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Results on a-C tubes subjected to synchrotron irradiation

V. Baglin, P. Chiggiato, P. Costa-Pinto, B. Henrist (CERN, Geneva)

V. Anashin, D. Dorokhov. A. Semenov, A. Krasnov, D. Shwartz, A. Senchenko (BINP, Novosibirsk)

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A.A.Krasnov@inp.nsk.su BINP, Novosibirsk

OUTLINE

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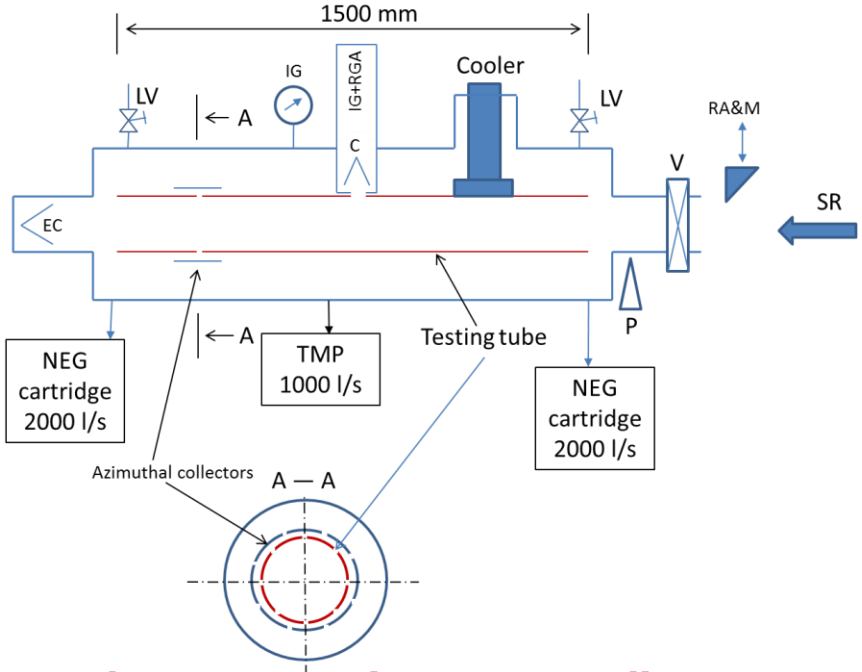
- **Parameters of SR beam line and experimental set-up at BINP**
- **Experimental program for HiLumi**
- **First SR on**
- **Comparison of Cu and C-α samples**

- **Options for future investigations**
- PEE at high magnetic field

Collaboration R&D CERN – BINP (Addendum P110/A2)

In the framework of the HL-LHC project, the vacuum performance of new surface material needs to be studied in details. In particular, amorphous carbon (a-C) coating is proposed as an anti-multipactor surface with the objective to minimize the heat load deposed on the shielded beam screen and the background to the experiment due to proton scattering onto the residual gas. Since the protons in the HL-LHC Inner Triplets generates SR with ~ 10 eV critical energy and ~ 10^{16} ph/m/s flux, it is therefore of great importance to study the impact of such photons on a-C coating held at room and cryogenic temperature and compare the results against present LHC material.



The experimental set-up is installing on BEP SR beam line at BINP

Experimental program in frame of Collaboration R&D CERN – BINP (Addendum P110/A2)

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- quantitative photon stimulated gas desorption by a calibrated residual gas analyzer (RGA);
- photo-electron yield; forward reflectivity in SR power and photon flux units; azimuthal distribution of photoelectrons and azimuthal distribution of diffusely scattered photons.

These measurements will be done for two CERN supplied samples: uncoated and a-C coated OFE-Cu tubes.

The experimental program:

- an accumulated photon dose > 10^{23} ph/m, a SR incident angle of 13 mrad, a SR critical energy in accumulated photon dose mode is in the range 40 ÷ 50 eV, a scanning over SR critical energy at 100, 200, 400, 800, 1300, 1700 eV at selected doses of 10^{21}, 10^{22}, 10^{23} ph/m, a total number of azimuthal collectors of 10.

BINP will repeat the measurements in the temperature range 60 ÷ 300 K for exchangeable Cu tube samples perforated with holes in order to simulate a distributed pumping

Experimental set-up

Parameter	min	nominal	max
E [MeV]	193	**390**	899
Beam current [A]	0.2	0.5	0,05
Banding magnet radii [mm]		1280	
SR critical energy [eV]	12,5	100	1250
SR flux [ph/mrad/s]	1.1E15	**1.5E16**	4,7E15
SR power [W/mrad]	0.009	0.045	3.6
SR vertical divergence [mrad] at Ec	2.5	1.7	0.56

