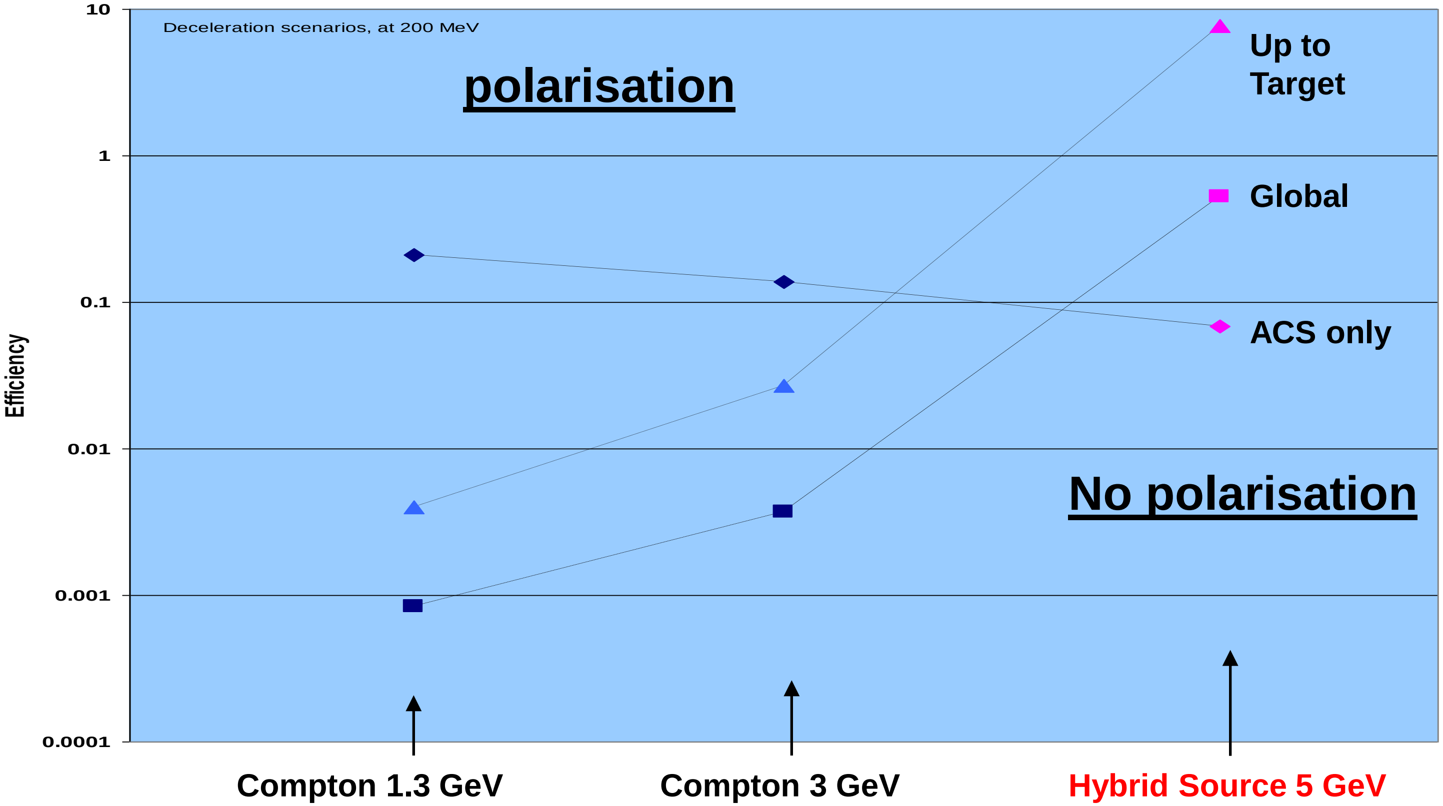
CLIC RF manipulation for positron at CLIC

Scenarios studies on hybrid source

Freddy Poirier

12/08/2010

Efficiency snapshot



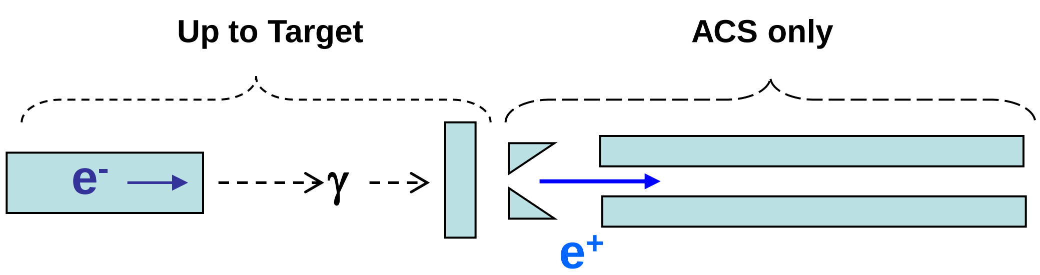
Single 5 ip

Results here with old aperture structures

On the way to be updated

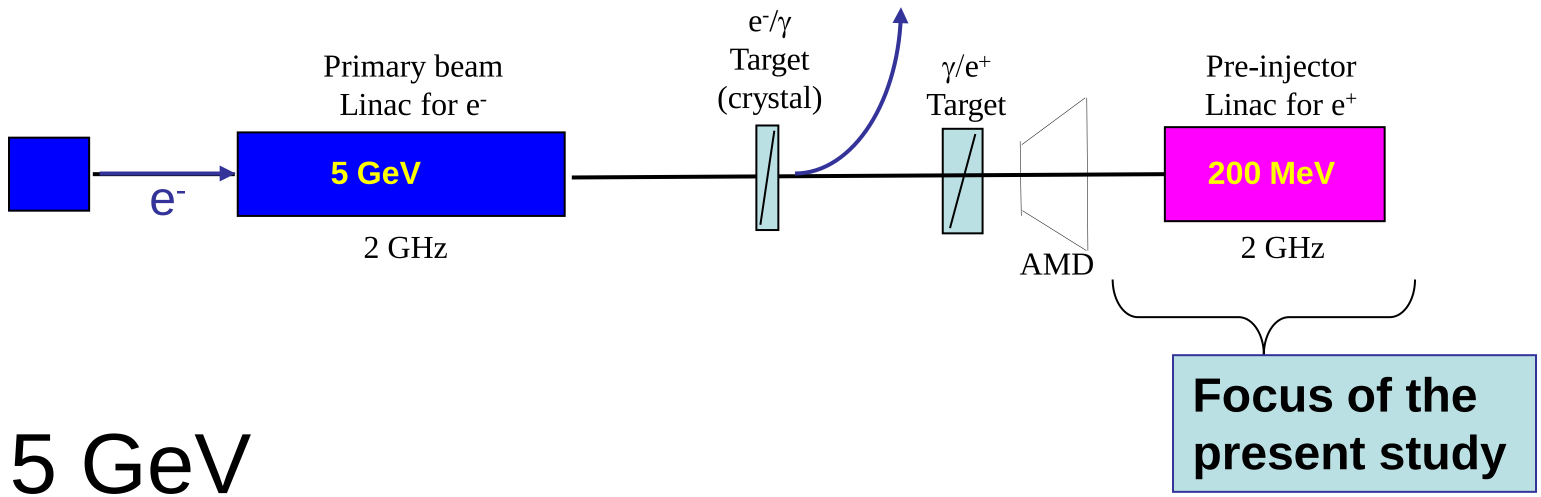
Efficiency (here): Nb e+ /nb e- at 200 MeV, E>165 MeV

