Progress on investigation of dynamic vacuum (RF structures only)

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Requirements from beam dynamics

- The vacuum threshold for preventing fast ion beam instability (essentially due to direct field ionization and not the usual impact ionization) :

Main beam linac requirements :

total $p \leq$ few 10^{-9} Torr each for CO, N_2 and/or H_2O.

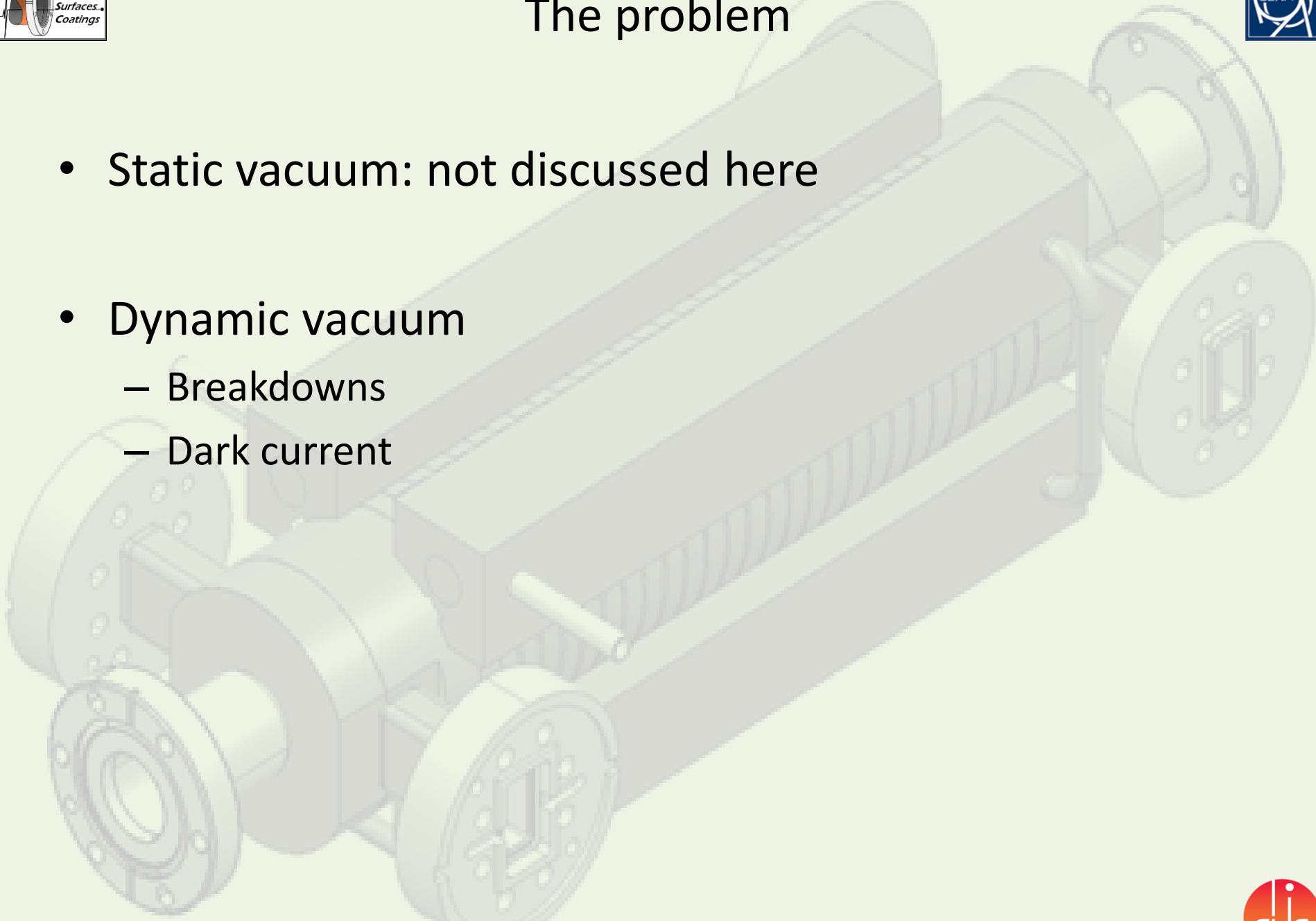
H_2 is not harmful ($p \leq$ few10^{-8})

