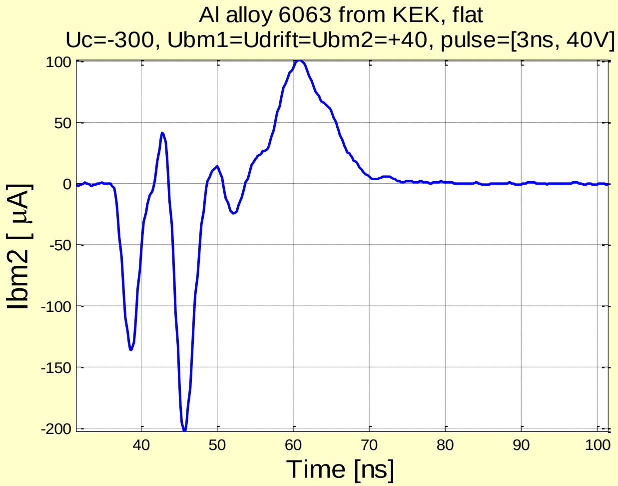
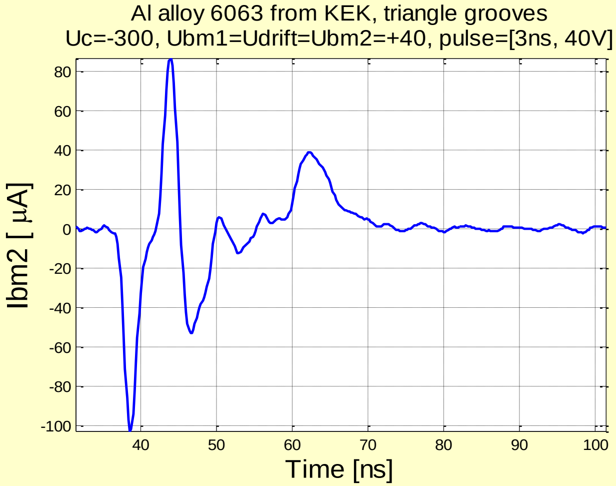
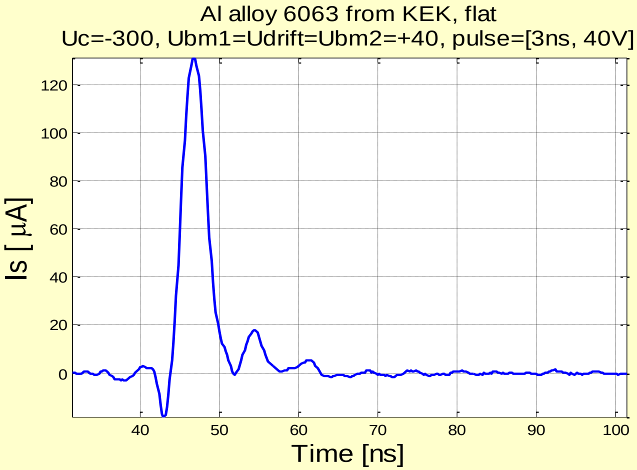
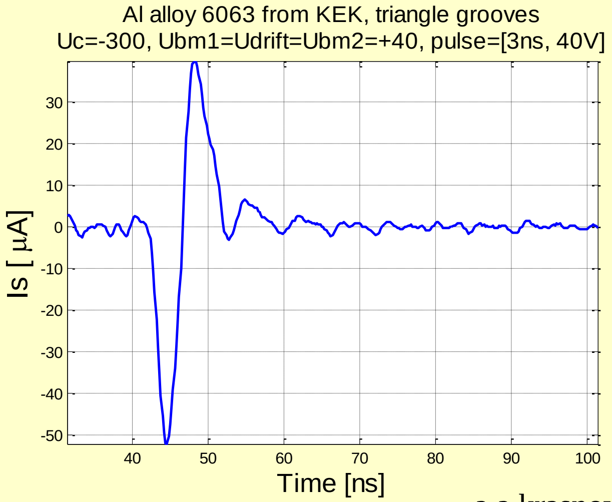





Al alloy 6063 from KEK, flat
Uc=-300, Ubm1=Udrift=Ubm2=+40, pulse=[3ns, 40V]


Al alloy 6063 from KEK, triangle grooves
Uc=-300, Ubm1=Udrift=Ubm2=+40, pulse=[3ns, 40V]


Al alloy 6063 from KEK, flat
Uc=-300, Ubm1=Udrift=Ubm2=+40, pulse=[3ns, 40V]


Al alloy 6063 from KEK, triangle grooves
Uc=-300, Ubm1=Udrift=Ubm2=+40, pulse=[3ns, 40V]

