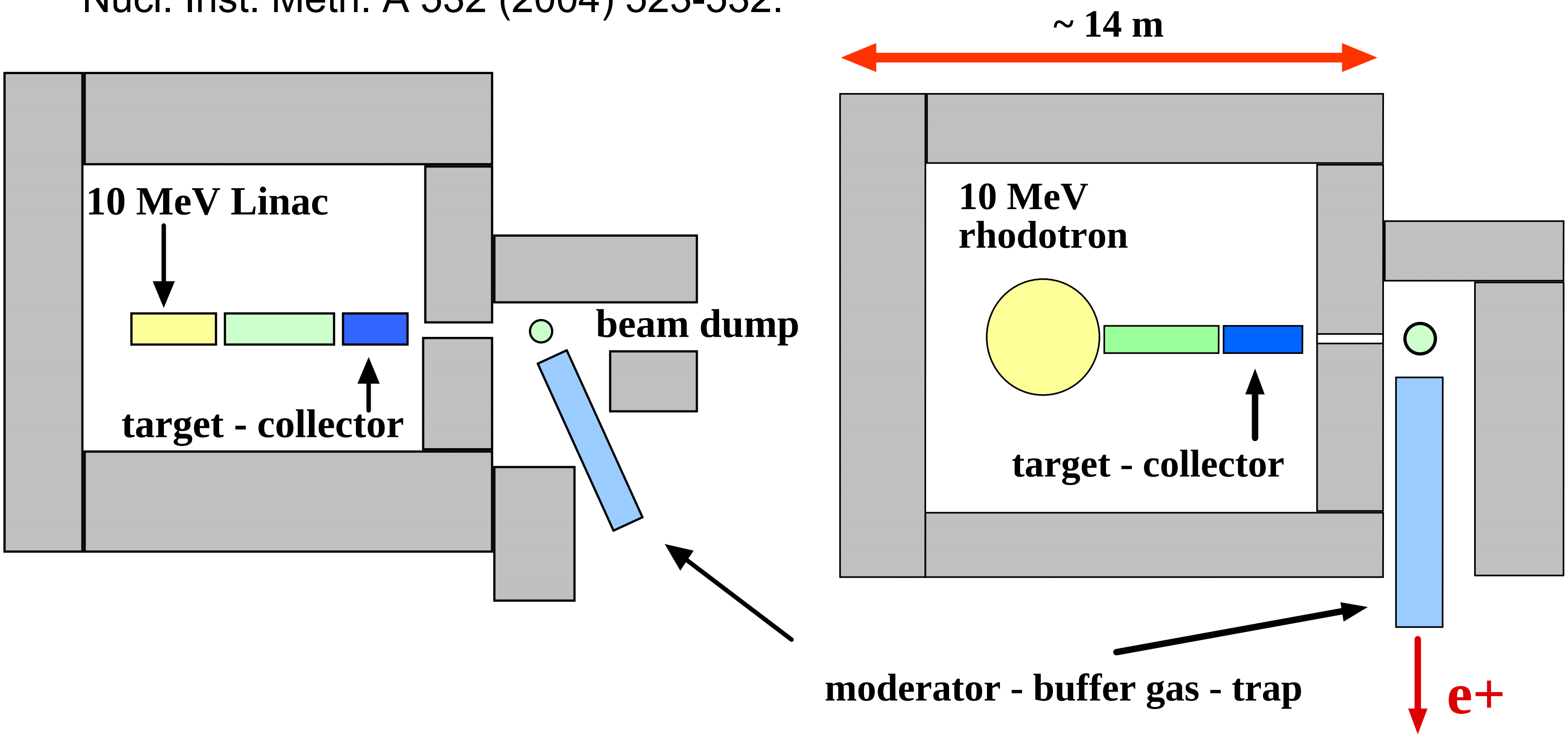
Intense Slow Positron Source

Nucl. Inst. Meth. A 532 (2004) 523-532.



~ 14 m

10 MeV Linac

beam dump

target - collector

10 MeV rhodotron

target - collector

moderator - buffer gas - trap

e+

Intense Slow Positron Source

- Introduction
- Geometry, heat inside target, e^+ production rate
- Collection
- e^- spread, e^- dump
- e^- beam , e^+ e^- separation, rotating coils

e^+ Production and Collection

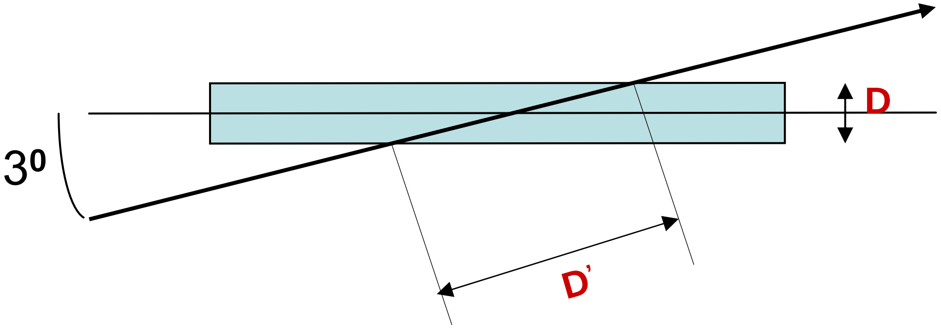
- Beam energy/intensity : 10 MeV 2~10 mA
- Target geometry : thin foil at grazing incidence (3 degrees)
- Probability of first interaction (e^+ & Xrays)
- Thermal effects : Xrays + e^- leak
- Large angle collection and selection < 1 MeV

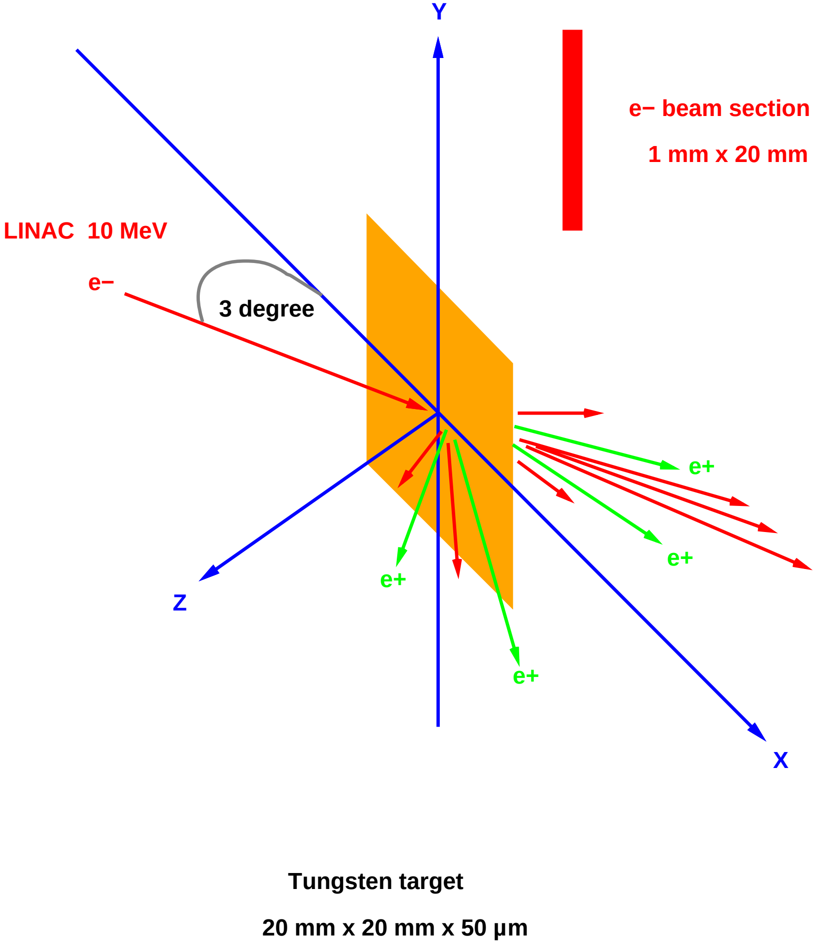
Thin Target at Grazing Angle

Study energy deposit as a function of incidence angle

Thickness = D

equivalent thickness: D' = D / sin 3^0

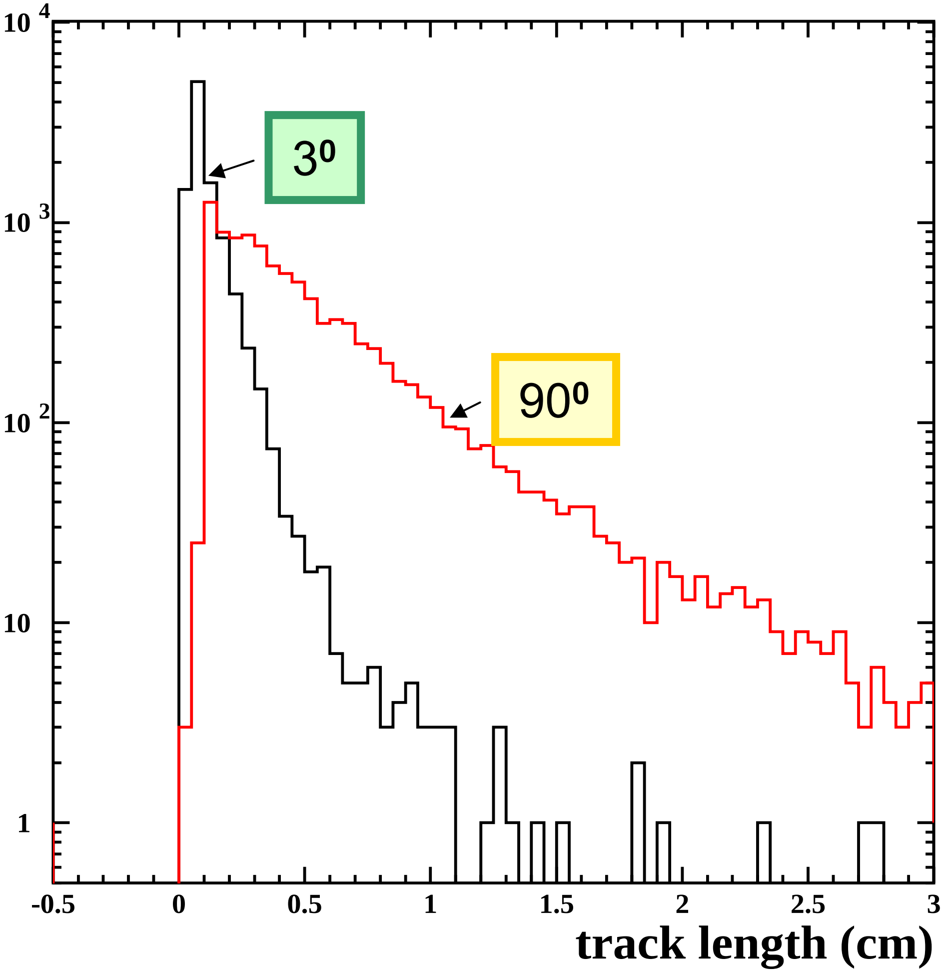




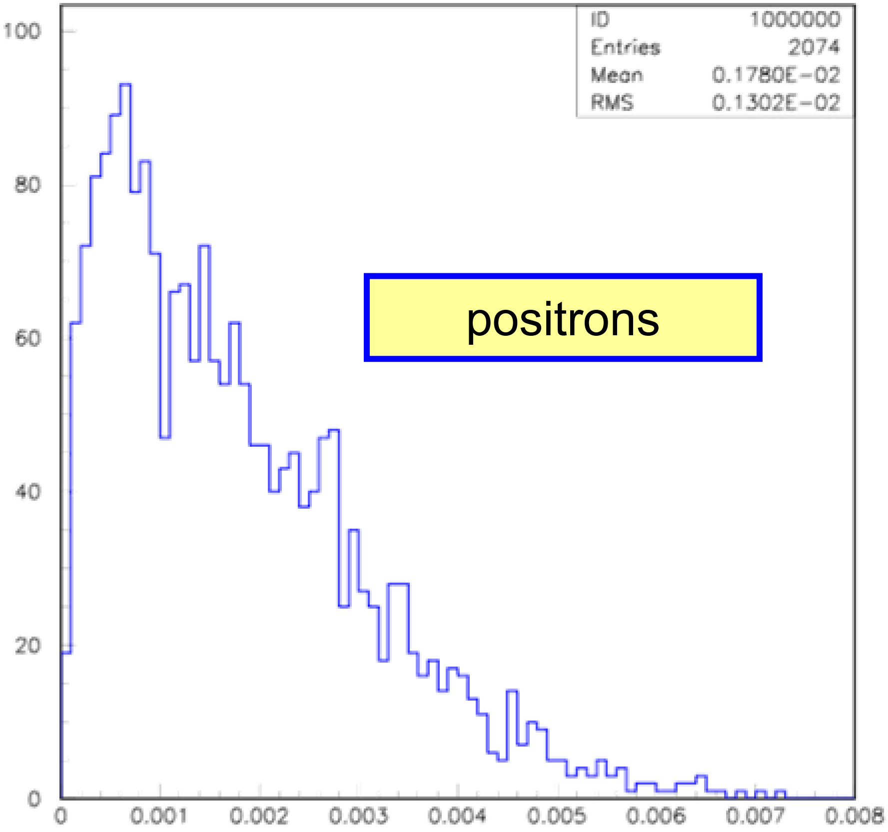
Track Length inside Target

e^- track length inside targets of 1mm equivalent thickness

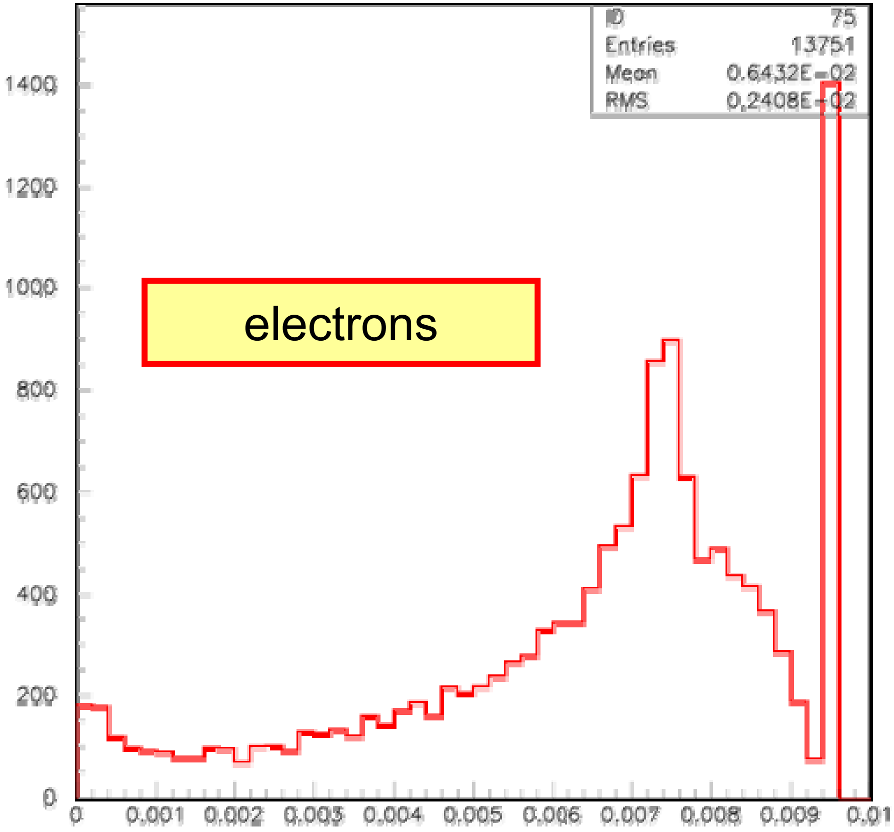
	<L> (cm)	rms (cm)
3^0	0.11	0.11
90^0	0.53	0.48