- True for practically all the main LINAC length, also inside the RF accelerating structures
- For details see:
  - G. Rumolo, A Oeftiger http://cdsweb.cern.ch/record/1406050?ln=en
  - C. Garion https://edms.cern.ch/document/1095288/1

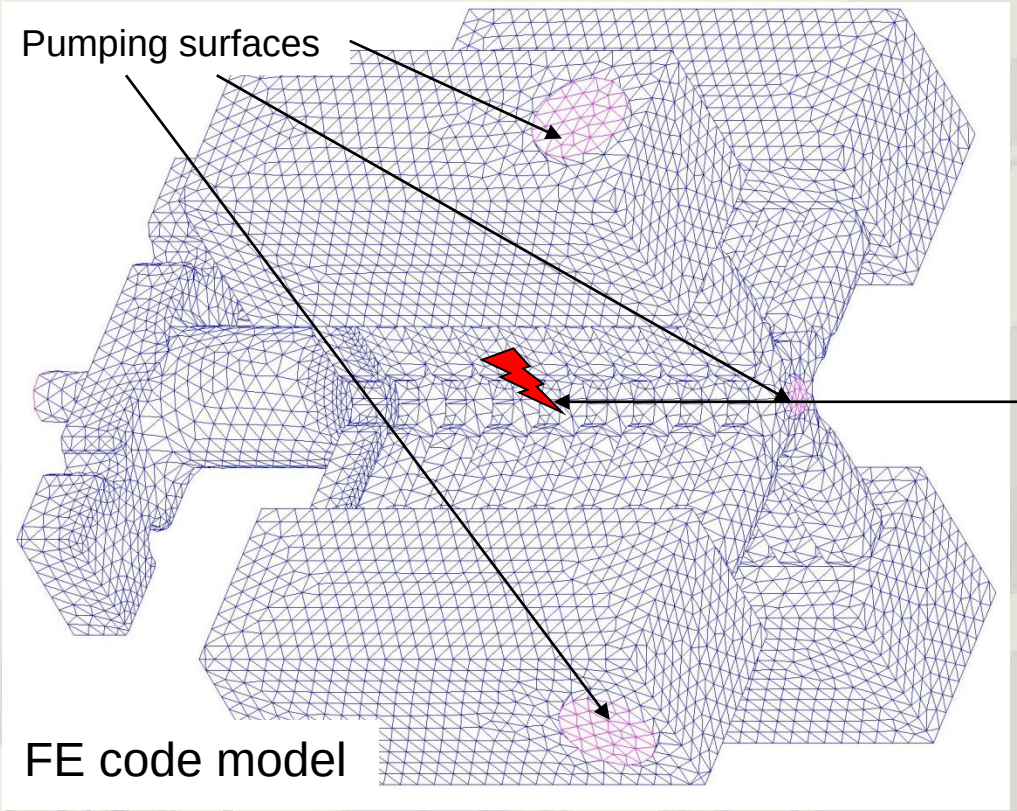
The problem

- Static vacuum: not discussed here

- Dynamic vacuum
  - Breakdowns
  - Dark current



Dynamic vacuum – Breakdown I



2.10^{12} H_2 or CO molecules released during breakdown (in a baked system)

Data measured in DC “spark test” reported in PRST-AB12, 092001 (2009)

