Electron Cooling

Developments for AD/LEIR e-cooling and Ionisation Profile Monitors

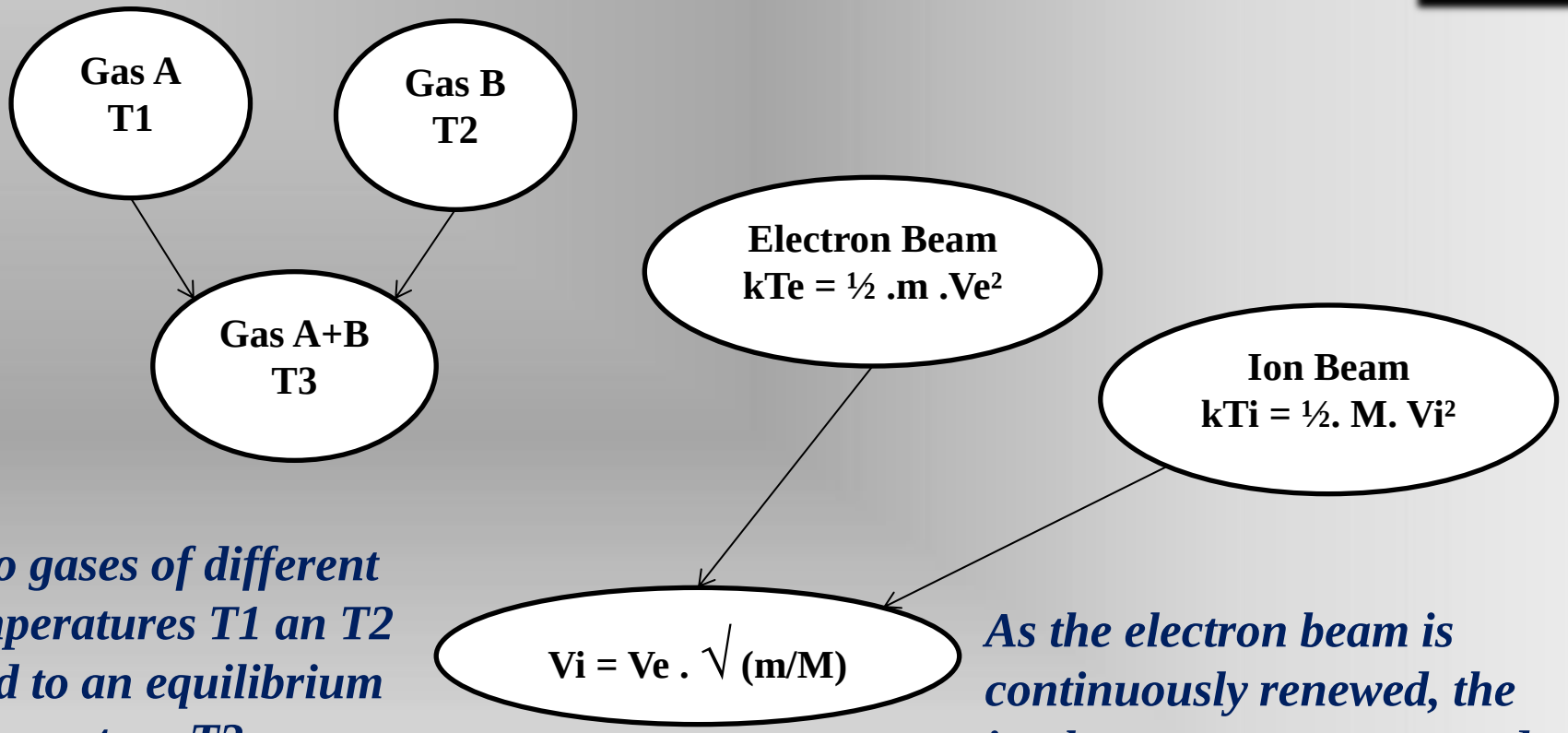
BE-BI-EA

Alexandre Frassier

What is electron cooling?

- **Means to increase the phase space density of a stored ion beam.**
- **Mono-energetic cold electron beam is merged with ion beam which is cooled through Coulomb interaction.**
- **Electron beam is renewed and the velocity spread of the ion beam is reduced in all three planes.**