Kinetic energy at target exit



Energy (GeV)



Energy (GeV)

2004

Target

e^- soldering test on

Tungsten 50 µm

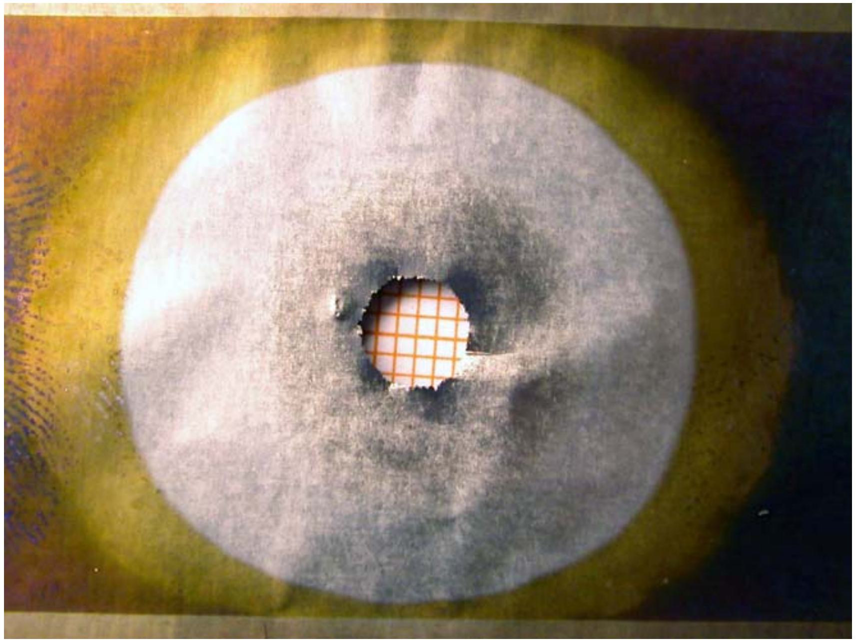
40 kV / 20 mA on 20 mm²

not perforated at 15 mA

Melting limit: 4 kW / cm²

Working hypothesis: 2 kW / cm²

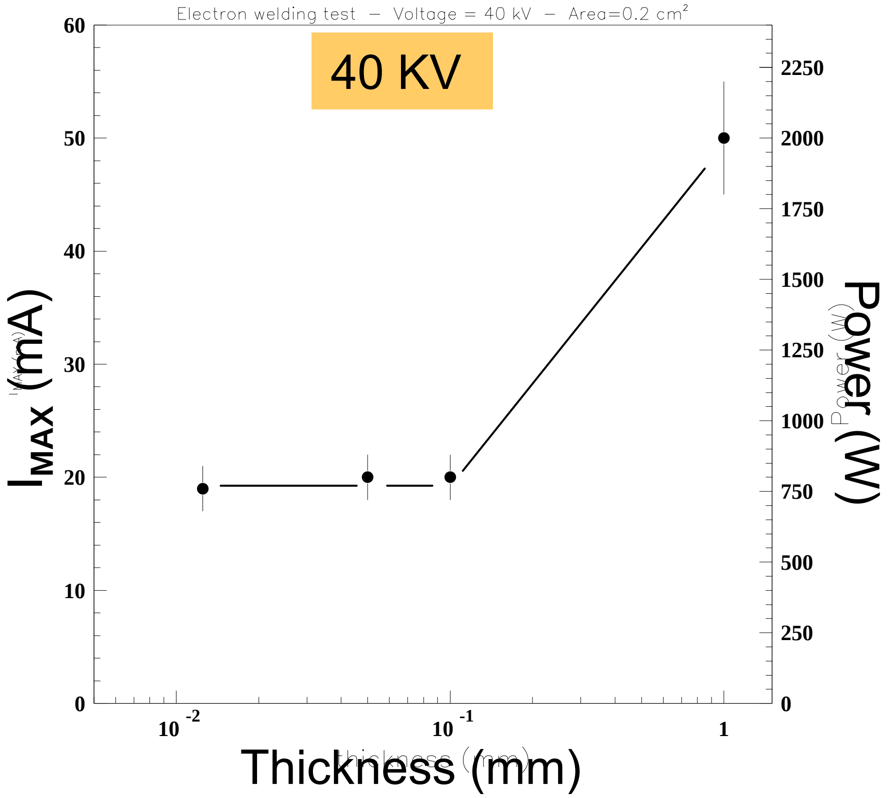
Study hypothesis: 1 kW / cm²

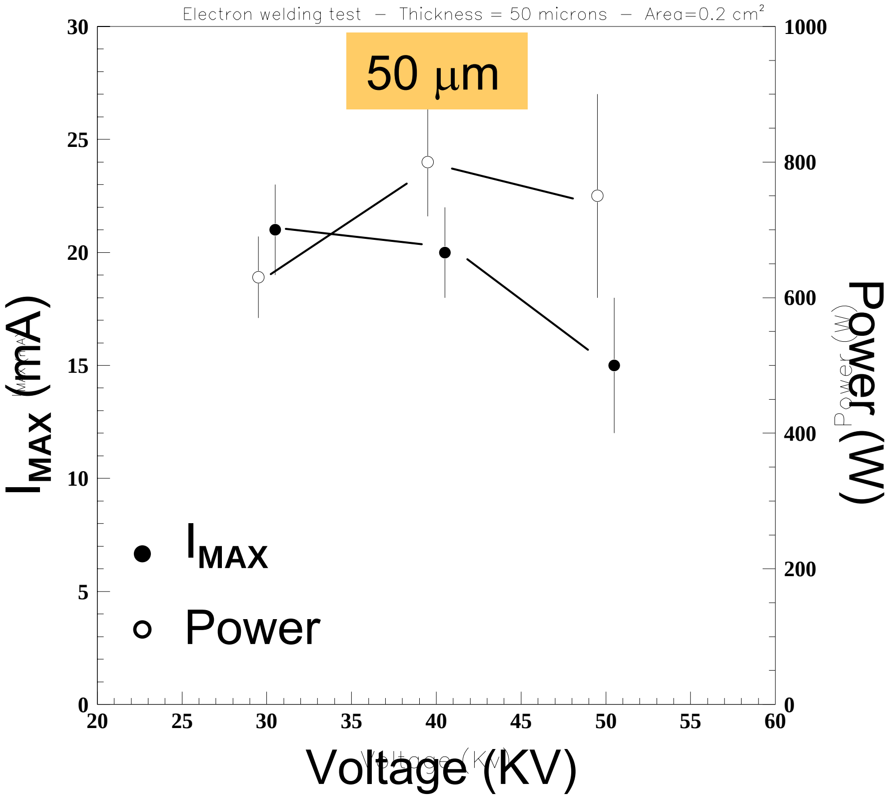


Test with high intensity beam from IBA foreseen → T rise, evaporation…

Electron welding tests

Illuminated area = 0.2 cm²





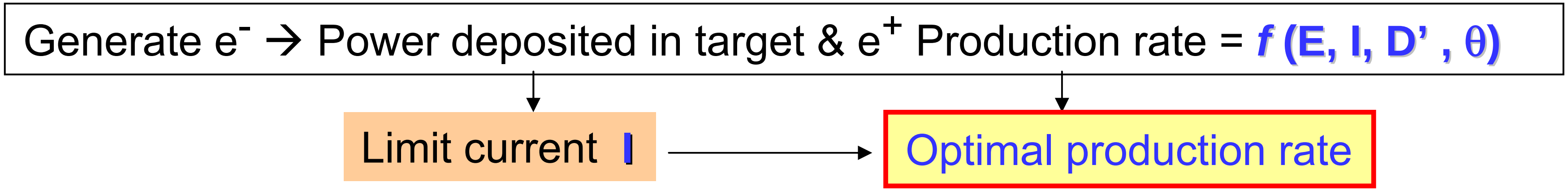
Input e^- energy comparisons

- *Rule of the game*: Target sustains 1 KW continuous deposited power per cm^2
- *Goal*: optimize rate of e^+ with $E_{e+} < 1$ MeV

Input variables:

E = e^- energy, **I** = e^- current,

θ = e^- incidence angle on target, **D'** = target equivalent thickness



Generate e^- → Power deposited in target & e^+ Production rate = ***f* (E, I, D' , θ)**

Limit current **I**

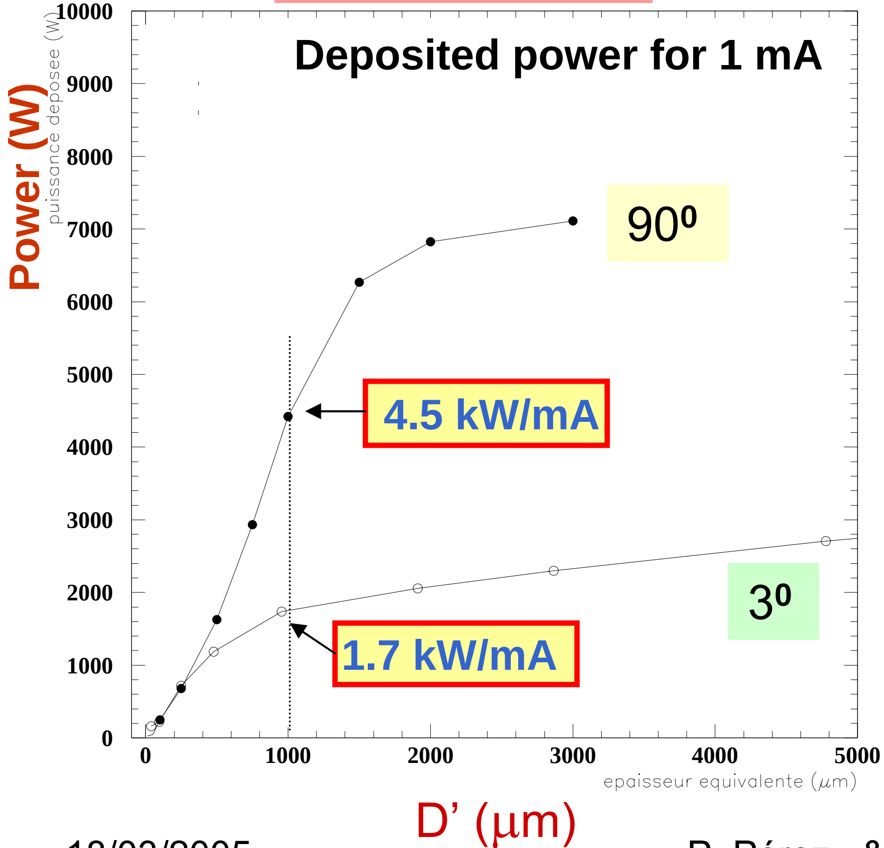
Optimal production rate

Here try 2 values for **E** (10 and 100 MeV) and **θ** (3 and 90 degrees)