Dynamic vacuum – Breakdown II

Calculated with Monte-Carlo and thermal analogy model

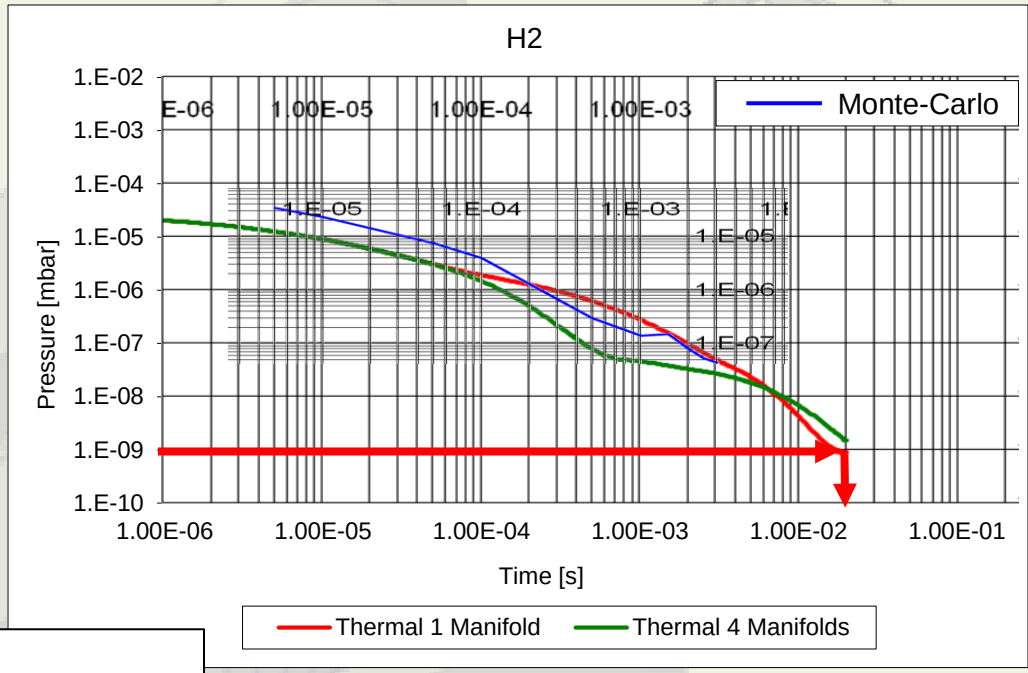
Maximum pressure vs time:

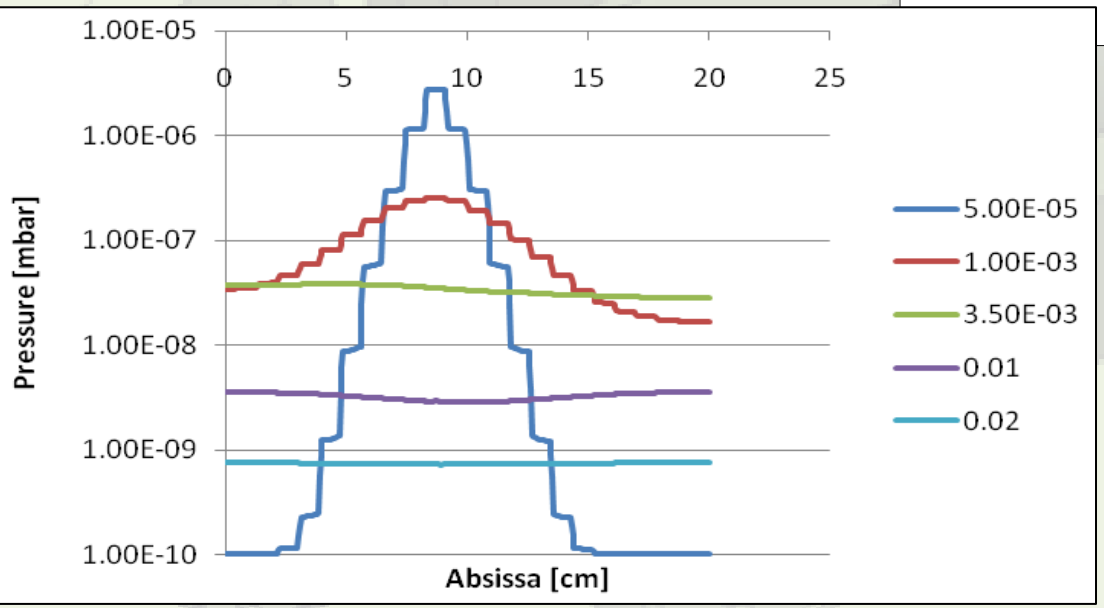
20 ms to reach 10^{-9} mbar for H_2

20 ms to reach $5x10^{-8}$ mbar for CO

(Note: CLIC repetition rate = 50 Hz

Duty cycle = 20 msec)





Calculated with thermal analogy model (and Monte-Carlo model)

