Search for CP violation in nuclear beta decay:

The MORA project

XXIInd **Colloque GANIL**, Autrans-Méaudre en Vercors **- 01/10/2021 -**

- Physics behind MORA -

Matter's Origin from RadioActivity of trapped and oriented ions

Goal: Looking for new CP violations

(cf Xavier's talk)

$$D\frac{\langle \vec{J} \rangle}{J} \cdot \left(\frac{\overrightarrow{p_e}}{E_e} \times \frac{\overrightarrow{p_\nu}}{E_\nu} \right)$$

→ Maximal correlation in the plan ⊥ to the spin direction = detection plan

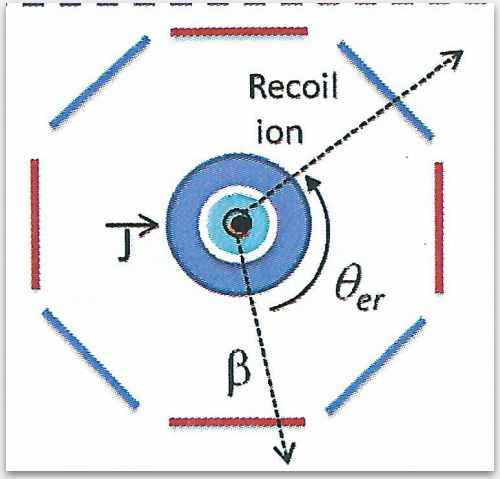
→ Laser polarisation to invert spin direction

Found by asymmetry in Beta - recoil ion counting → need trap

If D ≠ 0 then T violation (so of CP)

Detection of Beta and recoil ion in coïncidence

$$\frac{N_{coinc}^{+45^\circ} + N_{coinc}^{+135^\circ} + N_{coinc}^{-45^\circ} + N_{coinc}^{-135^\circ}}{N_{coinc}^{+45^\circ} + N_{coinc}^{+135^\circ} + N_{coinc}^{-45^\circ} + N_{coinc}^{-135^\circ}} \alpha \; D.P$$



Delahaye et al, HI, 2018

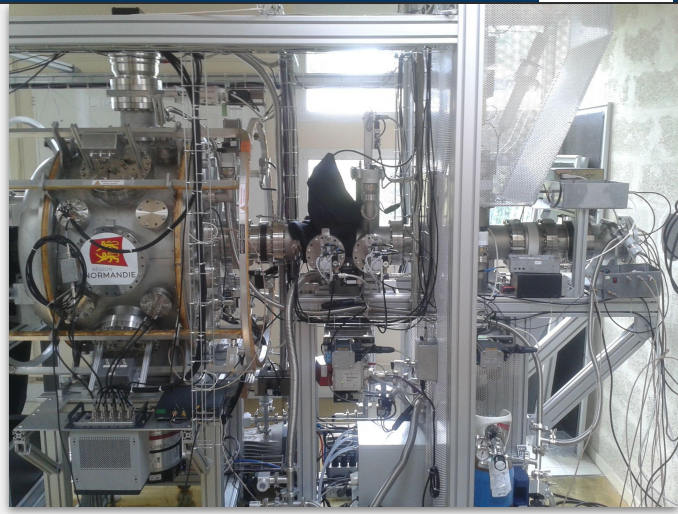
Polarisation P, monitored by Si detectors along beam direction

- General Status of the MORA experiment -

THE MORA PROJECT
MATTER'S ORIGIN FROM RADIOACTIVITY

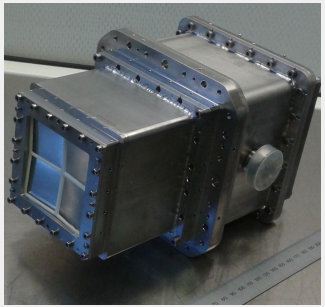
Trap and injection line:

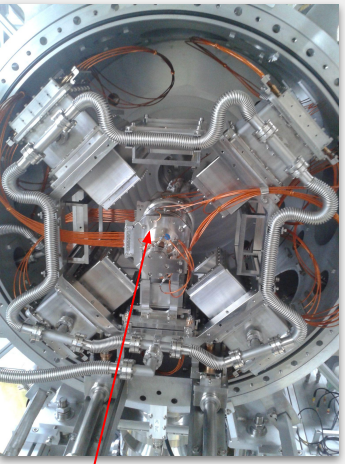
All pieces have been built and installed (trap, line and electronics)
Almost all electronics monitored by the Slow Control



2 types of detectors:

4 RIDE (Micro channel plates) for recoil ions
⇨ cf ***Nishu Goyal's poster***
4 Phoswichs(Plastic Scintillators) for Beta