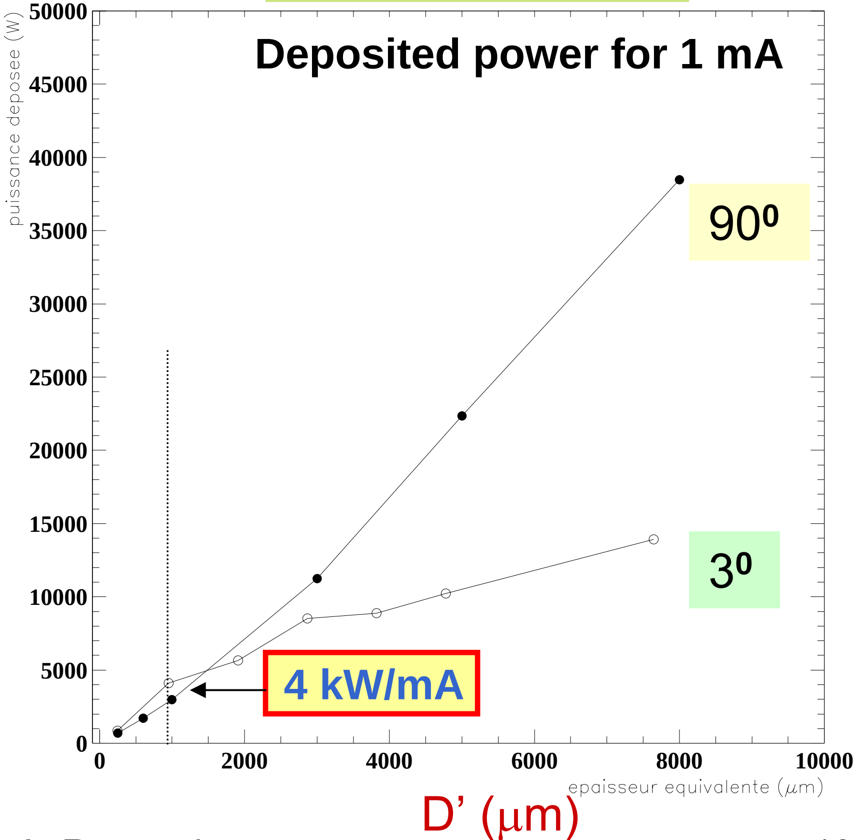
Energy Deposit in 1cm^2 Target

Simulation with GEANT

E(e$^-$) = 10 MeV



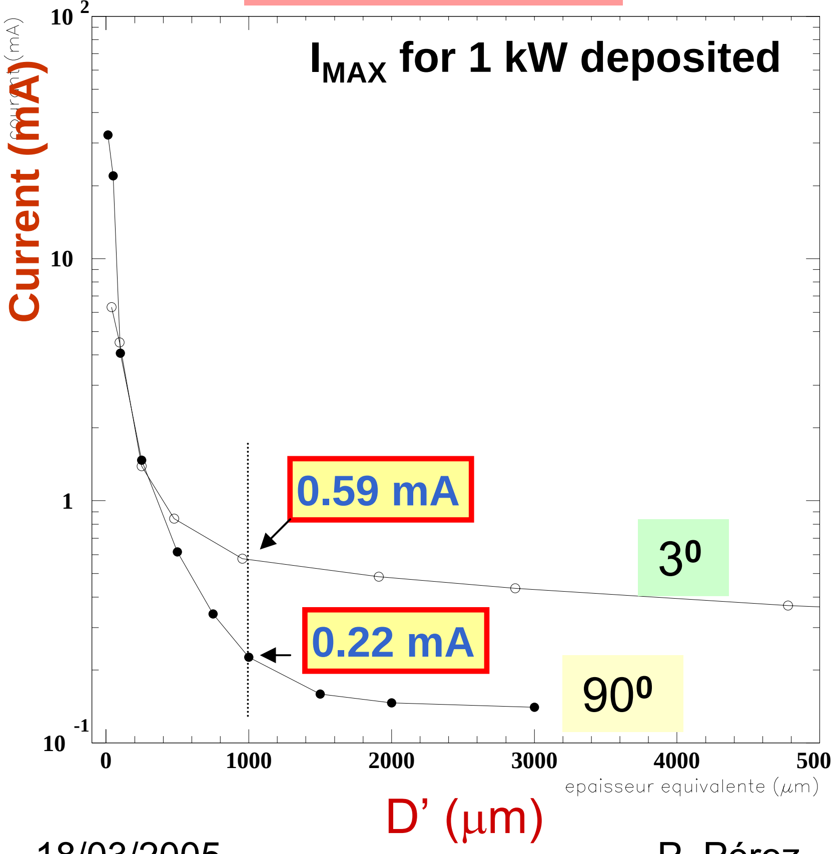
E(e$^-$) = 100 MeV



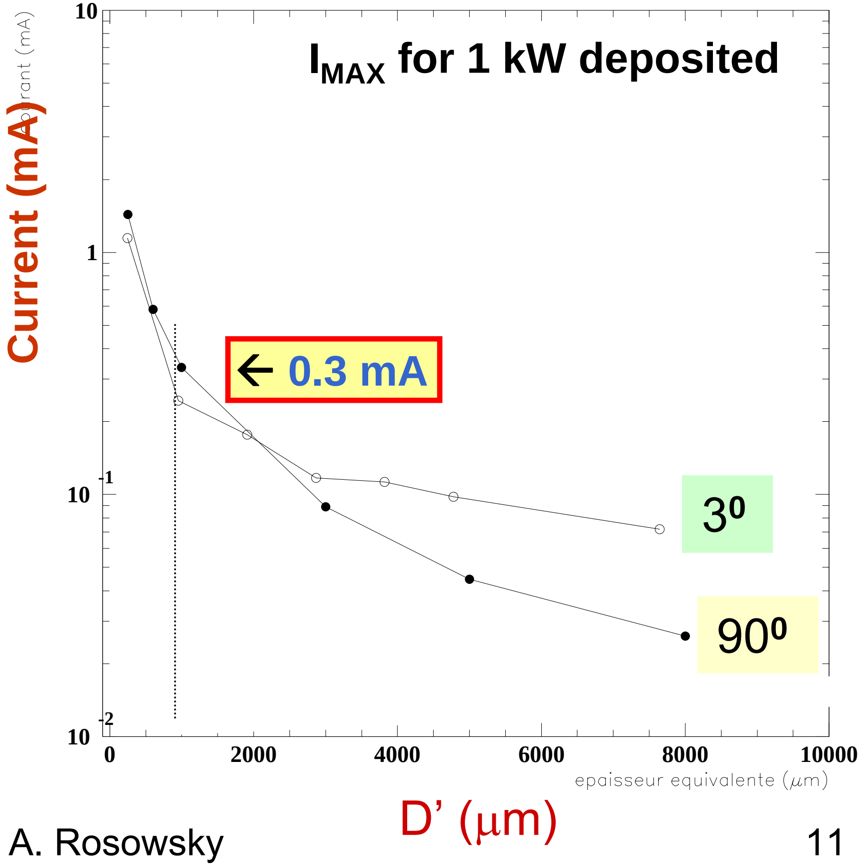
Maximum input current

Simulation with GEANT

E(e⁻) = 10 MeV



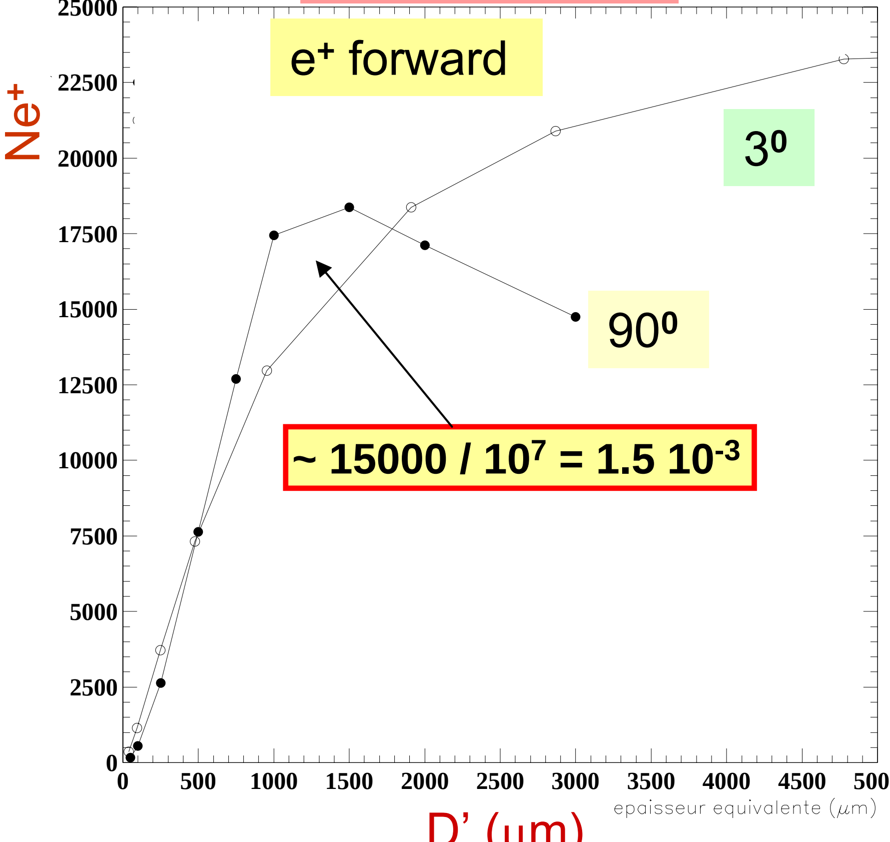
E(e⁻) = 100 MeV



Production Rate (forward)

10^7 electrons on 1 cm^2 target

$E(e^-) = 10$ MeV



e^+ forward

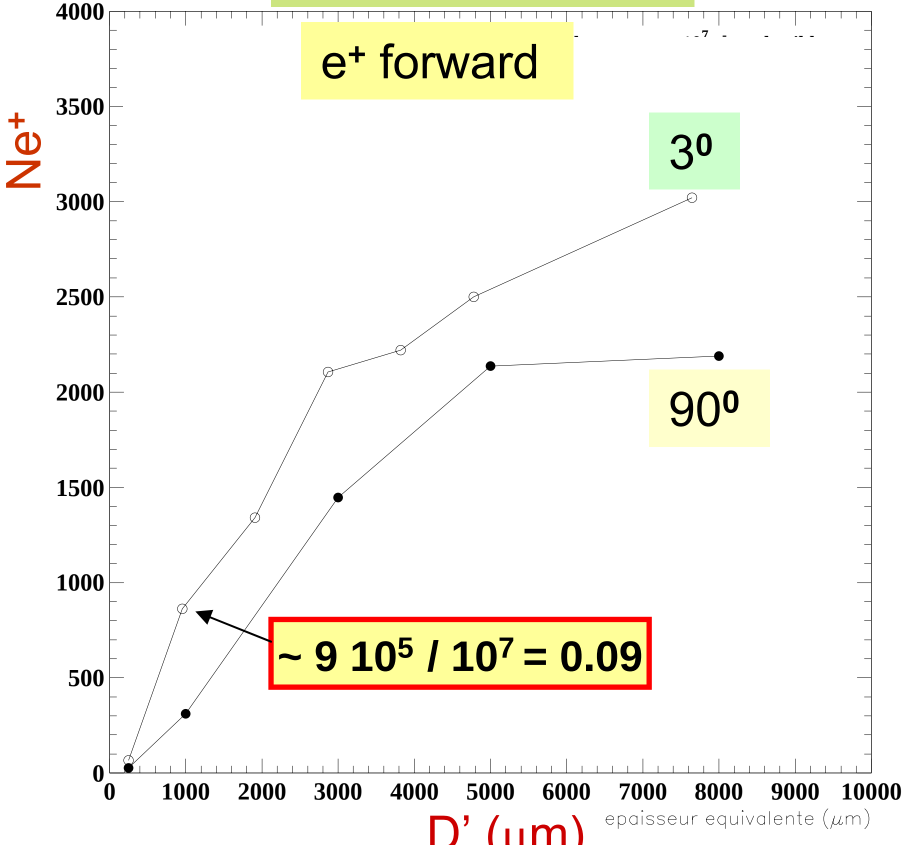
3^0

90^0

~ 15000 / 10^7 = 1.5 10^{-3}

x 10^3

$E(e^-) = 100$ MeV



e^+ forward

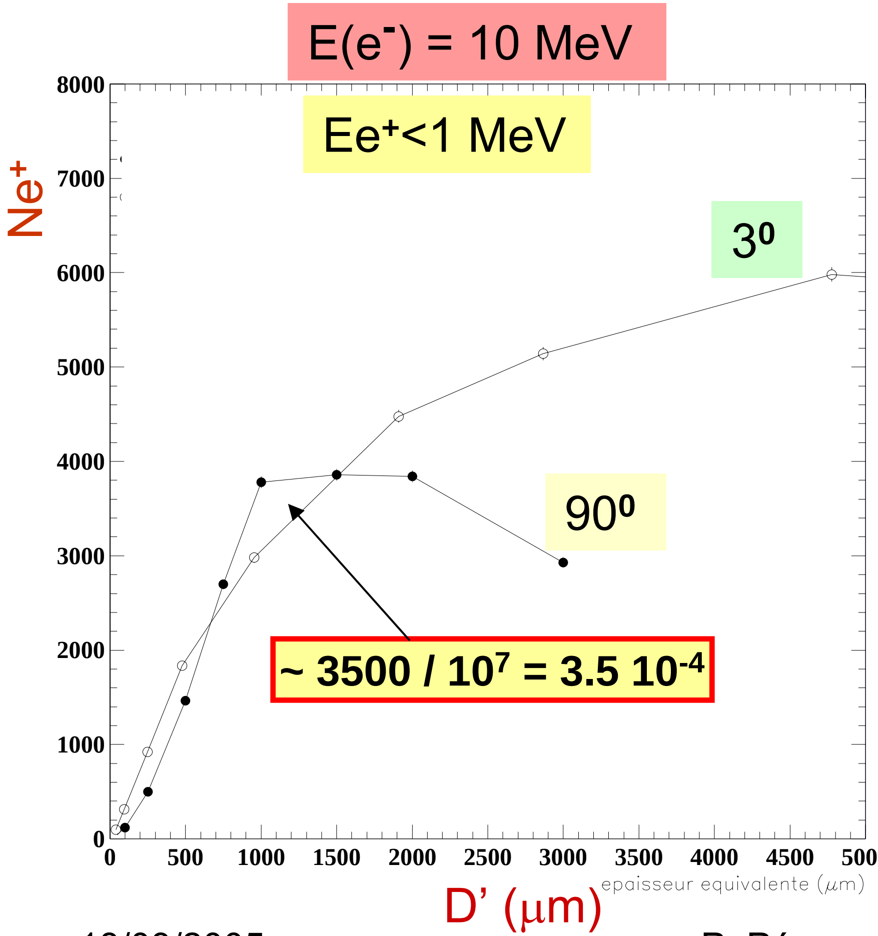
3^0

90^0

~ 9 10^5 / 10^7 = 0.09

Production Rate (E_{e+} <1 MeV)