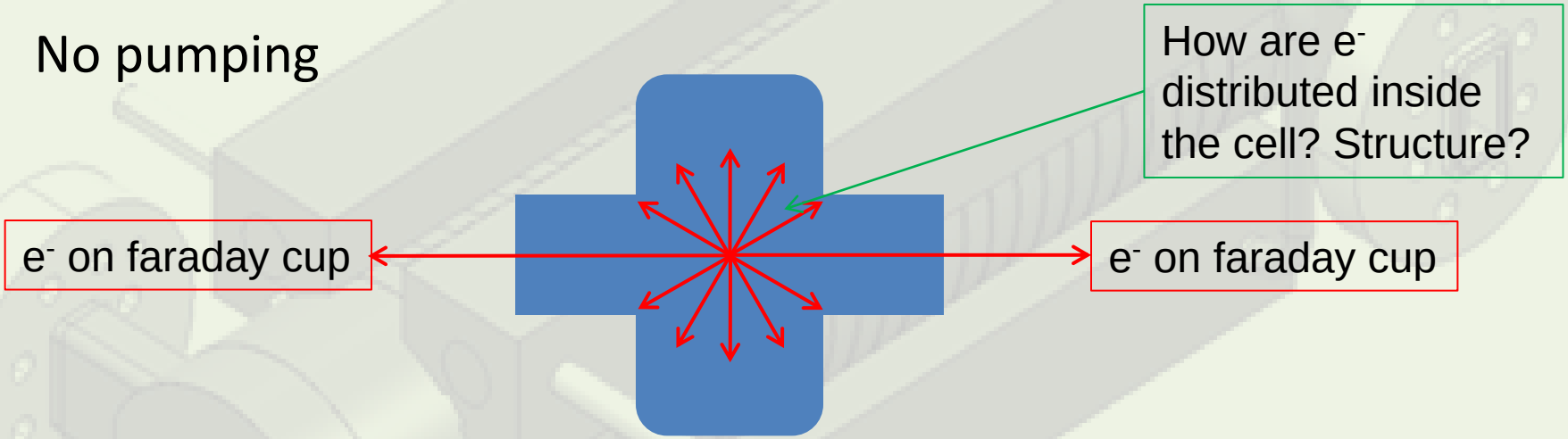
Four manifolds

Longitudinal pressure distribution in the cells:

Uniform after ~3 ms

Dynamic vacuum - Dark currents

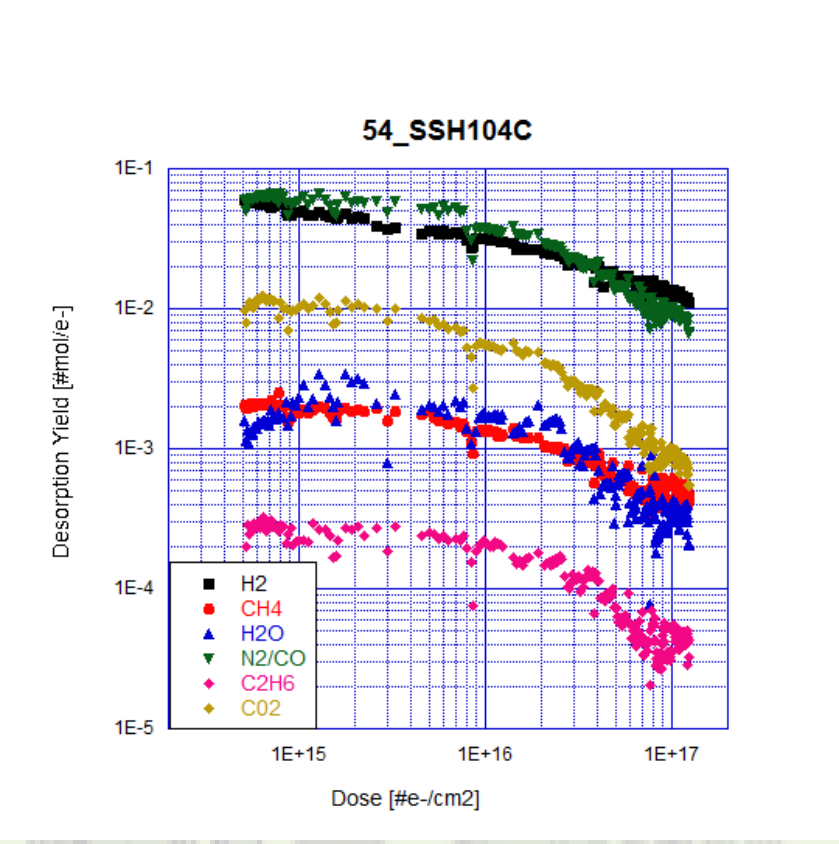
- Dark-current electrons are field-emitted, impact on surfaces and desorb gas
- Dynamic vacuum by ESD: desorbed molecules fill the whole cell volume
- No pumping

