BEAM HEAT LOAD IN THE ANKA SUPERCONDUCTIVE UNDULATOR

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for

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Overview

- Introduction
- Measurements: beam heat load, pressure
- Potential beam heat load sources
- Experimental results and comparison with theory
- Conclusions and open questions

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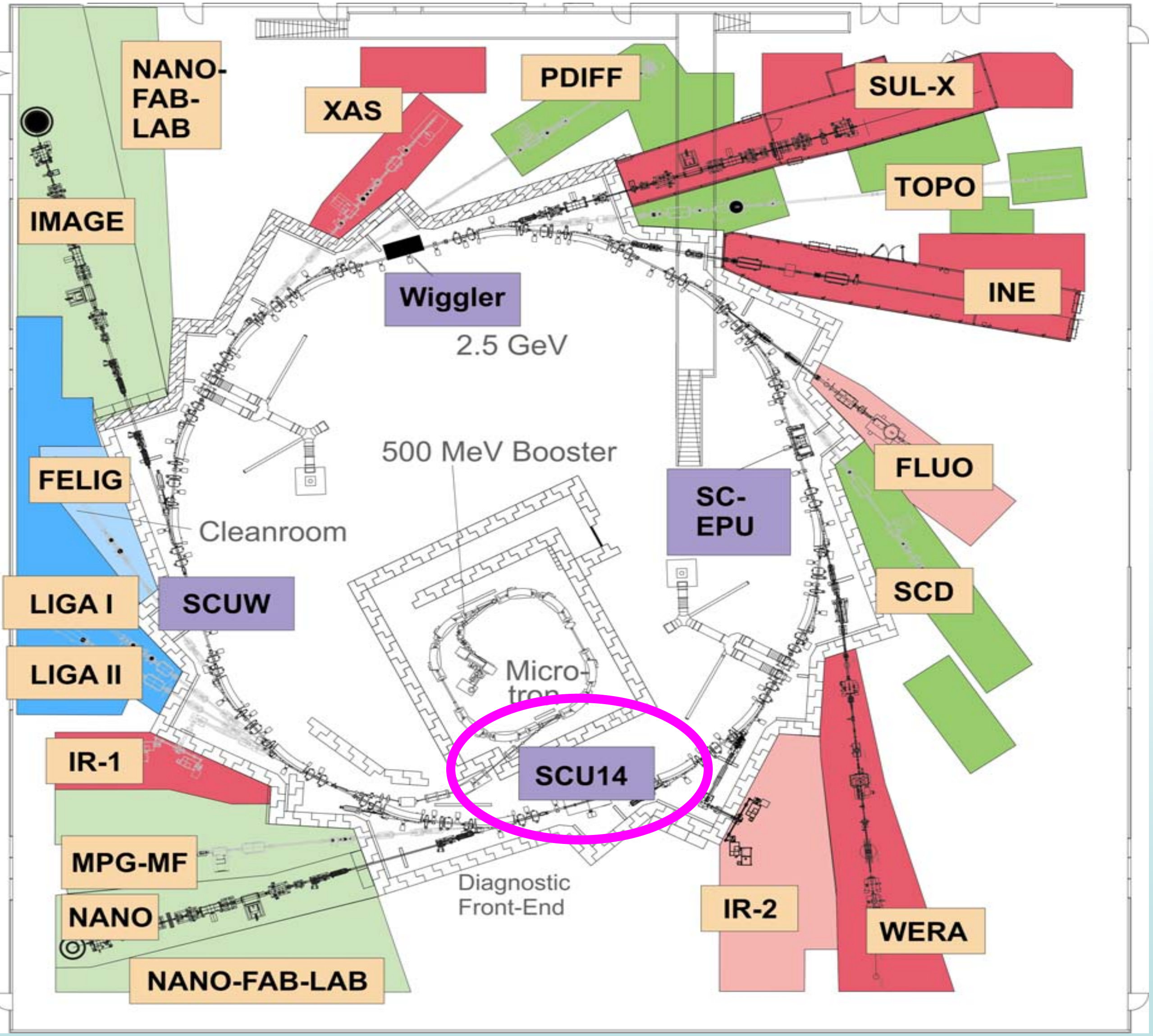
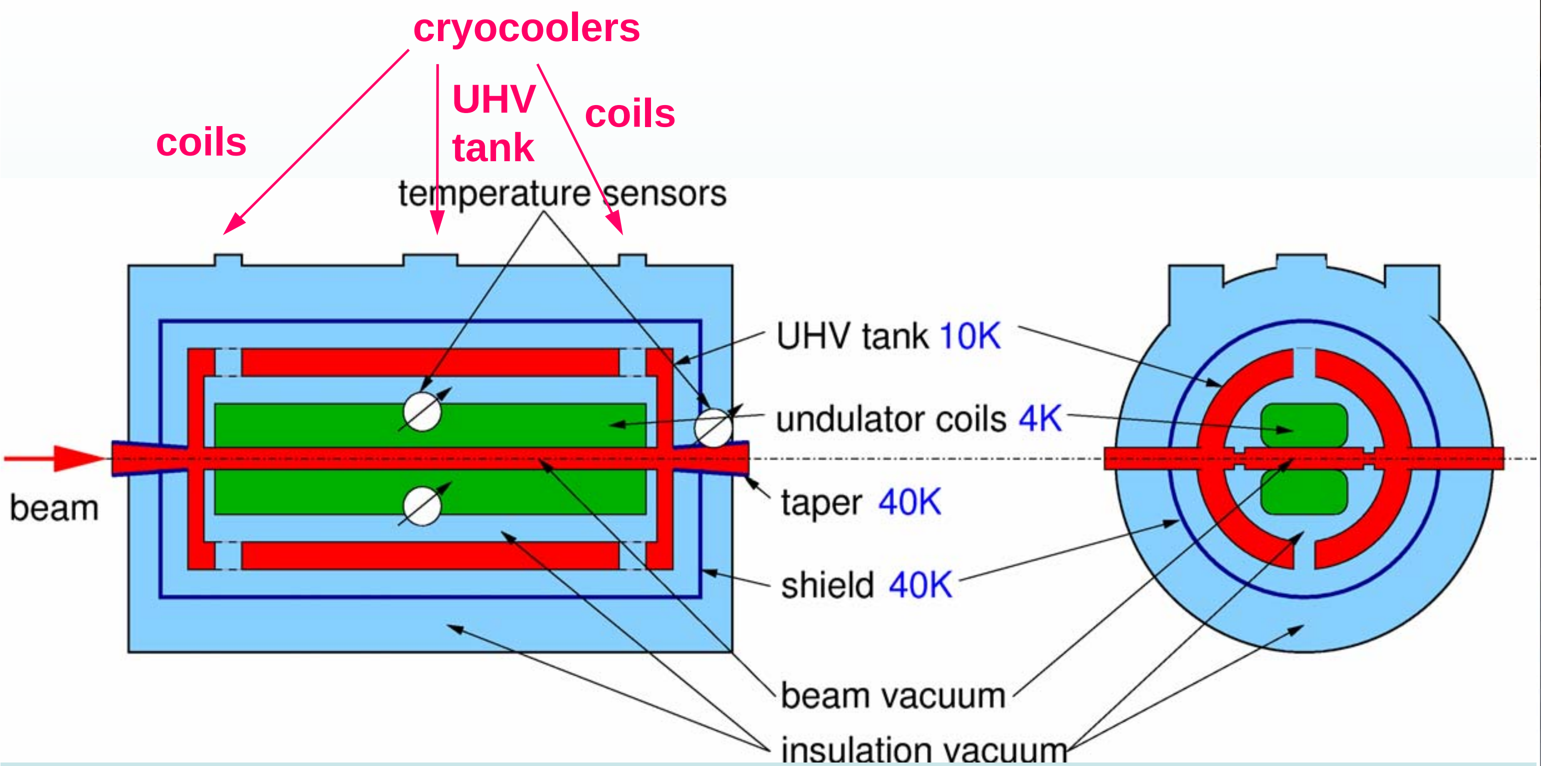
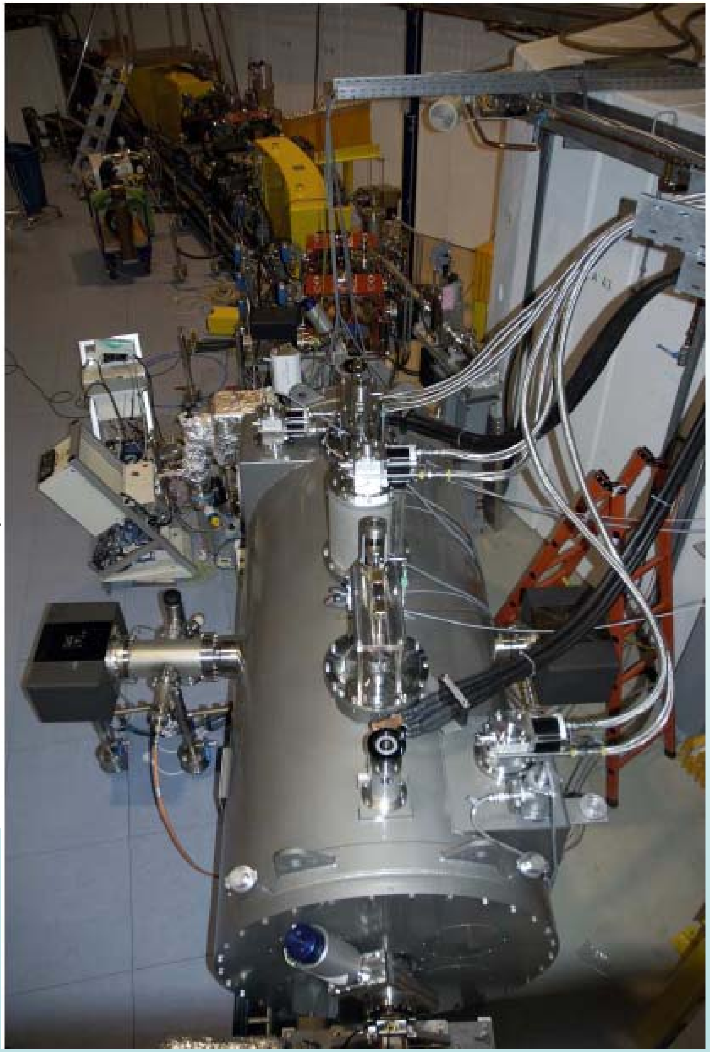
Energy: 2.5 GeV
Current: 200 mA
Circumference: 110.4 m