10^{7} electrons on 1 cm^{2} target



E(e^-) = 10 MeV

Ee^+<1 MeV

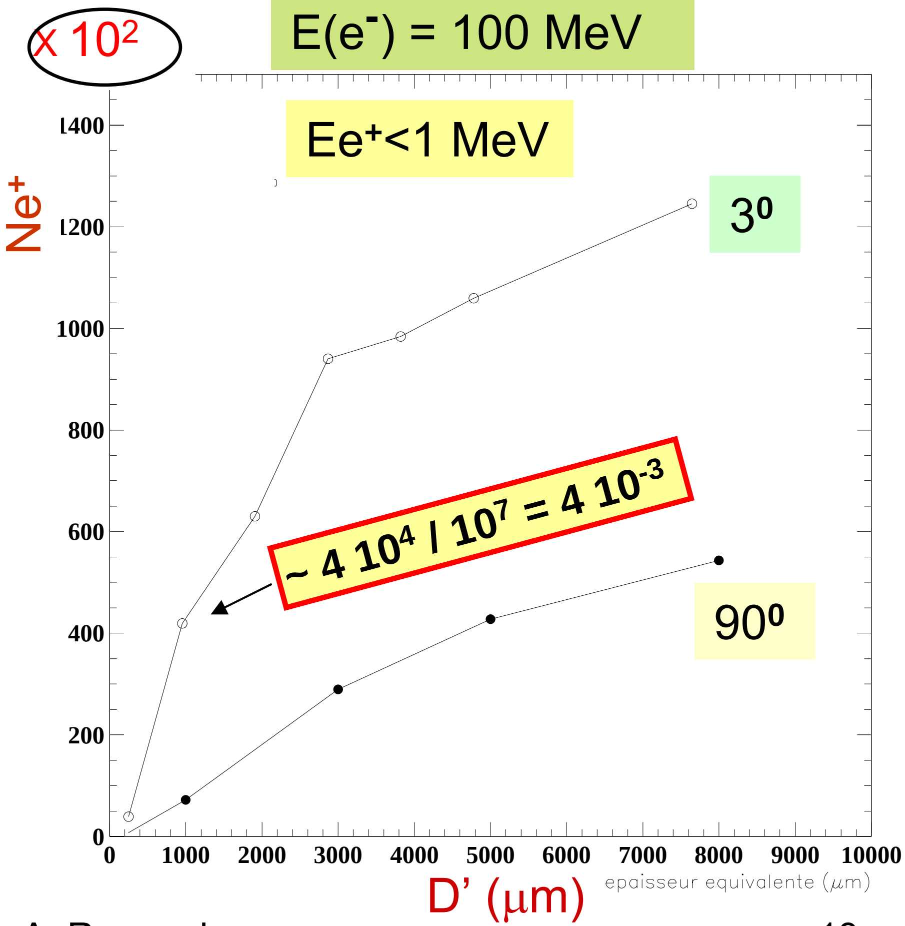
3^0

90^0

~ 3500 / 10^7 = 3.5 10^{-4}

Ne^+

D' (μm)



X 10^2

E(e^-) = 100 MeV

Ee^+<1 MeV

3^0

90^0

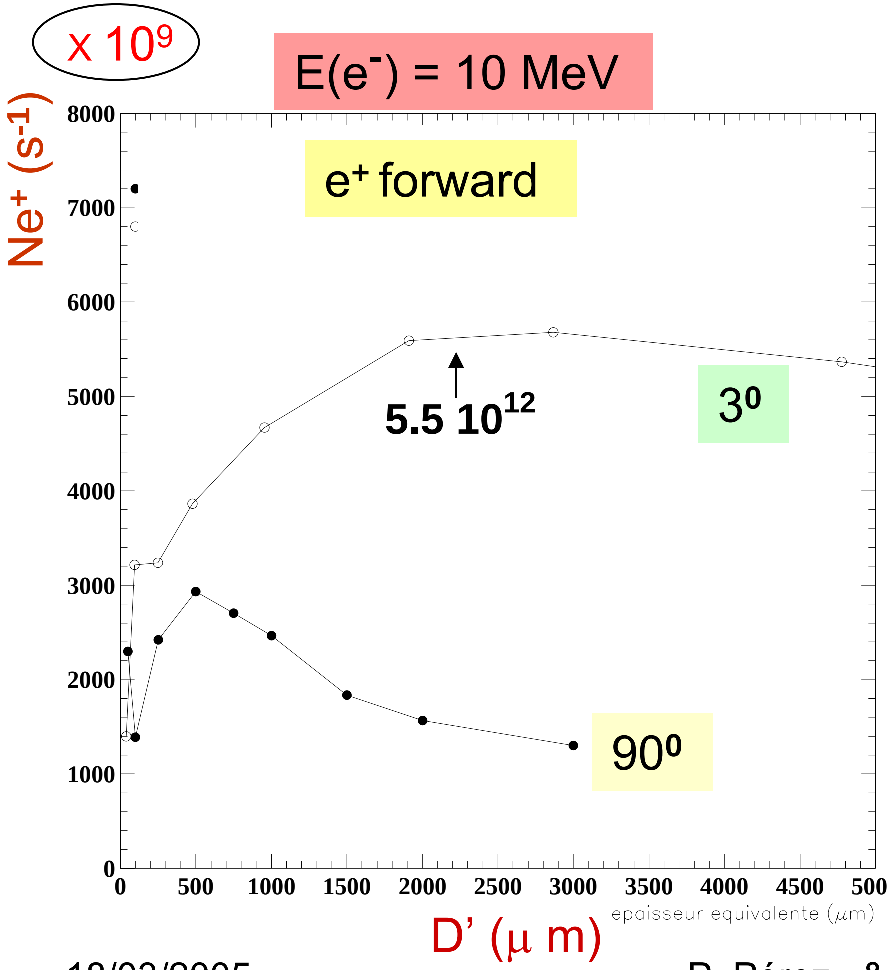
~ 4 10^4 / 10^7 = 4 10^{-3}

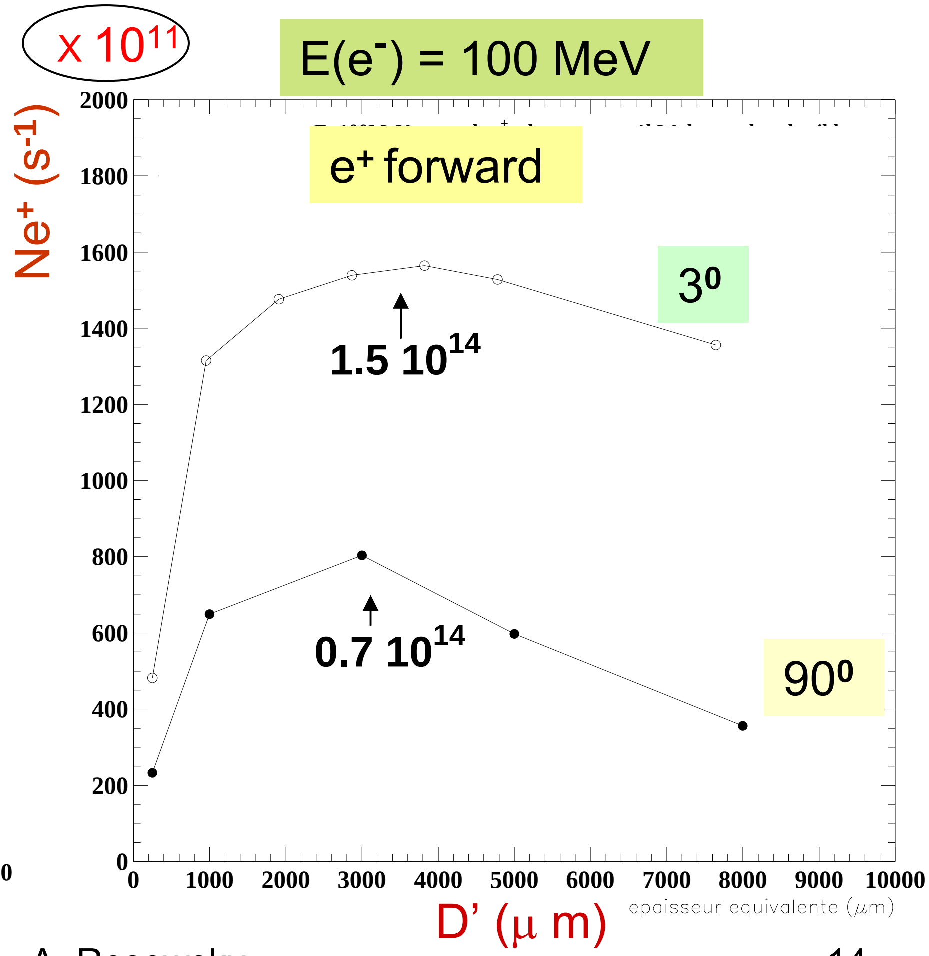
Ne^+

D' (μm)

Optimal Production Rates (forward)

Power deposited in 1 cm^2 target = 1 kW

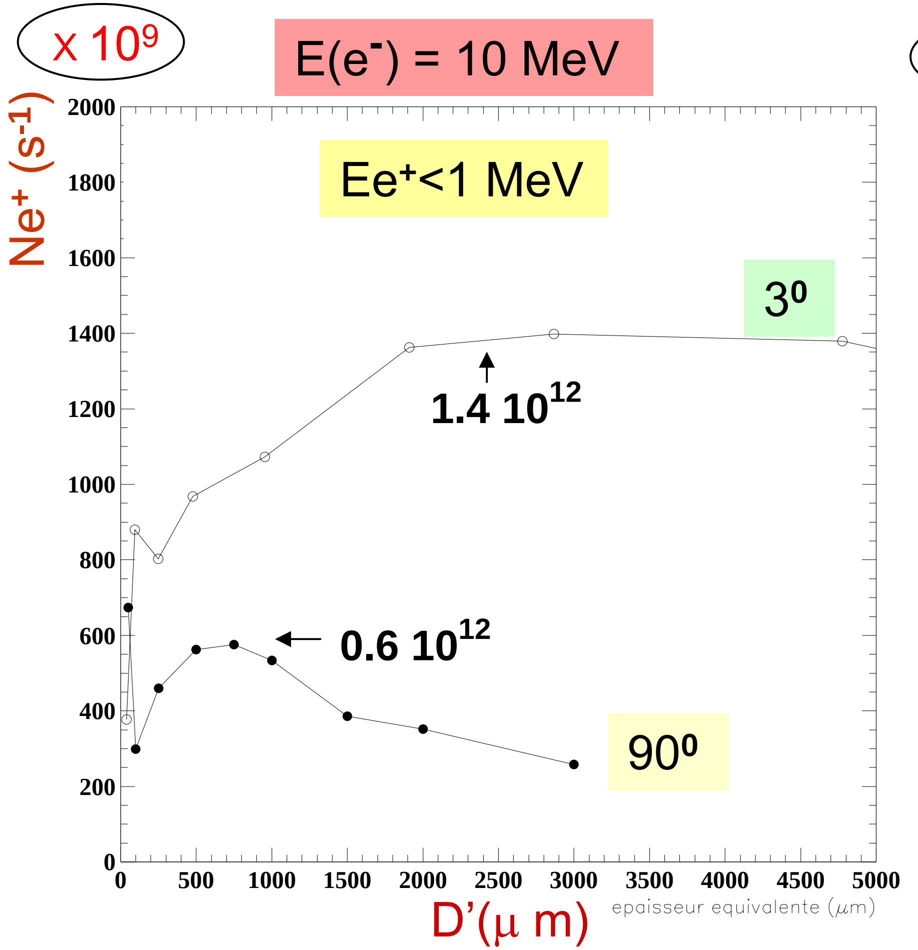




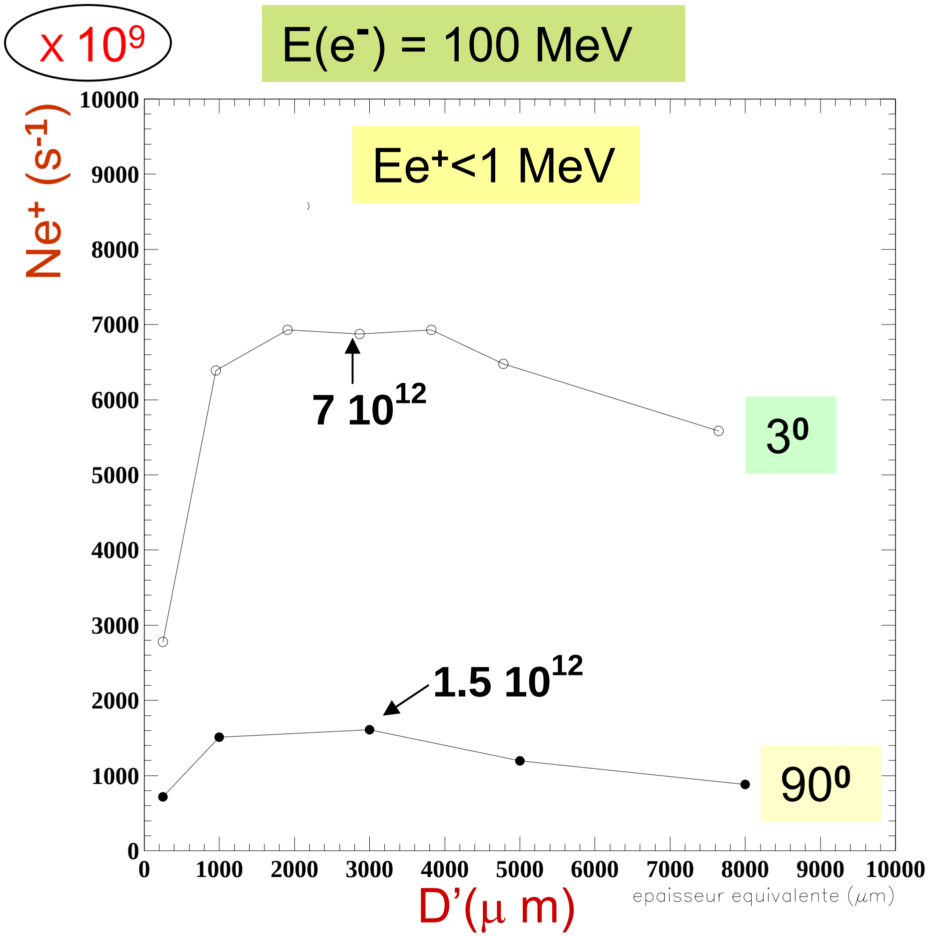
Optimal Production Rates (E_{e+} <1 MeV)

