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Expected vacuum performance in CMS

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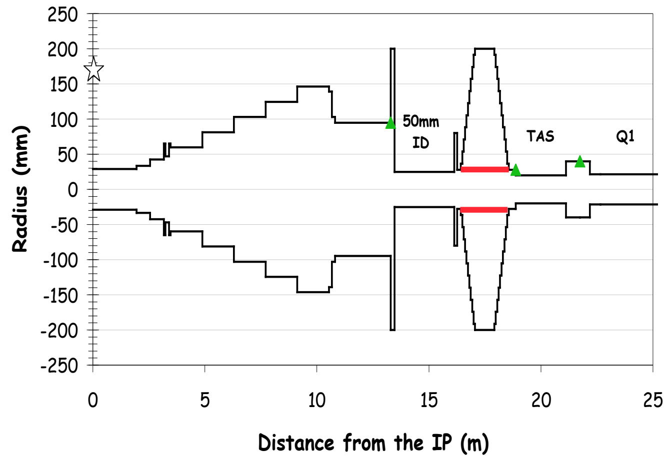
- CMS geometrical layout
- Vacuum calculations assumptions and parameters
- Vacuum stability results
- Residual gas density results
- Summary and conclusions
- Pure gas injection
- Baking procedure

CMS layout



- **Beam pipe between sector valves**
  - NEG coating except bellows and pumping ports
  - Approximated to cylinders
- **Lumped pumps**
  - Sputter Ion Pumps at ~ ± 13.3 m from IP: 3 x8 l/s nominal. (the size of the pump fits within the available space in the experiment)
  - Sputter Ion Pumps at the two sides of TAS: 75 l/s nominal. (~ ± 18.87 m and ± 21.74 m from IP)
- **Geometry for calculations**
  - Section between 2 cold magnets + Q1
  - Inner diameter of TOTEM pipe = Ø50 mm
  - Pipe between 16.6 and 18.6 m from IP replaced with Ø56 mm (modified to reduce RF losses)

Assumptions and parameters

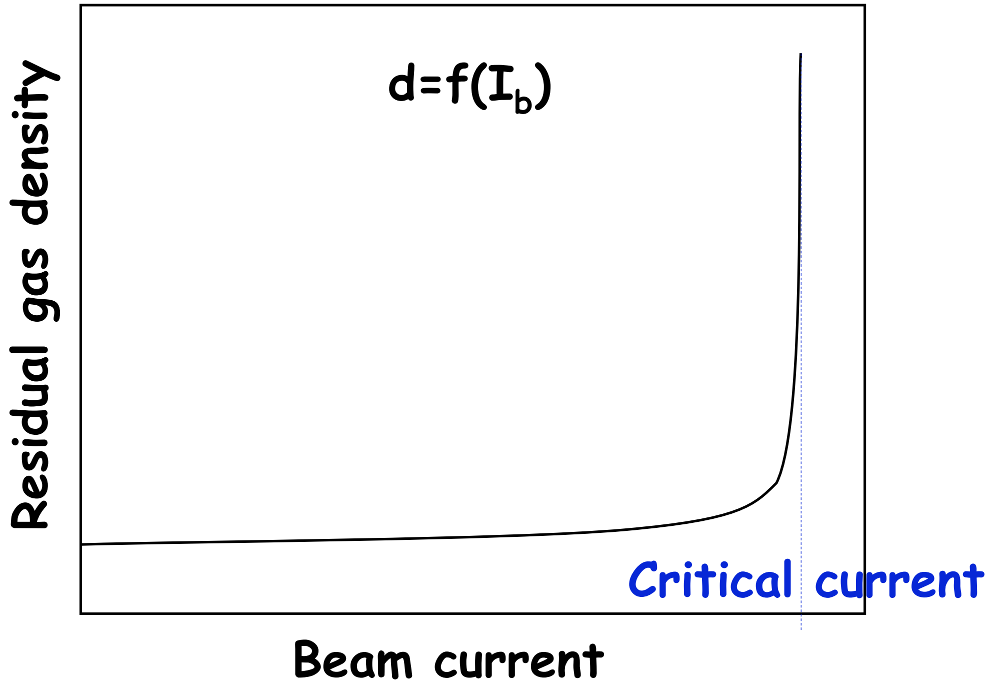
- **Synchrotron radiation**
  Flux to the wall assumed uniform along chamber
  - ~ $5 \cdot 10^{15}$ photons/m/s in experimental area [FZ], ε_c ~ 12eV
  - ~ 10^{16} photons/m/s in LSS, ε_c ~ 12eV
- **Photoelectrons** with energy at wall ~ 100eV [AR]
- **2 operation periods considered when electron cloud can be neglected** [VB] (physics)
  - **machine start up** ➢ 7 TeV ~ $3 \cdot 10^{10}$ protons/bunch (below electron cloud threshold), 25ns bunch spacing
  - **after machine conditioning** ➢ 7 TeV, nominal beam intensity ~$1.15 \cdot 10^{11}$ protons/bunch, 25ns bunch spacing
- **Ions from residual gas ionization**
  Ion energy
  - experimental area ~ 500 eV except central region (± 6 m from IP) due to detector magnetic field
  - ~ 300eV in LSS