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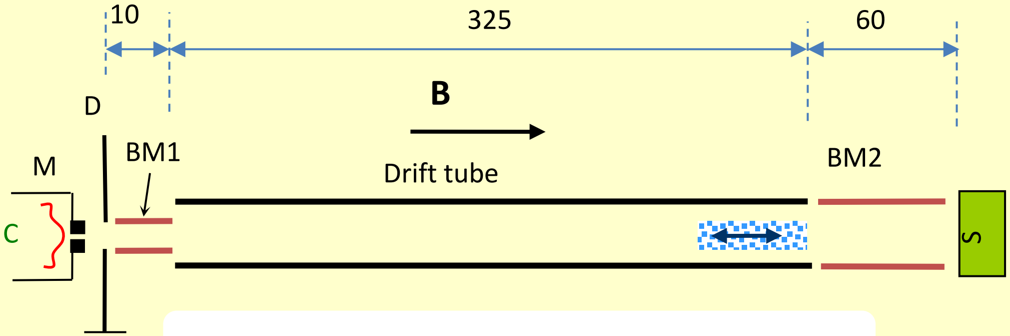
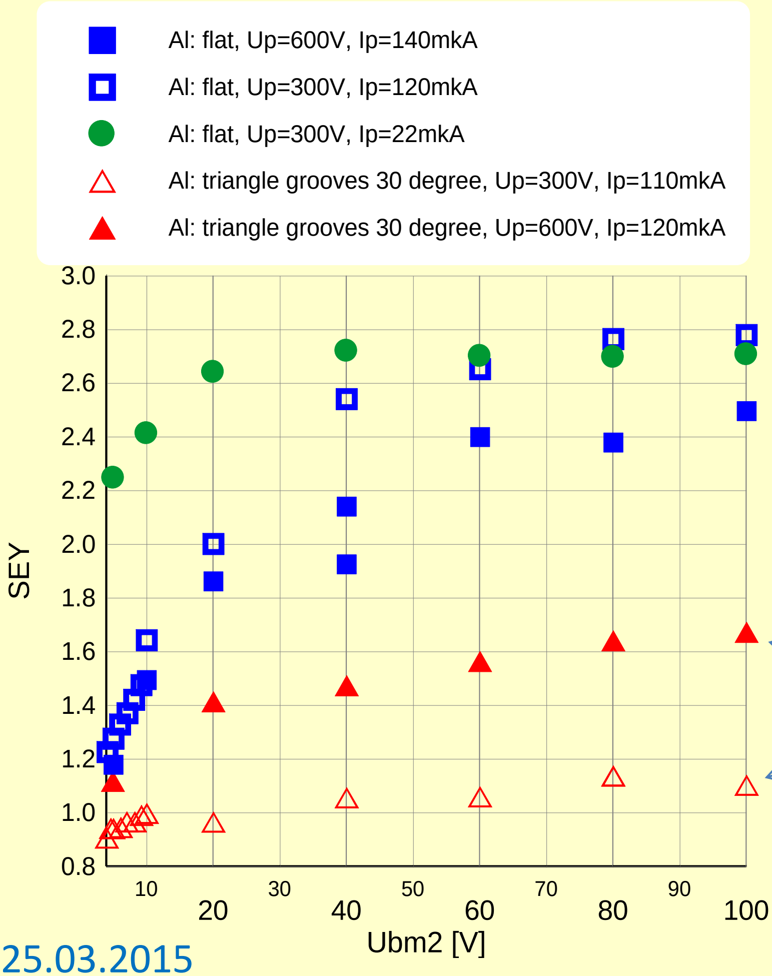
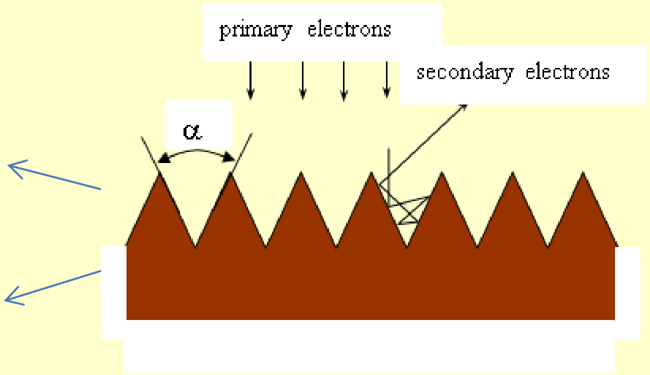
# SEY vs extracting bias Ubm2