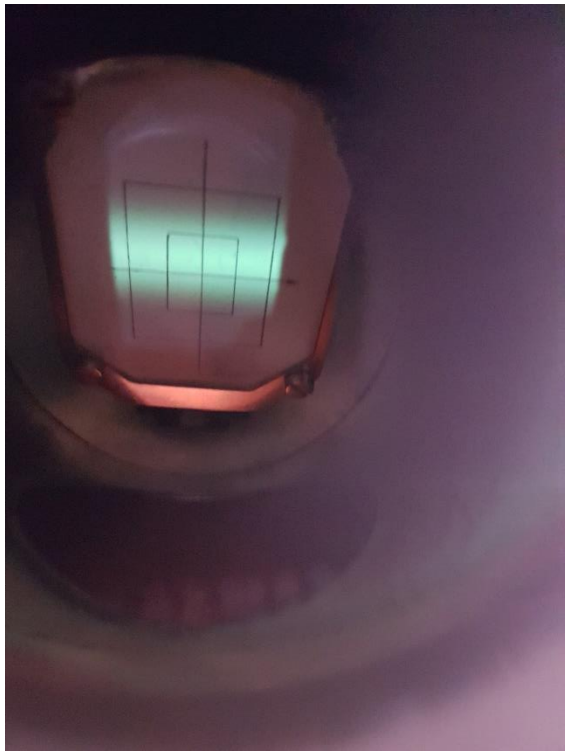
First SR on

Conditions without SR: P=5e-9 Torr in measuring port. P=1.7e-9 Torr in vessel (NEG cartridge is not activated)

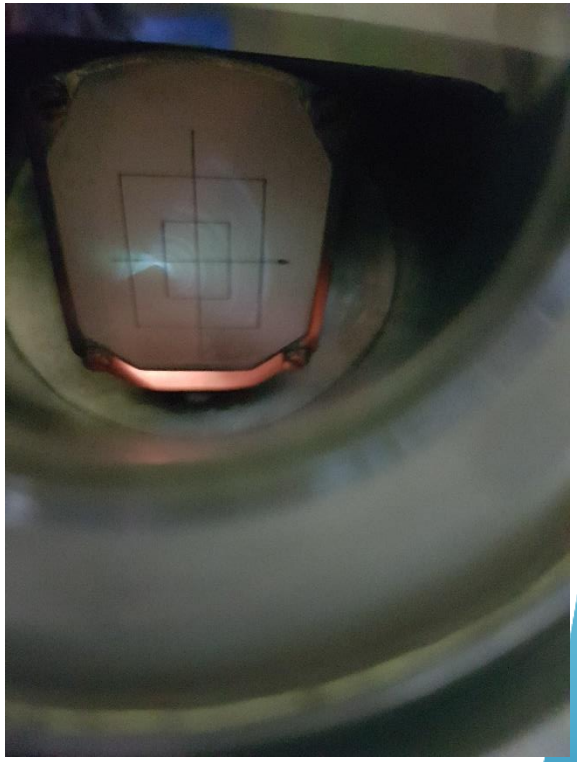
SR on: Ie=70 mA, Ee=390 MeV, Ec=102 eV, Ph flux=4.5e16 Ph/s (SR angle 9 mrad), or 3e16 ph/m/s:

Pressure in measuring port 1.2e-7 Torr

Before inlet to testing tube
W≈10 mm



After outlet of testing tube
W≈30 mm



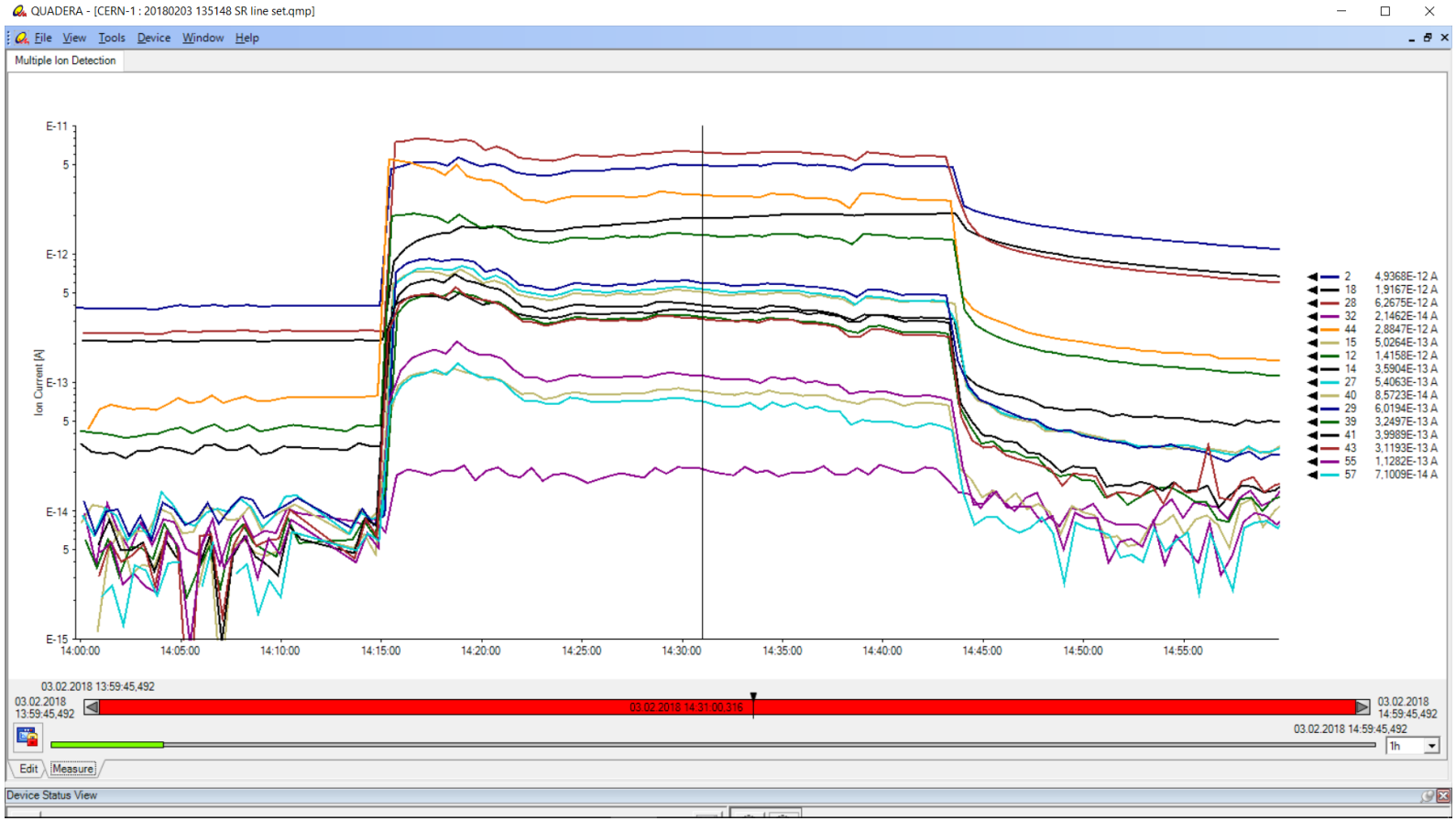
Reflected from testing tube

First SR on, RGA spectra

SR on: Ie=70 mA, Ee=390 MeV, Ec=102 eV, Ph flax=4.5e16 Ph/s (SR angle 9 mrad):

Pressure in measuring port 1.2e-7 Torr

Pressure in vessel 2e-8 Torr at +60 V on end calorimeter and 4.2e-8 Torr at -60 V on end calorimeter, **Testing tube**: Cu HCP cleaned and passivated at CERN, ID=40.5 mm, L=1500 mm



First SR on, desorption yield

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SR on: Ie=70 mA, Ee=390 MeV, Ec=102 eV, Ph flax=4.5e16 Ph/s (SR angle 9 mrad):

Pressure in measuring port 1.2e-7 Torr

Pressure in vessel 2e-8 Torr at +60 V on end calorimeter and 4.2e-8 Torr at -60 V on end calorimeter

η=3.5e-3 molecule/ph – nitrogen equivalent. Dose is small. Less than 1e19 ph/m.

Desorption yields

Gas	ΔP [Torr]	η [mol/ph]
H_2	2.9e-8	5.1e-3
CH_4	3.7e-9	2.2e-4
H_2O	1.1e-8	6.5e-4
CO	3.8e-8	1.8e-3
C_2H_6	3.7e-9	1.7e-4
CO_2	1.8e-8	6.6e-4