Desorption yields (η) [AR]

- **NEG coated sections: activated to 200°C for 24h**
  - η_i =1/10 baked Cu surface, η_e , η_{ph} from measurements
  - **No η reduction during machine conditioning**
  - Pumping reduced 1/10 H_2, 1/3 CO and CO_2 after machine conditioning
- **Bellows and pumping ports: baked Cu at room temperature**
  - η_{ph} reduced 1/100 by photon during start-up
    + 1/100 by electrons during machine conditioning (scrubbing period)
  - η_e only reduced 1/100 by electrons during machine conditioning
  - η_i only reduced 1/100 by electrons during machine conditioning
- **Superconductive magnets: unbaked Cu**
  - η_{ph} reduced 1/10 by photon during start-up
    + 1/10 by electrons during machine conditioning
  - η_e only reduced 1/10 by electrons during machine conditioning
  - η_i only reduced 1/10 by electrons during machine conditioning

Vacuum stability

- Critical current = pressure runaway.
- I_c > ultimate current (0.85 A) x 2 beams x 2 = 3.4 A



Vacuum stability

- Critical current with reduced NEG pumping speed to simulate partial or total saturation of the surface
- With and without pumps @ 13.3 m to simulate failure

NEG pumping	Pumps @ 13.3 m	Critical current	Max. stored current (A per beam)	Pre-shutdown re-activation
1 %	yes	22.1	> 0.85 (ultimate)	not required
1 %	no	9.4	"	"
0 %	yes	1.8	0.45 (0.56 nominal)	required ??
0 %	no	0.6	0.15	required

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Critical current limited by CO

Critical current limited by CH_4

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Vacuum stability : comments

- **Considering that if ion pumps @ ±13.3 m fail**
  - Stored LHC current < 3 w.r.t. nominal
  - NEG reactivation time consuming (detectors opening)
  - Ultra-pure gas injection (< few tens of ppb impurity) procedure is delicate
- **and that neon or krypton (not pumped by NEG)**
  - Ne gas injected to bring beam pipe to atmospheric pressure
  - Kr (in very small quantities) released from NEG during activation
  - Cannot be pumped by turbo-molecular pumps < 10^{-10} Torr
  - More ion pumps = lower the residual pressure
= and the higher the capacity
- **it is highly recommended to keep these pumps**