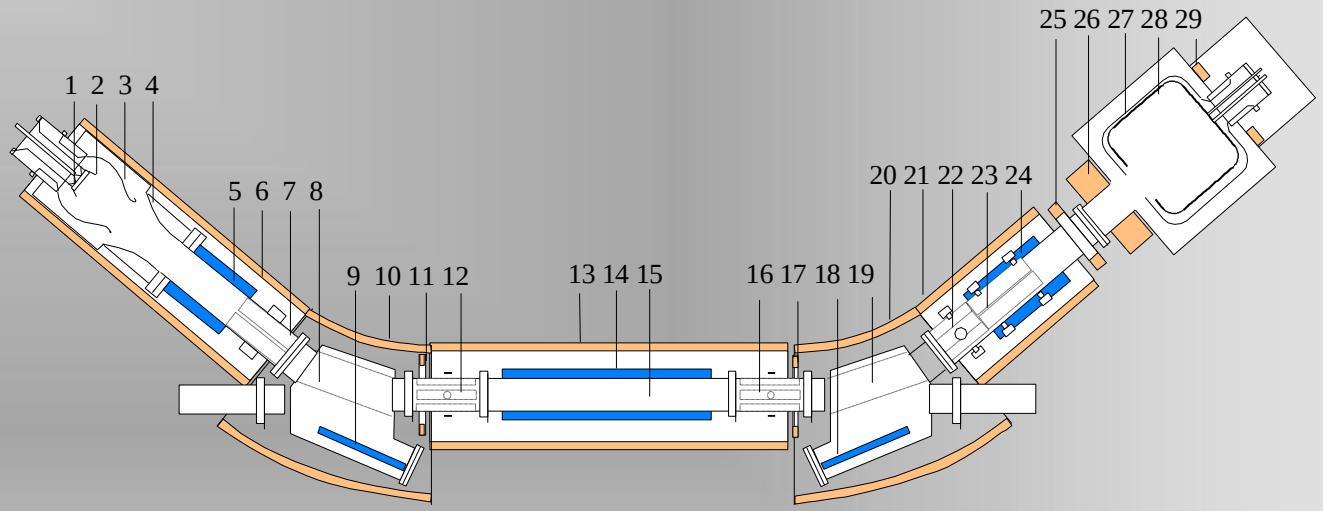
Analogy with the mixing of gases



Two gases of different temperatures T1 an T2 tend to an equilibrium temperature T3

As the electron beam is continuously renewed, the ion beam temperature tends to the electron beam temperature. The velocity spread is reduced by a factor $(m/M)^{1/2}$

Electron cooling setup



- **E-gun:** thermocathode, Pierce shield, Grid control, accelerating anodes
  - *final current given by Child's Law:* $\mathbf{I = \mu . V^{3/2}}$
  - *the parameter* **μ** *is the perveance and is given by* $\boldsymbol{7{,}3 . 10\text{-}6 \ (r/d)^2}$
- **Interaction section**
- **Collector**
- **The whole system is immersed in a longitudinal field**

Cooling time

- **Electron cooling theory gives :**

$$\tau \propto \frac{\theta^3}{\eta I_e}$$

  - ***where Θ is the relative difference in angle between the ions and electrons (θ_i - θ_e), [$\theta_i = \sqrt{(\varepsilon/\beta)}$]***
  - ***the parameter $\eta = L_{cooler} / L_{machine}$***
  - ***and I_e is the electron current.***

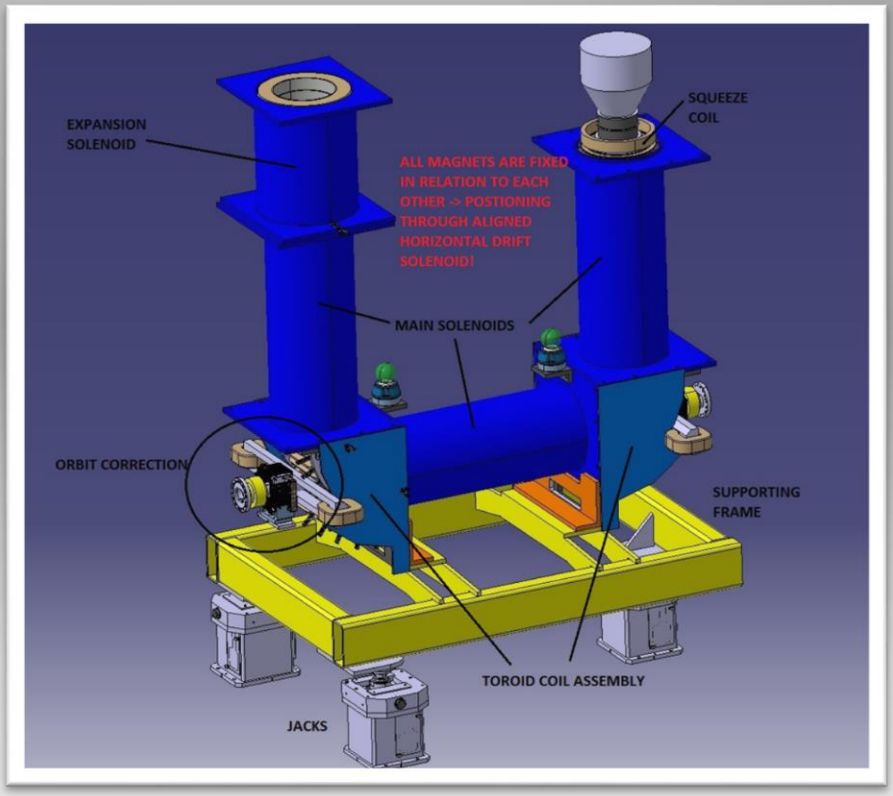
Electron cooling at CERN

- **Improve the quality of low energy ion beams**
  - ***many experiments on LEAR and AD not possible without electron cooling***
  - ***used to cool (anti)protons, H^-, oxygen, lead and argon ions***
  - ***first electron cooling device to be used routinely on a storage ring***

- **Increase of the duty cycle of the machine**
  - ***cooling time much less than what can be obtained with stochastic cooling at low energies (< 310 MeV/c)***