Power deposited in 1 cm^2 target = 1 kW

E(e^-) = 10 MeV



E(e^-) = 100 MeV



100μm at 3⁰ /10MeV ≈ 2mm at 90⁰ /100MeV

Production

For 1 cm^2 of target

D' = 1mm

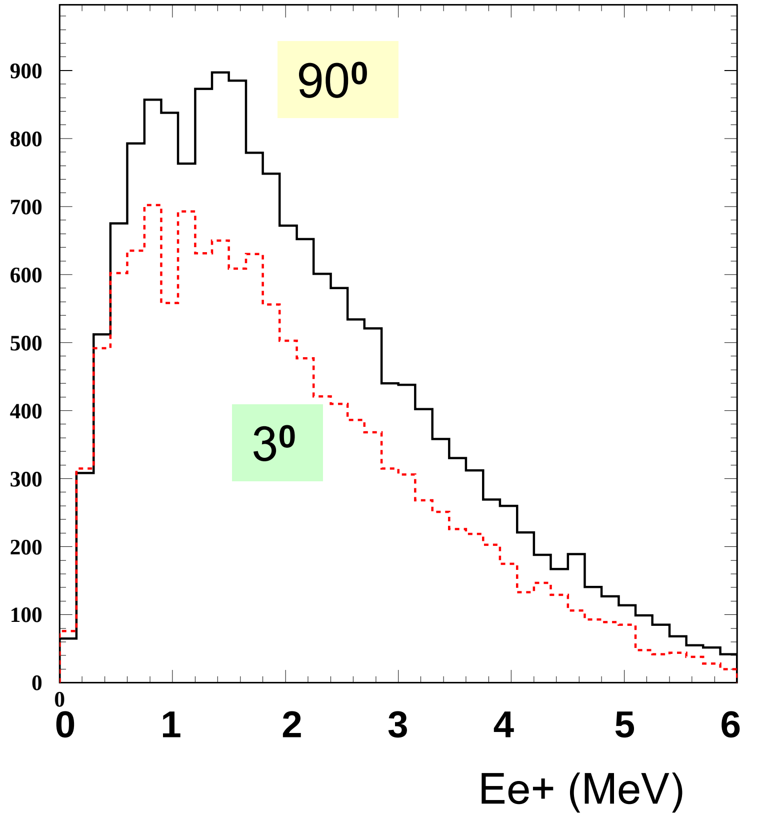
Limit 1 kW / cm^2

in units of 10^{12} s^{-1}

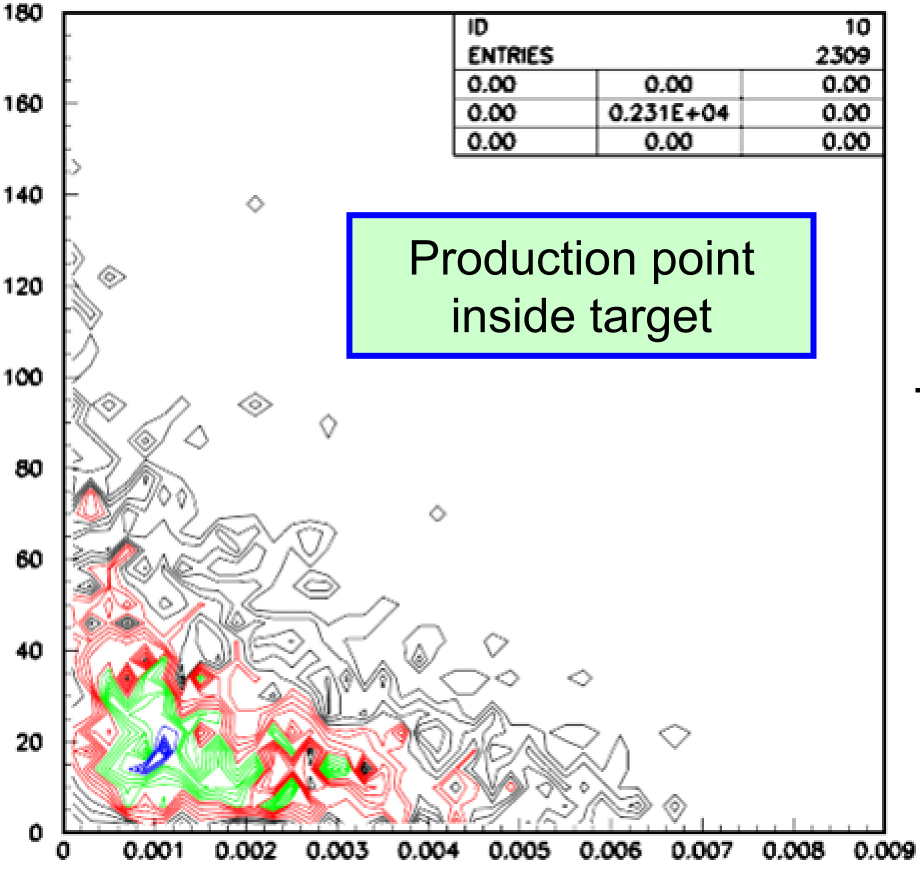
	Imax	Ne^+	Ne^+(<1MeV)
3^0	0.58 mA	4.6	1.1
90^0	0.25 mA	2.5	0.55

0.58 mA → 2.3 mA for 4 cm^2

Normalization to same number of e^- generated

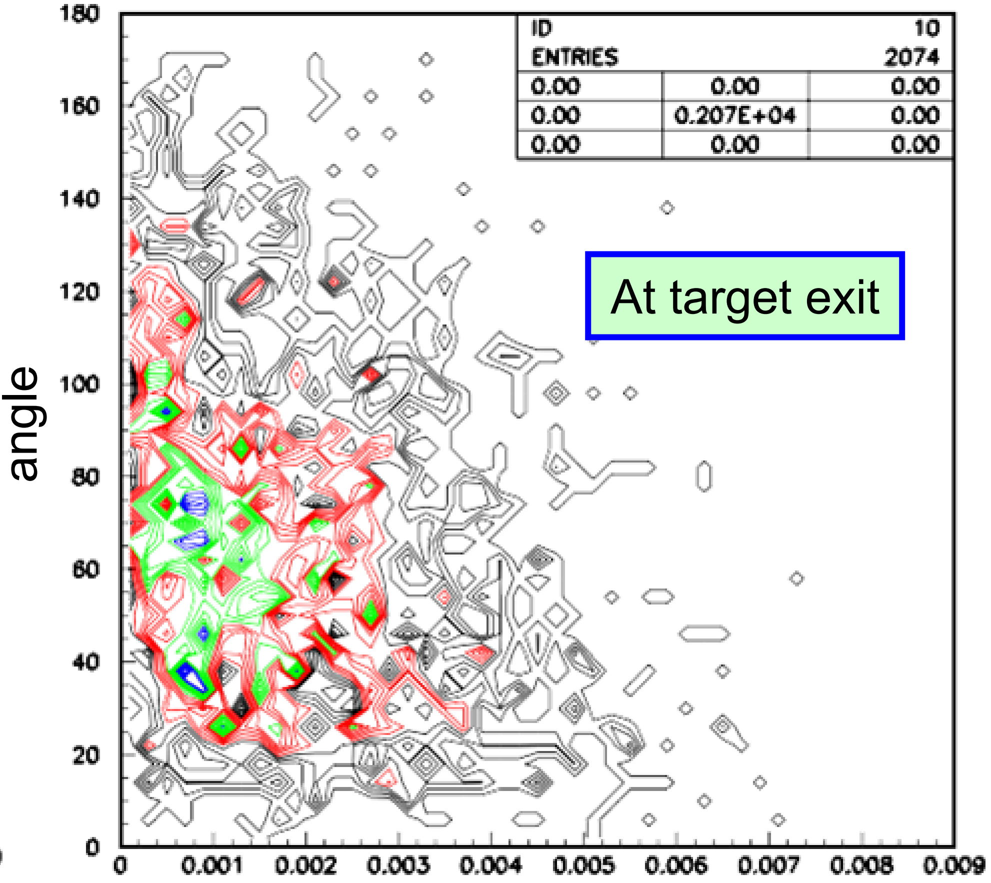


Energy versus angle



Production point inside target

Kinetic energy (GeV)

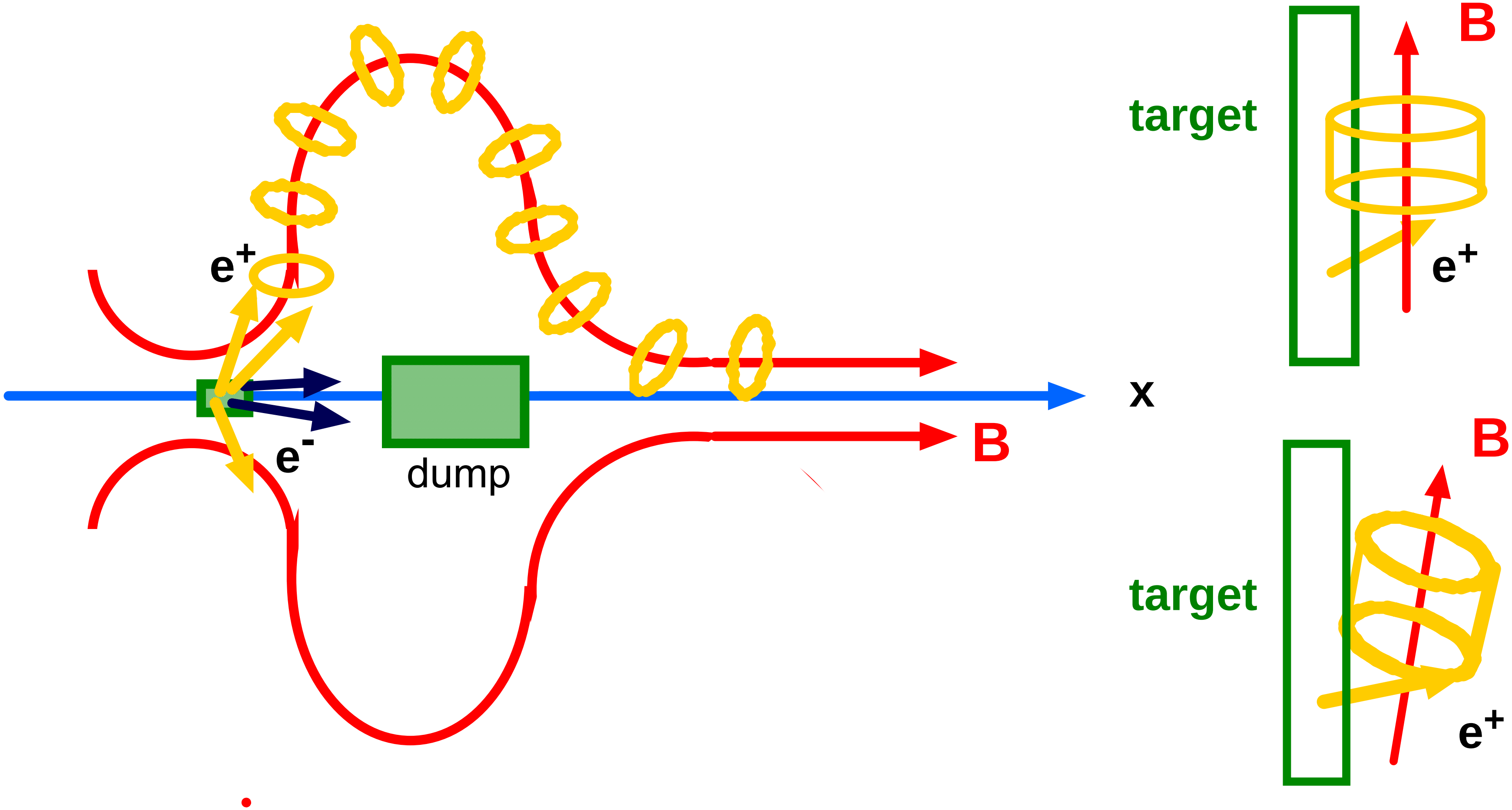


At target exit

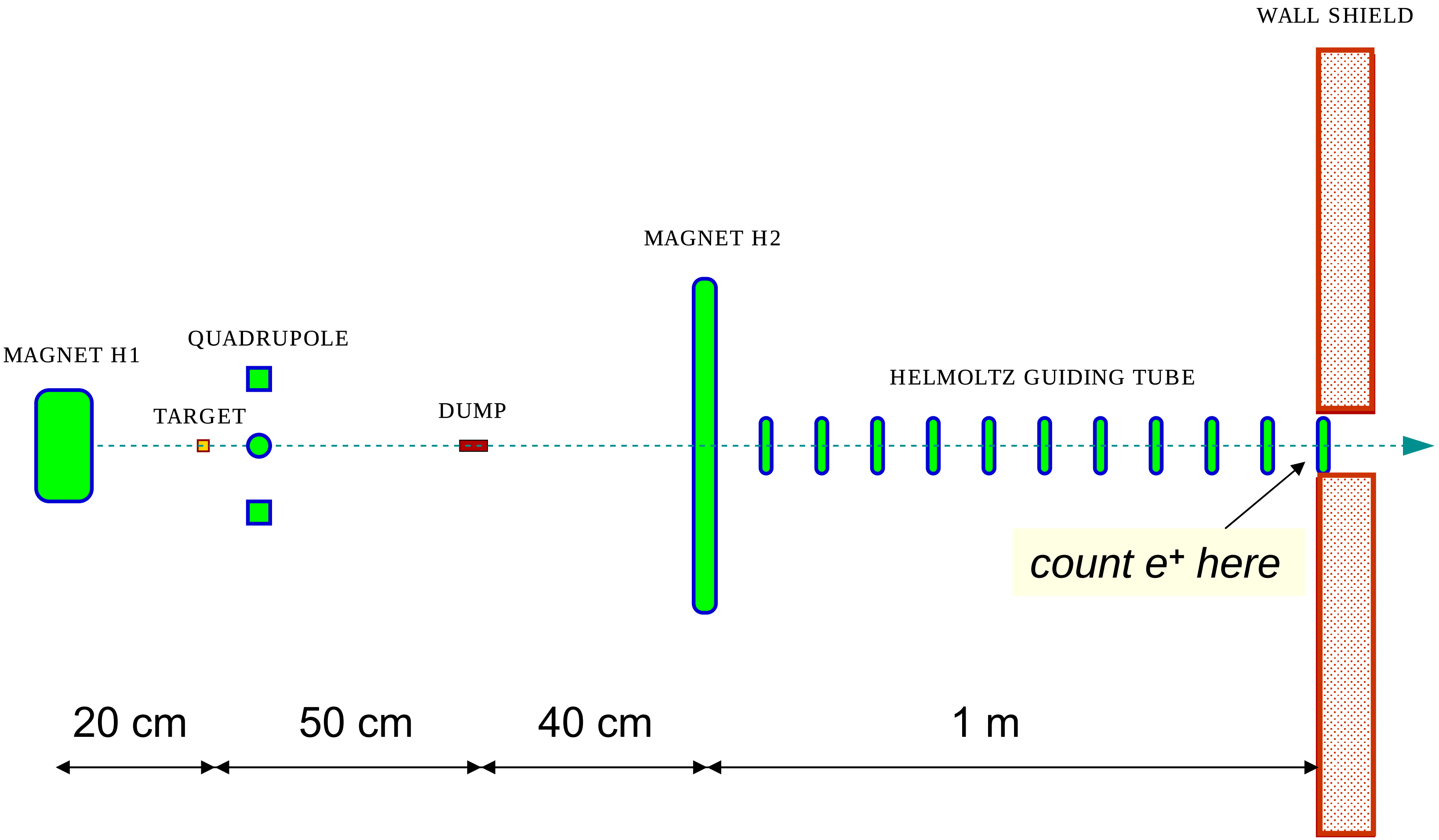
Kinetic energy (GeV)