As of 4 weeks ago



Sources scenarios (pol. and non-pol.) being studied:
- Hybrid source (CLIC baseline)
- Compton source (see talks from I.Chaikoska)

Hybrid Source Scenario (Baseline)



- 5 GeV
- 2 m between crystal and target
- 10 mm target thickness
- Positron Bunch length at target exit= 500 μm

Present Studies

- Capture and acceleration using Travelling Wave (TW) tanks.
  - 84 accelerating cells tanks + 2 couplers i.e. long cavity
  - Prior studies have used Standing Wave (SW) 6 cells cavities (see talk of A.Vivoli)
- For Hybrid source (HB)
  - Scenarios with modification phase of first TW
  - Space charge limits
  - Additional Scenarios
    - Solenoid field (1T)
    - Cavity within AMD

HB source

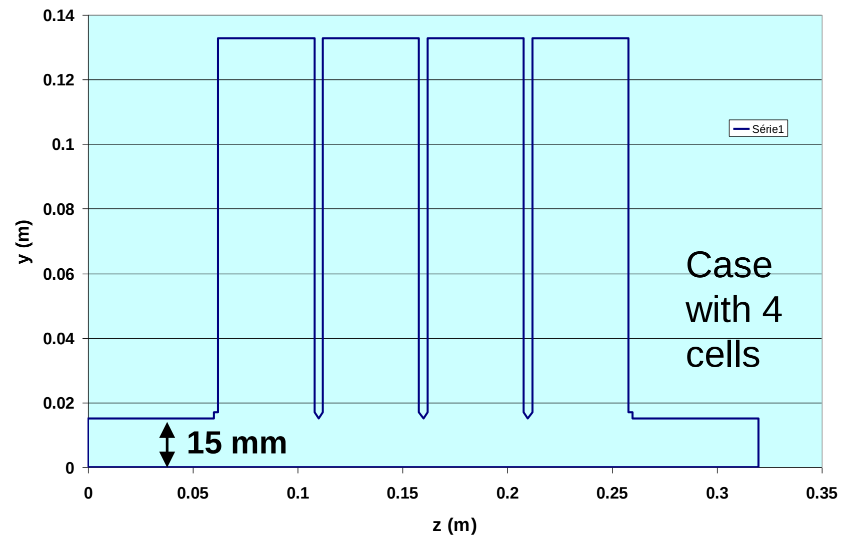
Physique des accélérateurs

2 GHz TW tanks

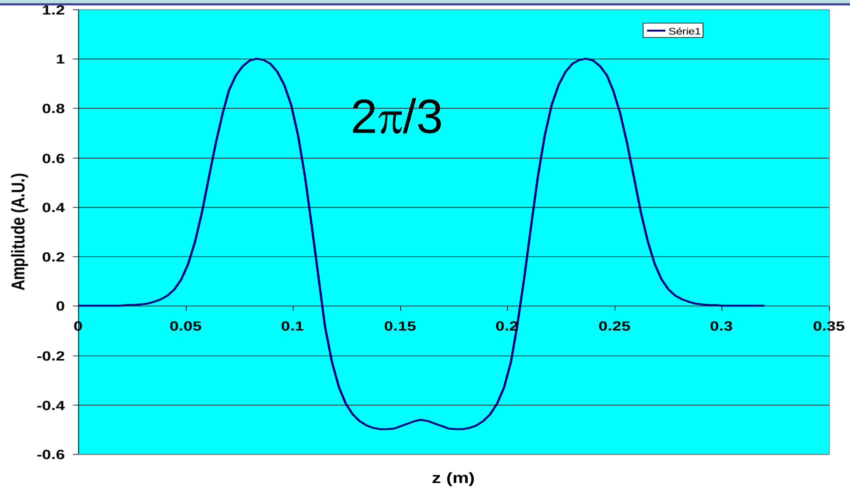
- 2 GHz
- 84 accelerating cells constitute the TW tanks
  - Note: 84 cells + 2 half cells for couplers within ASTRA
  - $2\pi/3$ operating mode
- 4.36 m long
- 15 MV/m
- Up to 5 tanks are used to accelerate e+ up to 200 MeV

First optimisation done on 15 mm iris (radius aperture) tanks but final results with 20 mm iris tanks

Typical cells dimension for the TW tanks



Typical electric field for the 4 cells cavity

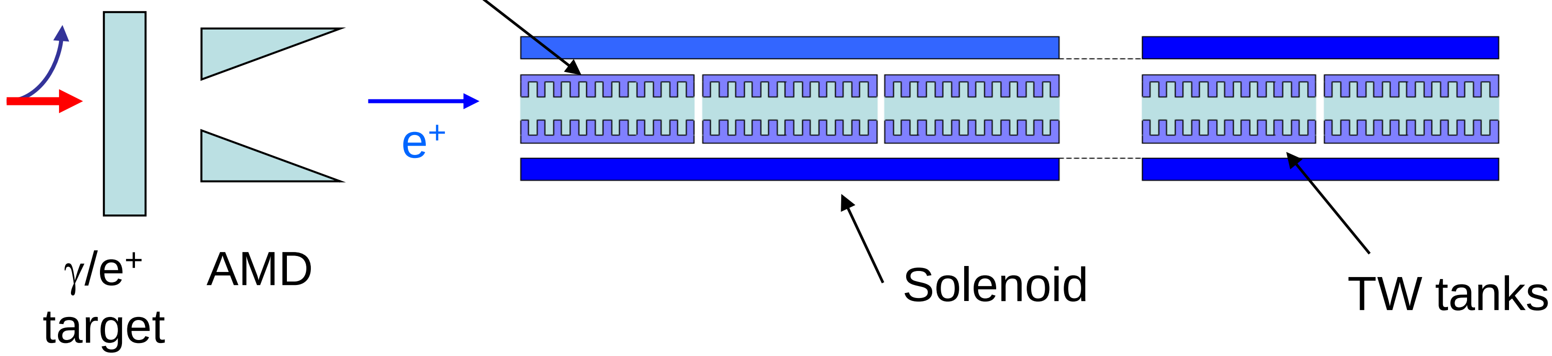


HB source

Capture Strategy

Capture strategy of the first tank?