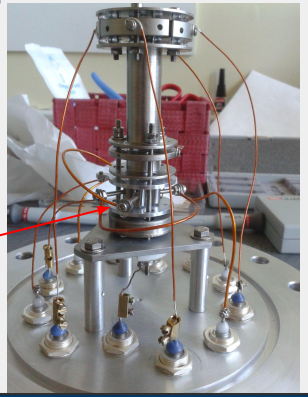


Trap (Benali et al,EPJA, 2020)

Trapping in commissionning phase @ LPC Caen:

Use of a stable source(Surface ionization) of ^{23}Na
But not pure: contaminants = K + Rb

Add a RFQ on the source to bunch ions
(ex: every 10 ms for a 60µs trap duration)



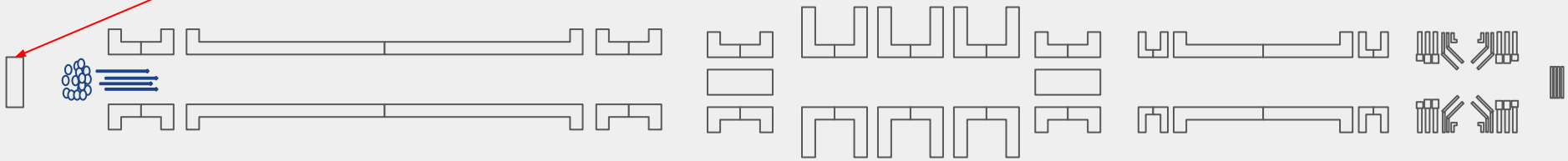
- Current set-up : Commissionning @ LPC CAEN -

THE MORA PROJECT
MATTER'S ORIGIN FROM RADIOACTIVITY

TO

Timings found by SIMION simulations

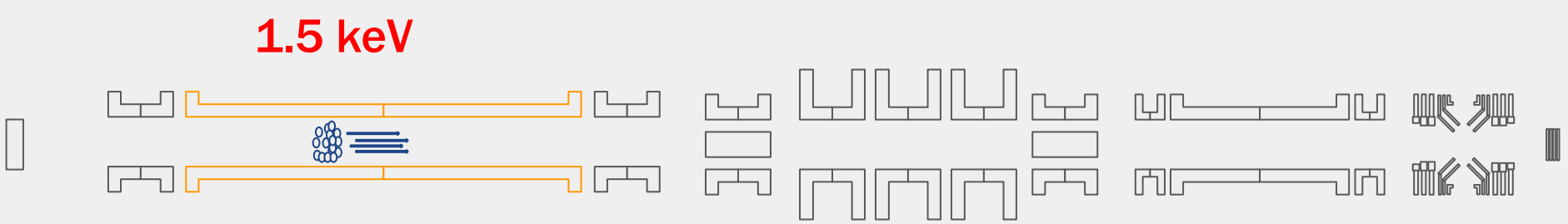
Ion source @ 1.5 keV



Travelling through the line:

- Current set-up : Commissionning @ LPC CAEN -

TO

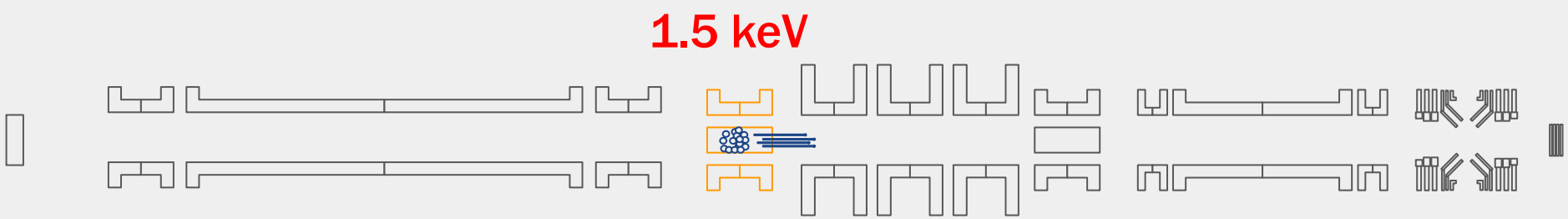


Travelling through the line:

- Pulse Drift tube (act as a lens for now)