- **LHC and North Area request a variety of ions**
  - ***the injection scheme requires fast cooling times and stacking***

ELENA e-cooler

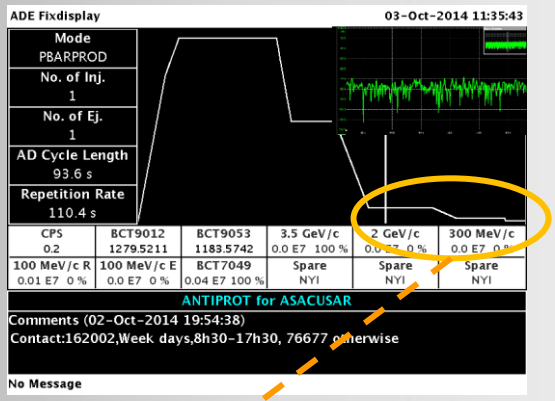


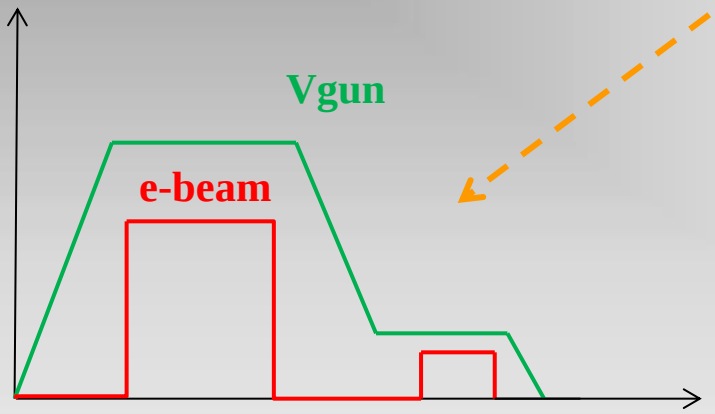
- **ELENA decelerator will increase X 100 the number of anti-protons for experiments.**
- **E-cooler will generate a cold and stable e-beam @ 55 eV in order to cool the 100 keV antiprotons.**

Momentum	35 MeV/c	13.7 MeV/c
Pbar-beam energy	648 keV	100 keV
E-beam energy	355 eV	55 eV
I e	5 mA	2 mA
Bgun	1000 G	
Bdrift	100 G	
Toroid bending radius	0.25 m	
Cathode radius	8 mm	
E-beam radius	25 mm	
Cooling drift length	1.0 m	

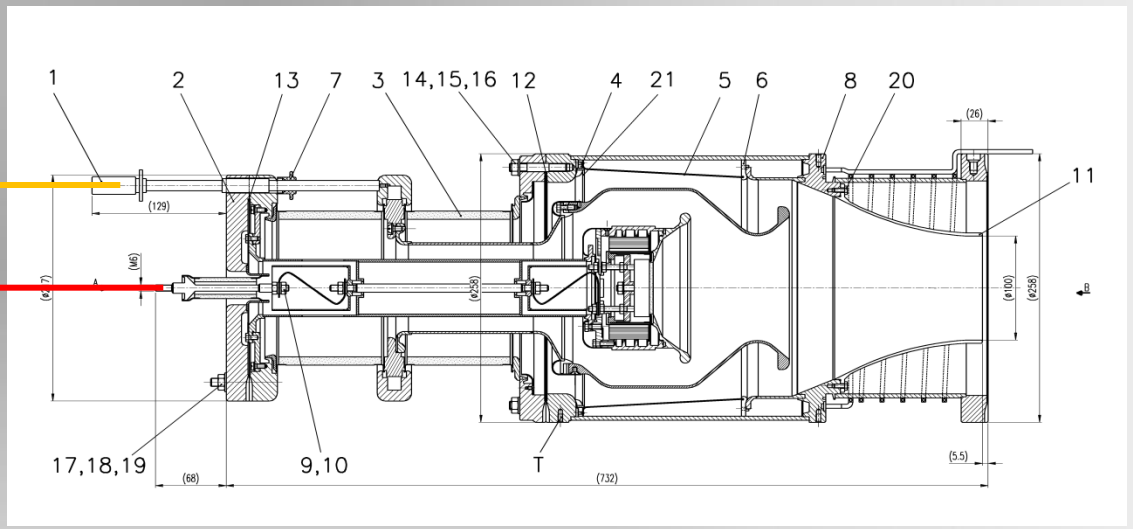
E-cooling development

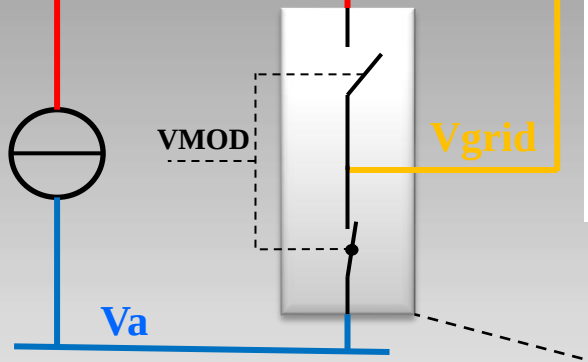
Eliminate the "parasitic" electrons beam due to the latency of the Gun high power voltage supply for the AD machine.