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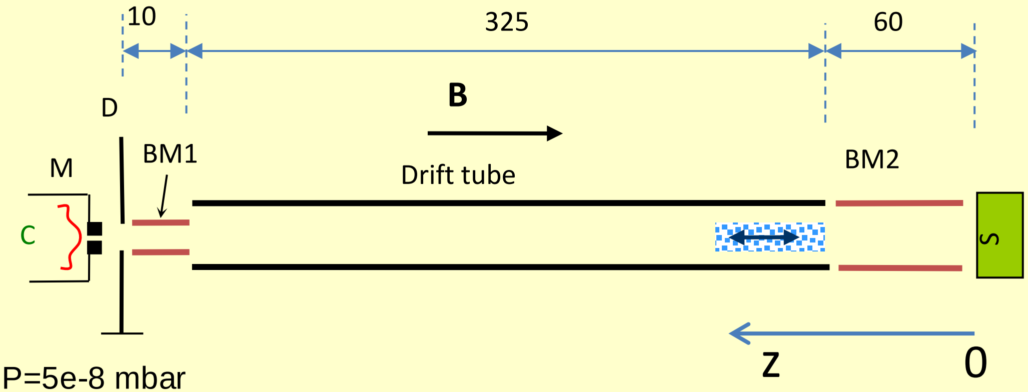
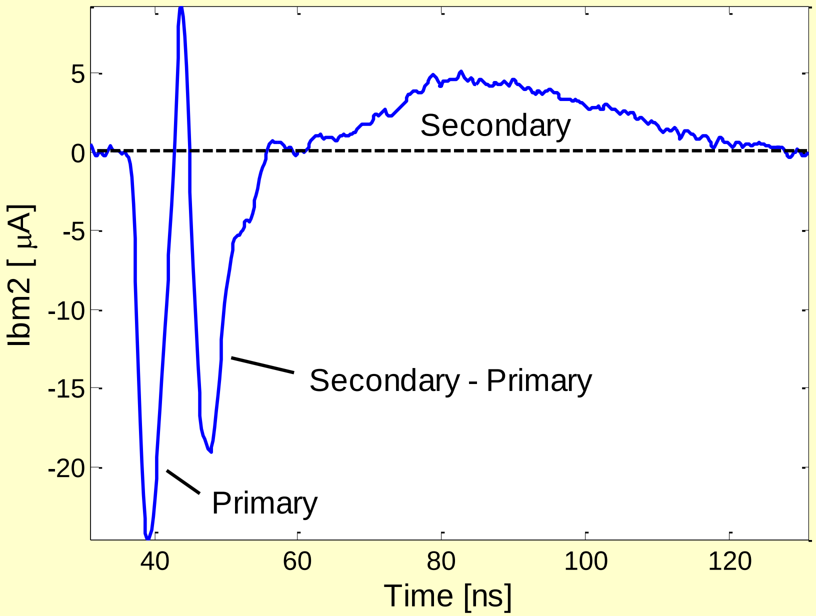
# Energy distribution




Stainless steal, P=5e-8 mbar
Uc=-300V, Pulse=[3ns,4.5V]

$$I_{s\_output}(t) \approx \int_{Ez\,\min}^{Ez\,\max} I_{s\_begin}(t-t')\rho_z(E_z)dE_z$$

where $E_z=E_{sz}+U_{bm2}$ and delay $t'$ is defined as:

$$t' \approx \frac{L_{bm2}+R_{bm2}}{\upsilon_s} = \frac{L_{bm2}+R_{bm2}}{\sqrt{E_z}}\sqrt{\frac{m_e}{2q_e}}$$