Estimated sensitivity – 2e-6 molecule/ph at Ie=500 mA

Sample with α-C coating

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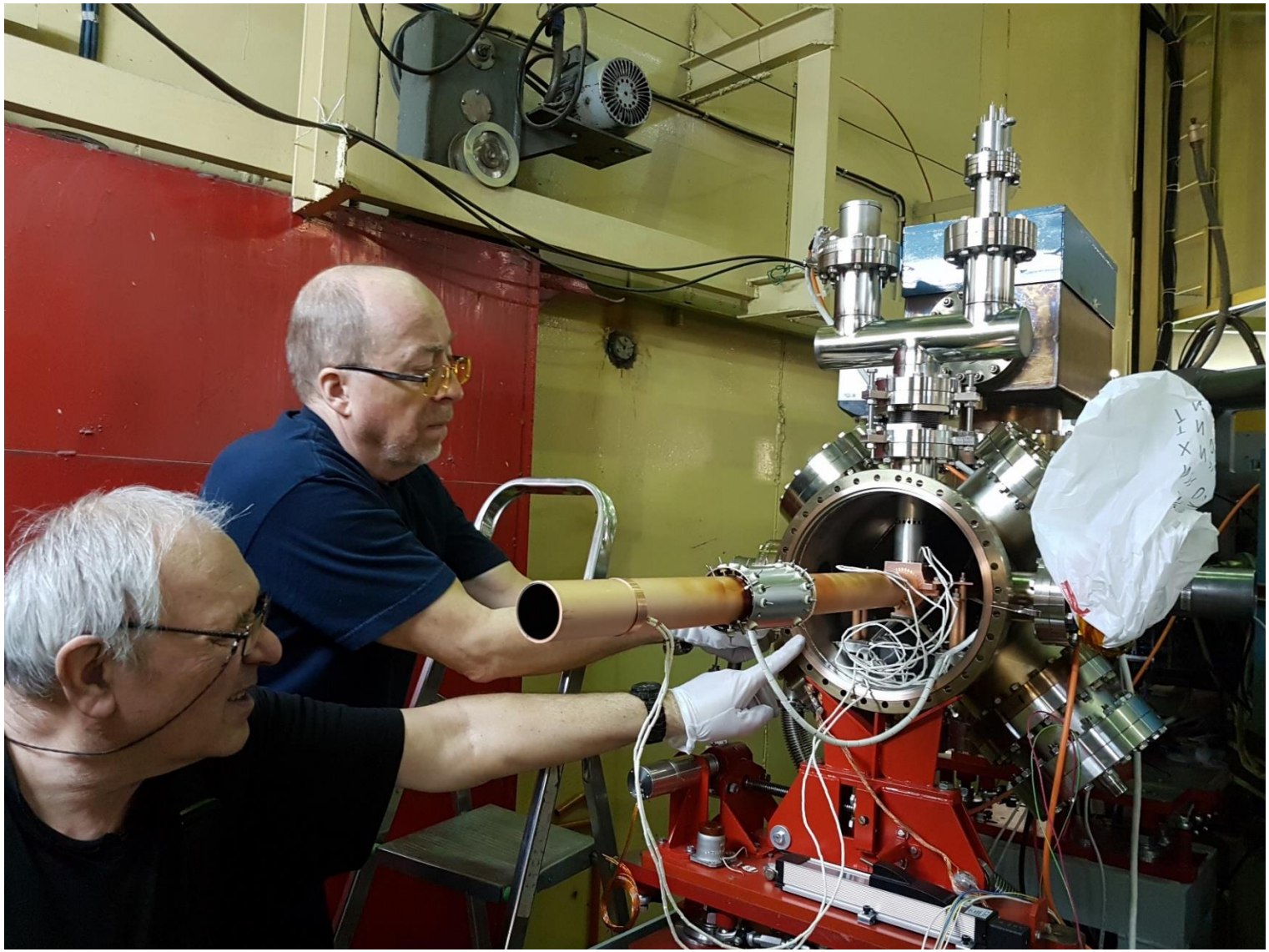


Installation of the sample with α-C coating

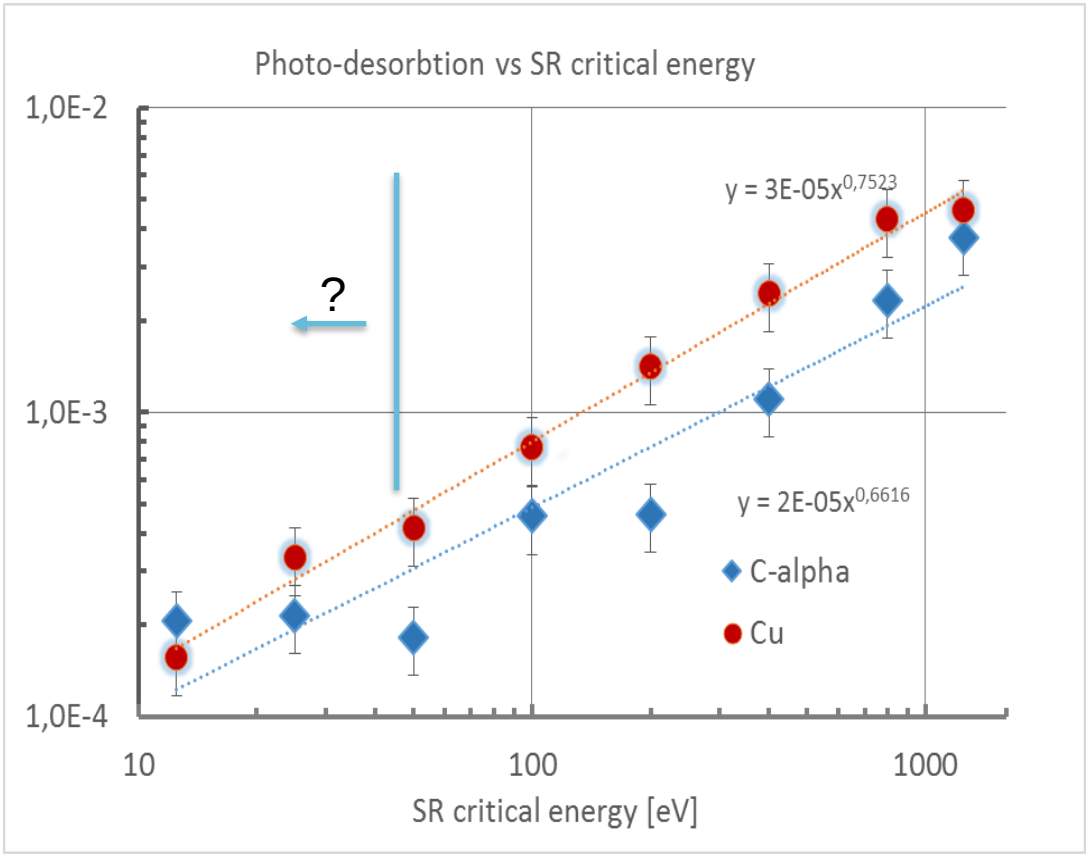
Desorption yield for α-C and Cu vs SR critical energy