- Current set-up : Commissionning @ LPC CAEN -

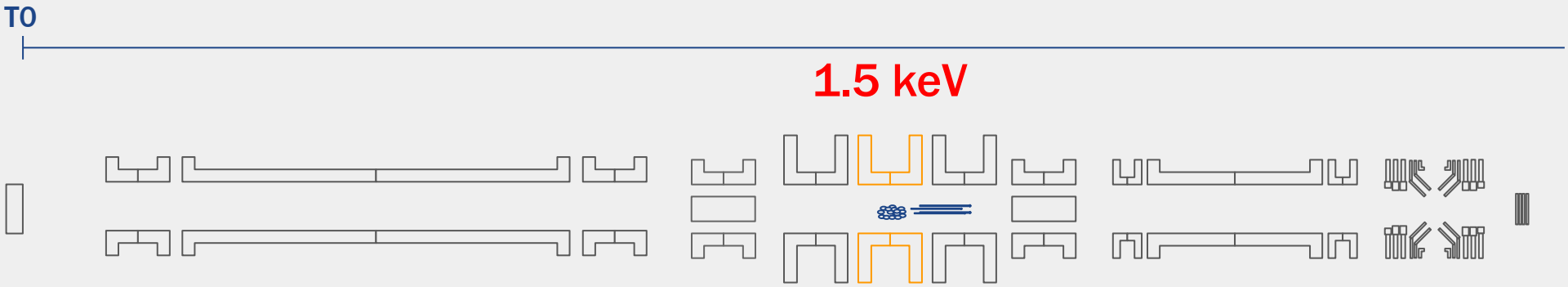
TO



Travelling through the line:

- Pulse Drift tube (act as a lens for now)
- Steerer 1 to correct the beam direction

- Current set-up : Commissionning @ LPC CAEN -

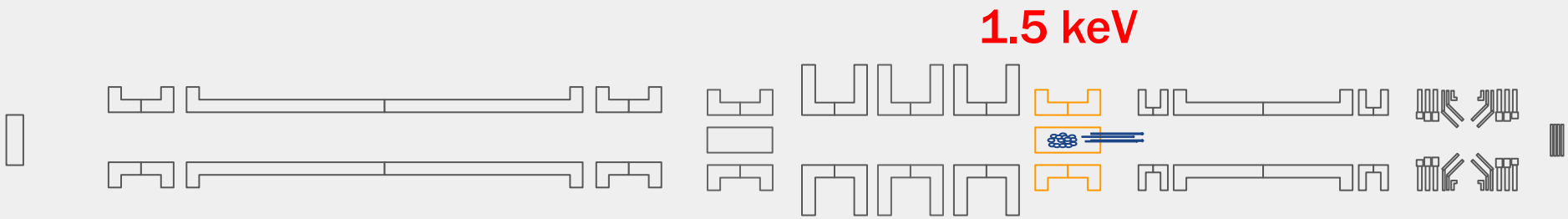


Travelling through the line:

- Pulse Drift tube (act as a lens for now)
- Steerer 1 to correct the beam direction
- Lens 1 to refocalise the beam

- Current set-up : Commissionning @ LPC CAEN -

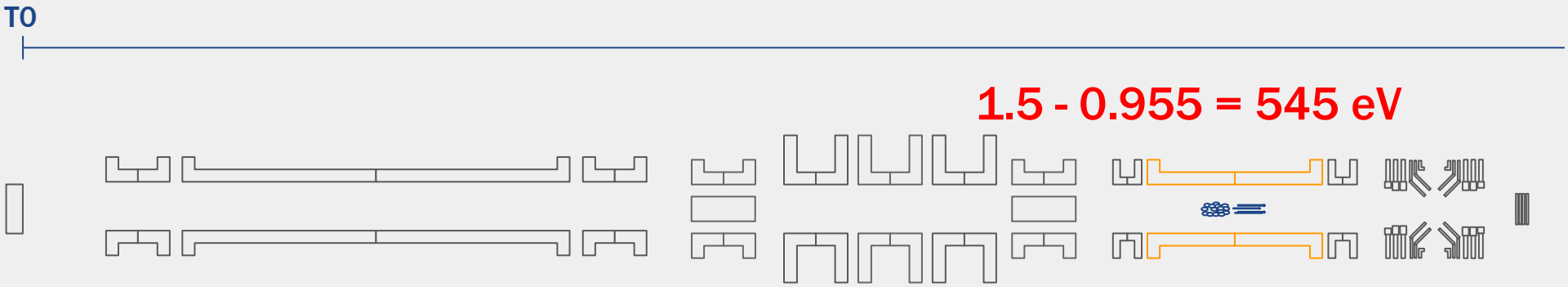
TO



Travelling through the line:

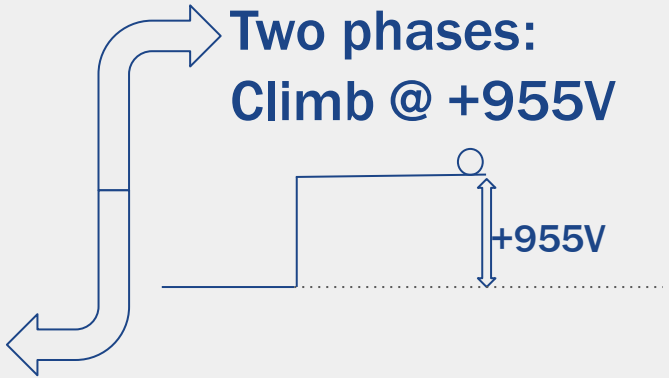
- Pulse Drift tube (act as a lens for now)
- Steerer 1 to correct the beam direction
- Lens 1 to refocalise the beam
- Steerer 2 to adjust the beam