HV Switch





HV push-pull switch BEHLKE®

HV Switch

- **The first manipulations show that the HV switch works fine when the Cathode is cold (e-beam=0).**
- **As soon as we have started the tests with the production of electrons a threshold appeared at ~85% of the maximum value.**
- **Variations on Vgrid (Va ± ΔV) have confirmed that the threshold is a e-beam threshold (electron cloud arising inside the gun ?).**

$$I_e = (\mu / \mu') V^{3/2}$$ **with μ'=virtual perveance (> 1)**

Ionisation Profile Monitors

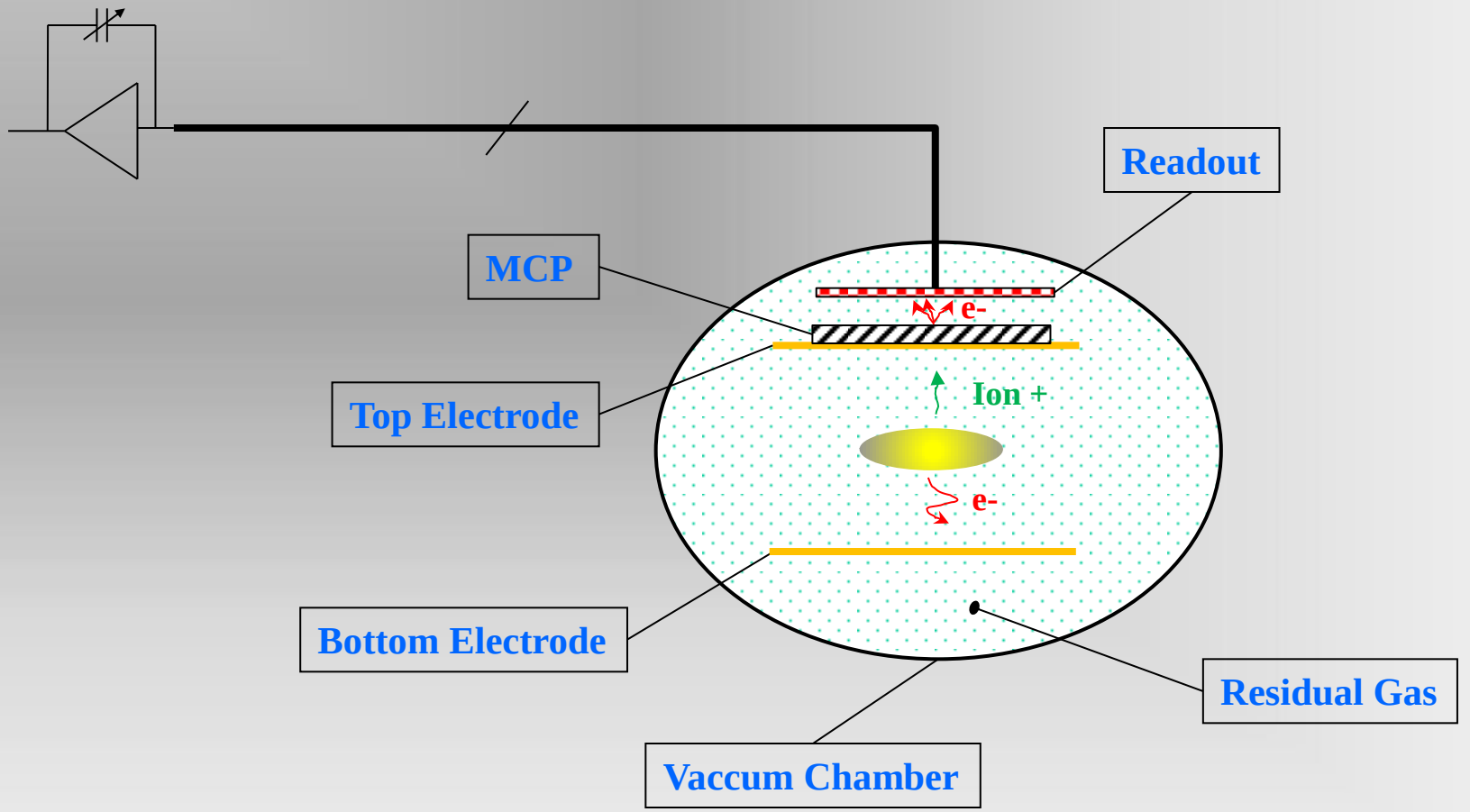
- **Design, build and install a new and common electronics for the AD & LEIR IPM for both H & V plan.**

- **Replacing the MCPs for the LEIR machine**
- **Build and Install in same sector new IPM V&H for the AD machine**