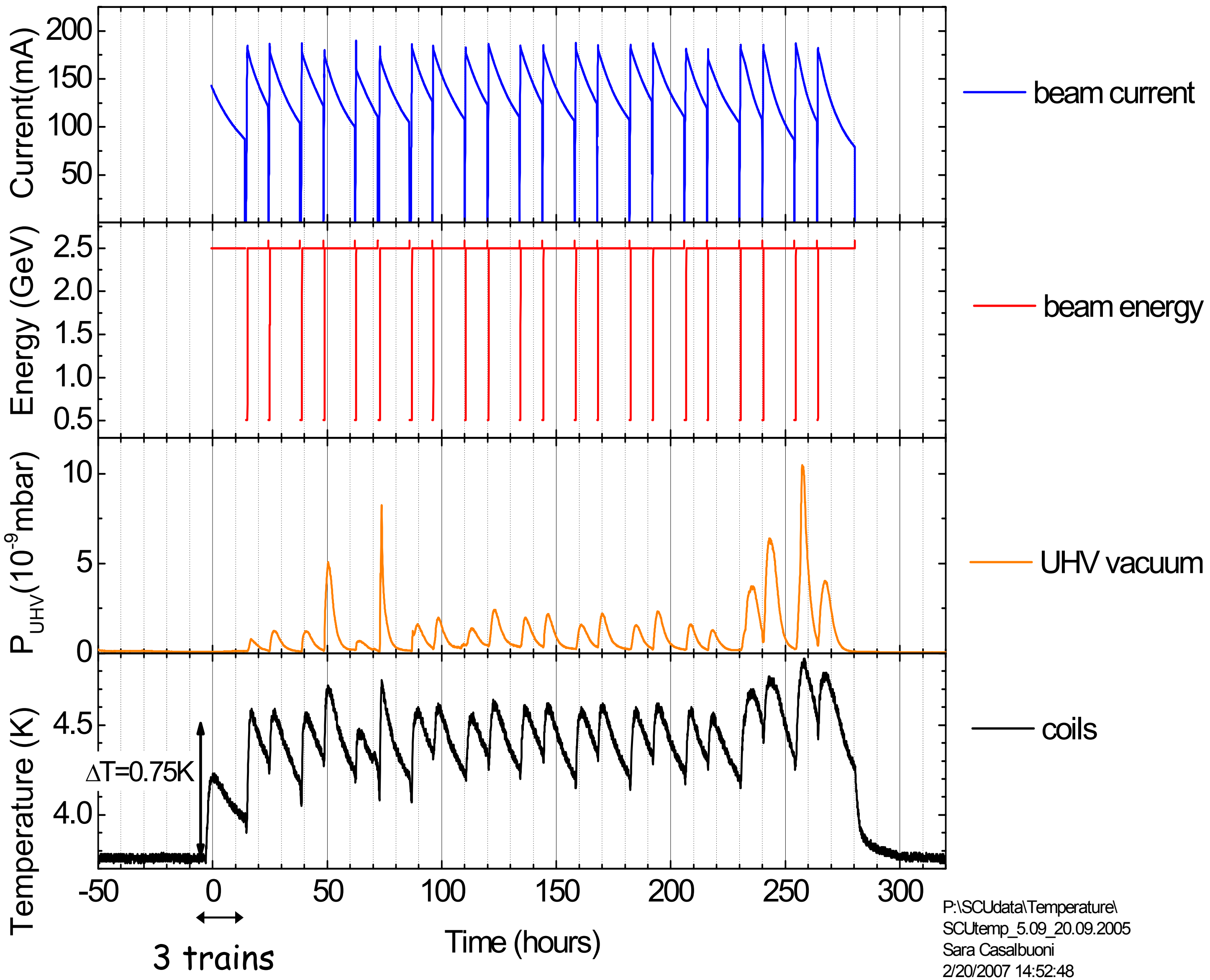
Superconducting undulator: vacuum and cooling system





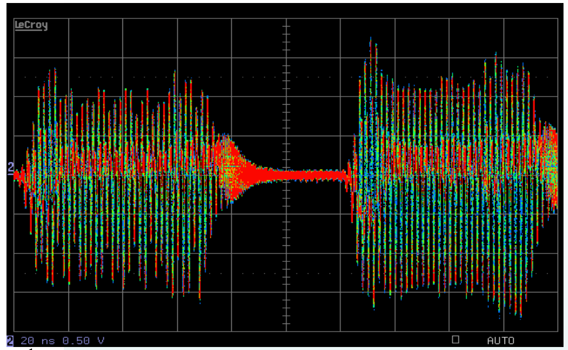
Magnetic gap width: 8, 12, 16 mm
Beam-stay-clear in the open state: 29 mm