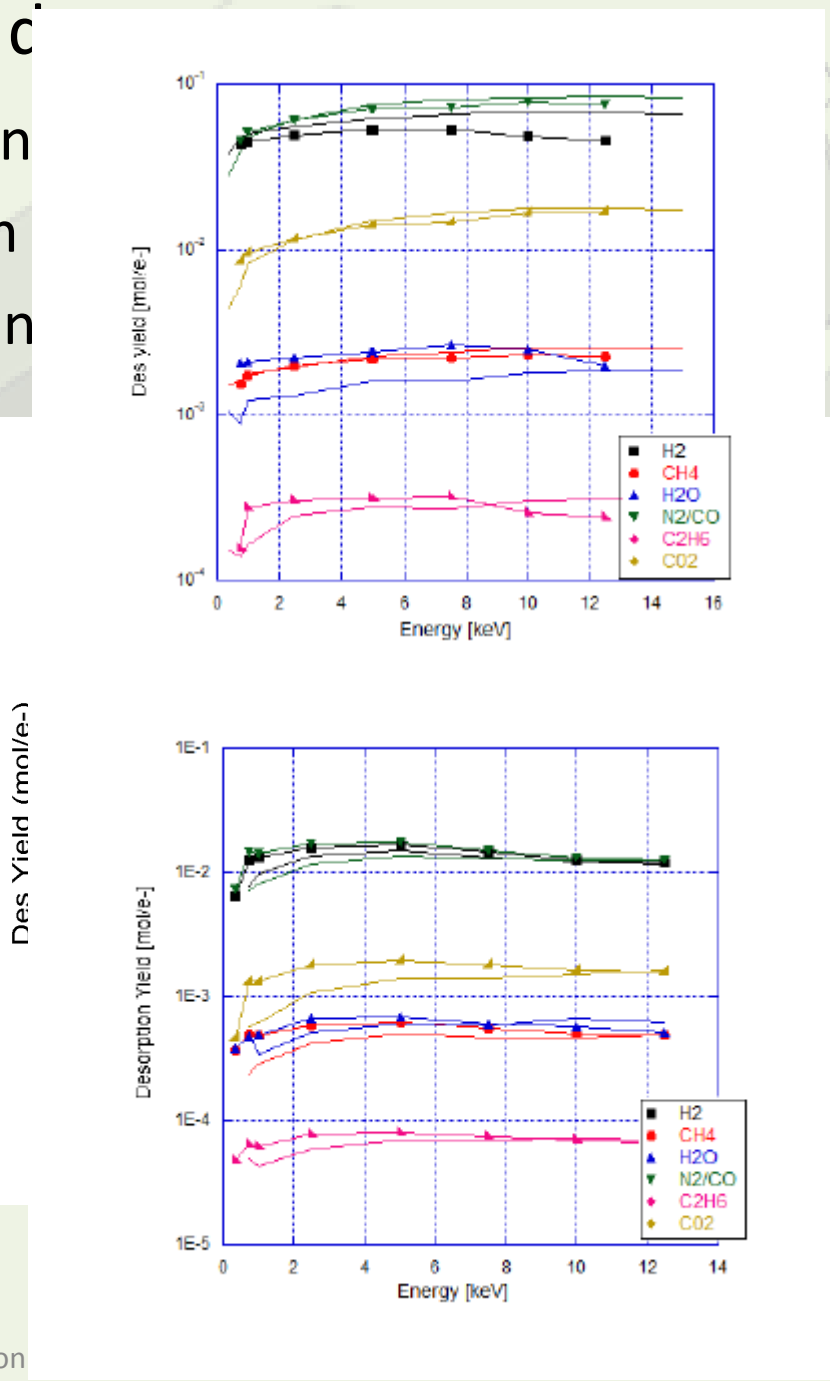


- e^- current ~ $10^{-4 \div -3}$ A during pulse
- Need e^- distribution and energy + ESD coefficients at high energy