- **NO baking = zero pumping + higher desorption**
→ **NOT possible**

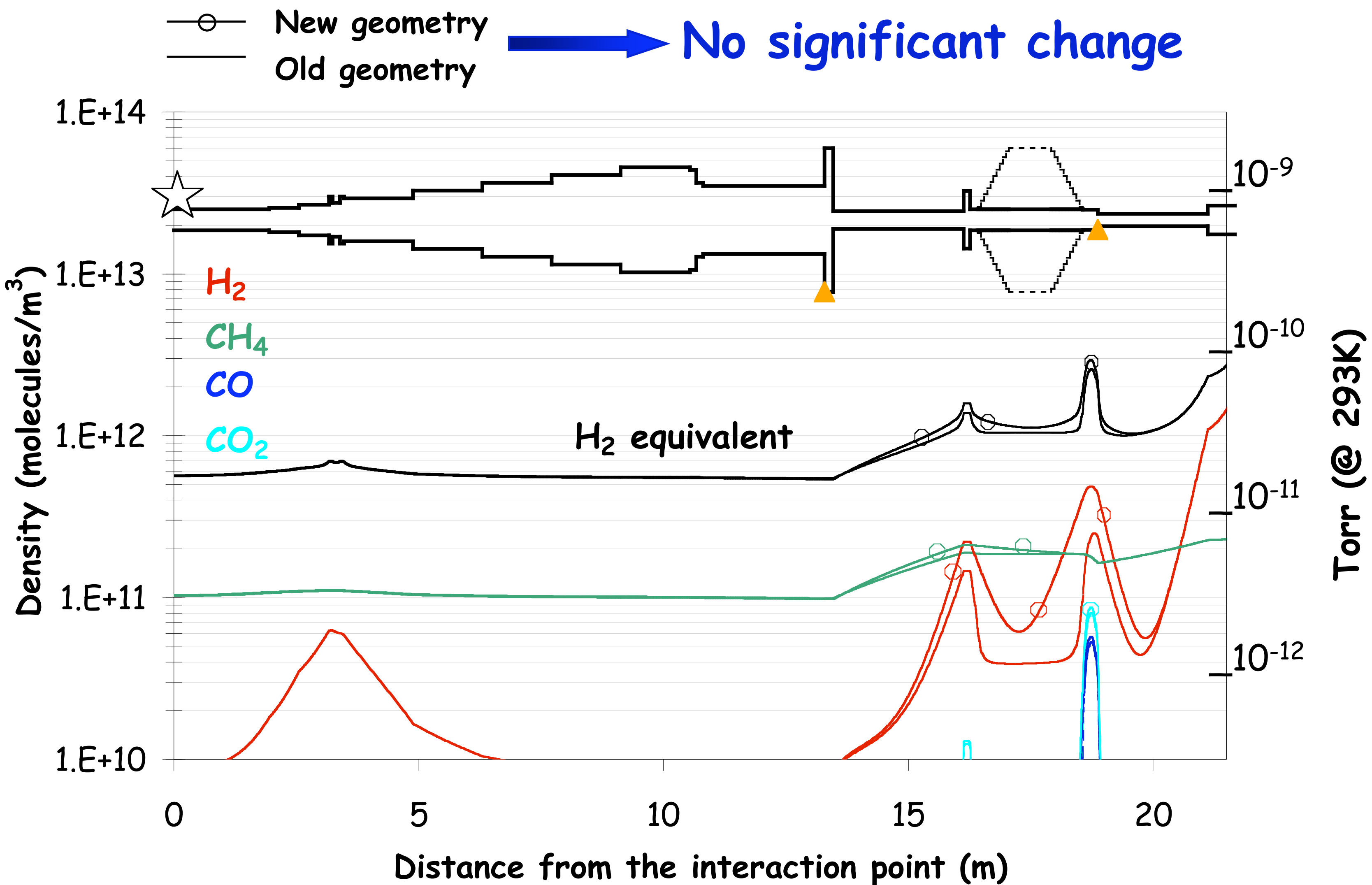
Residual gas density

- **Gas expected in a baked UHV system**
  - Hydrogen (H_2)
  - Methane (CH_4)
  - Carbon monoxide (CO)
  - Carbon dioxide (CO_2)

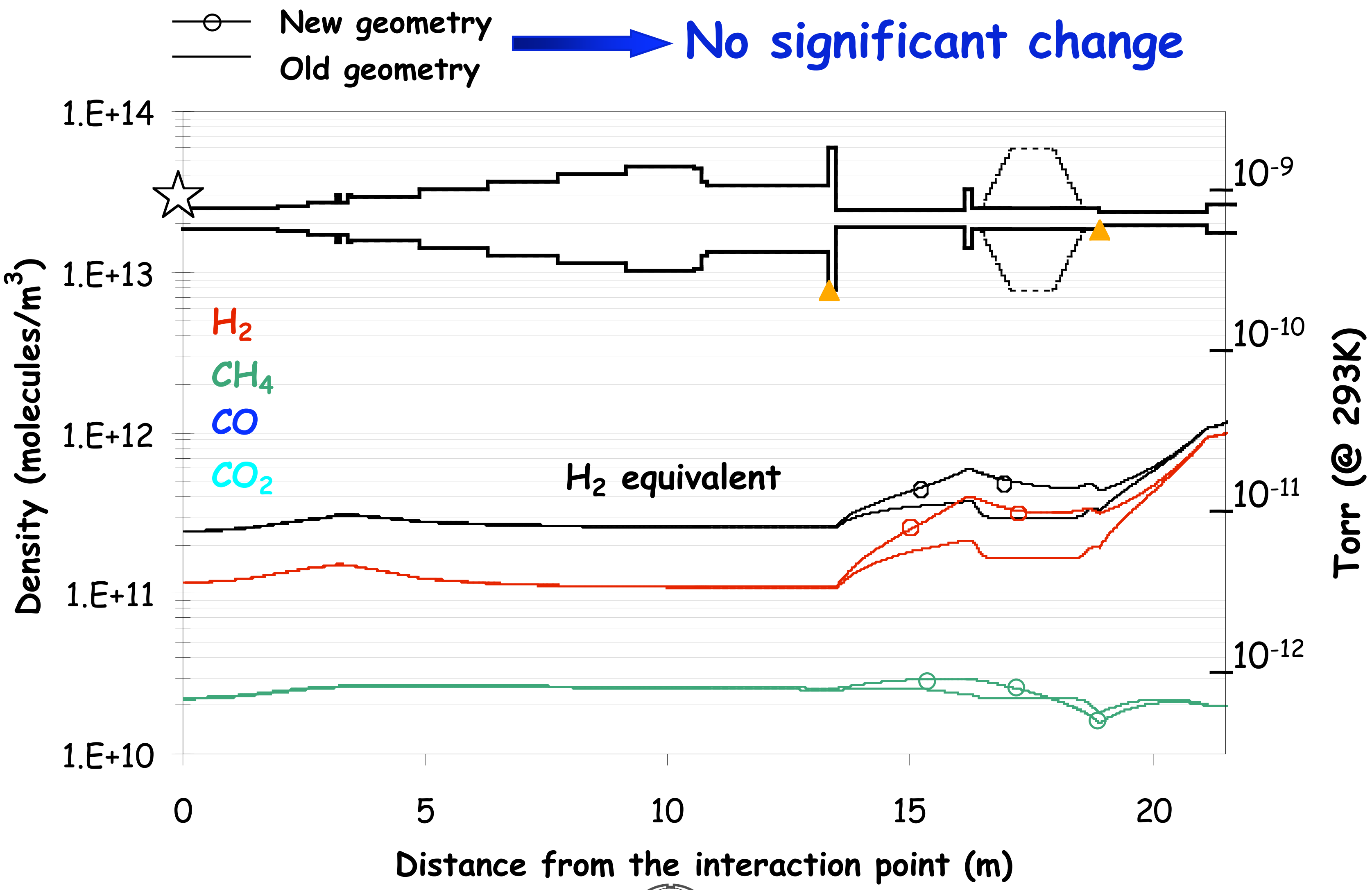
- **Hydrogen equivalent density: sum of gas densities weighted by total beam-gas scattering cross section (σ_{gas})**