Typical run for user operation



E_{beam} = 2.5 GeV; gap=29mm;
2 trains

1 train=32 bunches=64ns



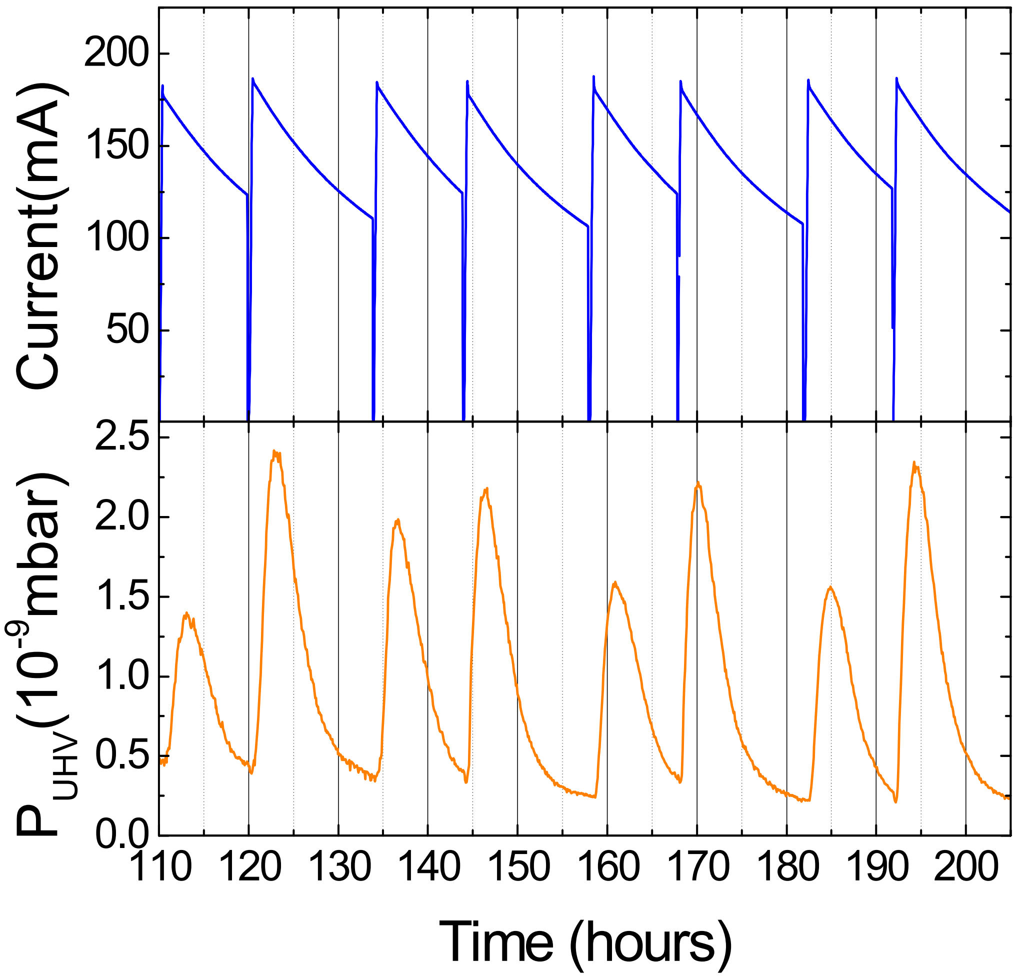
T_r=revolution time = 368ns

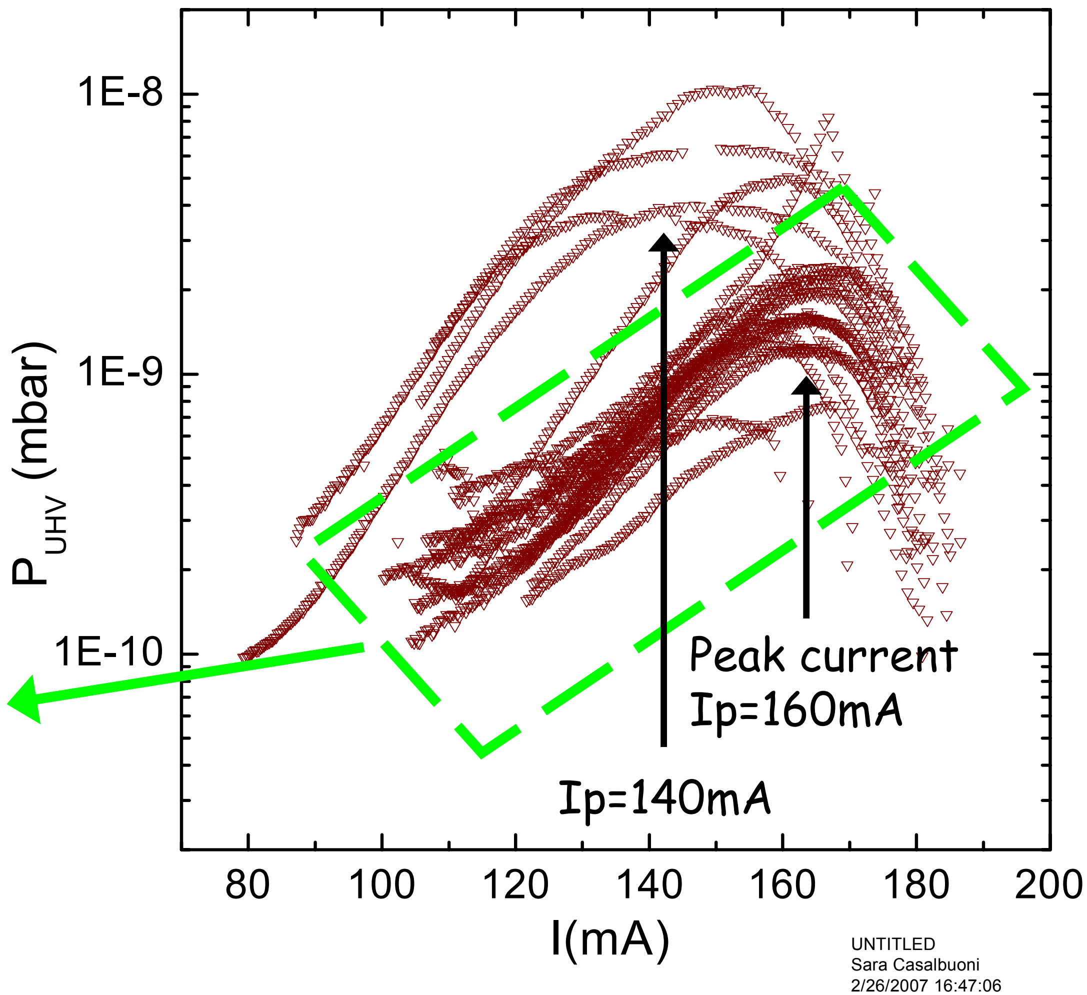
Pressure rise

Heat load coils

$P_{beam} = 0.94 \pm 0.05$ W

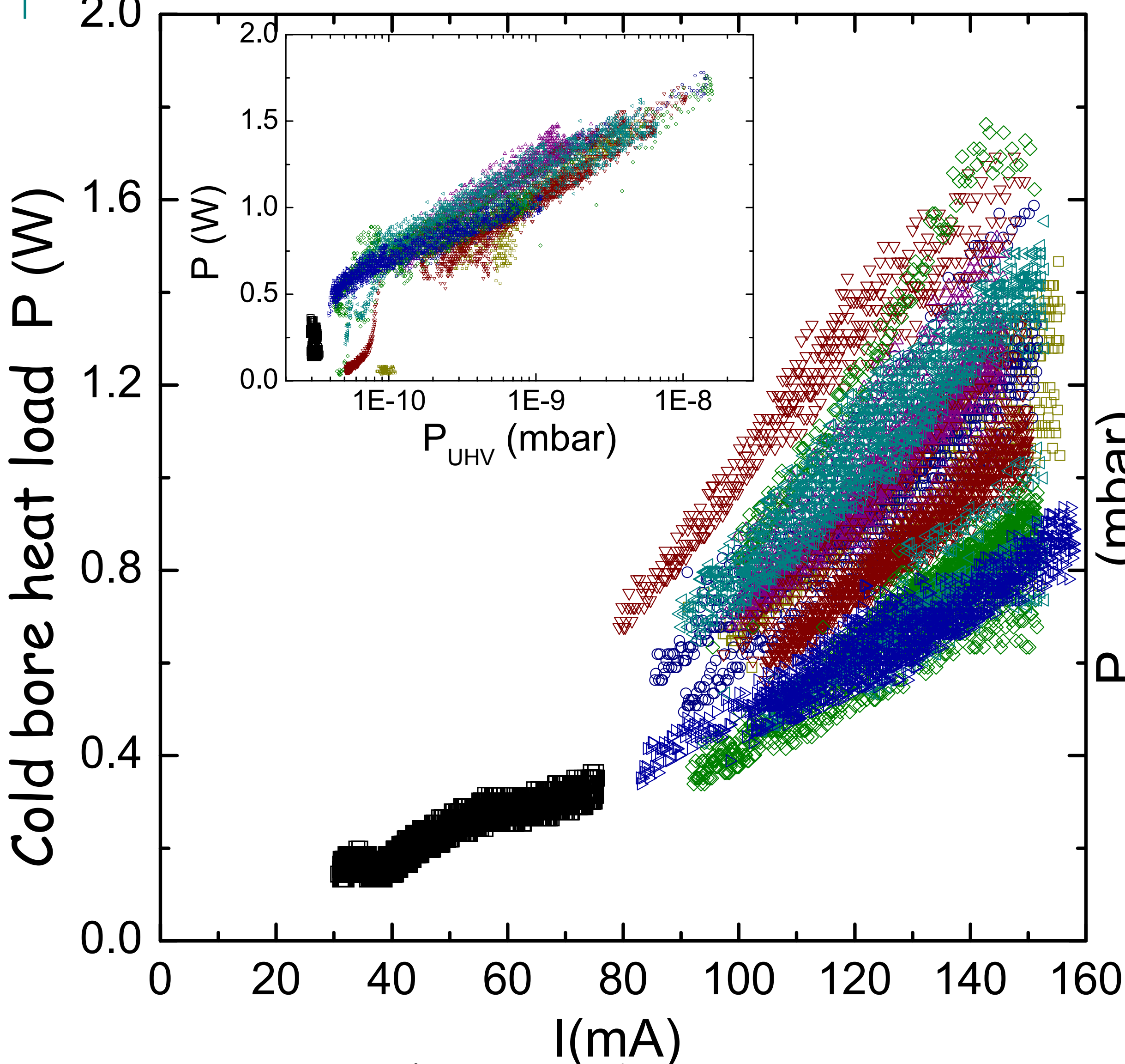
Pressure rise



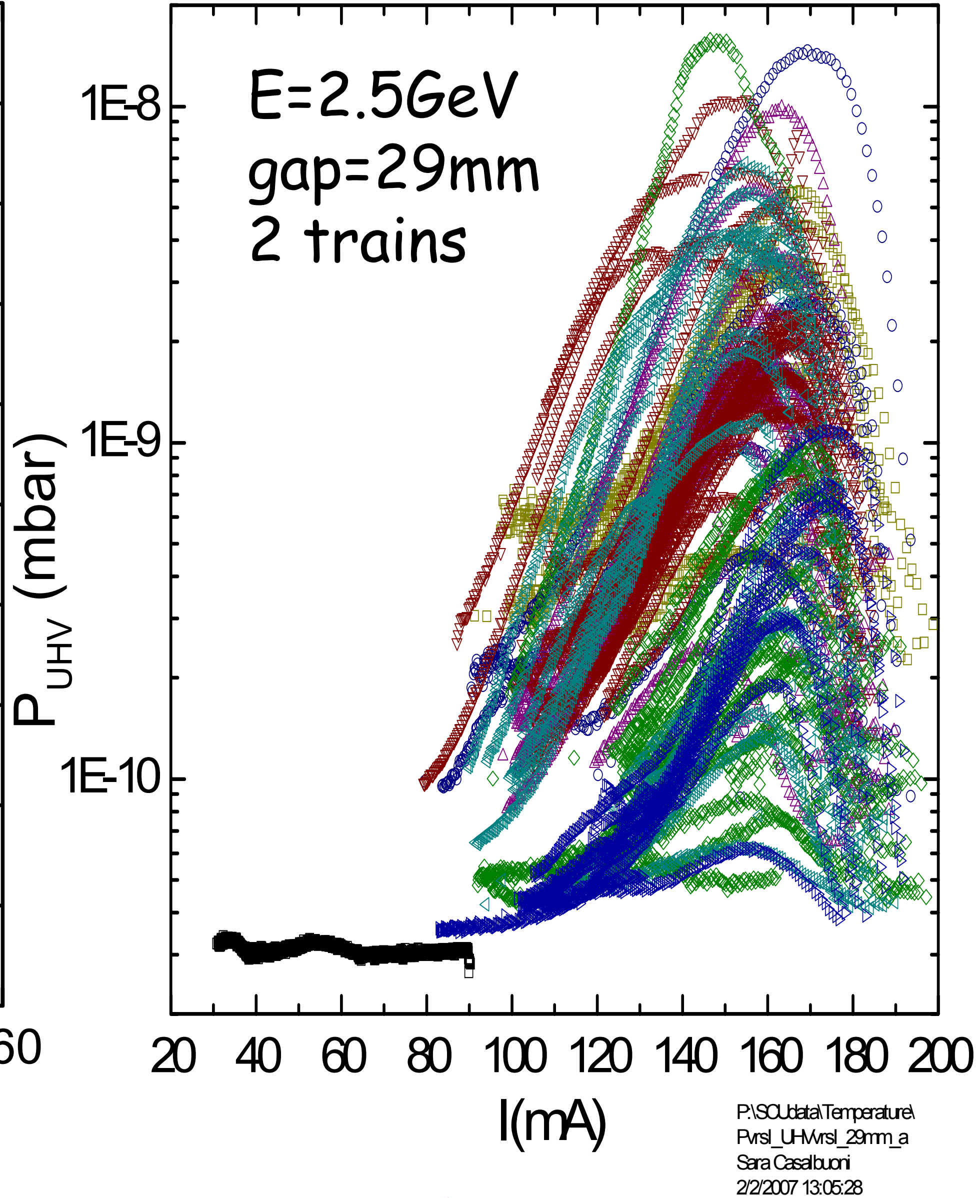


E=2.5GeV; gap=29mm; 2 trains

Variation of the beam heat load over half a year



Stored average beam current



Orbit in all cases identical

Beam heat load sources

Possible sources:

- Synchrotron radiation from upstream magnets
- Image currents on the cold surface (resistive wall heating)
- Ions
- Electrons

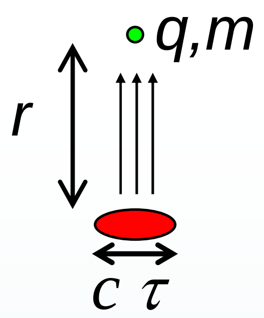
$$P_{\text{Synchrotron}} \propto I$$

$$P_{\text{Resistive wall heating}} \propto \frac{I^2}{M}$$

$$I = \text{stored average beam current}$$

$$M = \text{total number of bunches per revolution}$$

Beam heat load sources: Ions and Electrons



$$E(r)=\frac{\lambda}{2\pi\varepsilon_0 r};\qquad \text{line charge}=\lambda=\frac{eN_b}{c\tau}$$

$$\text{momentum transfer}=\Delta p=qE(r)\tau$$

$$c\tau=\text{bunch length}$$

O. Gröbner, "Beam induced multipacting", PAC1997

$$P_{\text{Electron bombardment}}=\Delta W\cdot\dot{N}$$

$$\Delta W=\text{energy increase of one electron due to the kick by a bunch}$$

$$\dot{N}=\text{electrons hitting the wall per sec}$$

$$\Delta W=\frac{\Delta p^2}{2m}=\left(\frac{q\cdot e\cdot N_b}{2\pi\varepsilon_0\cdot c\cdot r}\right)^2\Big/2m$$