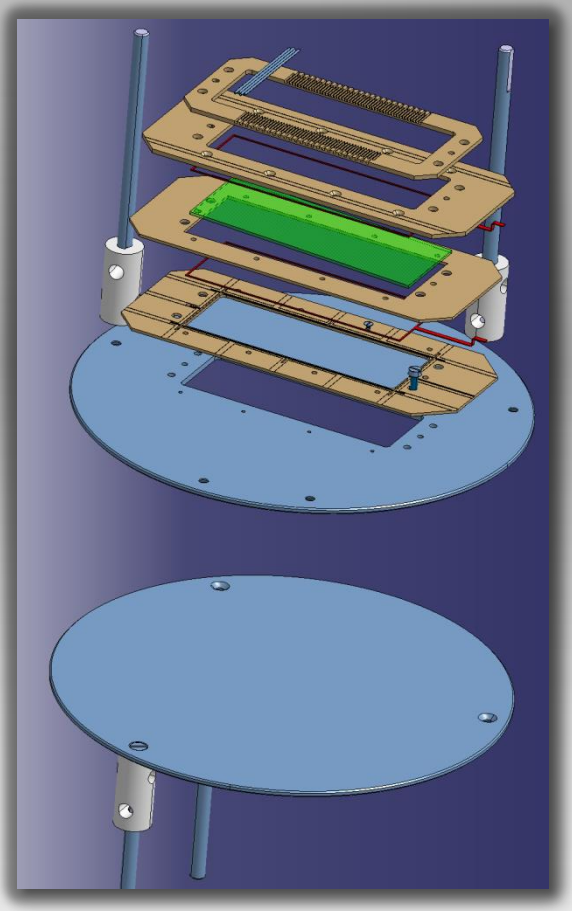
Done by J.Cenede during the LS1

Ultra–Vacuum

Ionisation Profile Monitors



BIPM : Mechanicals

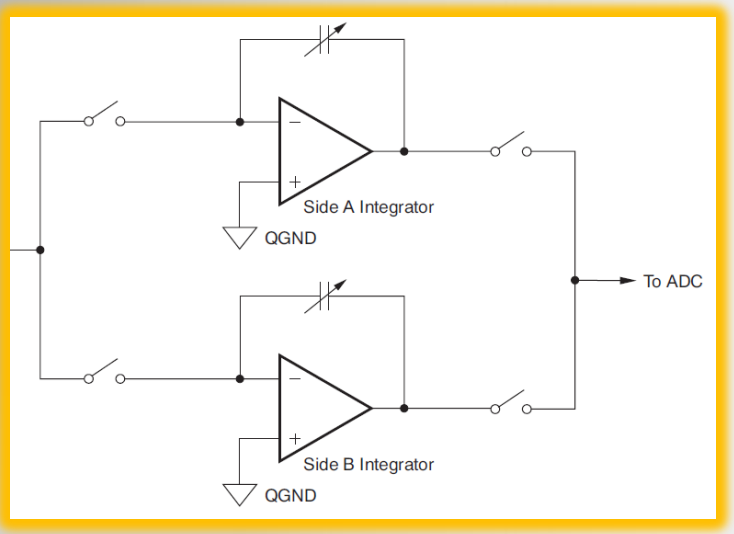


- Roland Sautier Original design
- Readout of 50 stainless tubes with a pitch of 1 mm.
- Brown : WESPEL; insulator and readout support.
- Blue : Stainless Electrode .
- White: MACOR ceramic support.
- Red : MCP Copper Electrode.
- Green : Photonis® simple stack MCP

BIPM : Electronics

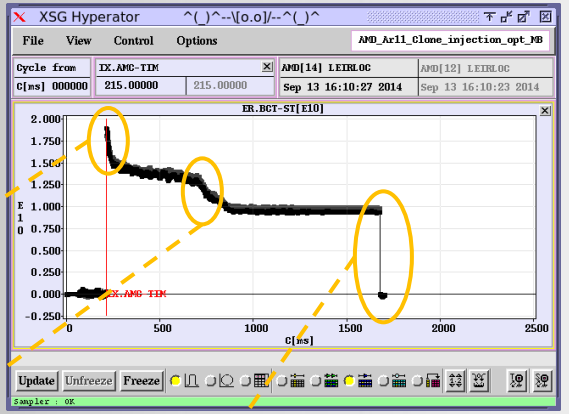
- New electronic has been built around DDC264 component which included multi-channels double integrator and ADCs.

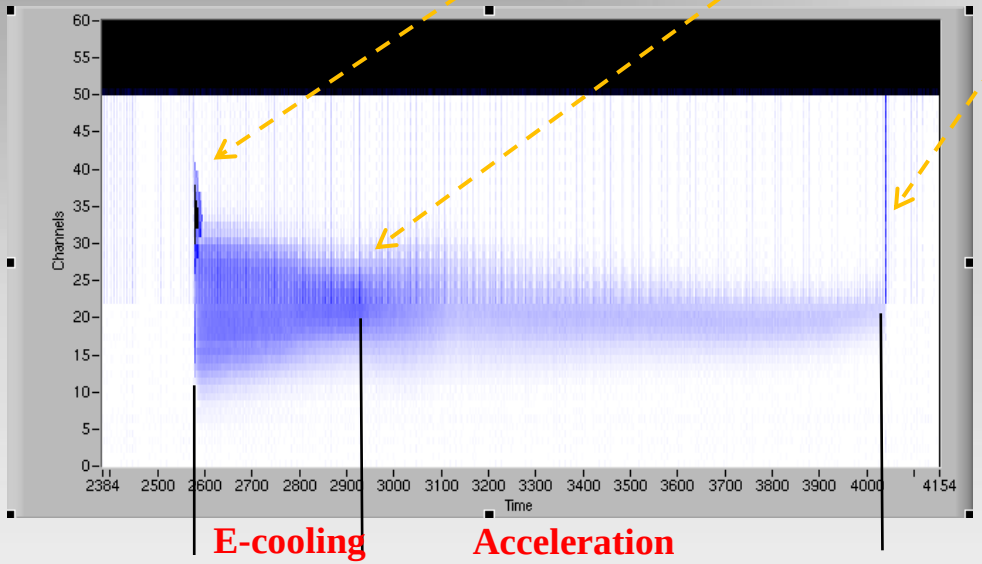
- The system is based on a VME BUS crate which drives 2 ISEG® HV VME board (+&- 6kV/4 ch) and 2 VIPMs home made VME board (V&H).