$$If\ \ I(t=0,z=0)=Q\cdot\delta(0)$$

$$\rho_z(E_z) \propto \frac{I_{s\_output}(t')}{t'^3}$$

Ubm1=Udrift=Ubm2=5V

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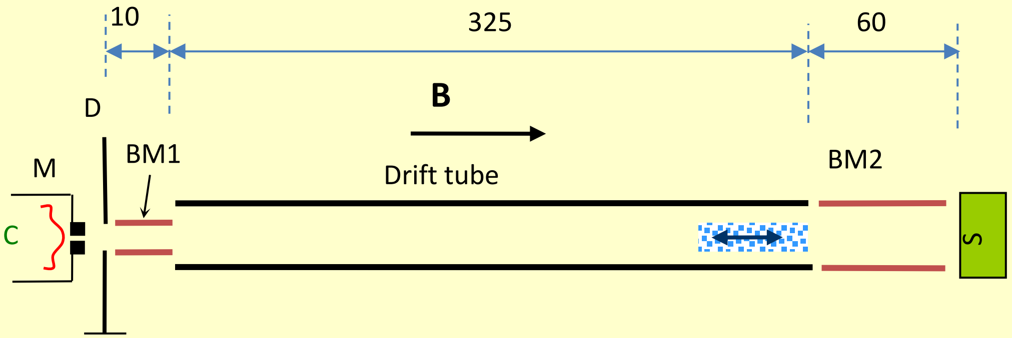
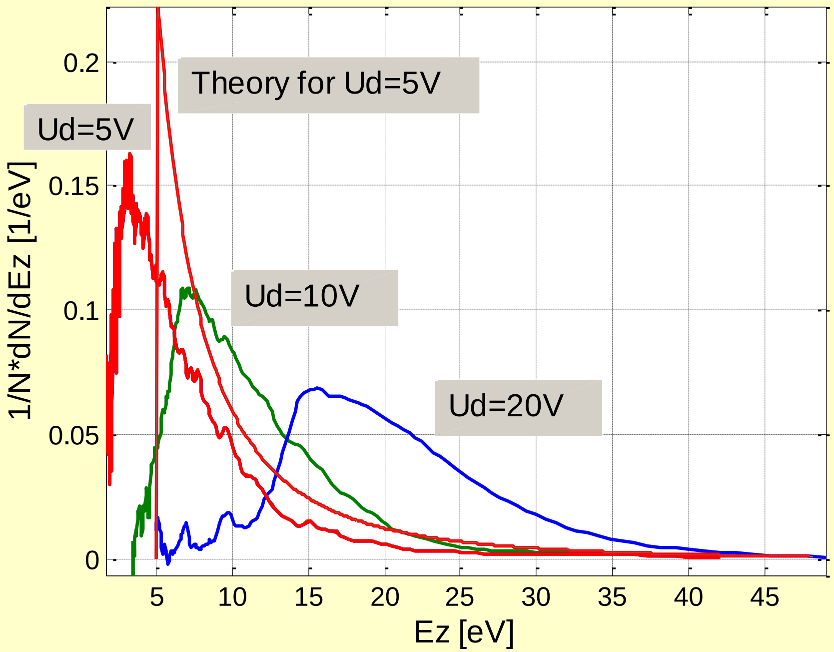
# Energy distribution

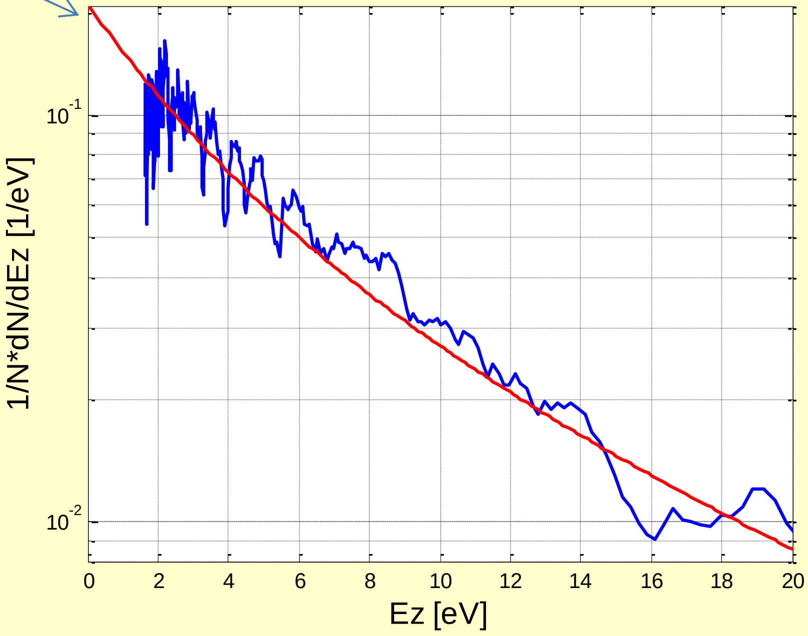
$$\rho(E_s) \approx \frac{1}{Z}\exp\left[-\frac{\ln^2\left(E_s / E_{s.\max}\right)}{2\Delta E_s^2 / E_{s.\max}^2}\right]$$



Stainless steel, Ep=300[eV], Ip=14mkA



Al: flat, Ep=300eV, Ed=0, Ip=120mkA. fitting: Emax=deltaE=2.5eV



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# Conclusion

- The installation provides adequate measurements of SEY in the present of magnetic field
- Effective reflectivity of secondary electrons cannot be measured ( electron density has to be decreased by a factor of 100 )
- Mitigation of effective SEY by a grooved surface more stronger than it was predicted. If its space charge effect, the application of grooves should significantly decrease saturation density of e-cloud

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# Conclusion/ proposals for future

SEY

- Installation into superconducting solenoid to provide experiments at magnetic field up to 10 Tesla
- Installation of photo-cathode to avoid electromagnetic excitation and increase beam diameter up to 4 – 6 mm to decease electron density by a factor of 100 at least
- systematic measurements samples with special coatings and surface treatments

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Thank for your attention!

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