Ions contribution negligible

$$\text{particles per bunch}:\ N_b=\frac{I\cdot T_r}{e\cdot M}$$

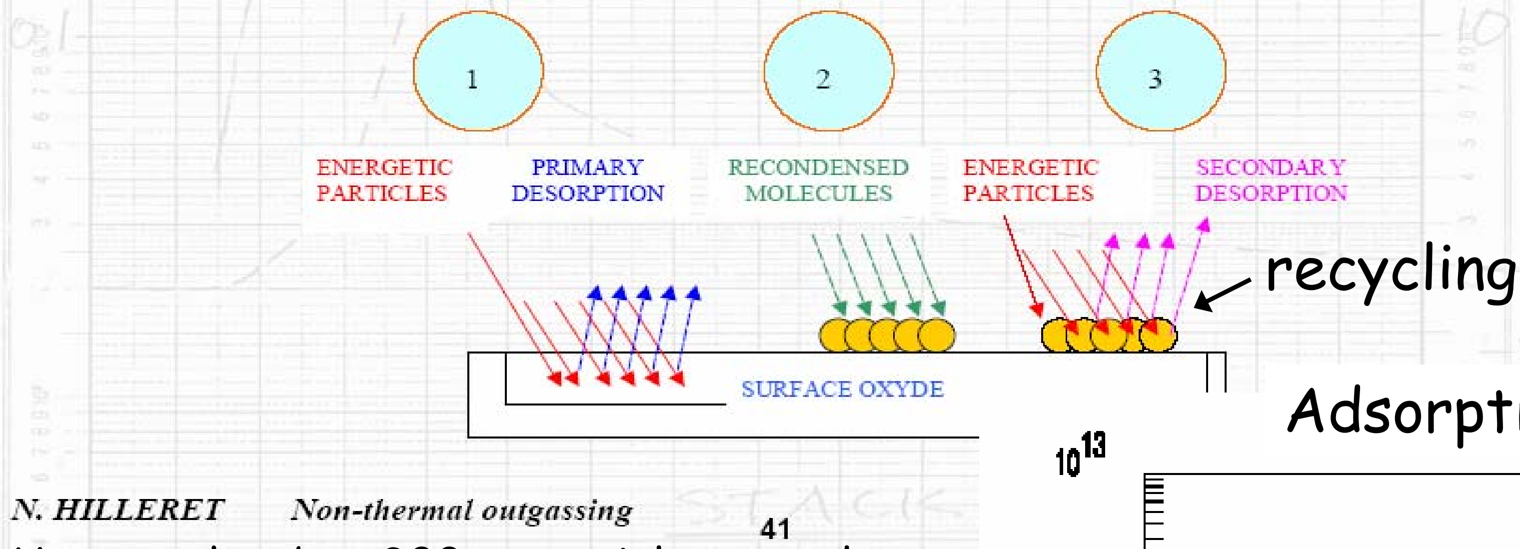
I = stored average beam current

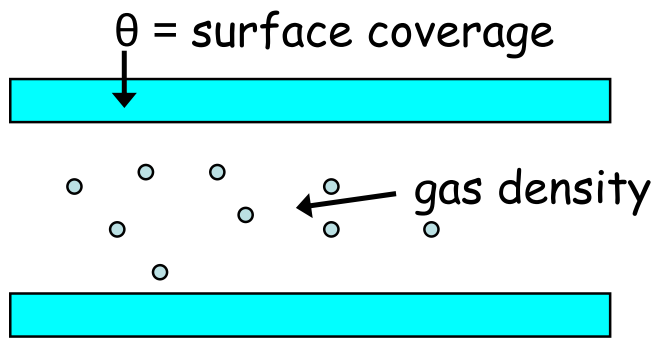
M = total number of bunches per revolution

T_r = revolution time

$$P_{\text{electron bombardment}}\propto\left(\frac{I}{M}\right)^2\cdot\dot{N}(E,I,M,r,\ldots)$$

Possible electrons source: condensed gas layer physisorbed on the surface





Vacuum chamber 300 μm stainless steel with 30 μm electroposited Cu

Dominating desorbed gases: H_2, CH_4, CO, CO_2

Only H_2 non negligible vapour press. at 4-20K

Adsorption isotherm varies with:

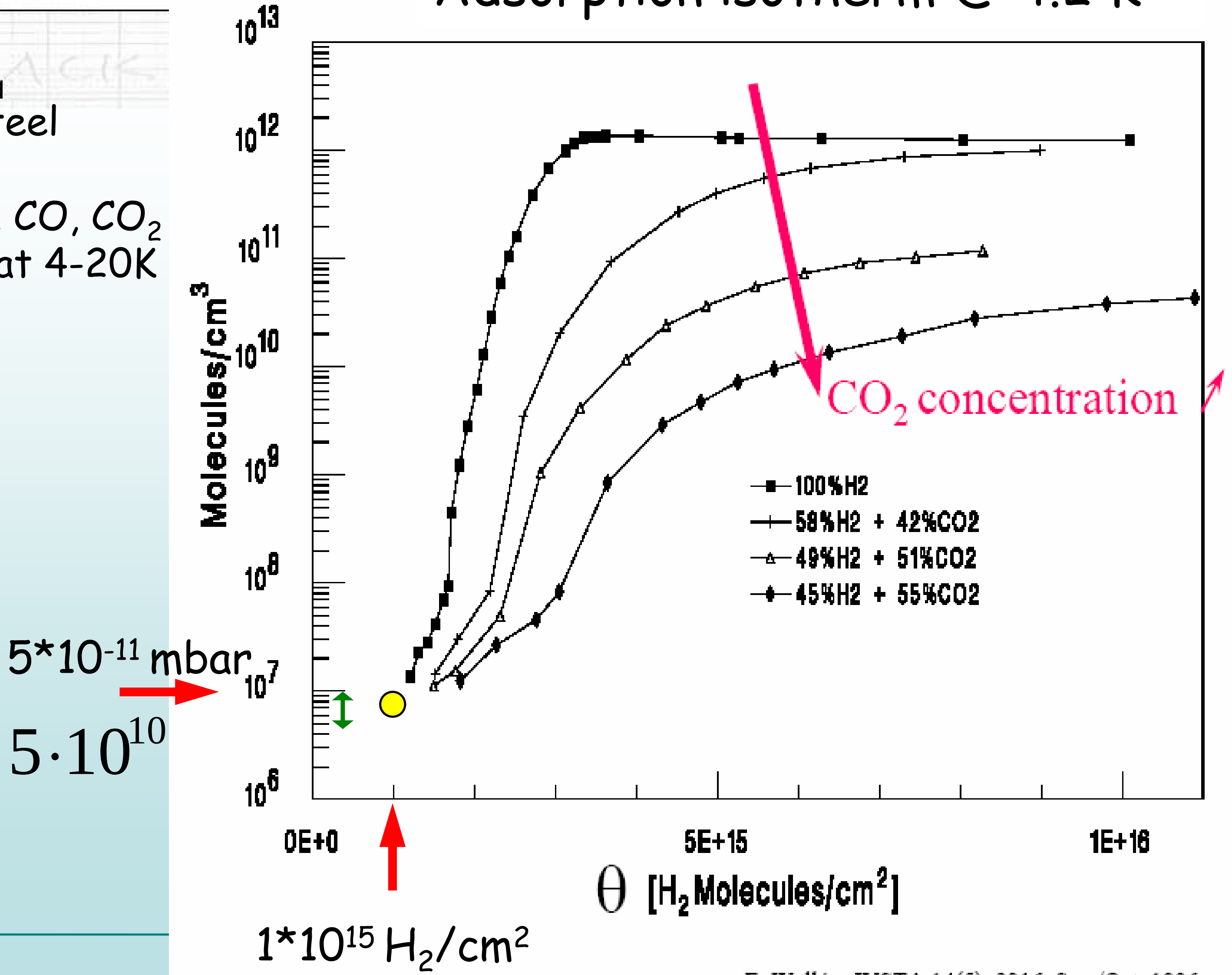
- molecular species
- surface temperature
- surface nature
- gas composition inside the chamber