Other tanks: full acceleration

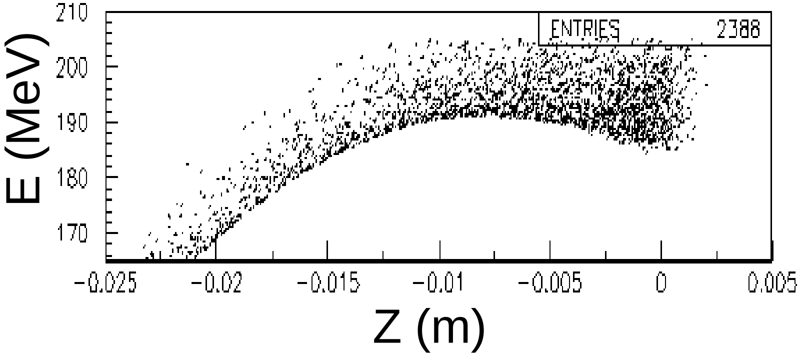


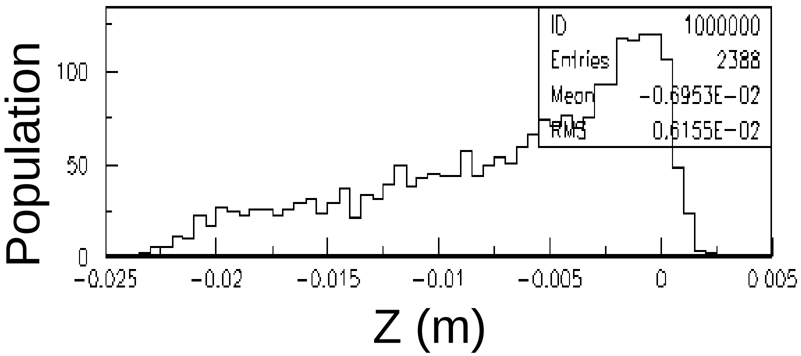
- **Acceleration**: Phase of the first tank tuned for use of maximum accelerating gradient for the first tank
  - 4 tanks are needed to reach ~200 MeV
- **Deceleration**: adapt the phase and gradient of the first tank to capture a maximum of positrons
  - 5 tanks are needed to reach ~200 MeV

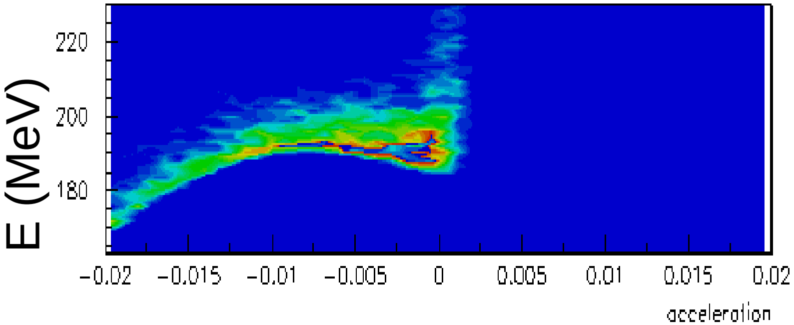
HB source

Acceleration

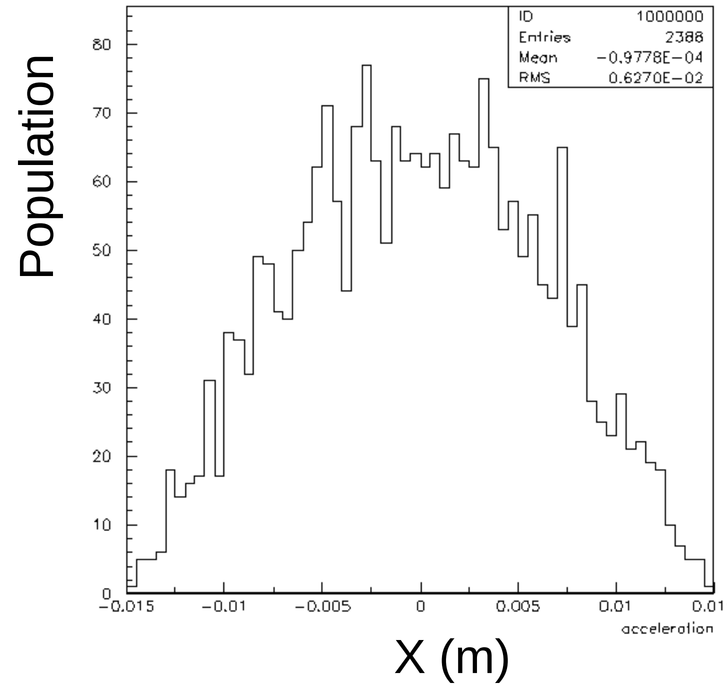
Acceleration case at 18.12 m (to reach ~200MeV)







Transverse distribution



→2388 positrons

With cut at e_{min}=165 MeV

Total Efficiency$_{(200MeV,emin)}$
2388/6000= **0.398**

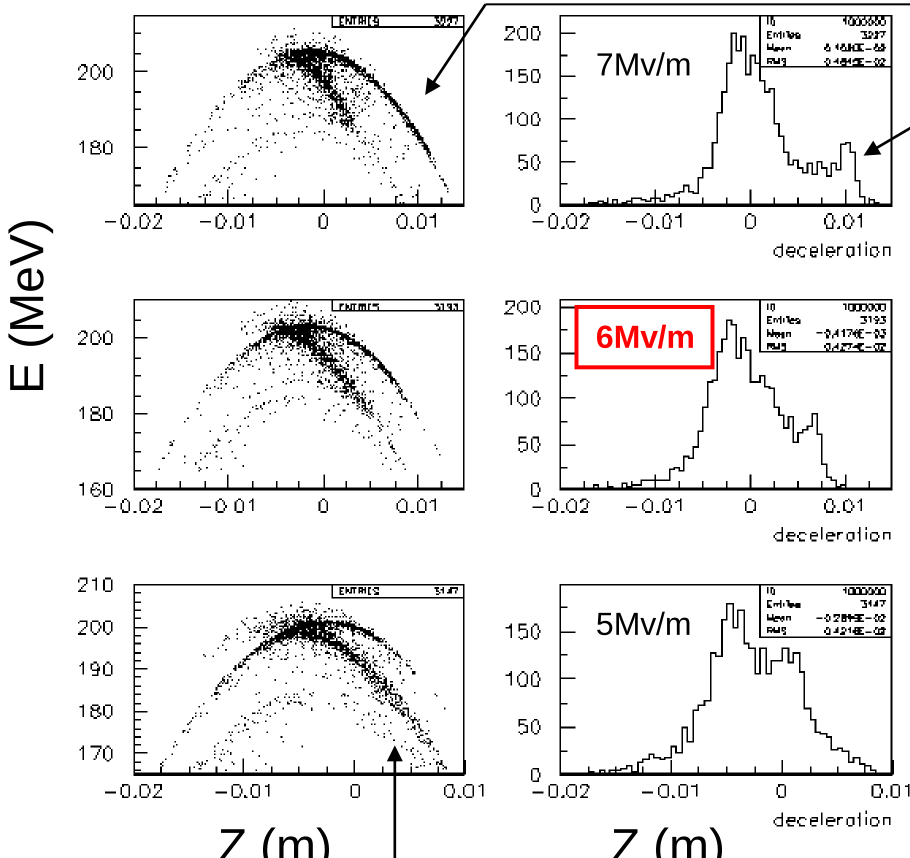
HB source

Deceleration

- First tank Phase = 280°
- Choice of gradient:

Values at 22.63 m (at ~200 MeV)

More positrons in the higher tail but tail further in z

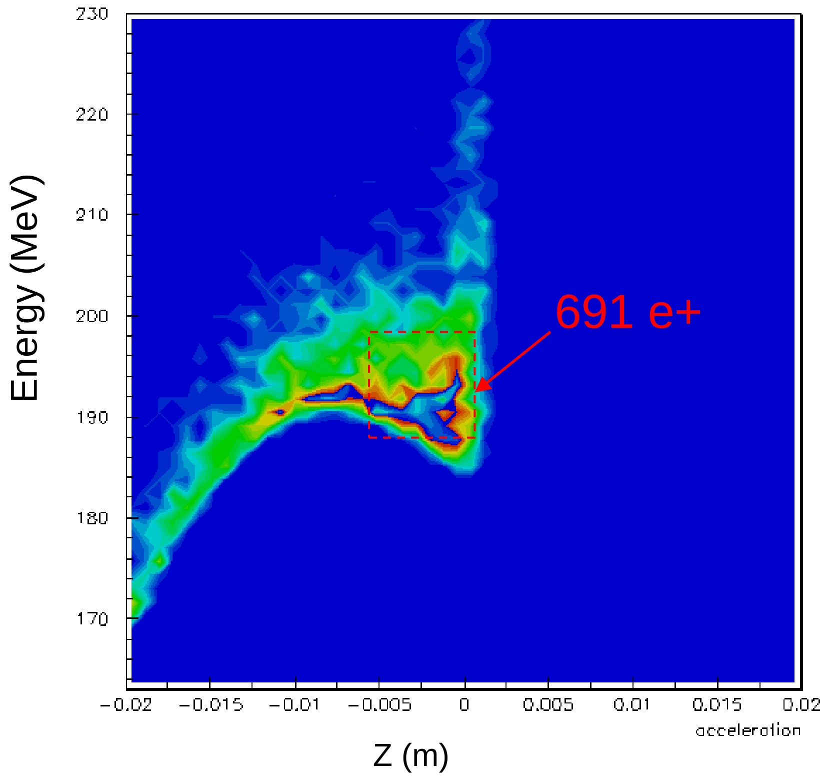


Gradient (MV/m)	Nb of positrons > 165 MeV	Nb of positrons > 185 MeV
7	3227	2832
6	**3193** **Eff=0.53**	2929 Eff=0.49
5	3147	2741

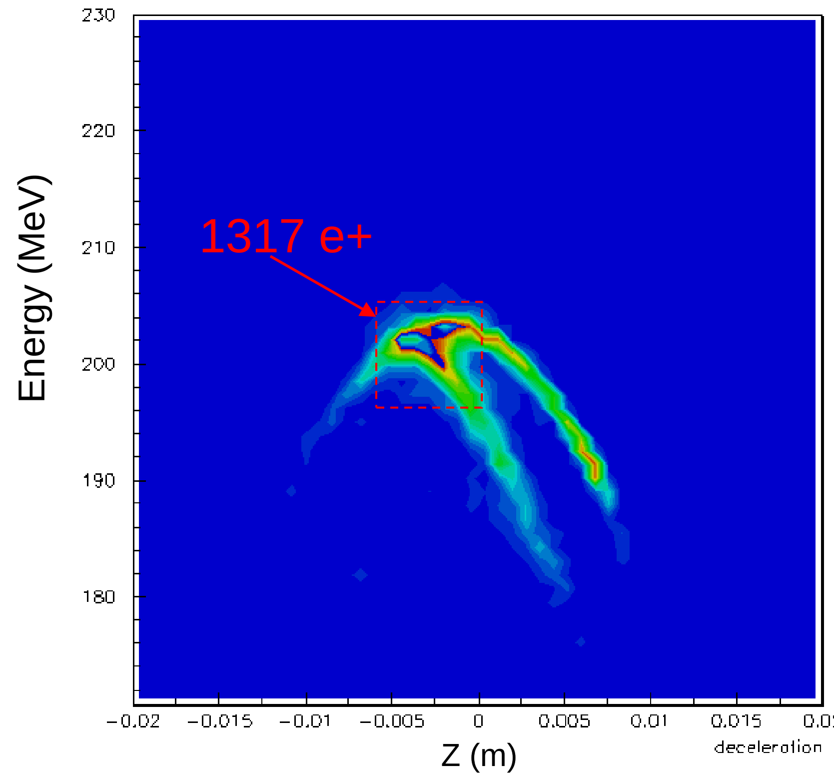
More positrons in lower tail but tail lower in energy

At 200 MeV

Acceleration case



Deceleration case



$\text{Eff}_{200\text{MeV}} = 0.40$

$\text{Eff}_{200\text{MeV}} = 0.53$

- **For the deceleration case the efficiency* at 200 MeV is higher than for the acceleration case**
- For further information: The value in red gives the number of positrons within the red dashed box

*Eff $_{200\text{ MeV}}$: Nb of particles entering target/ Nb of particles at exit of tank with energy greater than 165 MeV