- Current set-up : Commissionning @ LPC CAEN -

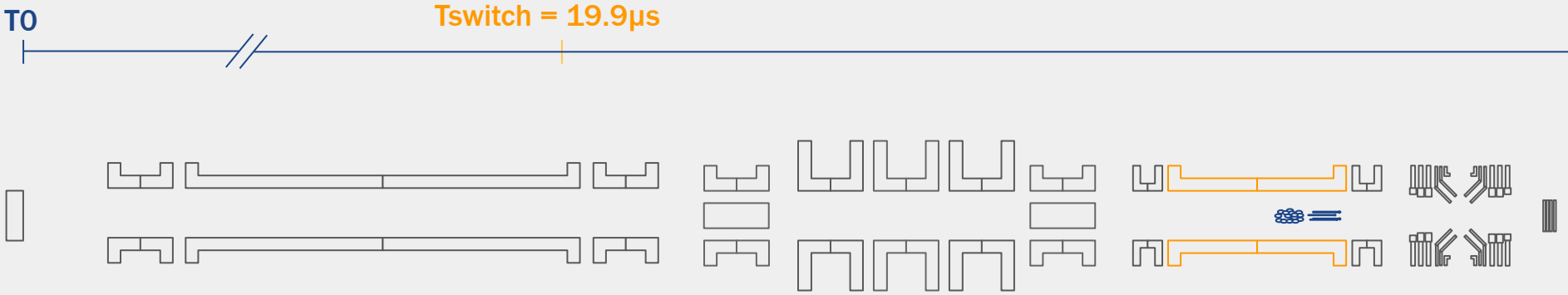


Travelling through the line:

- Pulse Drift tube (act as a lens for now)
- Steerer 1 to correct the beam direction
- Lens 1 to refocalise the beam
- Steerer 2 to adjust the beam
- Pulse Drift tube 2 to slow down the beam

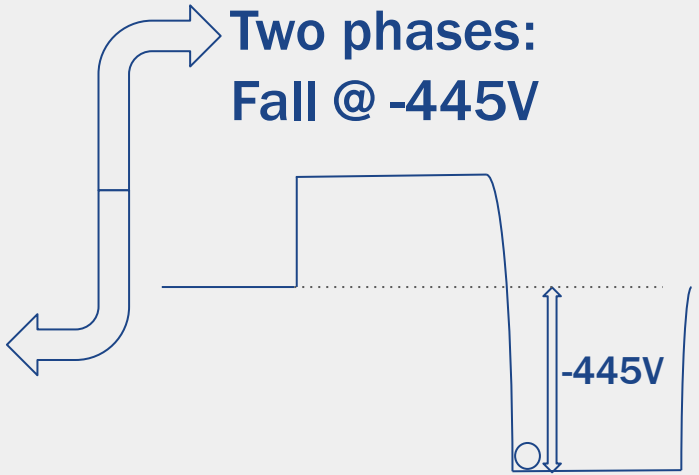


- Current set-up : Commissionning @ LPC CAEN -

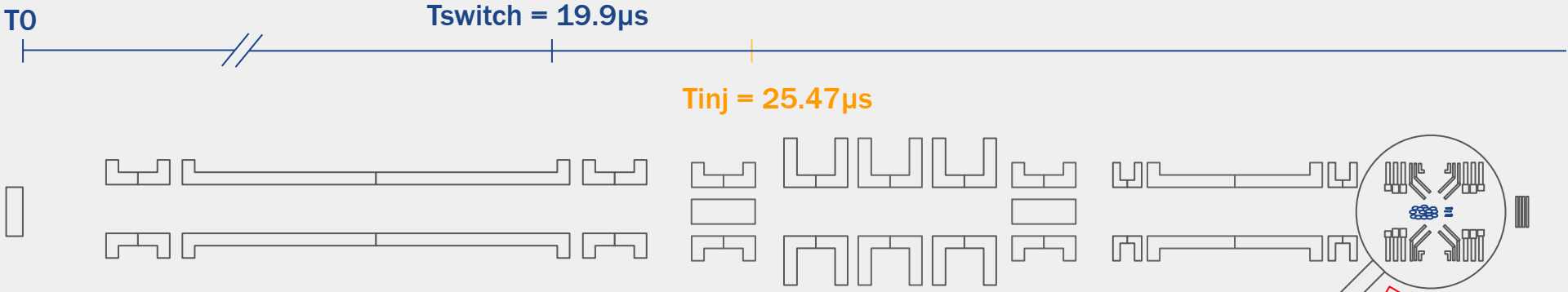


Travelling through the line:

- Pulse Drift tube (act as a lens for now)
- Steerer 1 to correct the beam direction
- Lens 1 to refocalise the beam
- Steerer 2 to adjust the beam
- Pulse Drift tube 2 to slow down the beam