$$N_{Surf} \approx 3 \cdot 10^{17}$$

$$N_{Vol}(P_{UHV} = 10^{-11}\text{mbar}) \approx 5 \cdot 10^{10}$$

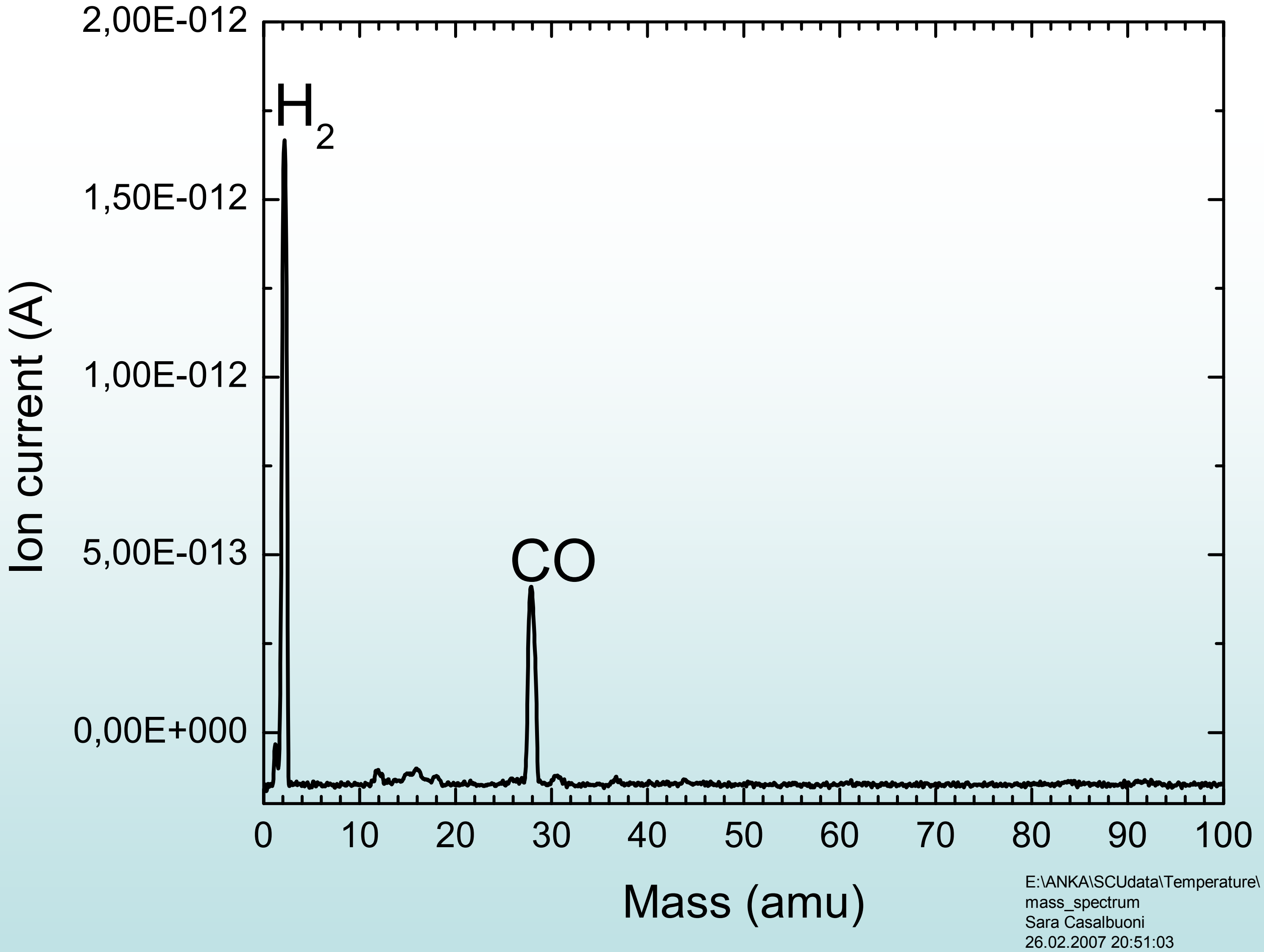
$$N_{Surf} >> N_{Vol}$$

Adsorption isotherm @ 4.2 K

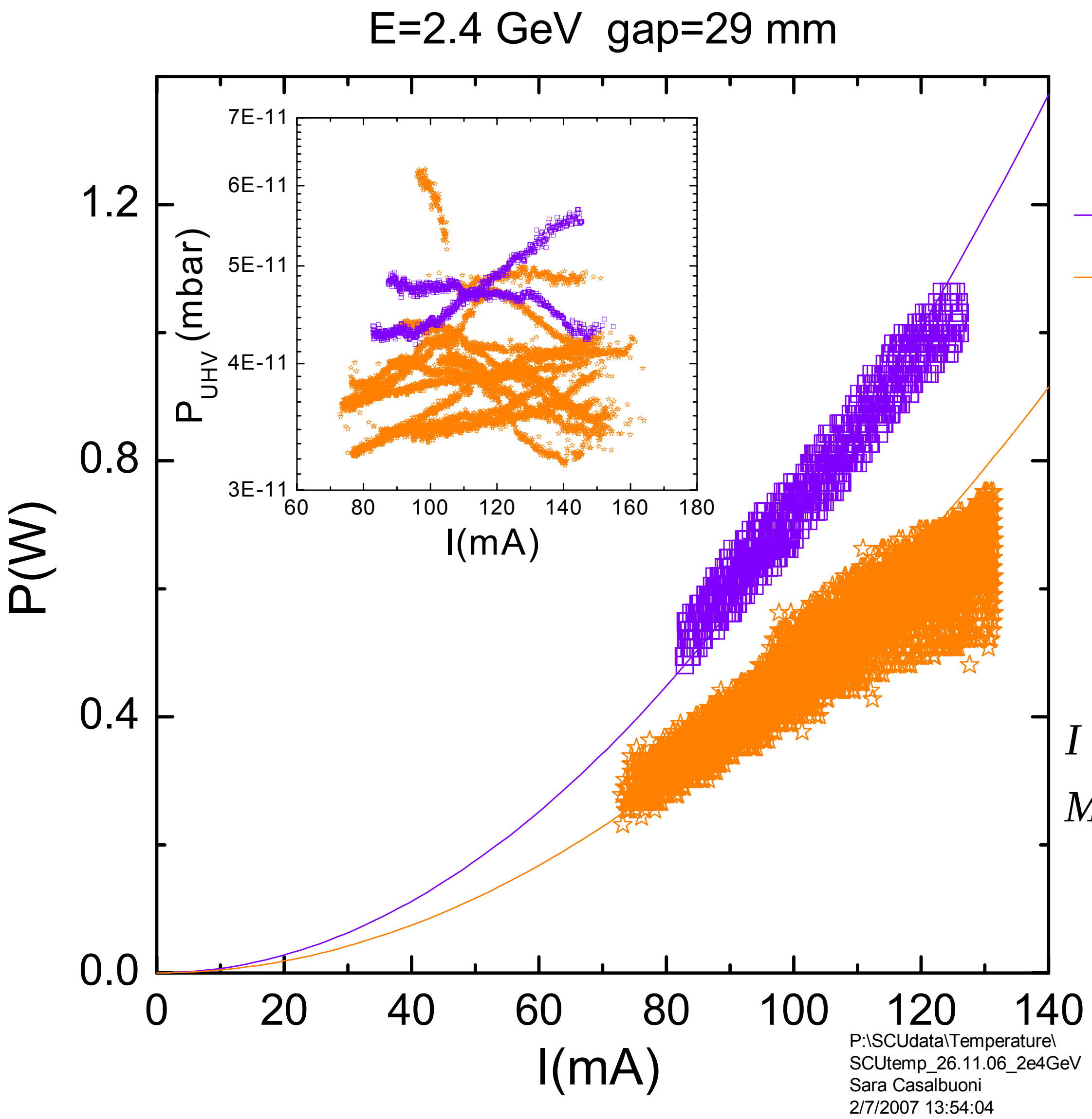


E. Wallén, JVSTA 14(5), 2916, Sep./Oct. 1996

Measured mass spectrum with beam in the warm section before the undulator



Beam heat load: current dependence



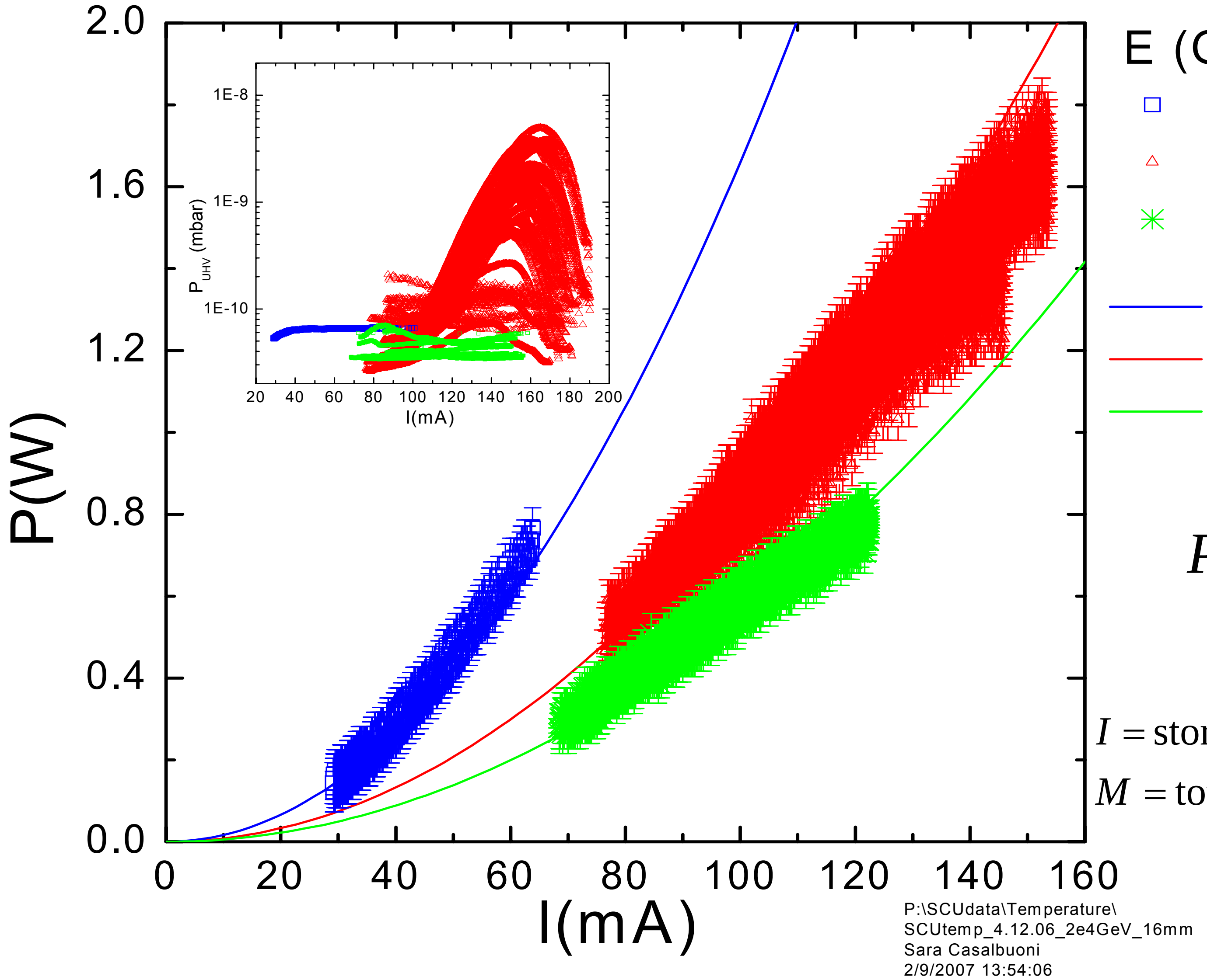