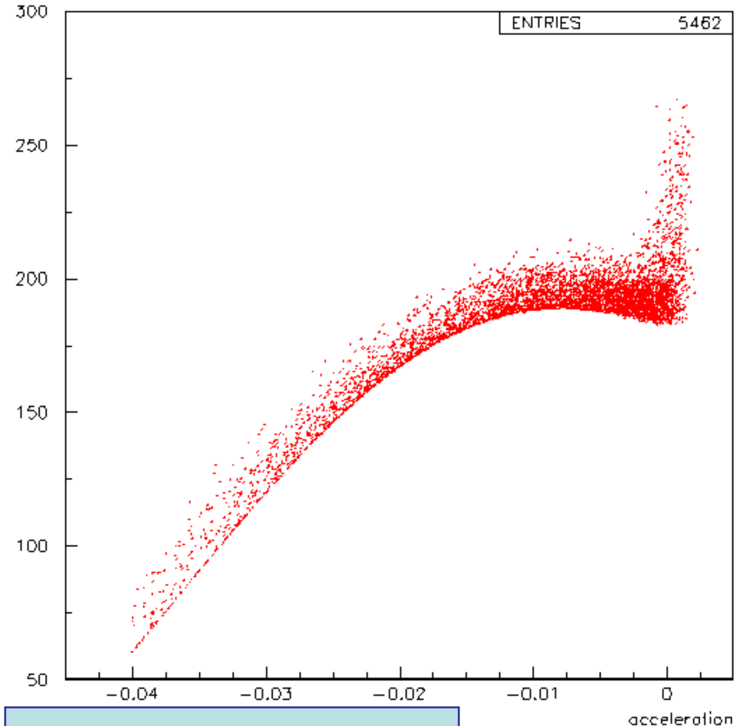
HB source

Physique des accélérateurs

20 mm aperture

New 2 GHz cavity and field provided by P.Lepercq

Acceleration scenario

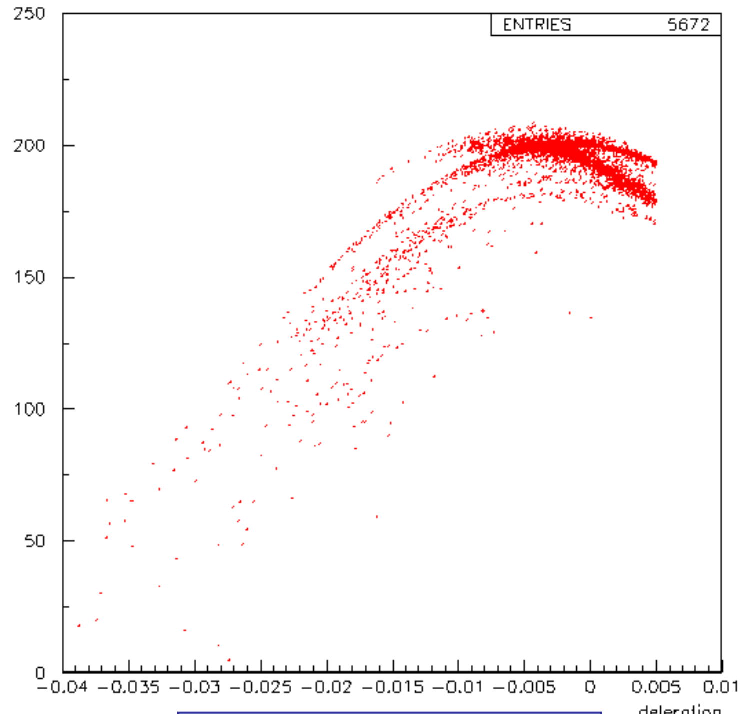


Total yield=0.9

Efficiency >165MeV=4621/6000= **0.77**

(was 0.4 for 15 mm aperture)

Deceleration scenario



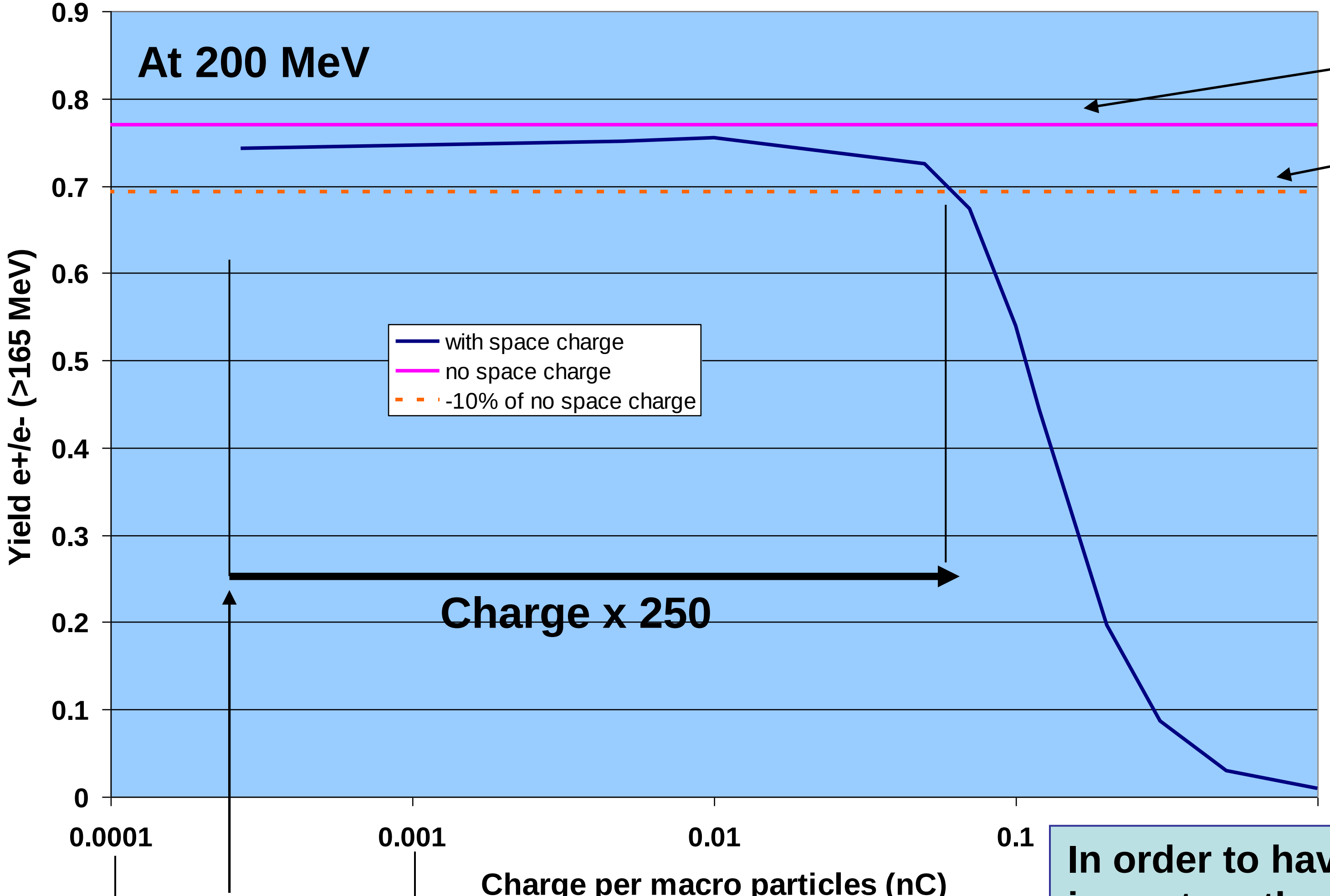
Total yield=0.95

Efficiency >165MeV=5335/6000= **0.89**

(was 0.53 for 15 mm aperture)

This is the big advantage of the deceleration technique

Impact of space charge



No space charge

-10% level

Negligible space charge effect to be expected

Charge per macro-particles (nC):

$C_{mp}=Ne^{+}_{i} \times qe^{+} / (1e\text{-}9 \times Ne^{+}_{s})$

Ne^{+}_{i}: initial nb of e^{+}

Ne^{+}_{s}: simulated nb of e^{+}

3.75 — 10 — 37.5 — 375 — x10^{9} e^{-}

Expected level of charge for HB

In order to have a 10% level impact on the result, the e- charge has to be multiplied by 250. We are far from this with the present CLIC values.