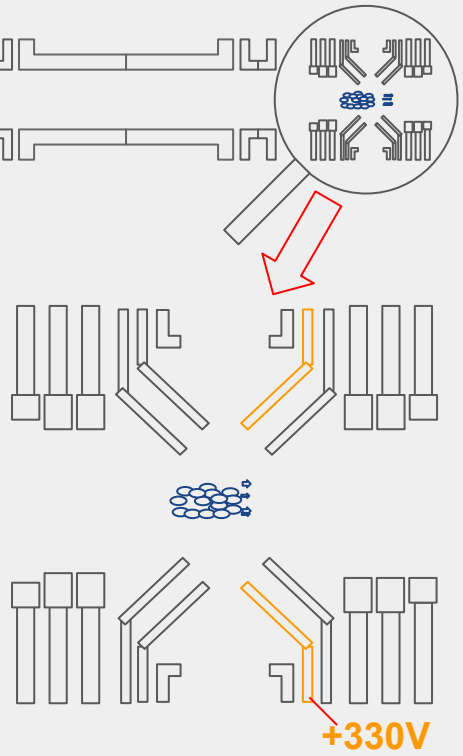


- Current set-up : Commissionning @ LPC CAEN -

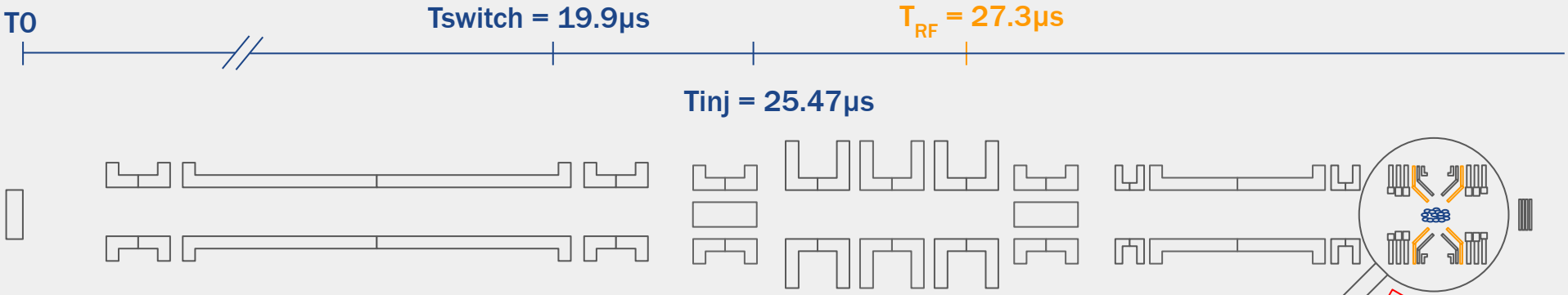


Trapping phase :

1) Approching the center ⇨ Get repelled



- Current set-up : Commissionning @ LPC CAEN -



Trapping phase :