Dose: 1E21 Ph/m

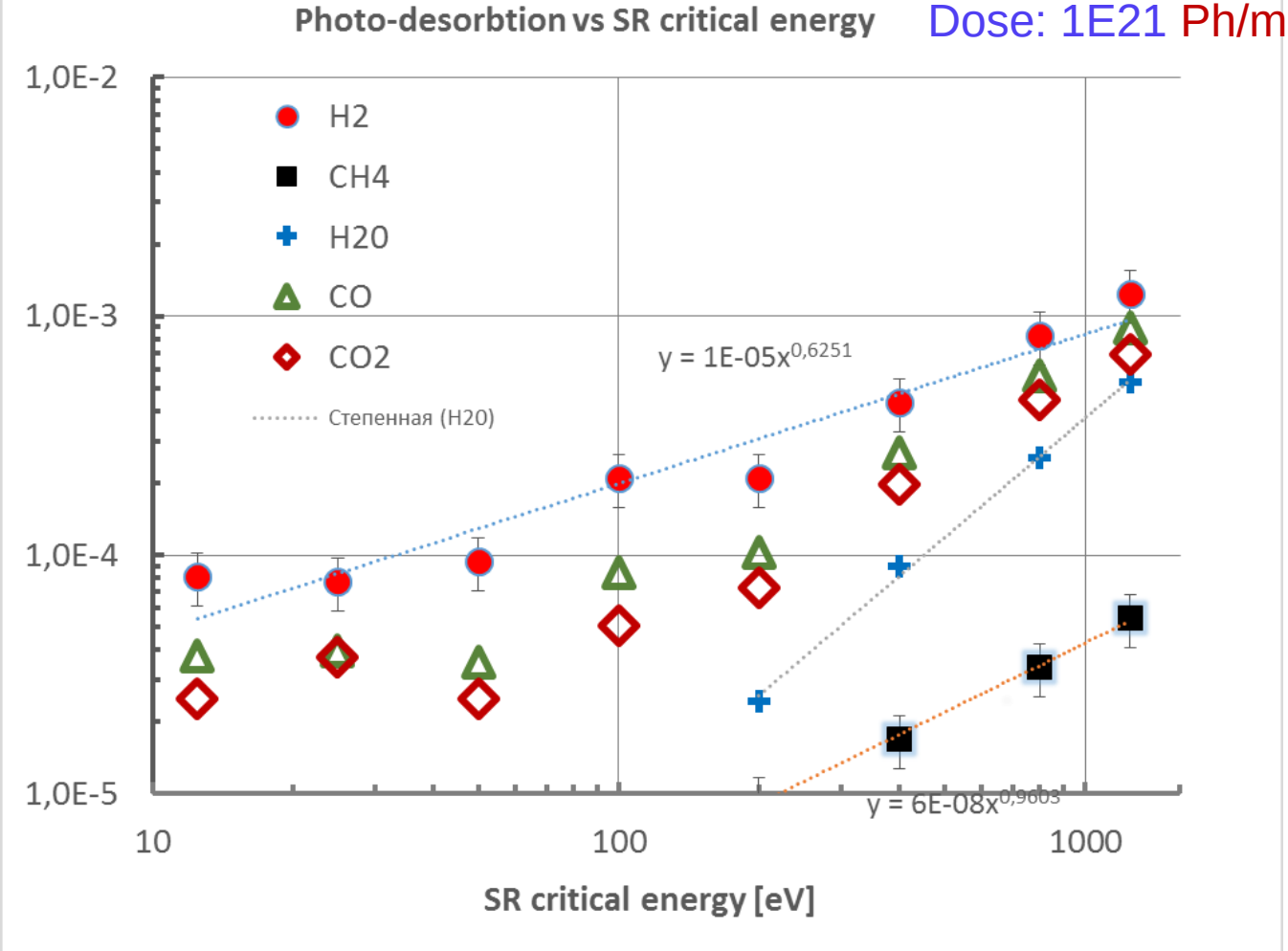
Ee=193….900 MeV

Ec=12,5… 1250 eV

Ec eV	α-C η [mol/ph]	Cu η [mol/ph]
12,5	2E-4 ?	1,6E-4
25	2,2E-4 ?	3,3E-4
50	1,8E-4	4,2E-4
100	4,5E-4	7,7E-4
200	4,6E-4	1,4E-3
400	1,1E-3	2,5E-3
800	2,3E-3	4,3E-3
1250	3,7E-3	4,6E-3