Impact of space charge

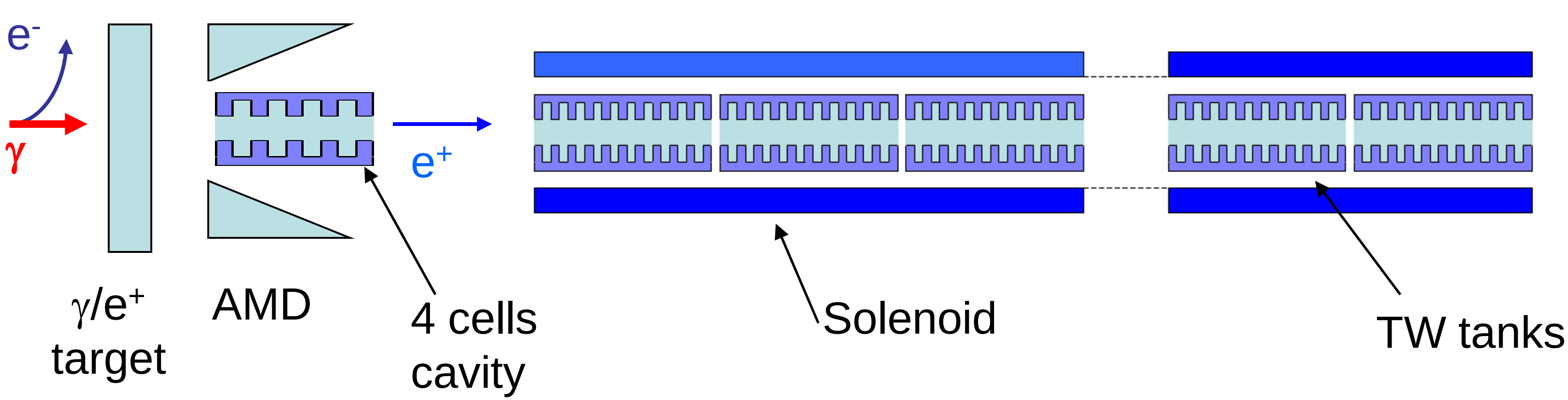
- Acceleration scenario:
  - The use of space charge imply -3.6% e+ at 200 MeV.
  - With the present e^- charge, we are at ~2.5 10^2 lower than a 10% effect
- Deceleration scenario:
  - The impact is -4.6%.
  - With the present e^- charge, we are at 10^2 lower than a 10% effect

The impact of space charge is here of the order of less than 5%

The difference from acceleration to deceleration is noticeable but the level is not detrimental in both case

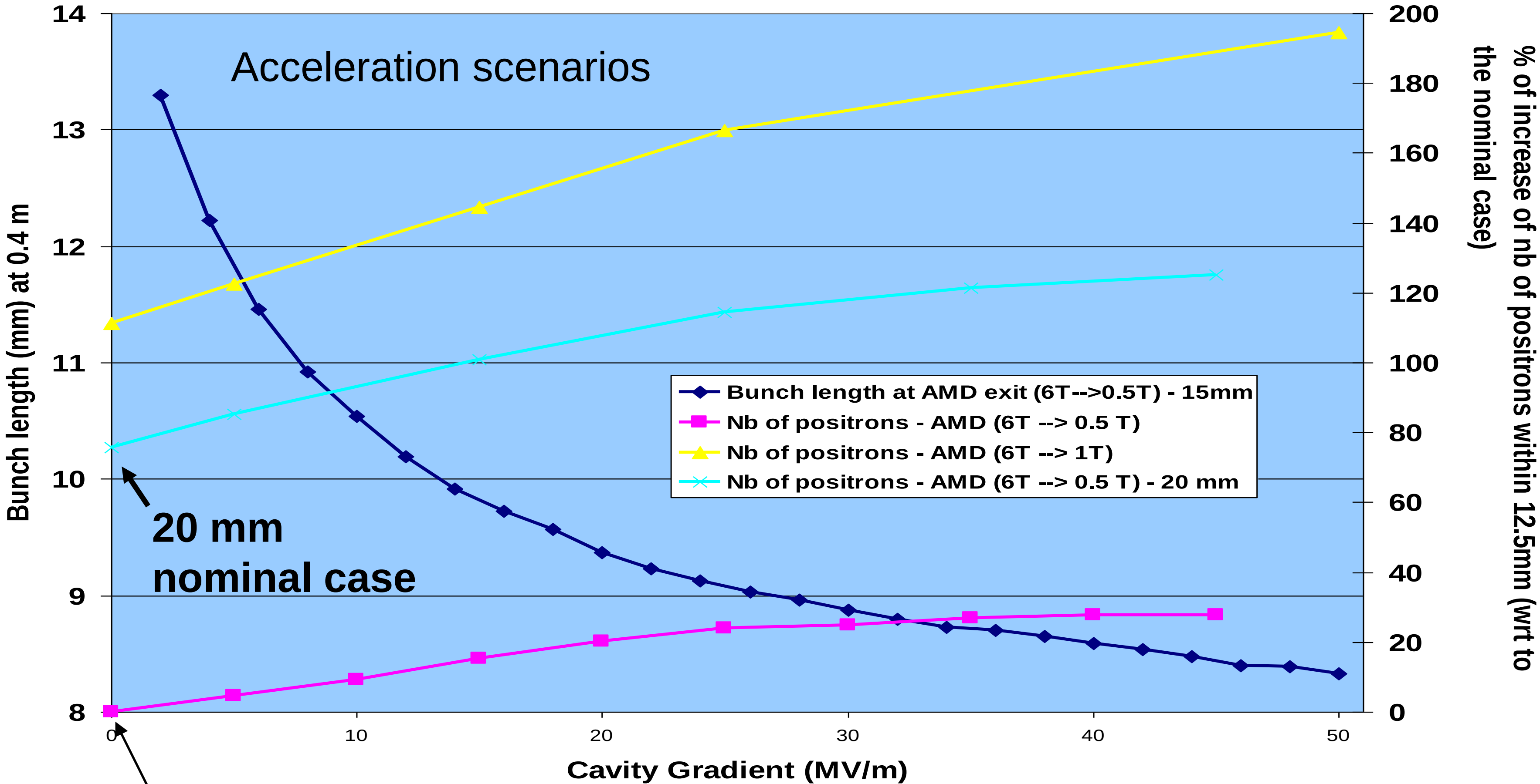
Additional Studies on the capture with hybrid source

- Additional scenario:
  - 1) An accelerating field within the Adiabatic Matching Device (AMD)
  - 2) Increase of the magnetic field surrounding the TW Accelerating section. Traditionally it is fixed at 0.5 T.