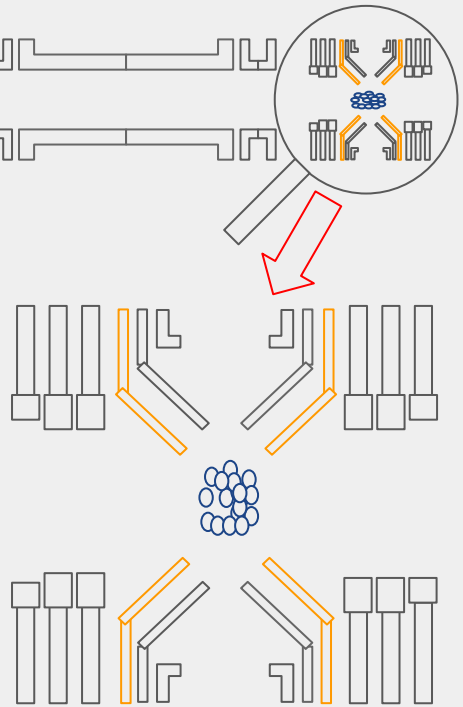
1) Approching the center ⇨ Get repelled

2) Starting the RF when E = ~0 eV

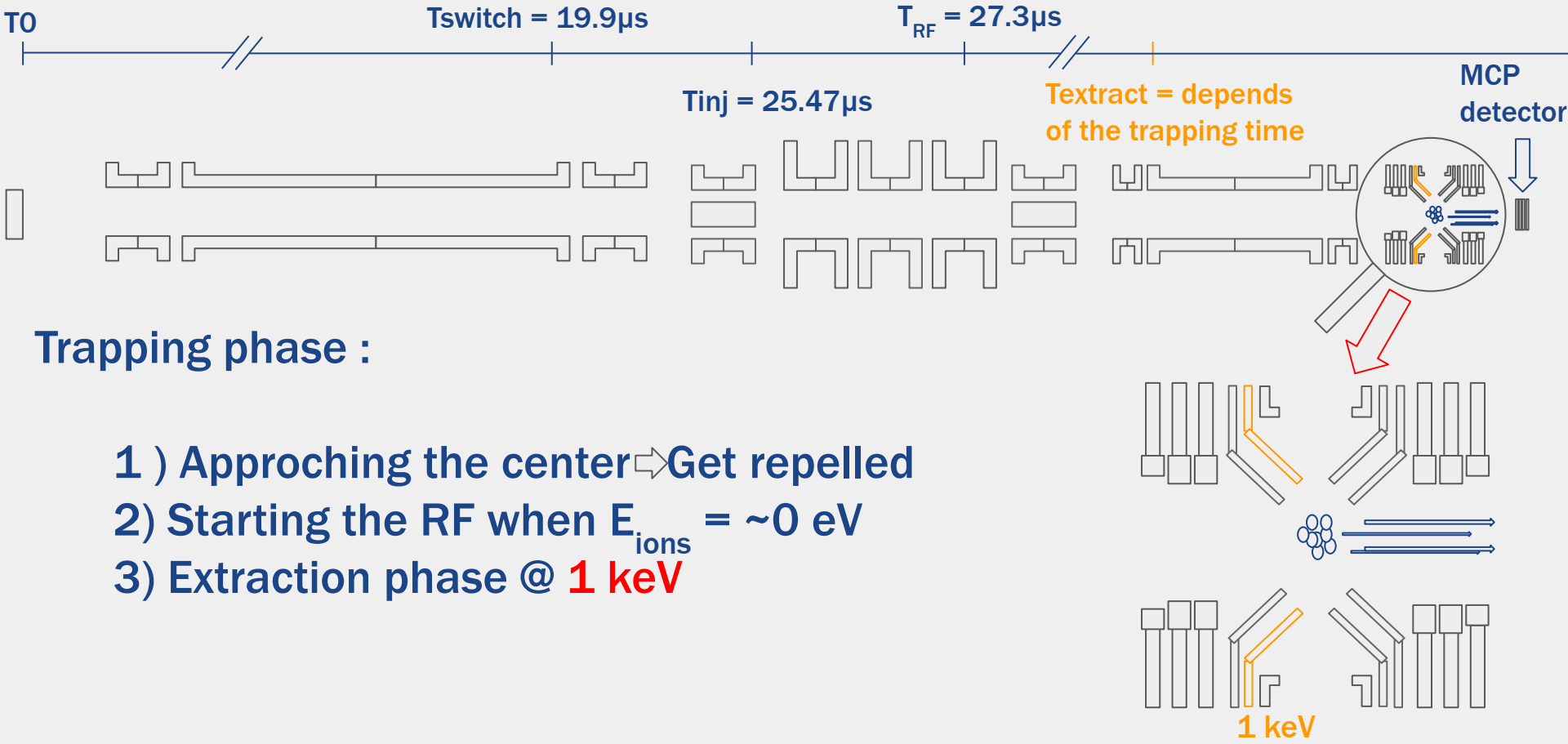
V_{RF} = ±76V

F = 333kHz

trapping time = ex: 60µs; 90ms; 450ms



- Current set-up : Commissionning @ LPC CAEN -



Trapping phase :

1) Approching the center ⇨ Get repelled

2) Starting the RF when E_{ions} = ~0 eV

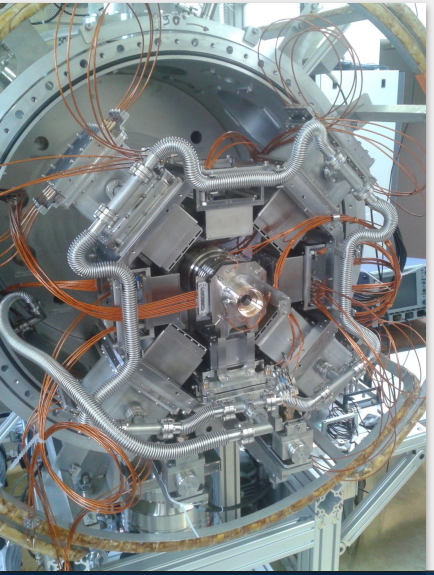
3) Extraction phase @ 1 keV

- Latest data : Trapping and optimization -

Trapping efficiency evaluation:

Three steps:

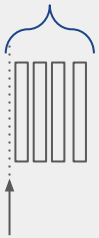
Collect data from the trapping process



Single peak

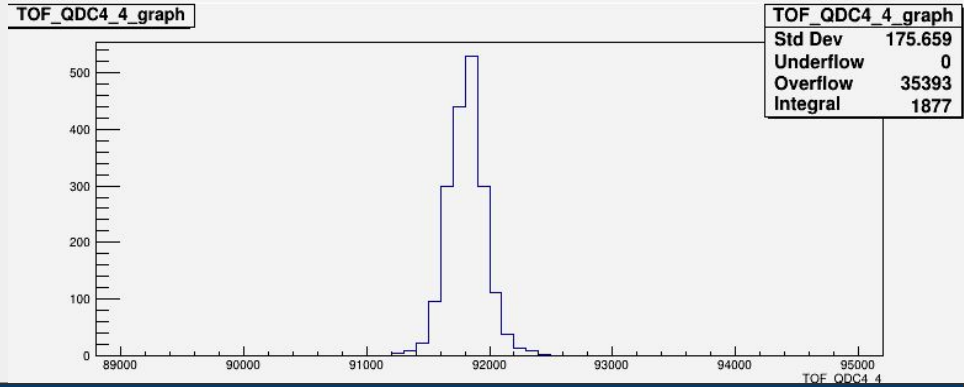
Trapping process “on”

MCP detector



Grid @ 0V

Data collected with trap: only Na



- Latest data : Trapping and optimization -

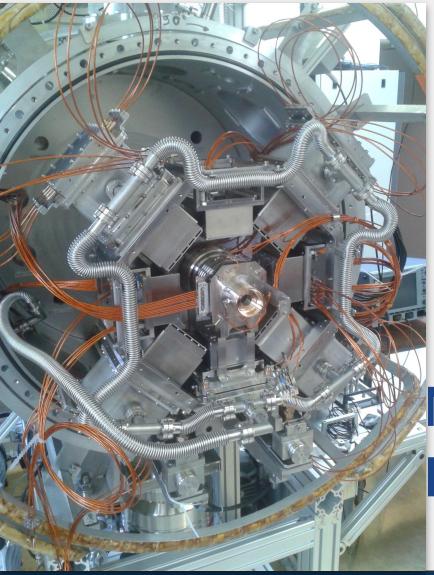
Trapping efficiency evaluation:

Three steps:

Collect data from the trapping process

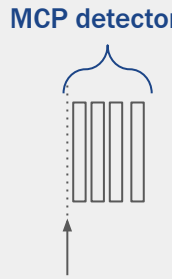
Disable the trap voltages and let ions passing through

Collecting data of the double peak (Na @ 112 eV + K @ 1.5 keV)

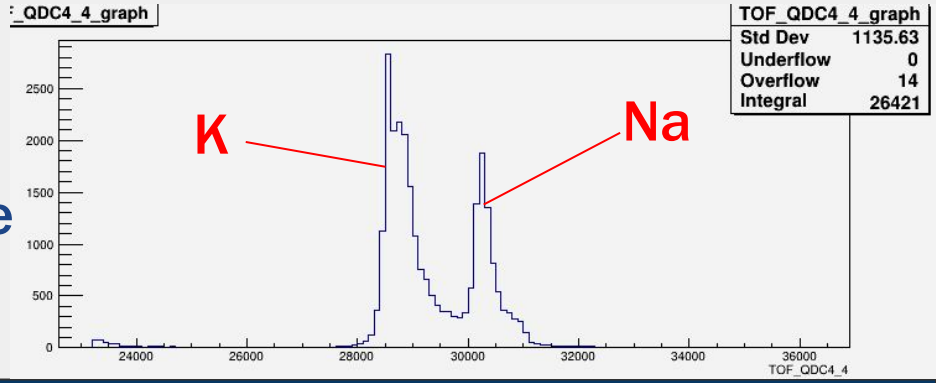


Double peak

Na slowed down by the PDT2 while not K



Data collected w/o trap: Na + K



THE MORA PROJECT
MATTER'S ORIGIN FROM RADIOACTIVITY

Trapping efficiency evaluation:

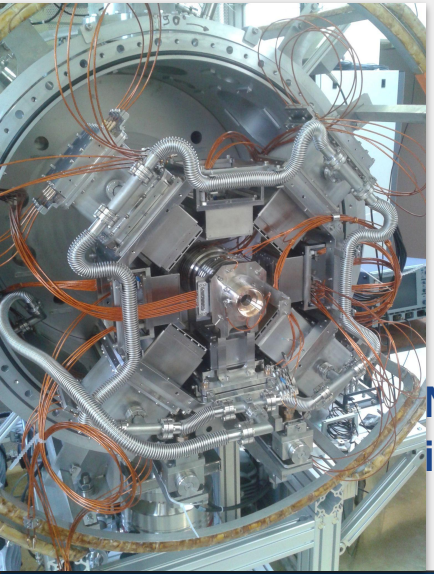
Four steps:

Collect data from the trapping process

Disable the trap and let ions passing through

Collecting data of the double peak (Na @ 112 eV + K @ 1.5 keV)