$$P(W) \propto \frac{I^2}{M}$$

I = stored average beam current

M = total number of bunches per revolution

Beam heat load: current dependence

Gap=16 mm



E (GeV)	trains
□ 2.5	1
△ 2.5	2
✳ 2.4	3

$P(W)=0.000166*I^2(mA)$

$P(W)=0.000166/2*I^2(mA)$

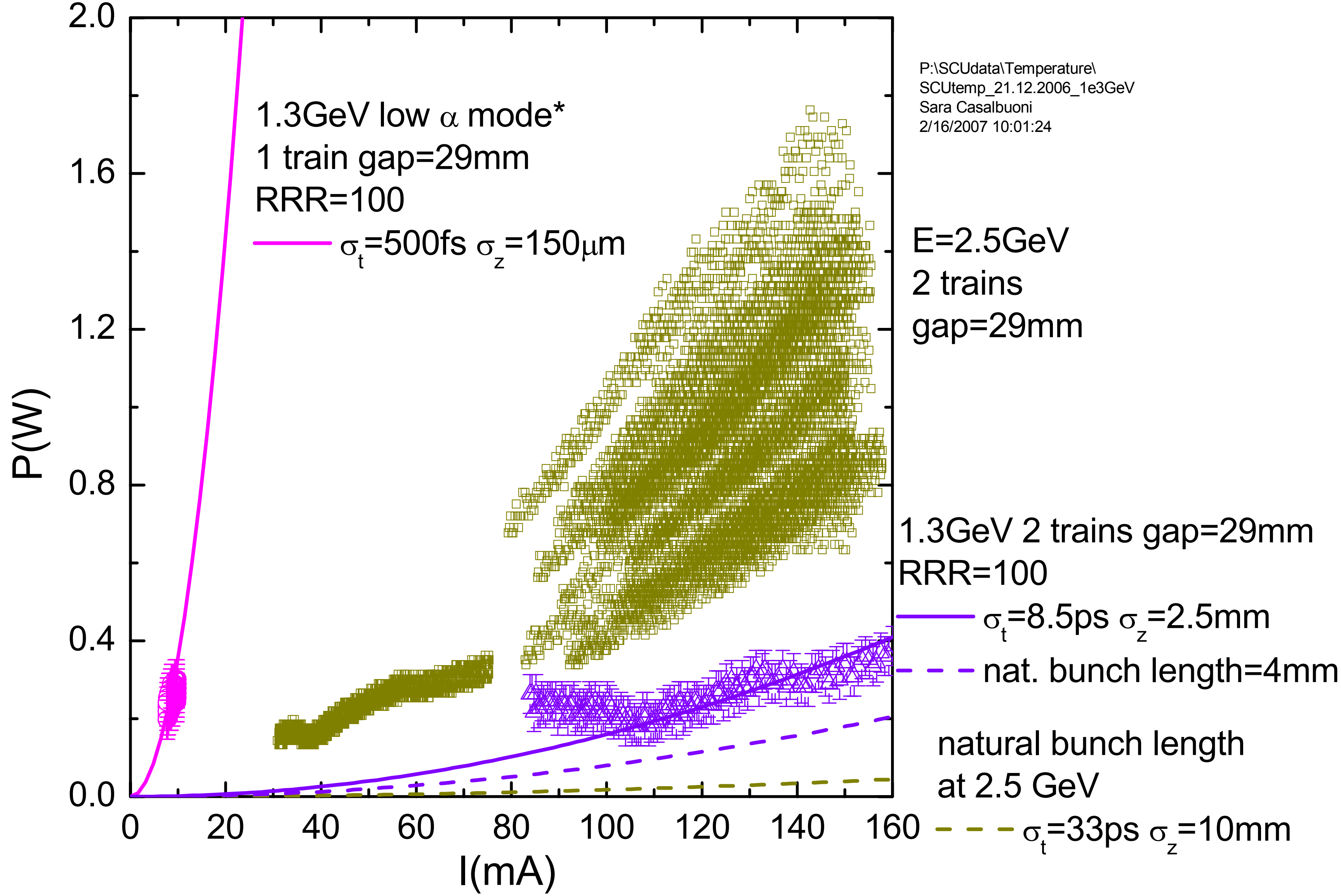
$P(W)=0.000166/3*I^2(mA)$

$$P(W) \propto \frac{I^2}{M}$$

I = stored average beam current

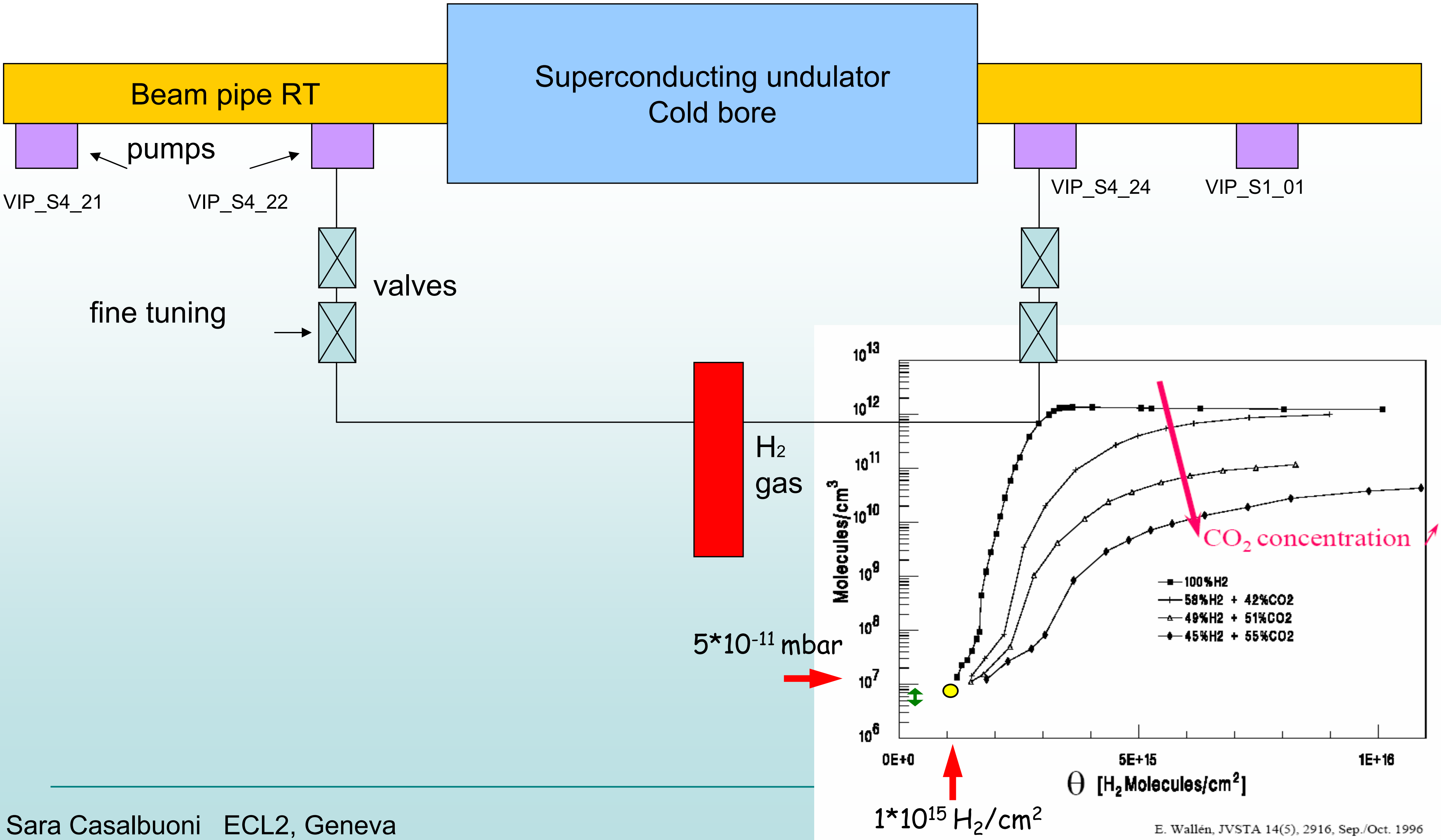
M = total number of bunches per revolution