BIPM : Results

- **First result V:**
  - *with a sampling @ 1kHz ,*
  - *Without HV fine tune ,*
  - *Without data processing .*



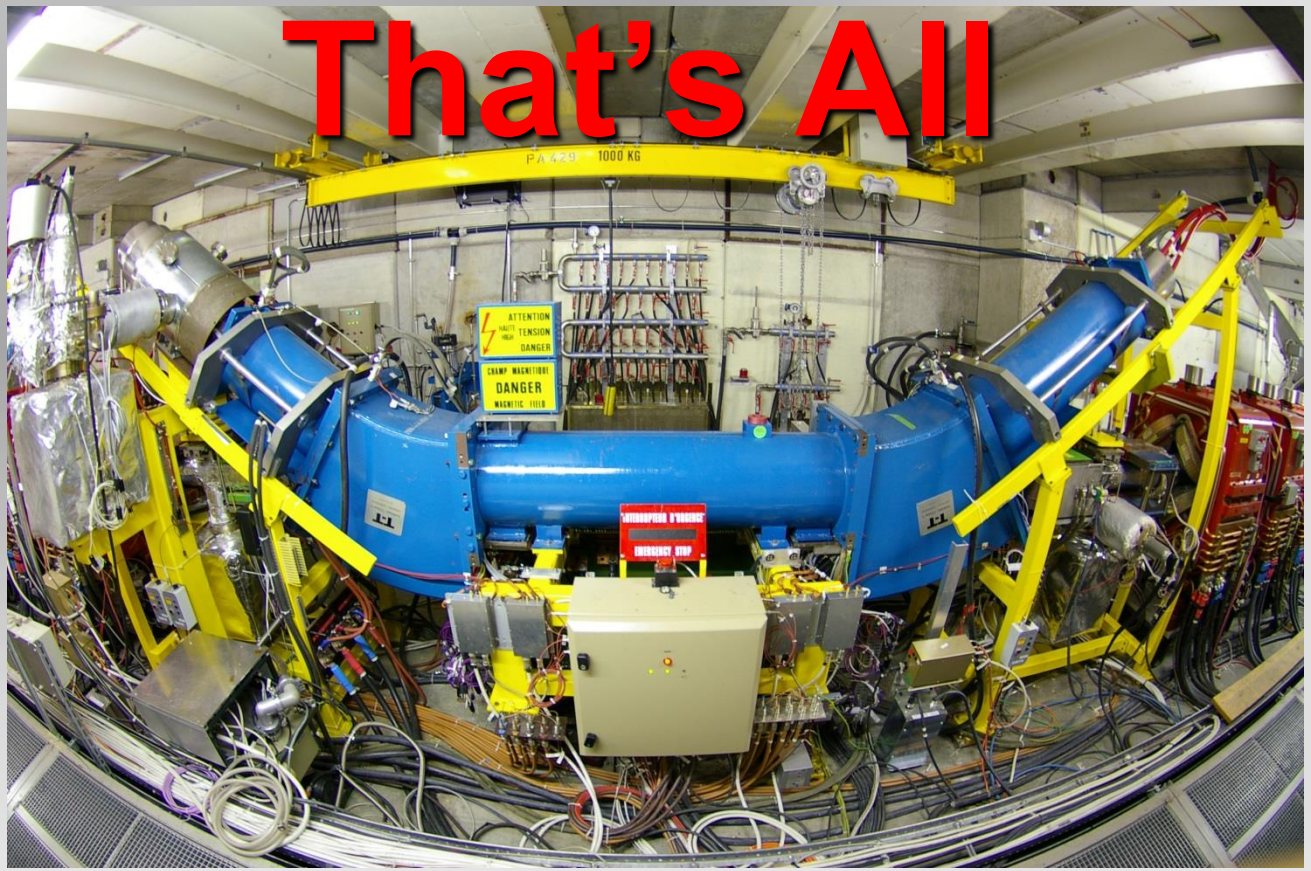


Conclusion

- **HV Switch :**
  - ***More studies and tests need to be done in order to understand the virtual perveance .***
  - ***Due to the operating range of AD machine (300mev/c => 100mev/c), High Voltage switch could be used anyway with a different timing.***

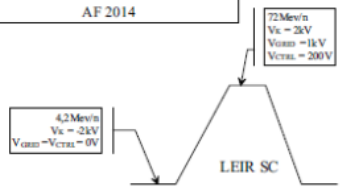
- **IPM**
  - ***First results show that electronics / installations are validated.***
  - ***Some Software layers have to be finished before delivering a secured equipment for the operation.***
  - ***Test still required on the AD machine (gas injection, checking of performance, MCP double stack …)***