$$n_{H_2 equiv.} = n_{H_2} + \frac{\sigma_{CH_4}}{\sigma_{H_2}} n_{CH_4} + \frac{\sigma_{CO}}{\sigma_{H_2}} n_{CO} + \frac{\sigma_{CO_2}}{\sigma_{H_2}} n_{CO_2}$$

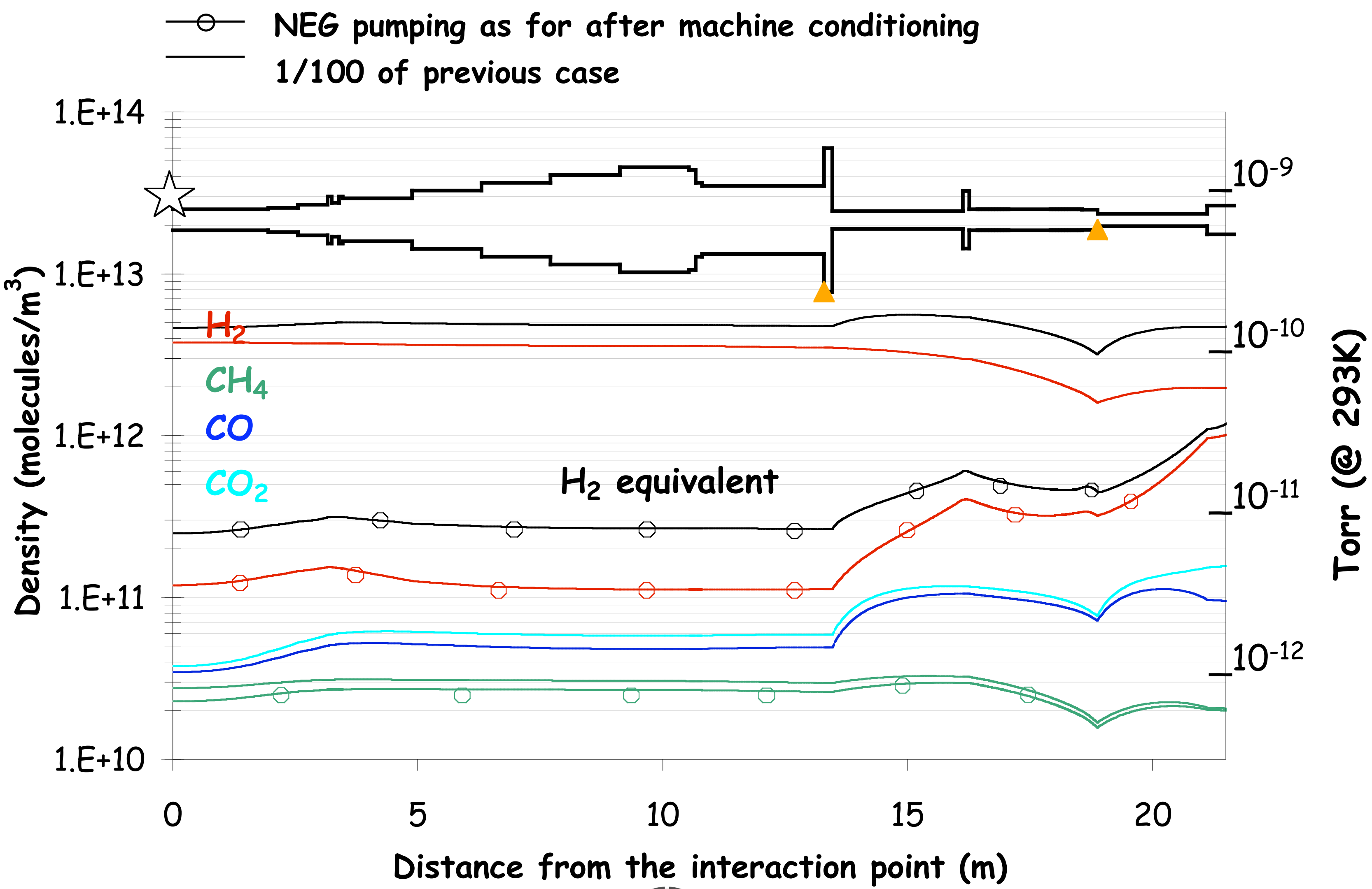
Machine start-up: comparison between geometries