2004

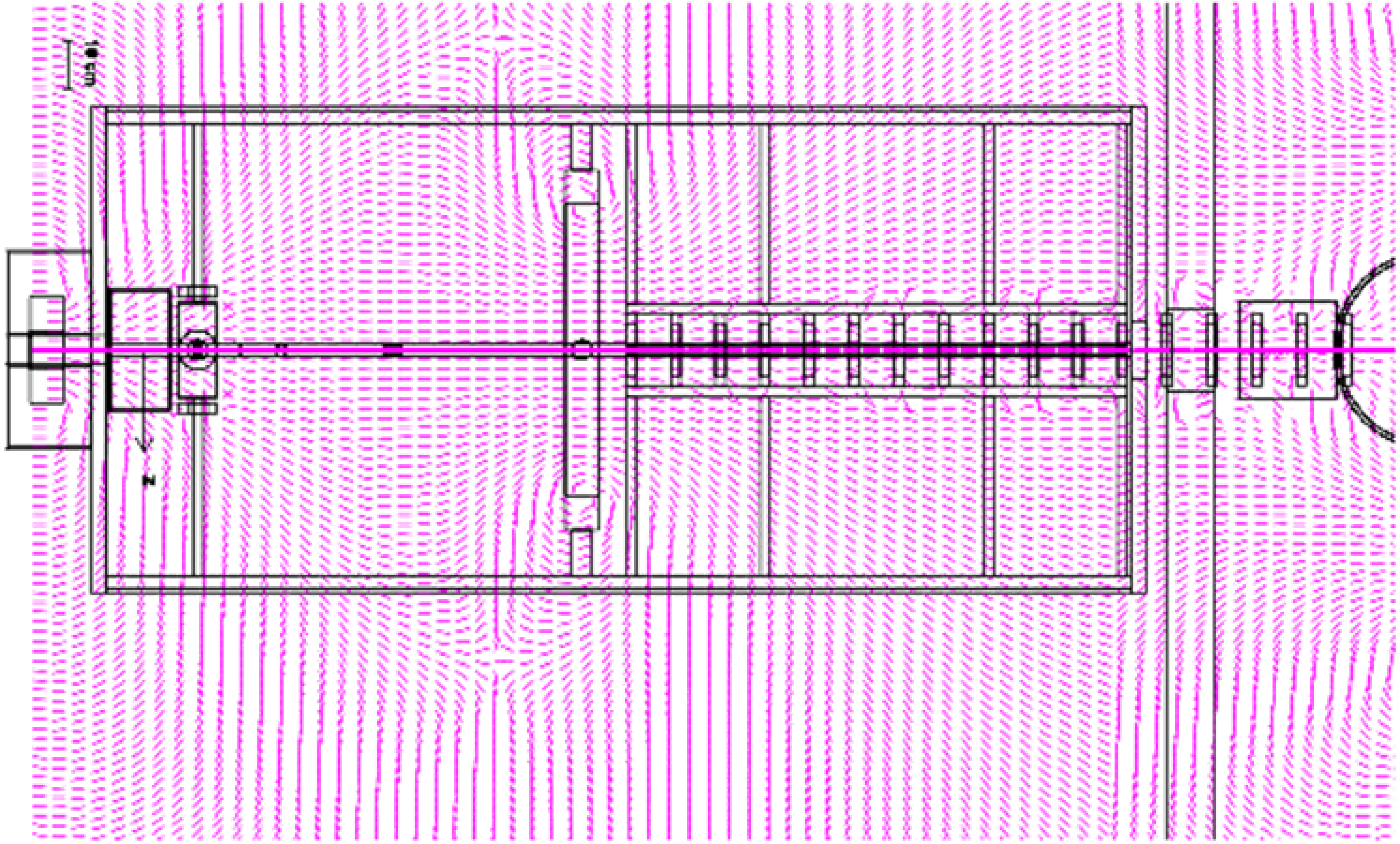
Magnetic Bulb



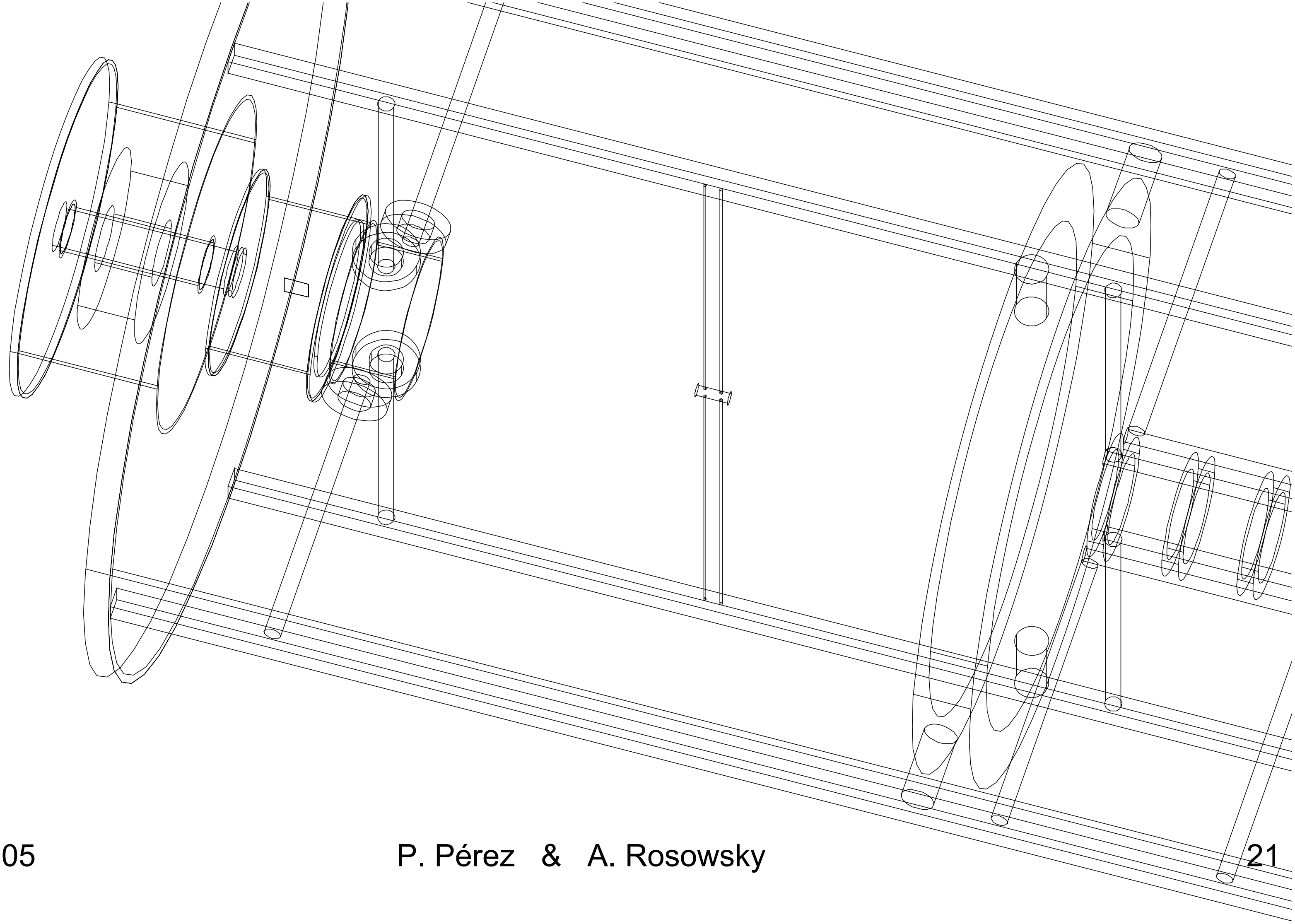
Collection Setup



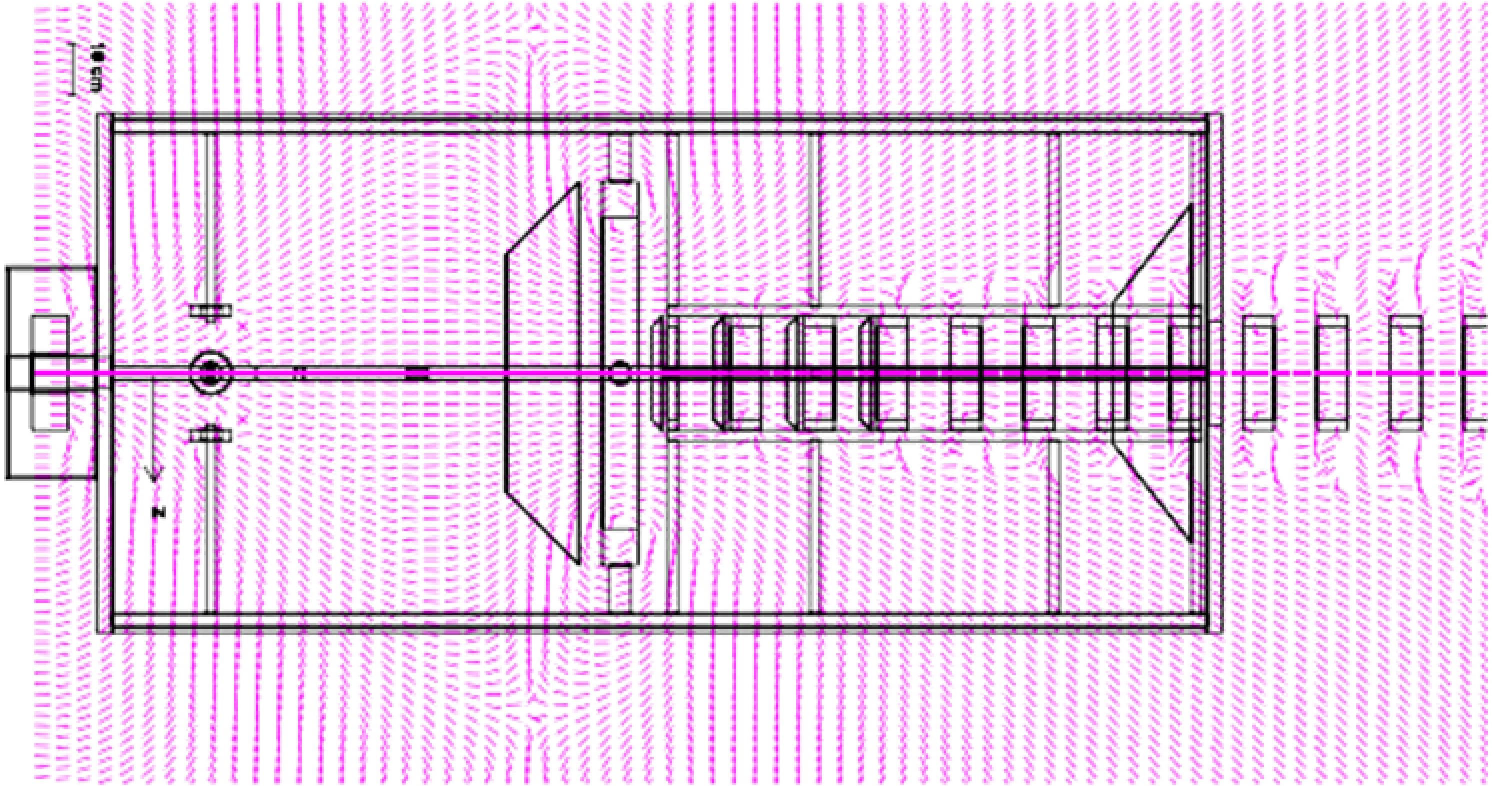
Setup 2003



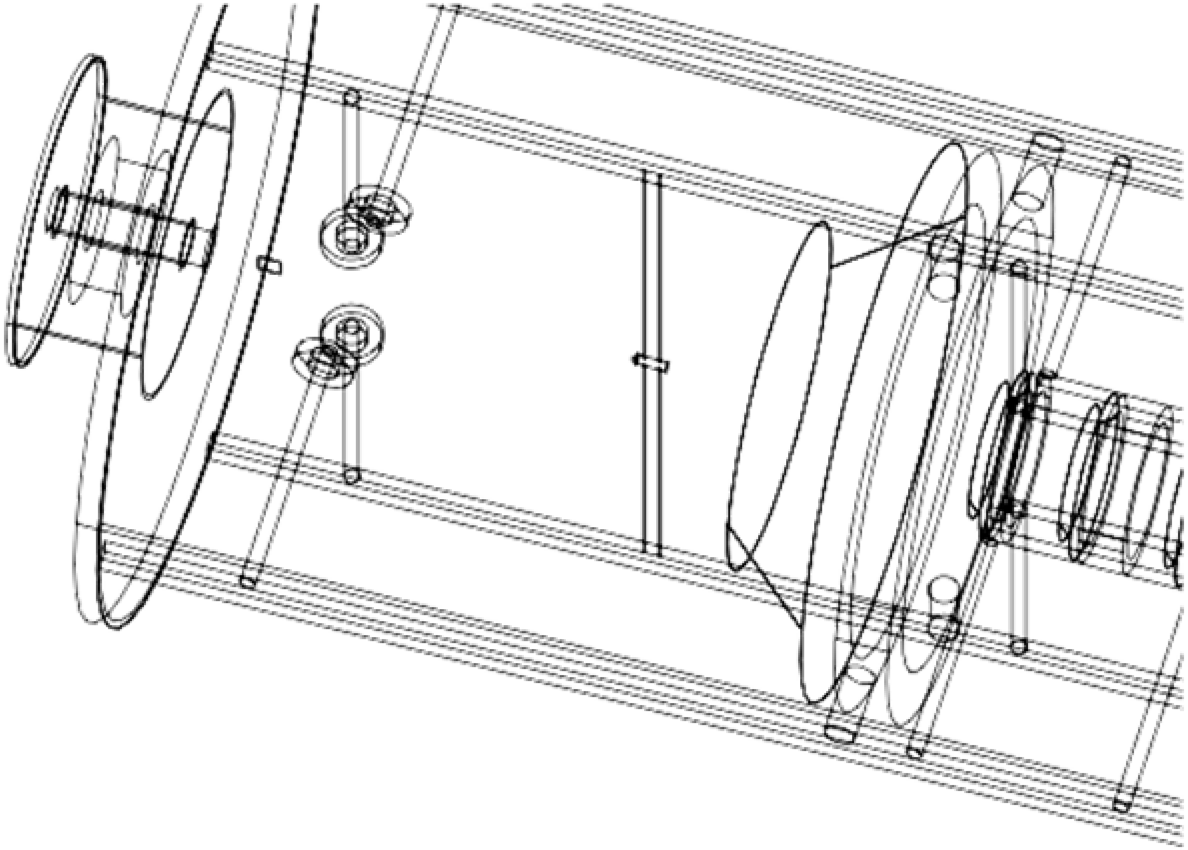
3D view



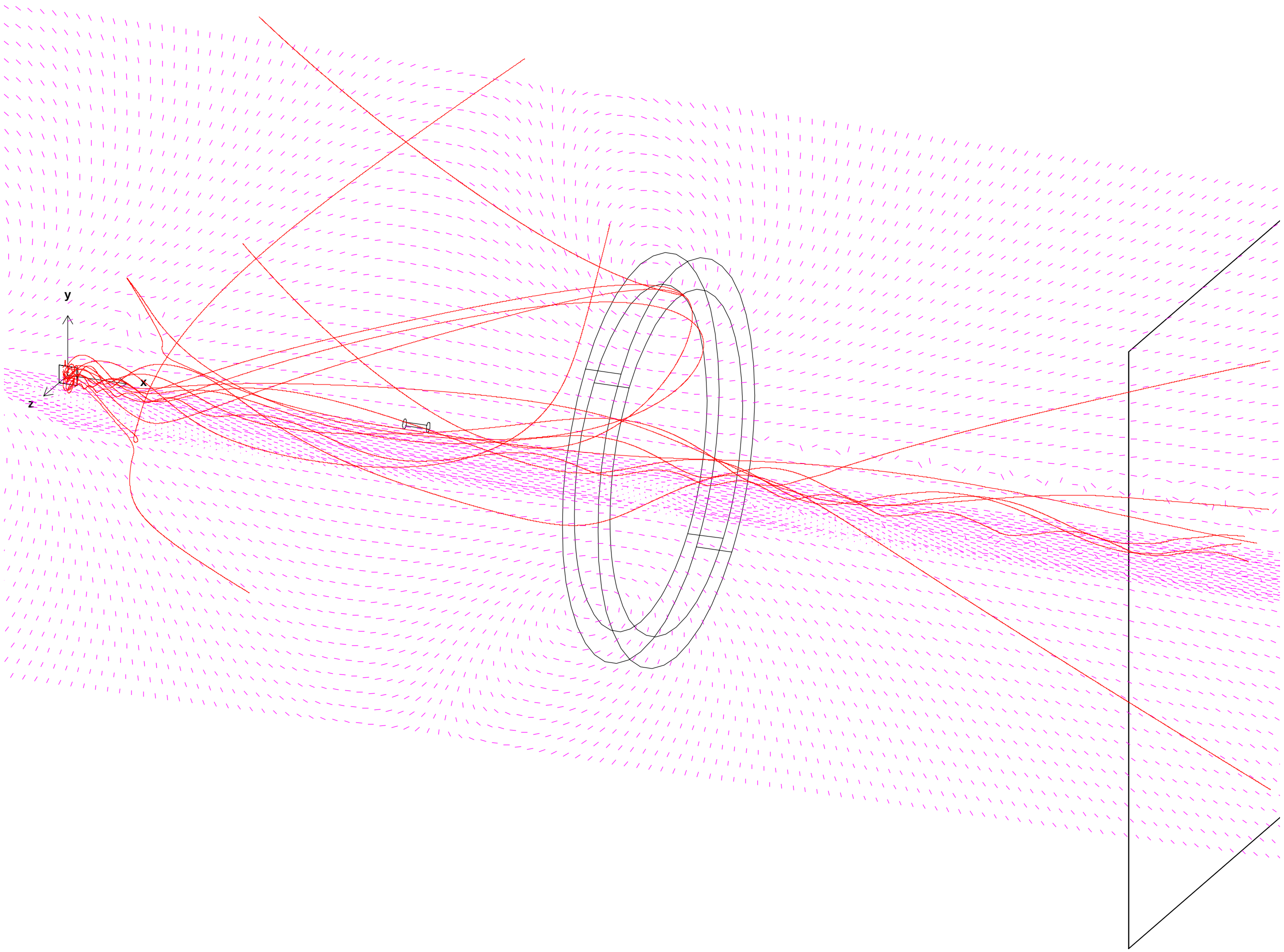
Setup 2004



3D setup 2004

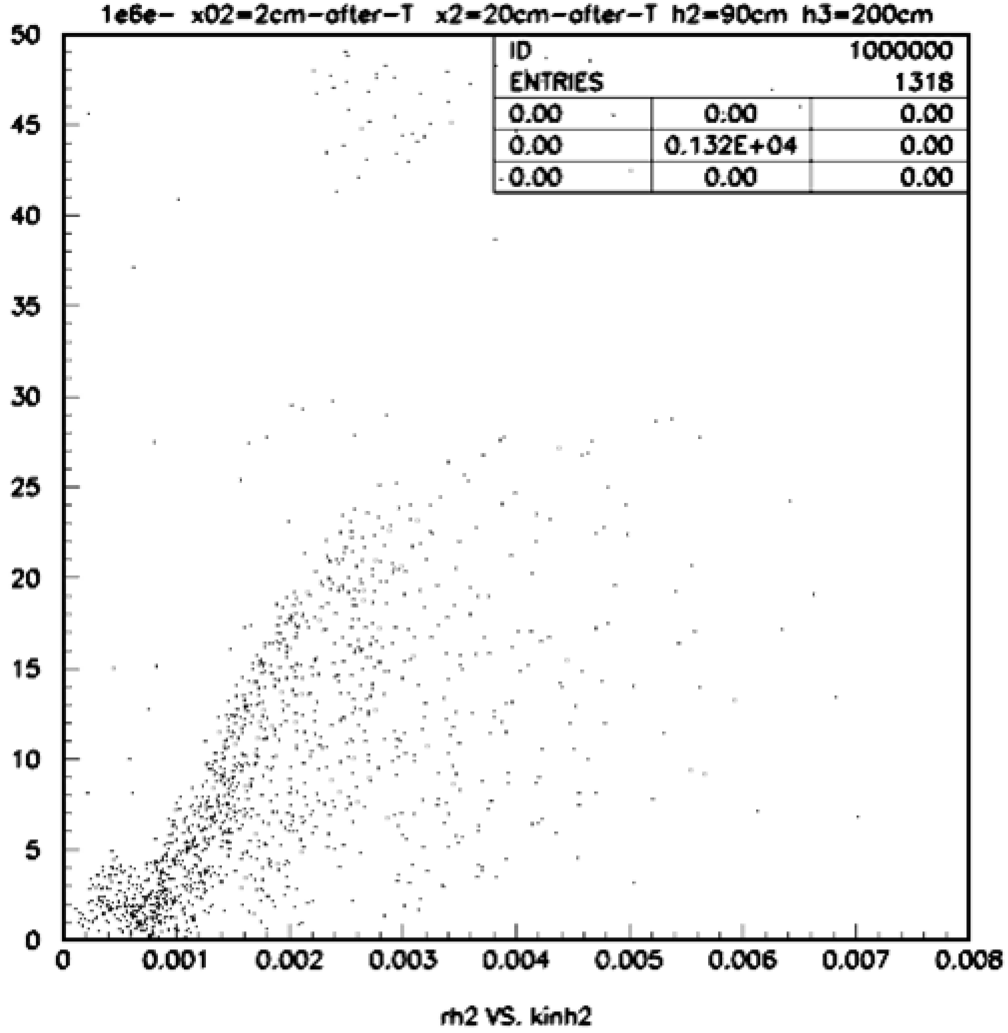