Beam heat load versus bunchlength



*A.-S. Müller et al., 'Far infrared coherent synchrotron edge radiation at ANKA', PAC05

H_2 experiment



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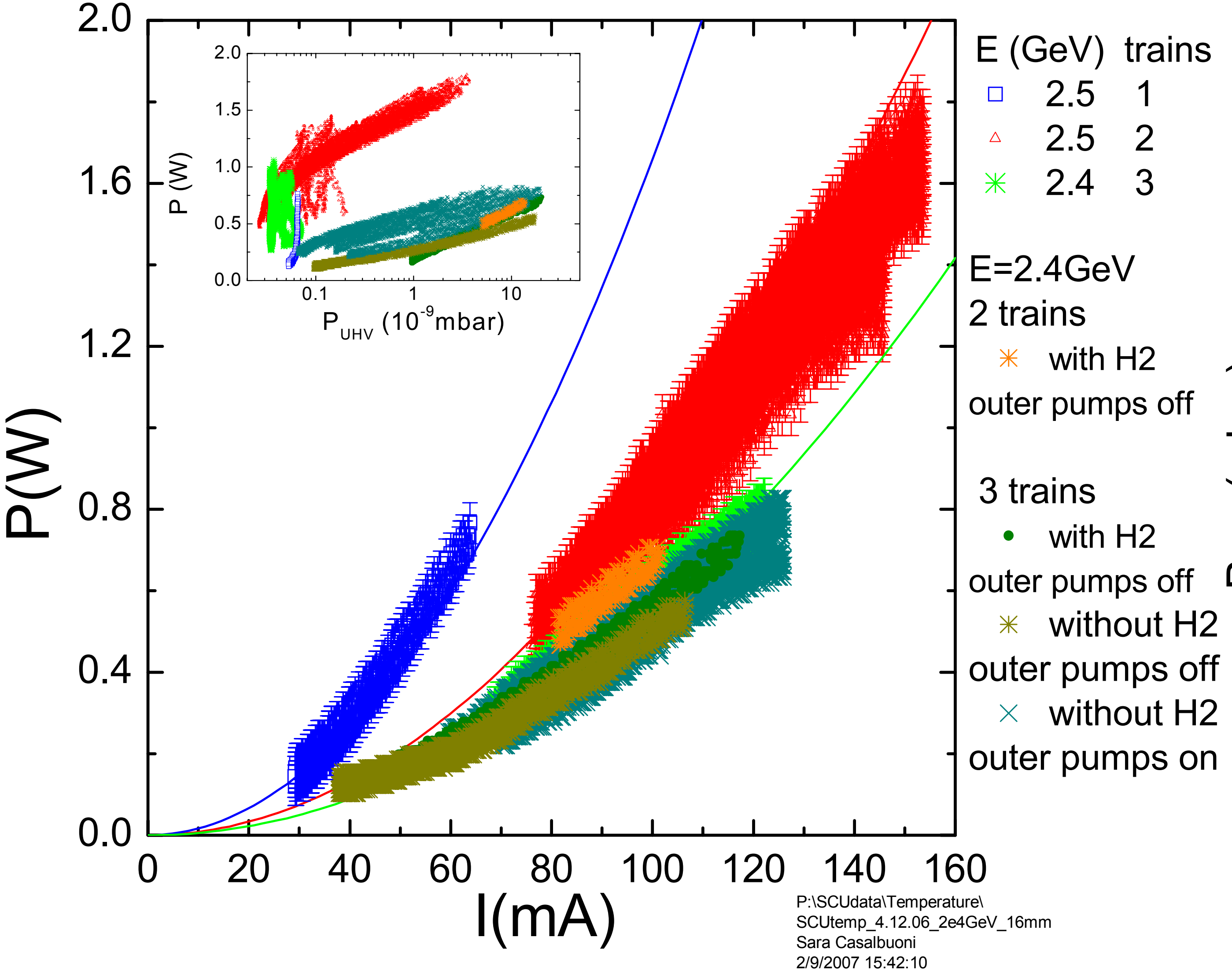
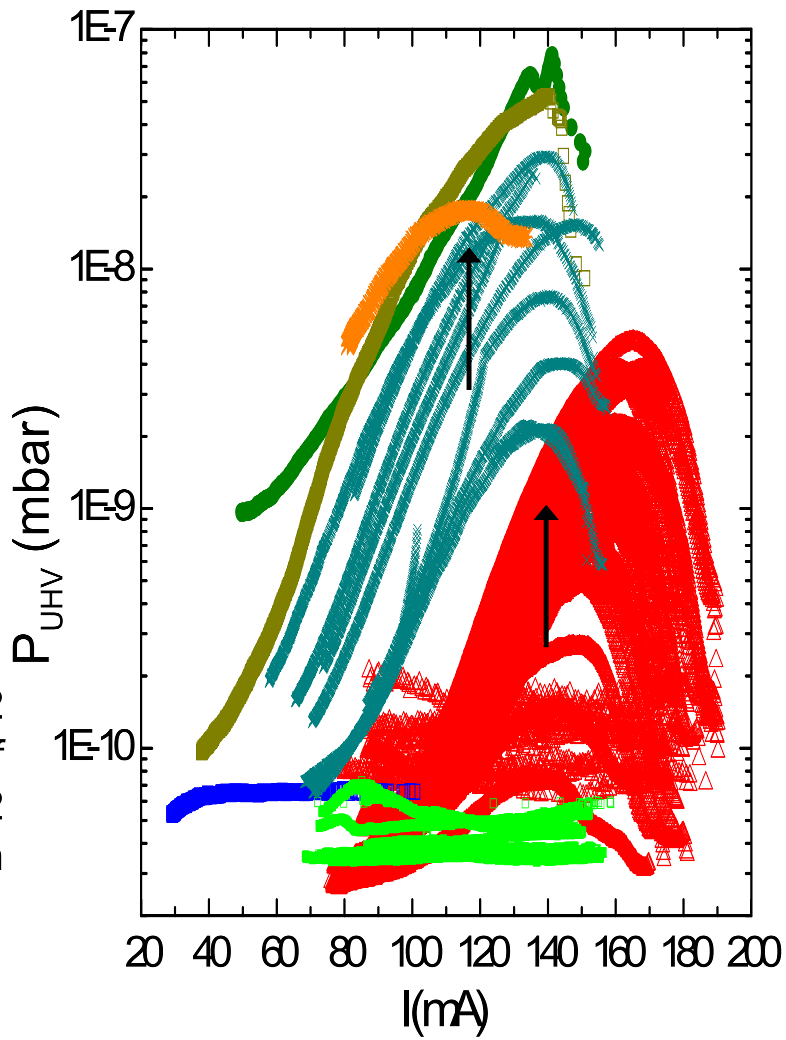
H_2 experiment

Gap=16 mm





Conclusions and open questions

•Non linear pressure rise with current

•Why? H_2 recycling and multipacting?
•For higher pressures the peak current is lower
•For lower M=total number of bunches per revolution the peak current is lower
•Not always observed: does the peak current depend on another parameter?

•Beam heat load

•Synchrotron radiation excluded by the data
•RWH can explain the heat load for short bunches
•RWH can NOT explain the heat load for long bunches
•Other resistive effects, for example from the taper? $P(W) \propto I^2/M$
But lower E $\Longrightarrow$ shorter bunch length $\Longrightarrow$ higher heat load
Why scattering in the data if resistive mechanism?

•Heat load from electrons from condensed gas layer?
•Which mechanism is responsible of releasing electrons?