ESD d

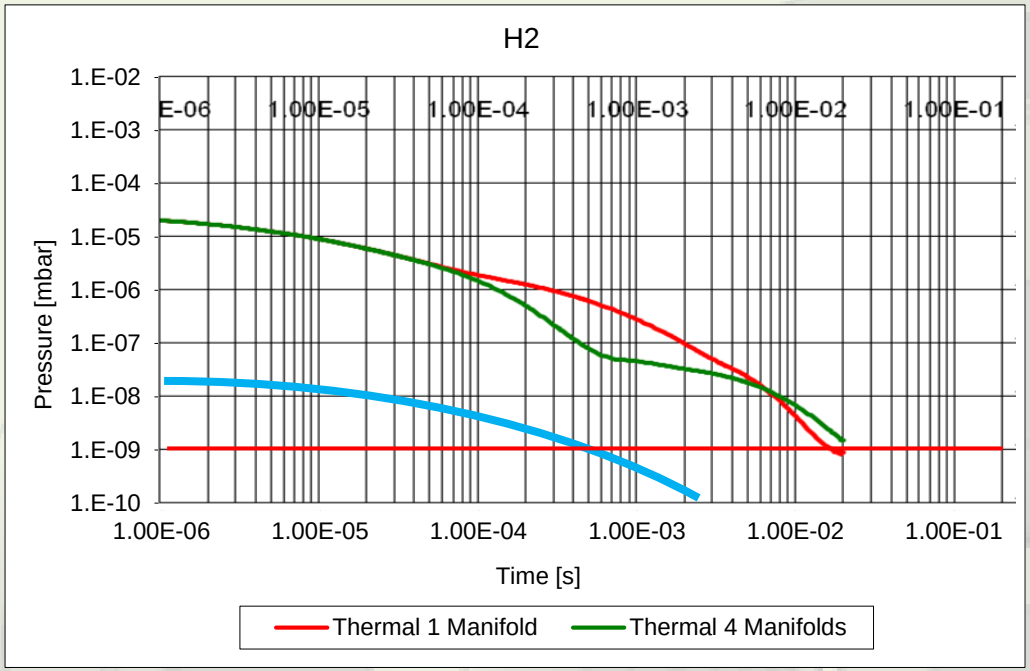
- Work of C. Pasquino & I. Martin
- New ESD measurement system
- Several surface treatments bein





Dynamic vacuum I – Results

Molecules released per pulse ~ few 10^7 both for H_2 and CO, resulting in pressure bursts of few 10^{-8} mbar locally



Pressure goes to < 10^{-9} mbar in less than 1 msec ! This is faster than the sampling time of common vacuum gauges...

Same plot as for dynamic vacuum due to breakdowns (2×10^{12} molecules released)

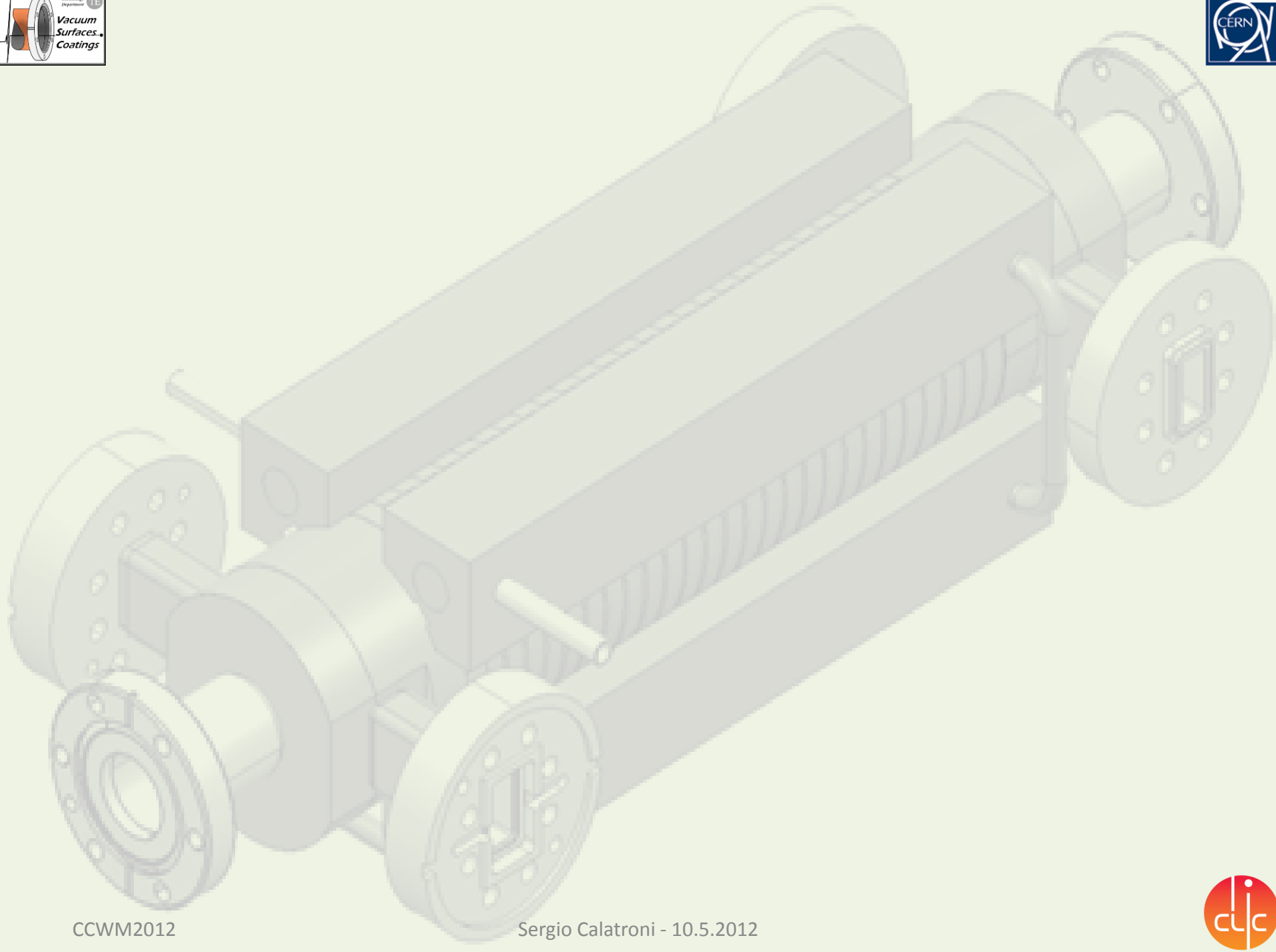
Extrapolating to 1000 less molecules released due to ESD