Positrons

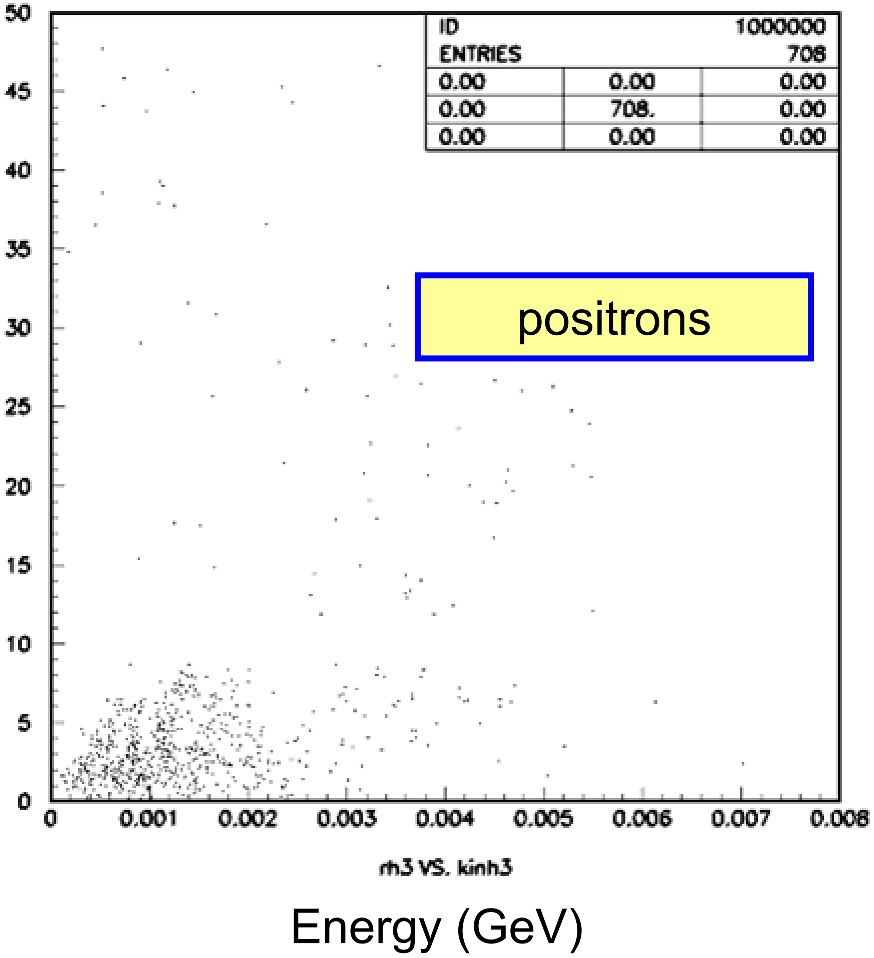


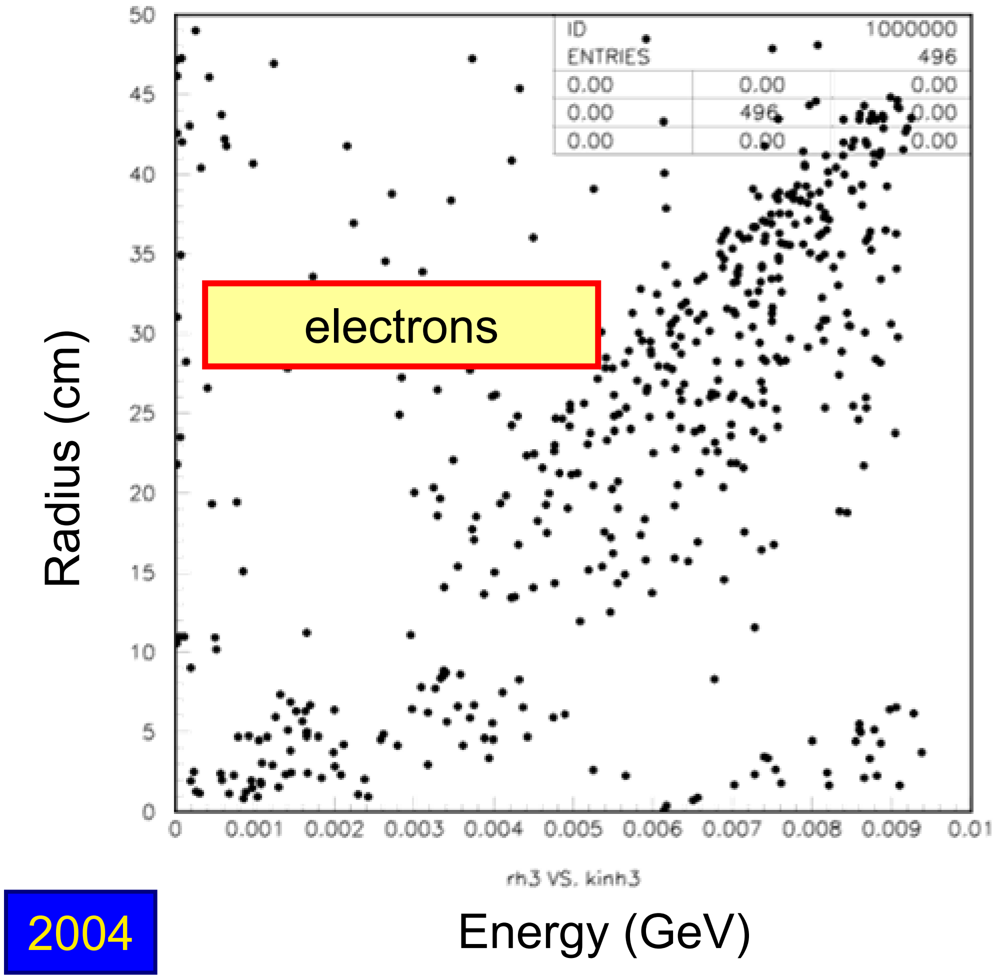
Positrons in plane H2

2004



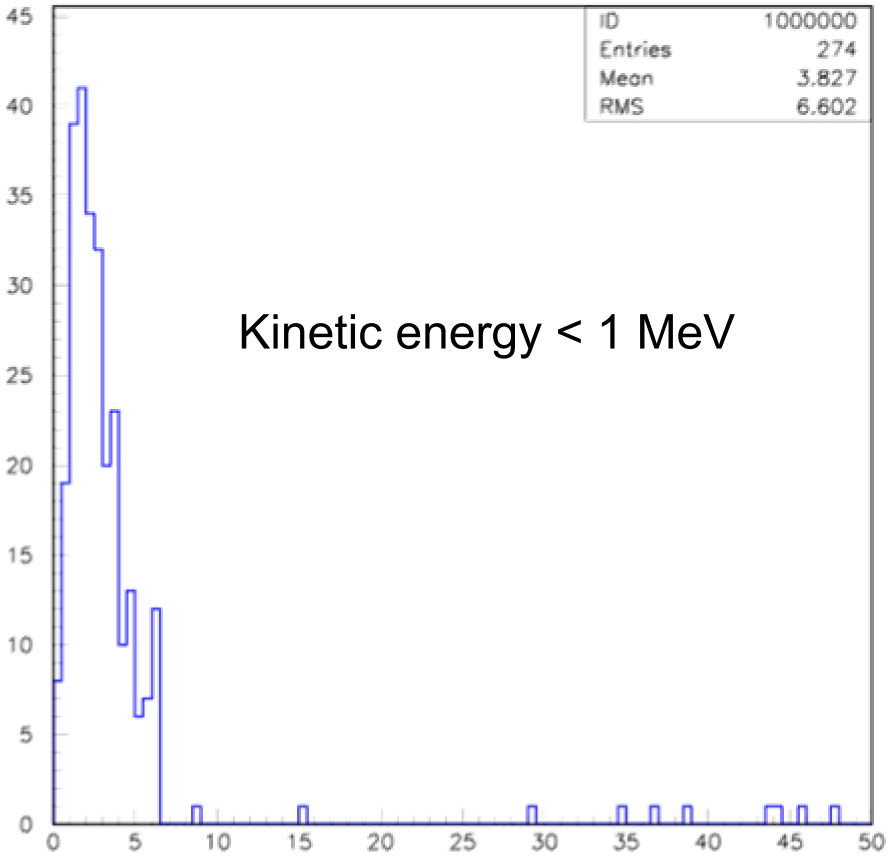
energy versus radius at x = 200 cm





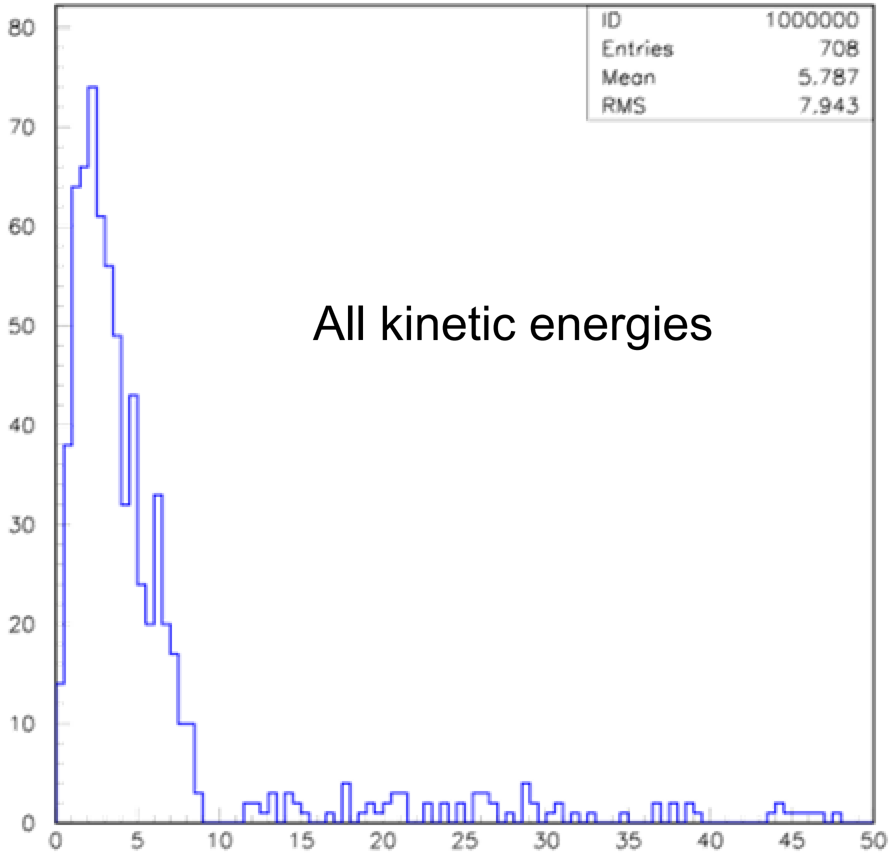
2004

Positrons radius at x = 200 cm



Kinetic energy < 1 MeV