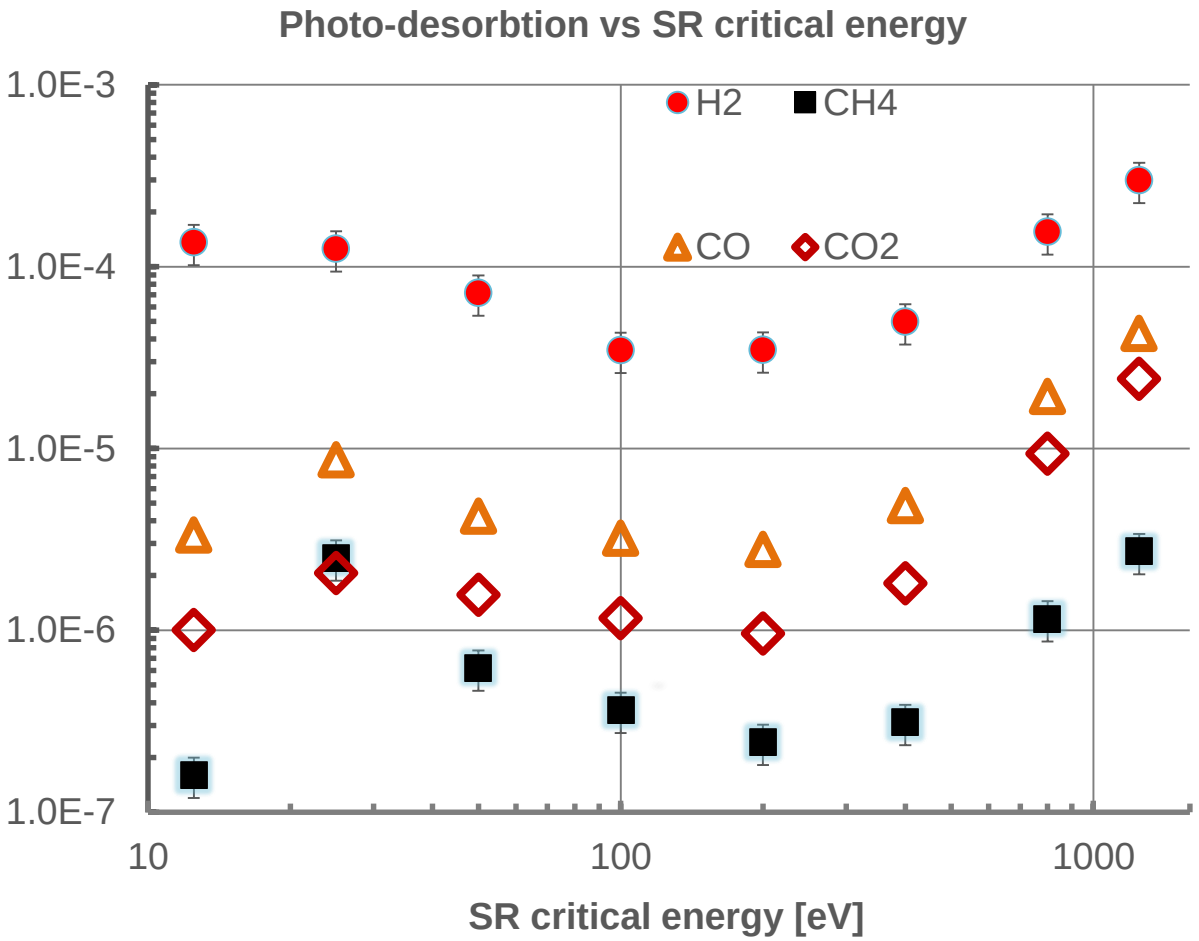


Desorption yield for α-C vs SR critical energy



Desorption yield for α-C vs SR critical energy

Dose: 7E22 Ph/m



Forward reflectivity

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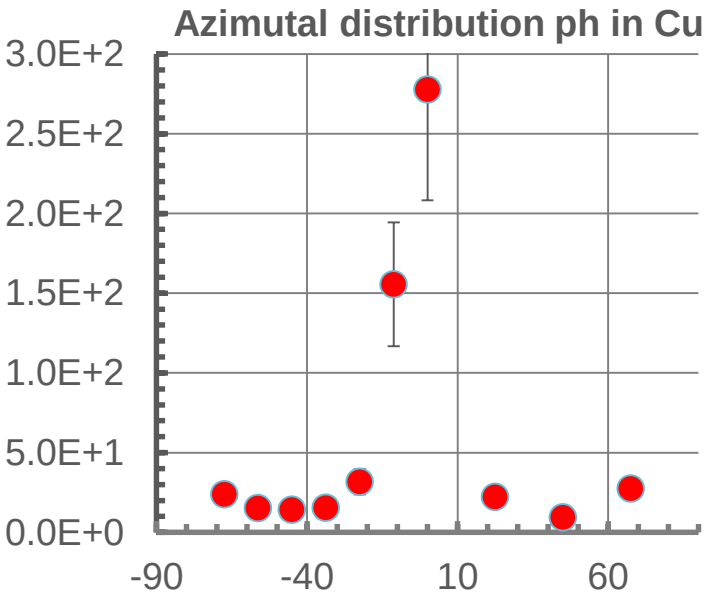
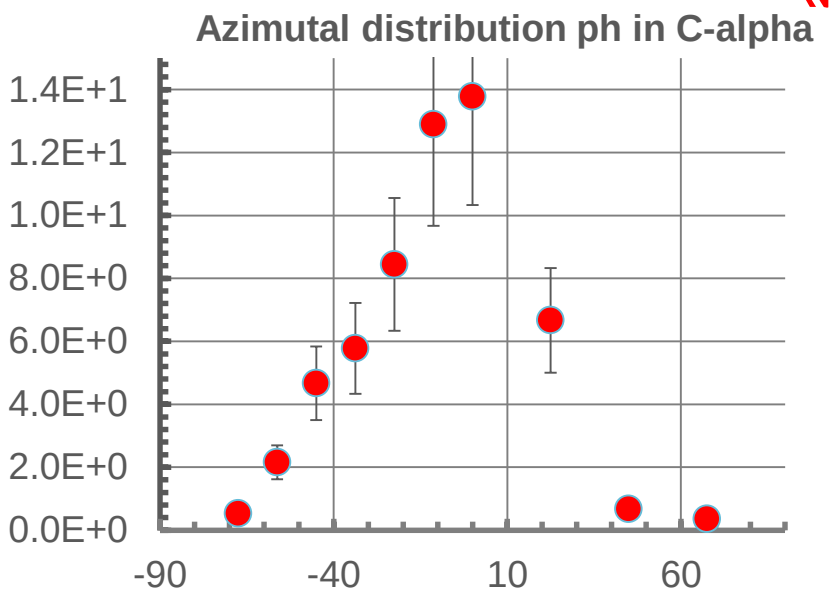