After machine conditioning: comparison between geometries



After machine conditioning: comparison between different NEG pumping



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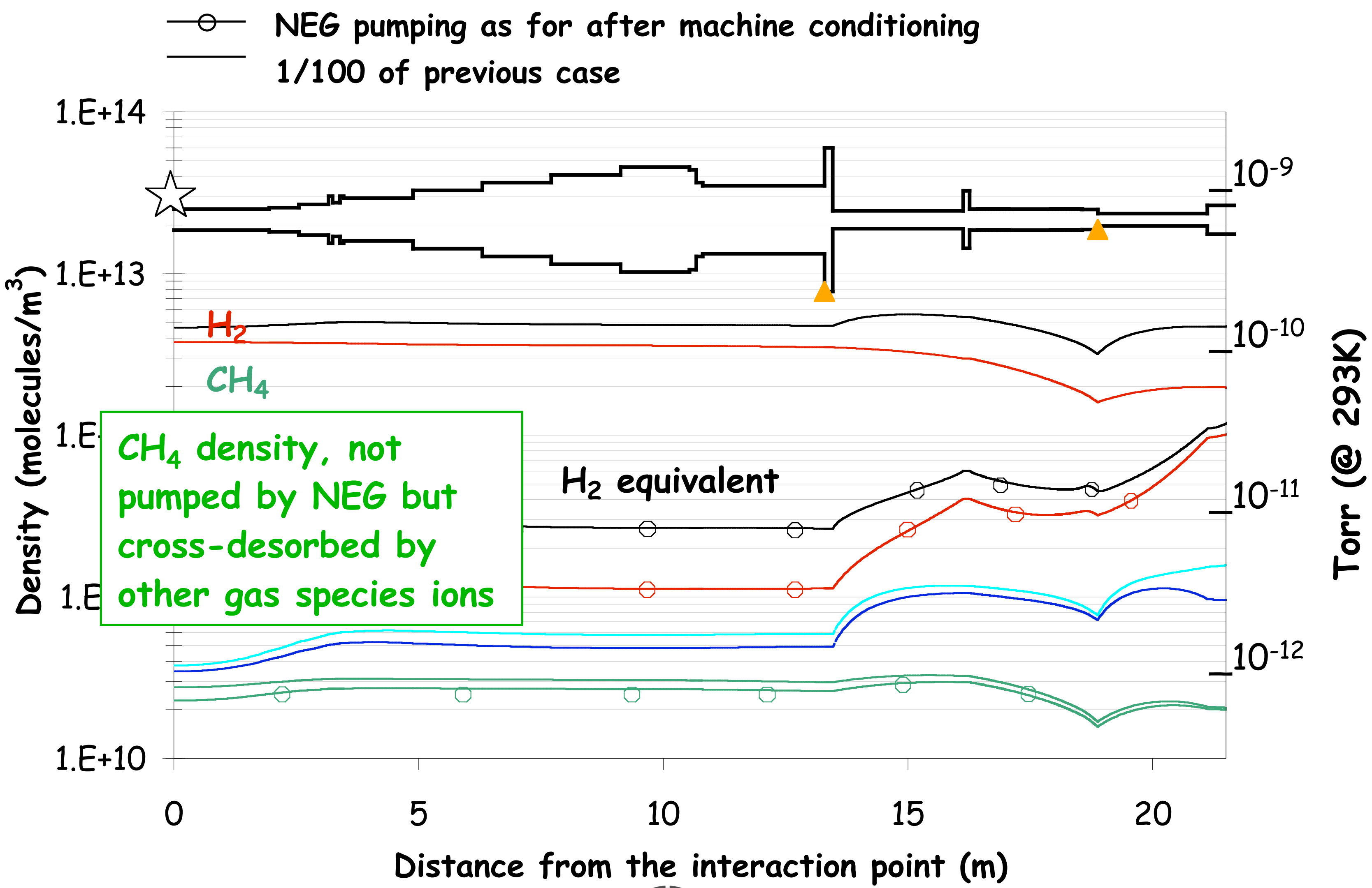