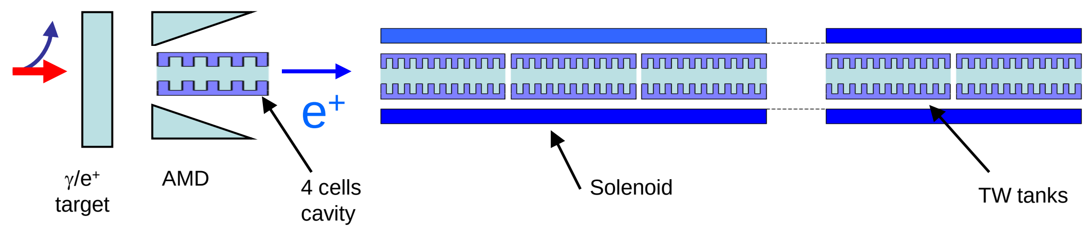


HB source

Additional Scenarios



Case (AMD 6T → 0.5 T and no cavity inside the AMD, but AMD inner radius=15 mm)



HB source

Physique des accélérateurs

Conclusion

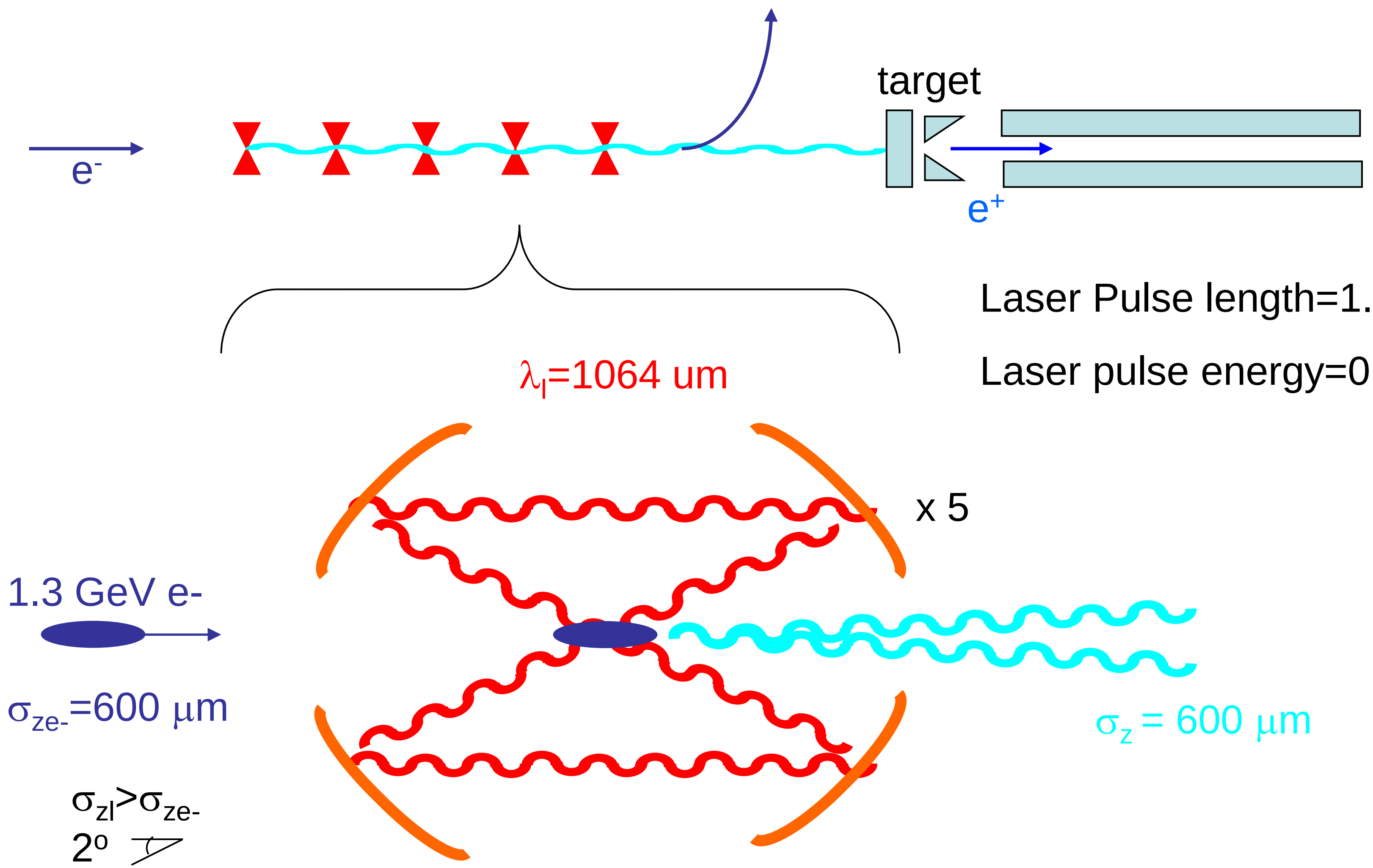
- 2 scenarios studied:
  - Acceleration and deceleration
  - Very interesting scenario is deceleration
- Further optimisation (on lattice) for capture can be done
- No major impact from space charge foreseen in both scenarios
- Additional scenarios are also studied (booster within the AMD and higher solenoid field) which shows good potentials

Perspectives

- What about power consumption (TW/SW)?
  - The choice of TW/SW is not done yet. It will highly depends on the power consumption.
  - Though if TW are in use for acceleration between 200 MeV up to DR then it is an attractive choice.
  - Review of dimension should be done (2 GHz → 1 GHz?)
- The results need to be sent to the bunch compressor and check the effective yield there