Outlook 1

- Static vacuum achieved but only marginally with present design
  - Need more precise data on water re-adsorption (sticking probability depends on coverage)
- Dynamic vacuum due to breakdowns seem to be under control (recovery time ≤ pulse repetition)
  - However, data from RF tests are needed for further cross-checking

Outlook 2

- Dynamic vacuum due to dark currents: still open question
- Experimental programme:
  - ESD data on unbaked copper at high e^- energy from CERN √
  - Dark current simulations from SLAC – ACE3P
  - Introduce these into MC+FEM models and get gas distribution
  - Direct measurements should be attempted in 12 GHz test bench
    - Feasibility should be demonstrated
    - Collaborations ?



Molecule speed

	Atomic mass	Molecule speed @ 300 K [m/s]	Molecule displacement in RF pulse [mm]
H2	2	1579	3.16E-01
H2O	18	526	1.05E-01
CO	28	422	8.44E-02
CO2	44	336	6.73E-02

Assuming a molecular speed of 300 K = 0.026 eV

Data

Total e- current [A]	Pulse duration [ns]	Total charge [C]	Number of electrons	Solid angle (one cell, one side)	Total electrons on copper	Dose per pulse (e- /cm2)
1.00E-04	200	2.00E-11	1.25E+08	0.027439024	4.56E+09	4.42E+08

G. Vorlaufer CERN-Thesis (2002)

ESD coefficient for H2 (unbaked copper)	Total H2 molecules per RF pulse	Equivalent pressure at RT (total volume)
2.00E-01	9.11E+08	1.12E-08
ESD coefficient for CO2 (unbaked copper)	**Total CO2 molecules per RF pulse**	
6.00E-02	2.73E+08	3.37E-09

Benvenuti et al LEP2 94-21

ESD coefficient for H2 (copper baked 250 C)	Total H2 molecules per RF pulse	
1.30E-02	5.92E+07	7.29E-10
ESD coefficient for CO2 (copper baked 250 C)	**Total CO2 molecules per RF pulse**	
6.00E-03	2.73E+07	3.37E-10

Mathewson JVSTA 15 (1997) 3093

ESD coefficient for H2 (copper baked 300 C)	Total H2 molecules per RF pulse	
3.00E-03	1.37E+07	1.68E-10
ESD coefficient for CO2 (copper baked 300 C)	**Total CO2 molecules per RF pulse**	
1.60E-03	7.29E+06	8.98E-11

10^7 pulses to start conditioning (~2 days at 50 Hz)

10 times maximum allowed

10^9 pulses for ÷10 ESD reduction (200 days at 50 Hz)

3 times maximum allowed

For the dynamic vacuum of breakdowns we were considering 2×10^{12} molecules.