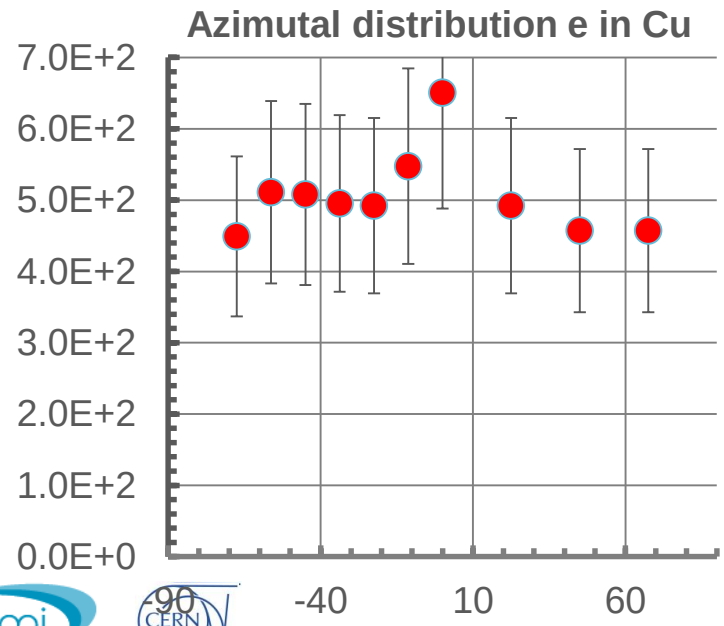
BEP: Ie up to 650 mA, Ee=193….900 MeV, Ec=12,5… 1250 eV

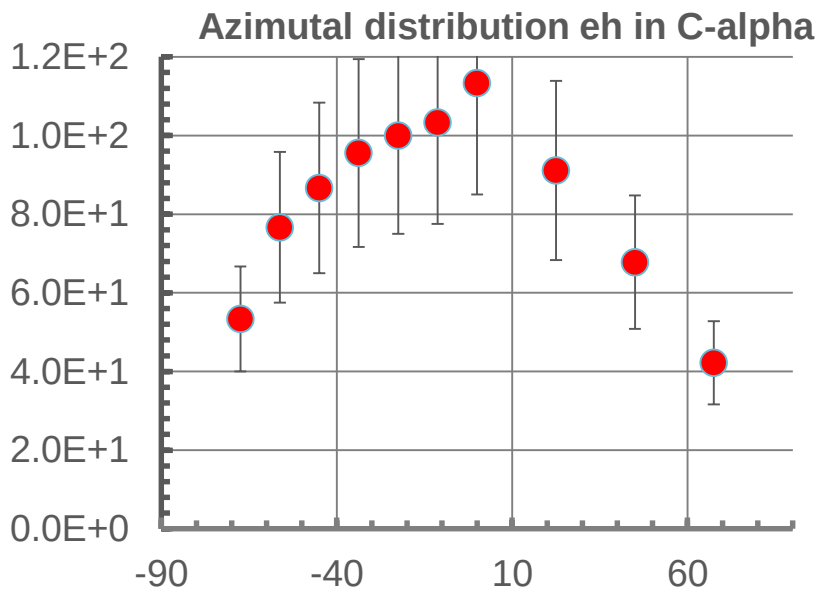
Ec eV	α-C R forward	Cu1 R forward
12,5	0,013	>0,75
25	-	>0,75
50	-	>0,7
100	0,027	0,6…0,75
200	0,018	-
400	0,028	-
800	0,021	-
1250	0,015	-