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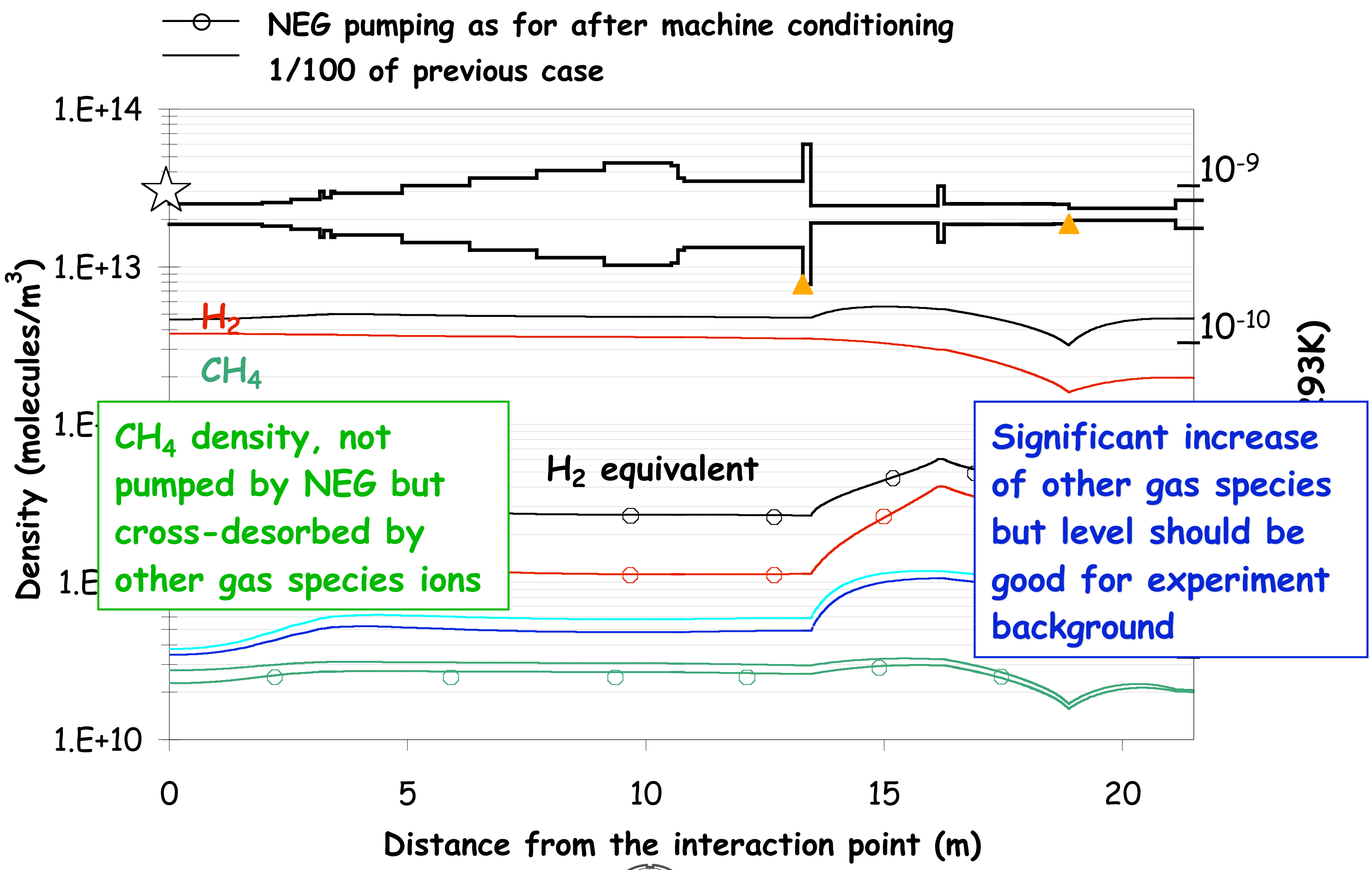