Conclusion



POWER DIAGRAM ECOOLING LEIR

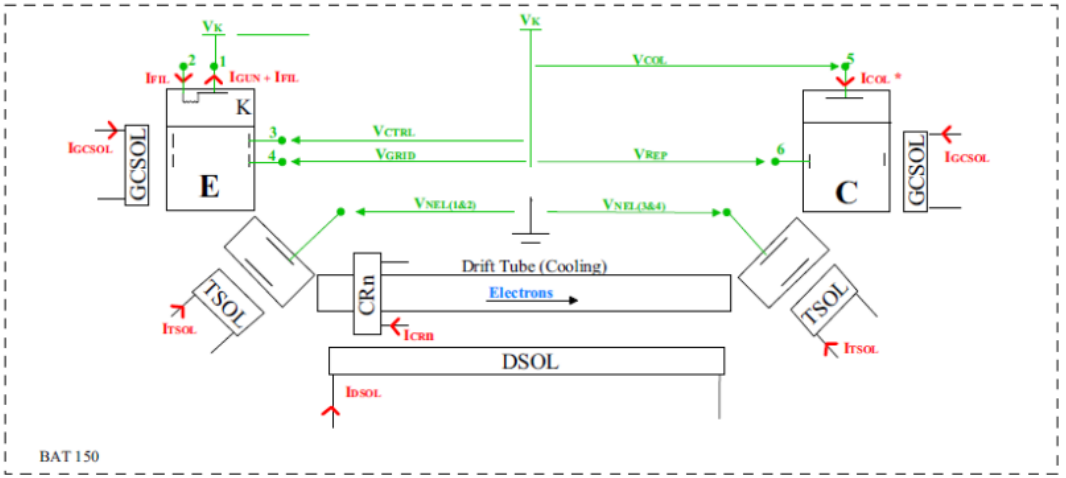
AF 2014



$I_{GUN} = P.V^{3/2}$

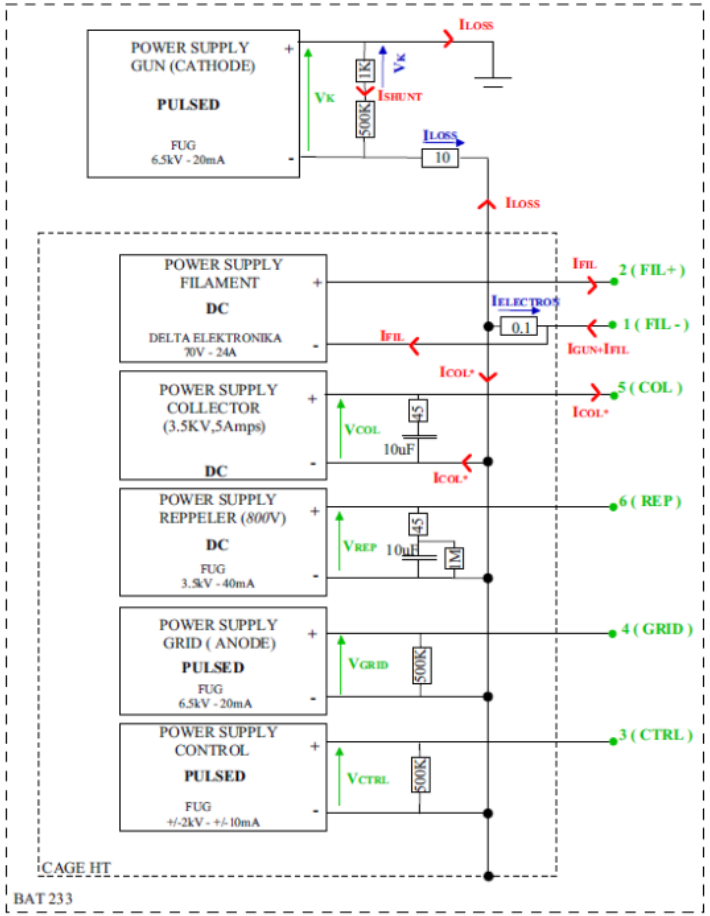
P = Gun Geometry = C^{ste}

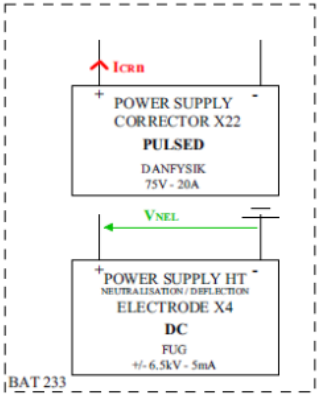
V = VK - VGRID

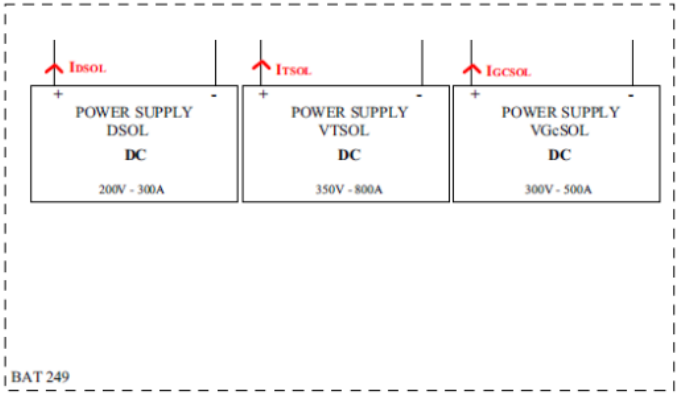


● CONNECTION POINT

* ICOL = IGUN - ILOSS





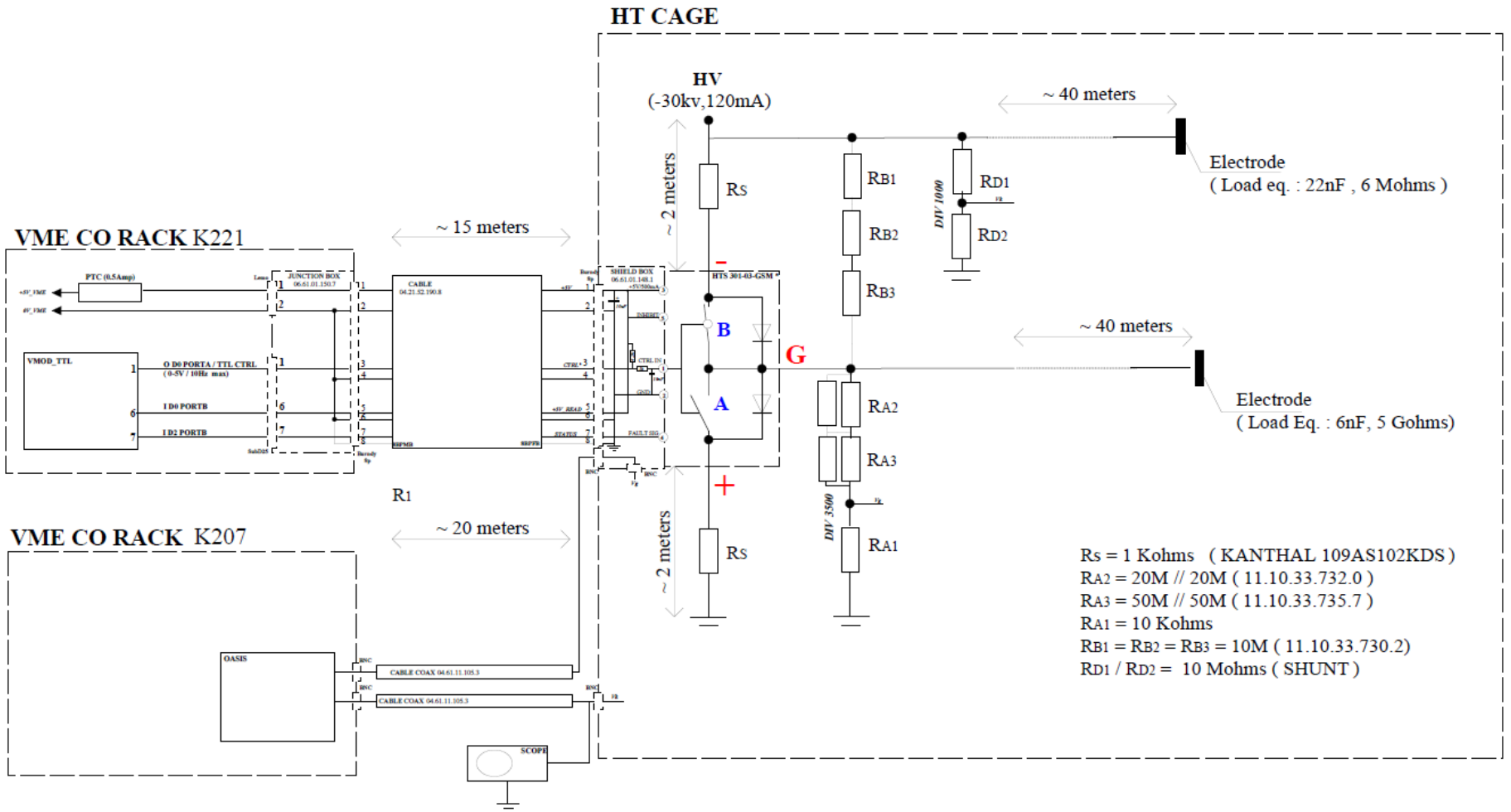


MAGNETS	
DSOL	Drift Solenoid
TSOL	Toroid Solenoid
GCSOL	Gun Collector Solenoid
CRn	Corrrector (n=1..22)

ELECTRODES	
K	Cathode
COL	Collector
REP	Repeller
GRID	Grid (Anode)
CTRL	Control
NEL	Neutralisation

ELECTRON BEAM FAST STOP
CABLING OVERVIEW
AF 2014

*CTRL=0 => B CLOSED => Vg = Vk => LED GREEN
CTRL=1 => A CLOSED => Vg = GND => LED ORANGE



1 YELLOW CTRL
2 BLACK GND
3 RED +5V
4 ORANGE STATUS
5 GREEN INHIBIT