Filter the ion: only K and Rb will pass

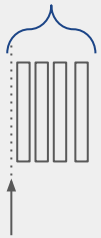


$$\varepsilon_{trap} = \frac{\text{Nb of trapped Na}}{\text{Nb of direct Na}}$$

Single peak

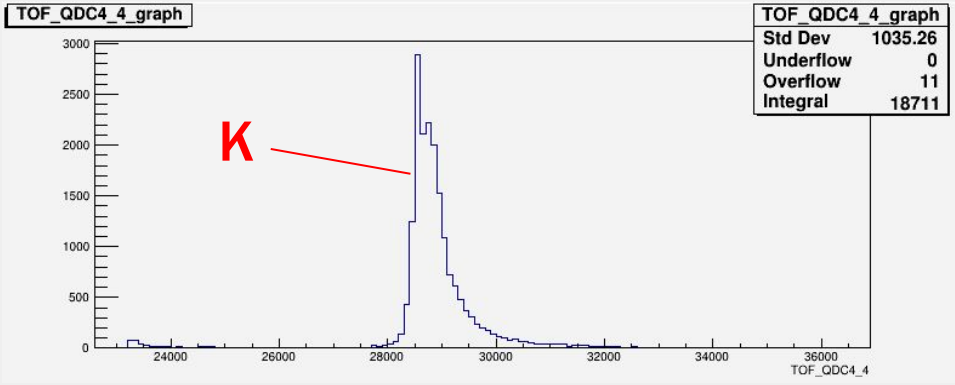
Na disappears by selecting
ions in energy

MCP detector



Grid @ 150V

Data collected w/o trap: only K



- Latest data : Trapping and optimization -

THE MORA PROJECT
MATTER'S ORIGIN FROM RADIOACTIVITY

Currently:

ε_{trap} = 56% for 60 µs trapping time
ε_{trap} = 22% for 90 ms trapping time
ε_{trap} = 10% for 450 ms trapping time

} Evaporation phase (~1 ms)
Half-life ≃ 350 ms

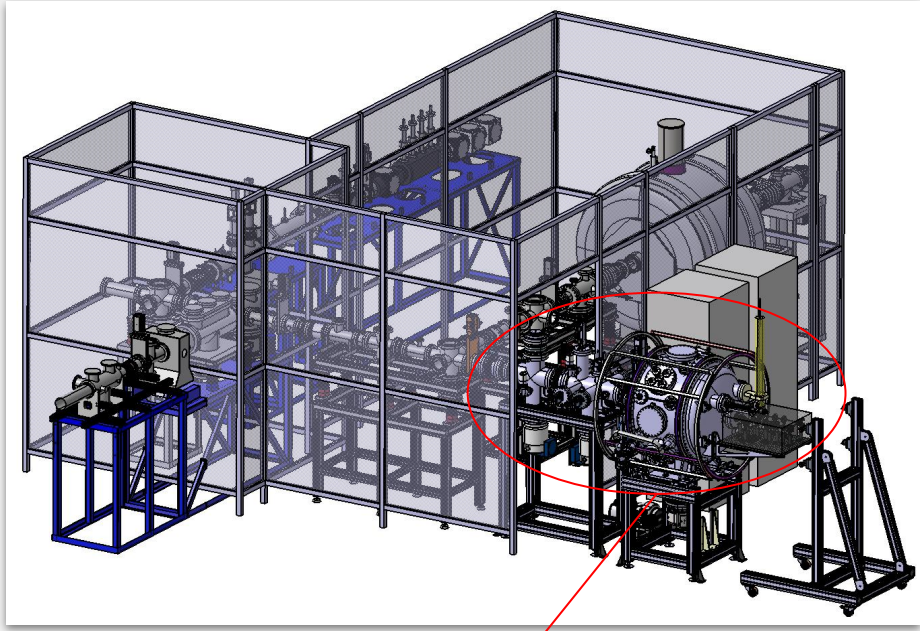
Conclusion:

The MORA line and trapping process are working very well and we are confident for future tests

- Future of MORA @ JYFL : Polarisation measurement -

Future schedule:

- Move the experiment to JYFL at the end of October
- Installing MORA beginning/mid November
- Offline tests of the new experimental set-up
- Beam time: 18 - 20 December (TBC)



MORA set-up @ JYFL

⇨ Test of online trapping and polarisation degree measurement

Thank you for your attention !

MORA collaborators:

P.Delahaye
F.De Oliveira
C.Fougères
N.Goyal
N.Lecesne
A.Singh
J.C Thomas

G.Ban
M.Benali
S.Daumas-Tschopp
X.Fléchard
E.Liénard
G.Quéméner

A.Falkowski
A. Rodriguez-Sanchez

R.P.De Groote
T.Eronen
W.Gins
A.Jaries
A.Jokinen
A.Kankainen
A.Koszorus
I.Moore
M.Reponen
S.Rinta-Antila
V.Virtanen

G.Neyens
N.Severijns

M.Kowalska

M.L.Bissel

A.De Roubin

M. Gonzáles-Alonso