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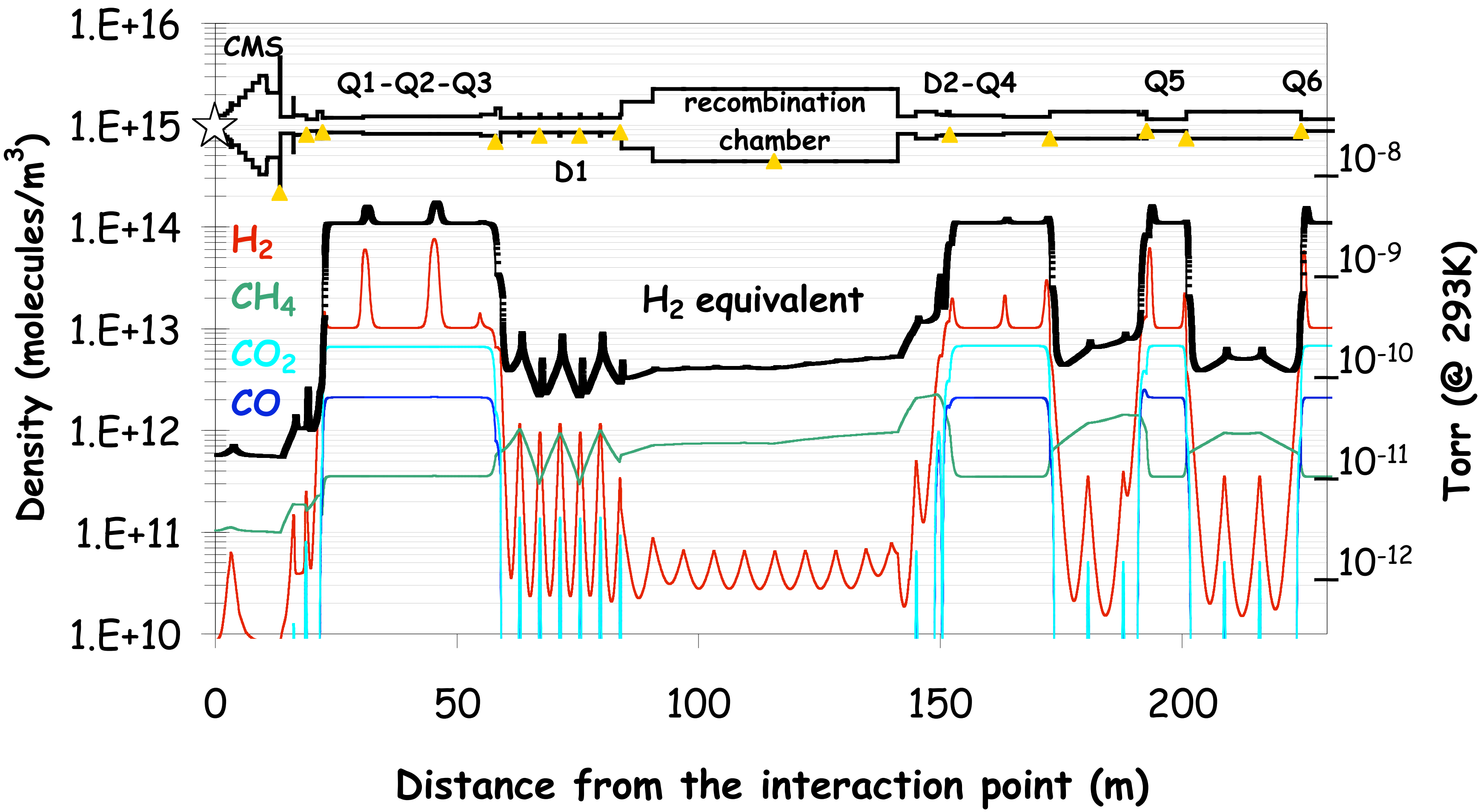
LSS 5 @ machine start-up