* Calibration and more experiments are needed to check the result


Azimutal distribution ph in Cu
3.0E+2
2.5E+2
2.0E+2
1.5E+2
1.0E+2
5.0E+1
0.0E+0
-90
-40
10
60


Azimutal distribution ph in C-alpha
1.4E+1
1.2E+1
1.0E+1
8.0E+0
6.0E+0
4.0E+0
2.0E+0
0.0E+0
-90
-40
10
60


Azimutal distribution e in Cu
7.0E+2
6.0E+2
5.0E+2
4.0E+2
3.0E+2
2.0E+2
1.0E+2
0.0E+0
-90
-40
10
60


Azimutal distribution eh in C-alpha
1.2E+2
1.0E+2
8.0E+1
6.0E+1
4.0E+1
2.0E+1
0.0E+0
-90
-40
10
60

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Conclusion

Desorption less than from Cu
Effective suppression of photoelectrons and diffusely scattered photons

Interesting to measure C-alpha with Ti sub-layer

Thanks for your attention

Options for future investigation

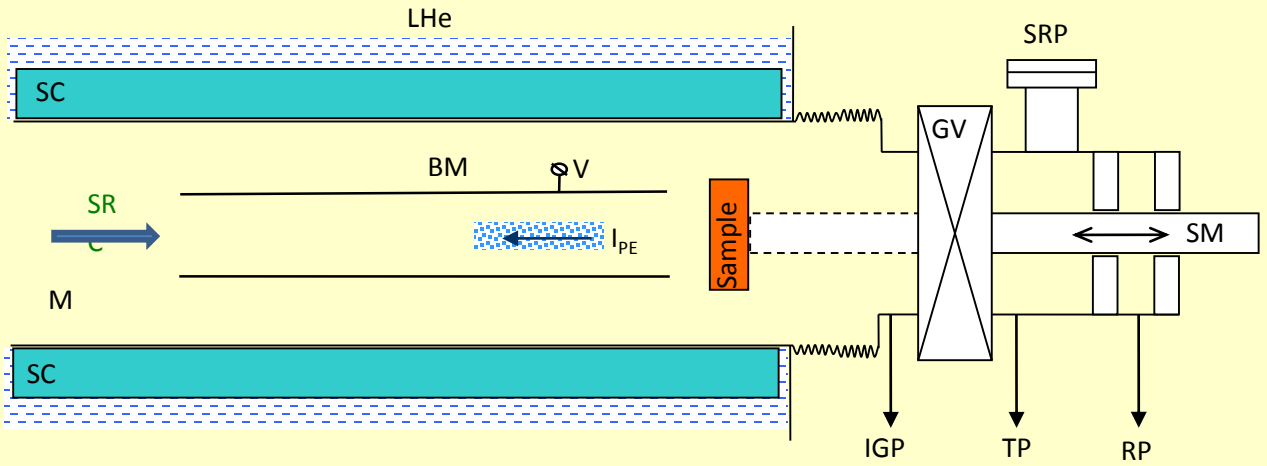
Future possible experiments on the BEP SR Beam Line

- **Photoelectron emission (PEE) from cold surface in presence of strong magnetic field (up to 10T)**
- SEE *in situ*
- XPS (Auger) *in situ (surface element analysis)*
- *Ion desorption under SR*
- RF stimulated electron cloud build-up in presence SR – experimental simulation of phenomena in LHC arc beam pipe
- **Behavior of NEG coating at Low temperatures**

Options for future investigation

PEE from cold surface in presence of strong magnetic field

Main question:
does PEE depend on magnetic field at cryogenic temperatures?



Experimental set-up for PEE measurements
Based on the new SR beam line and 14T SC solenoid of VEPP2000

"SR" – Synchrotron Radiation, "SC" – superconducting solenoid, "C" – thermo-cathode, "BM" – beam monitor, "V" – potential of BM, "LHe" – liquid helium, "GV" – all metal gate valve, "TP" – turbo-molecular pumps, "RP" – rough pump, "SRP" – sample replacement port, "SM" – sample manipulator with double Wilson seal.

Measurement options:

- PEY in strong magnetic field (up to 10 Tesla). DC and time resolution modes.
- TOF measurements of energy distribution of photoelectrons. Pulse repetition is 73,3 ns

Conclusion

- **Experimental program for C-α sample at RT is complete**

- **Experiments at cryogenic temperature are planned in Q1-Q2 2019**

- **A set of proposed investigations with the use the new SR beam line are under consideration**