More Slides

Compton Scenario



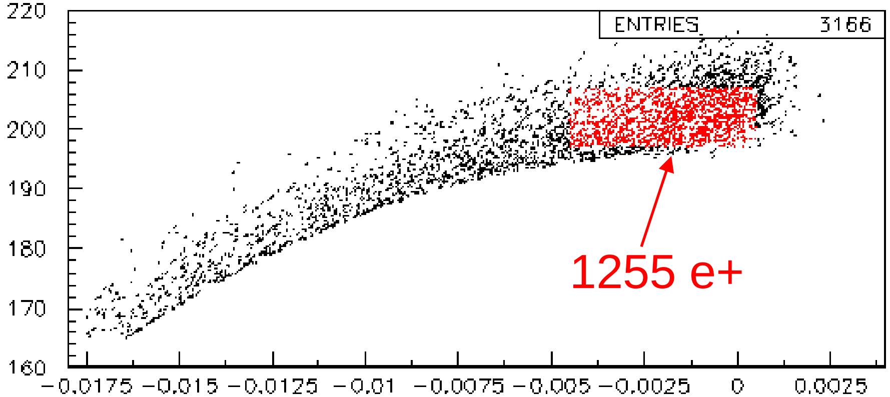
Laser Pulse length=1.5 mm

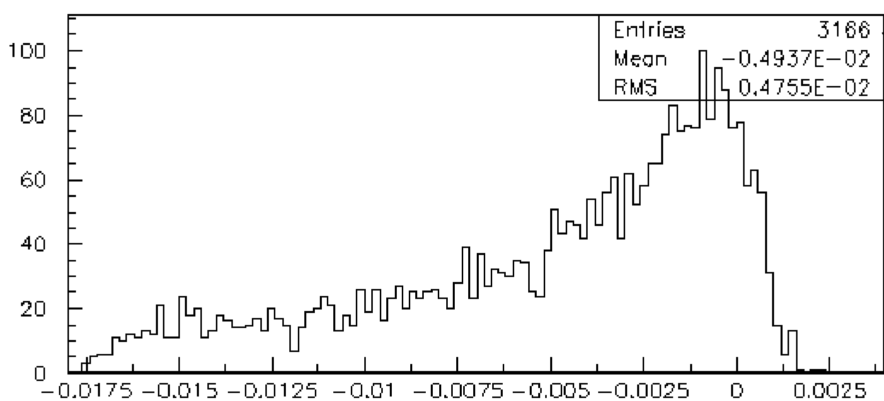
Laser pulse energy=0.1 J

Compton source

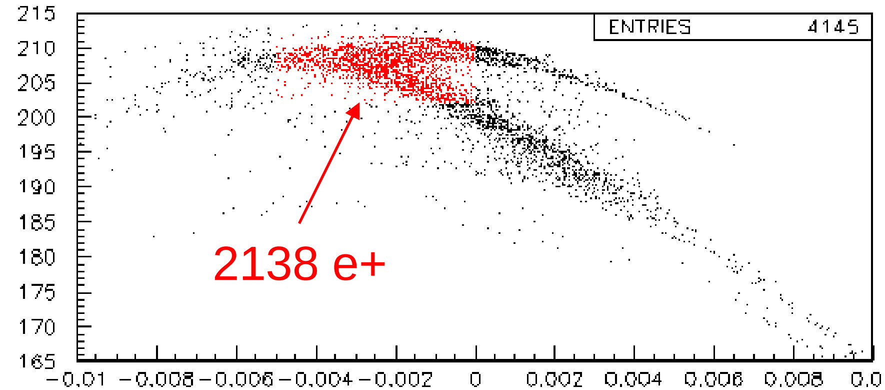
Distributions at ~200 MeV

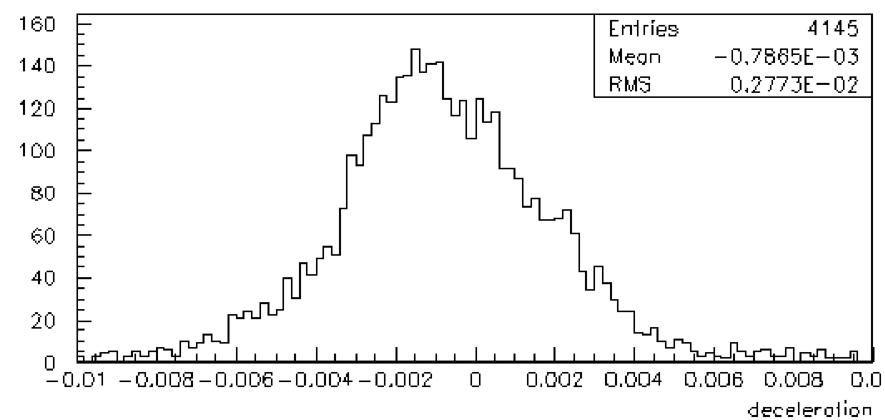
Acceleration case (18.12 m)





Deceleration case (22.63 m)





This value is used for the efficiency calculation

1.3 GeV, 5 IP

Red box: δe=10 MeV, δz=5 mm

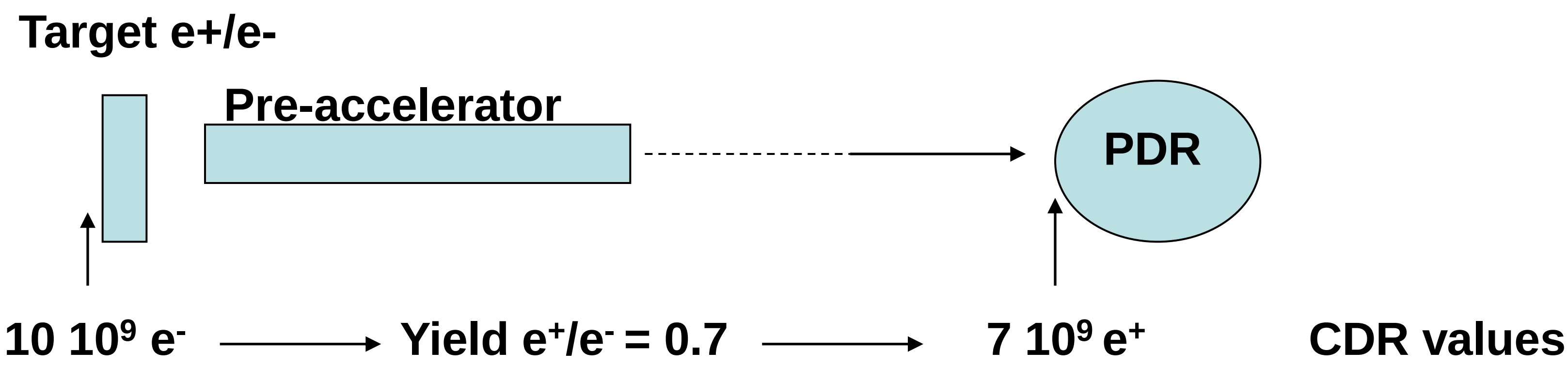
HB source

Impact of space charge

- The space charge is considered traditionally low because:
  - Large transverse size of the beam at exit of AMD
  - High enough energy (The positrons have an average energy > 5 MeV so quite relativistic)
  - Previous studies with Parmela simulation have shown an impact of space charge of the order of 1 % on the result
- Are we far from any effect due to Space charge?
  - What is the limit wrt to the charge of the bunch. i.e. if we increase the charge of the bunch at the exit of the AMD will there be a noticeable impact?
  - What happen to the space charge limit if we do deceleration?

HB source

The CLIC CDR yield hypothesis



We are simulating 6000 e$^-$ (macro-particles), representing 10 10^9 e$^-$ i.e. the charge per simulated particle is 2.7 10^{-4} nC.

PDR: Pre-Damping Ring