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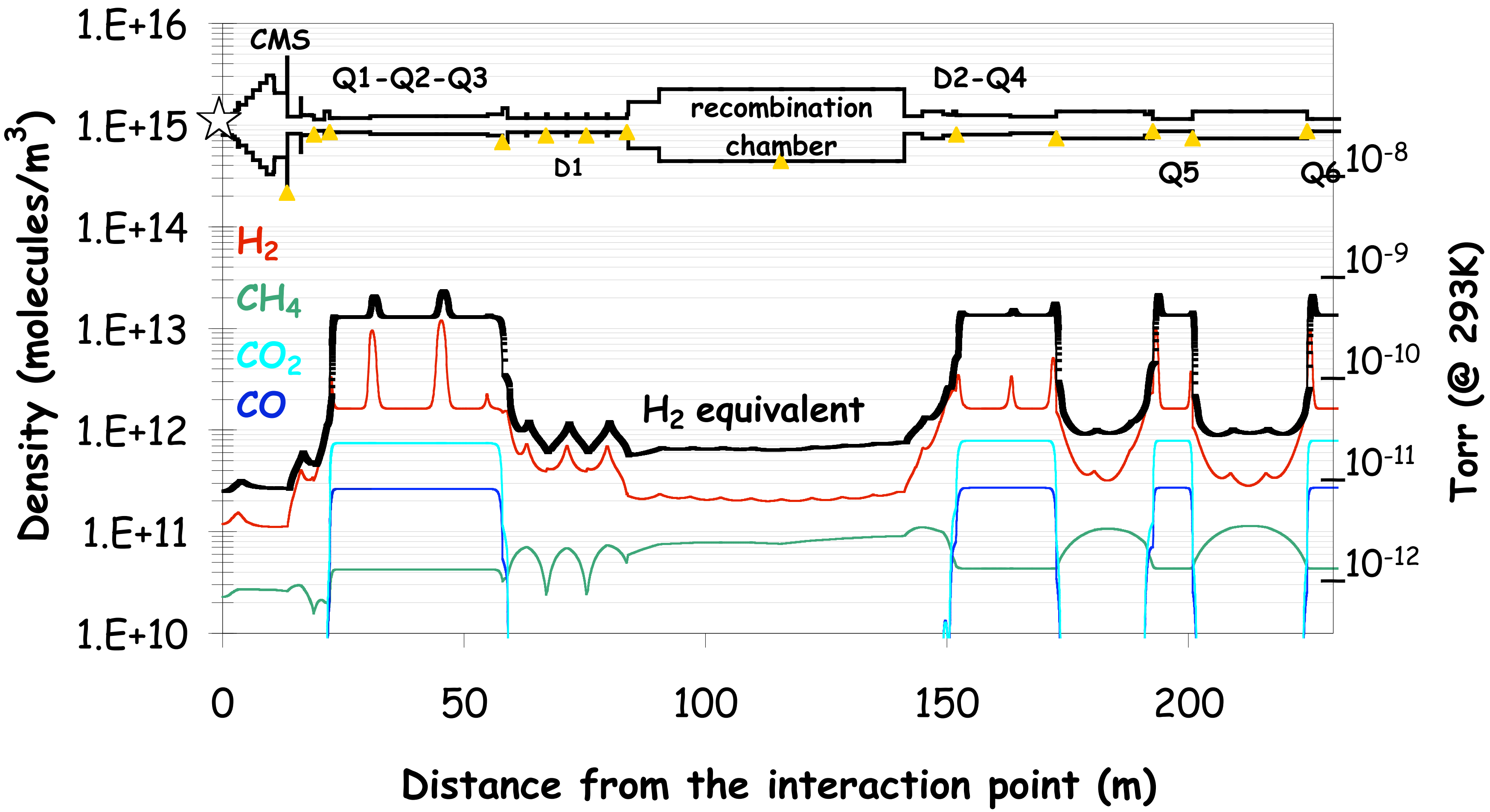
LSS 5 after machine conditioning



Summary and conclusions

New CMS-TOTEM beam pipe geometry where the pipe enlargement between ~ 16.6 and ~ 18.6 m from the IP

- **The vacuum is stable even if the NEG pump saturates to 1/100 of its initial pumping speed**
  - If the NEG is completely saturated, stored current close to nominal value
  - If the ion pumps @ ±13.3 m fail, the stored current in the LHC will have to be limited further by a factor of > 3
  - It is strongly recommended to keep the pumps

The density profile is presented for the 2808 bunch-filling scheme

- **The resultant density is higher in the region close to the modified geometry, but is understood not to be detrimental in terms of background to the experiment**

References

[VB] V.Baglin, Chamonix XII, 2003.

[AR] A.Rossi and N.Hilleret, LHC Project Report 674

[FZ] F.Zimmermann and A.Rossi, LHC Project Report 675

These results are published in:

A. Rossi, EDMS : 536503 (AT-VAC Technical Note 04-15)

Pure gas injection

starting time	duration	activity
01/07/07 8:00	2h	transport of equipment (including bake-out)
01/07/07 10:00	2h	connection of flanges, electronics, bake-out, bottle, valves
01/07/07 12:00	1h	leak detection
01/07/07 13:00	2d	system baking + cartridge activation
03/07/07 13:00	1h	check gas quality
03/07/07 14:00	2h	injection (0.1 l/s)
	56h	
	2h	pumping
	4h	dismantling + transport

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Bake-out: general procedure