Radius (cm)

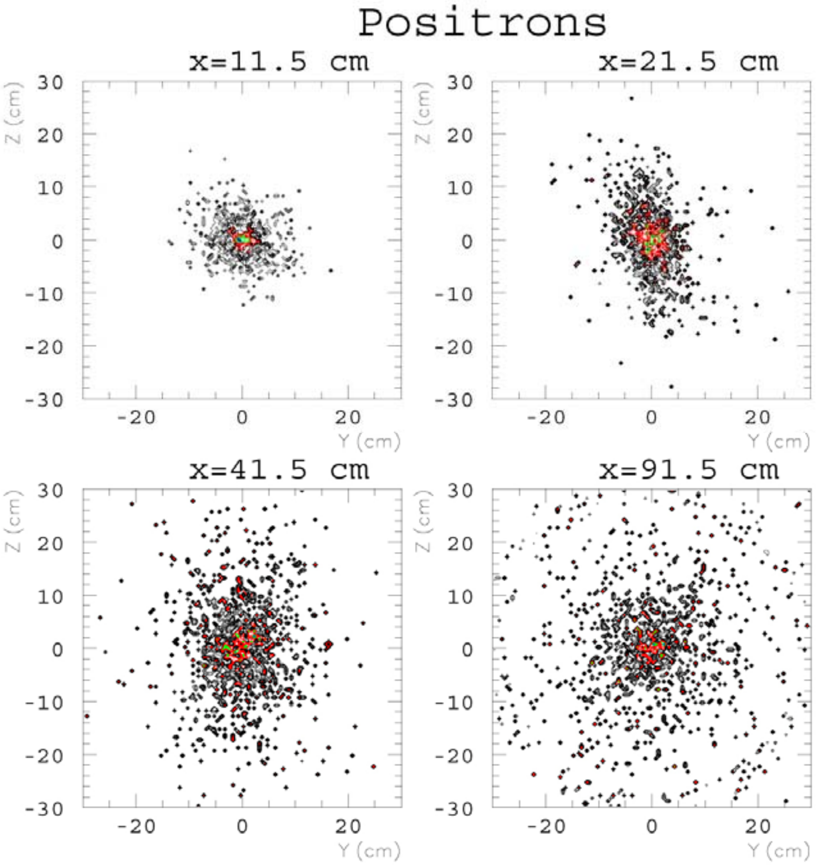


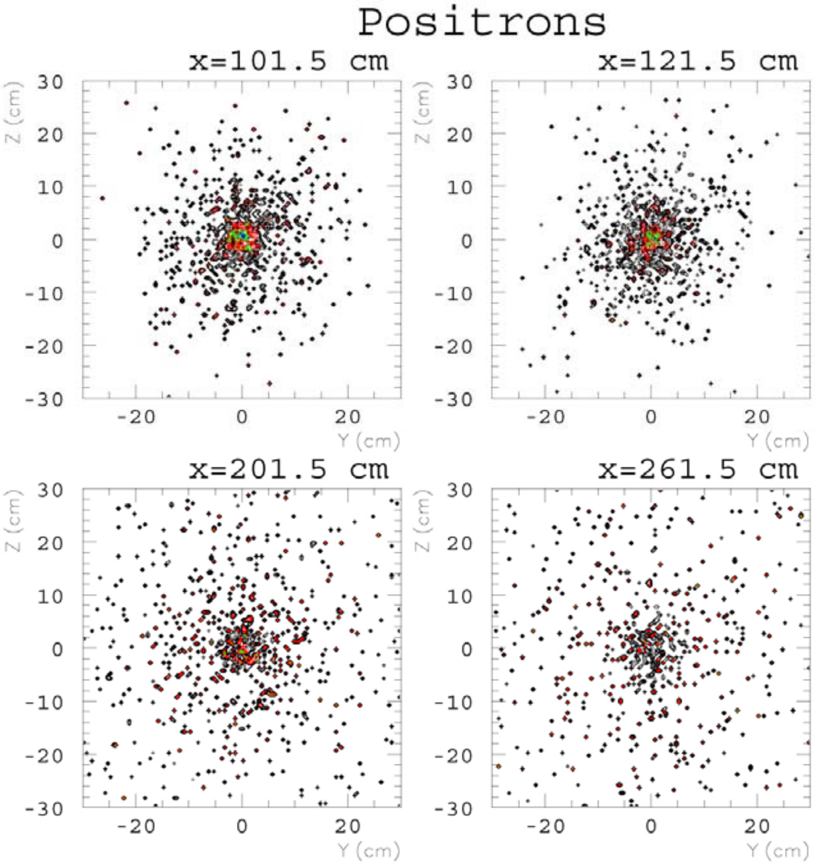
All kinetic energies

Radius (cm)

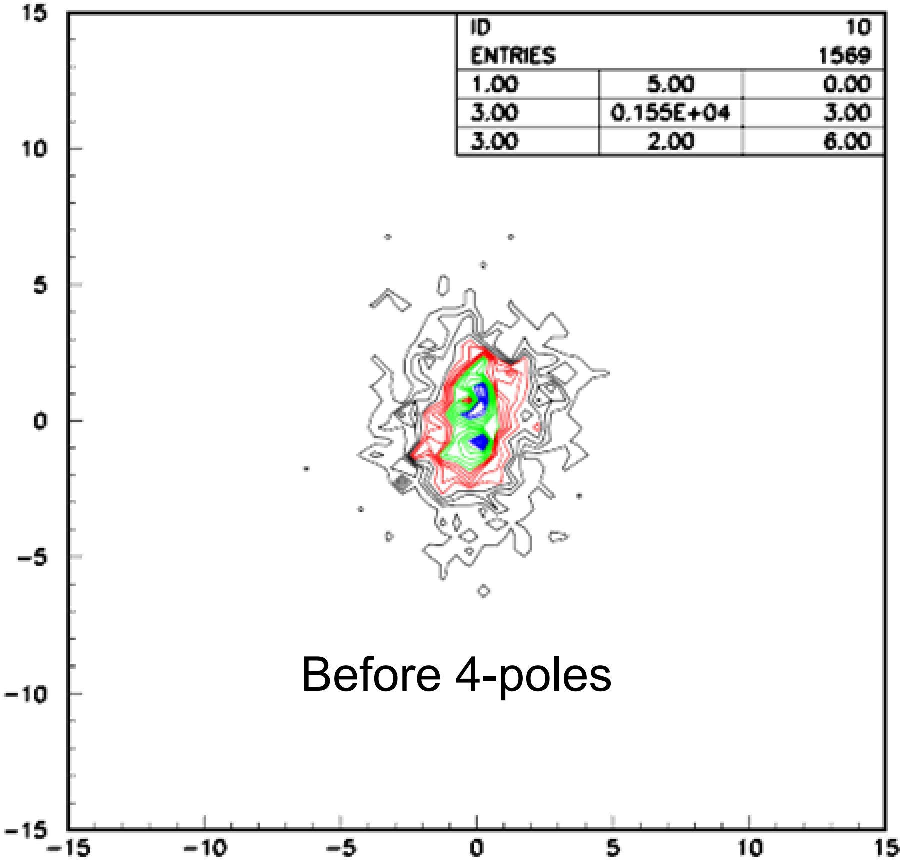
2004

Transversal cuts: positrons



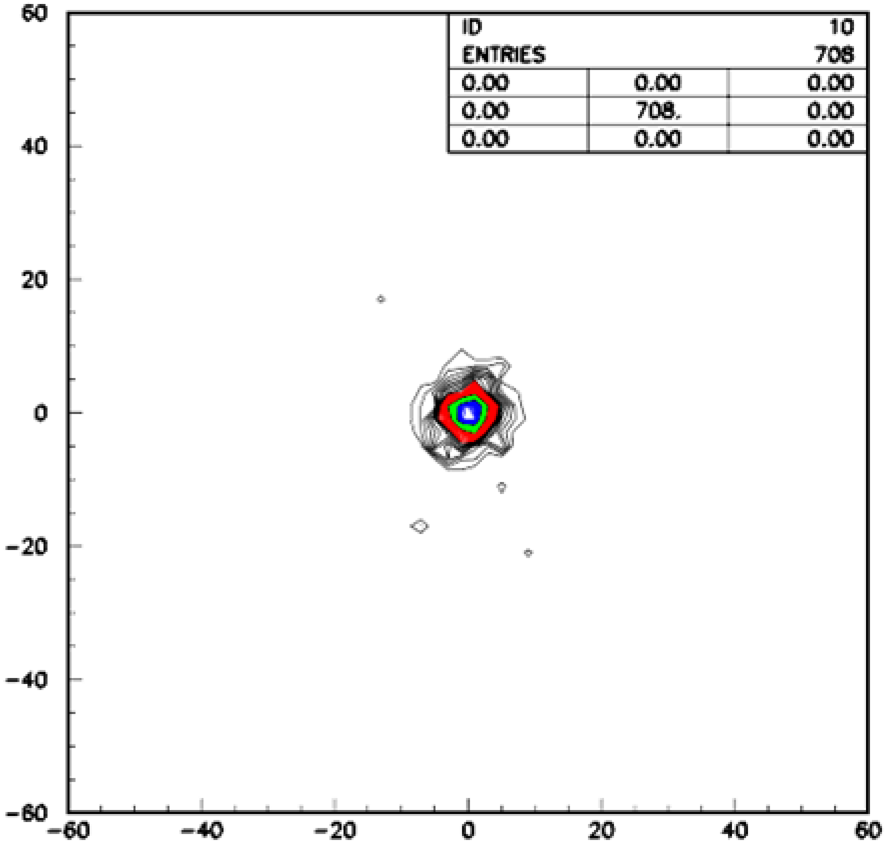


e+ position in (y , z) planes



Before 4-poles

X = 3 cm



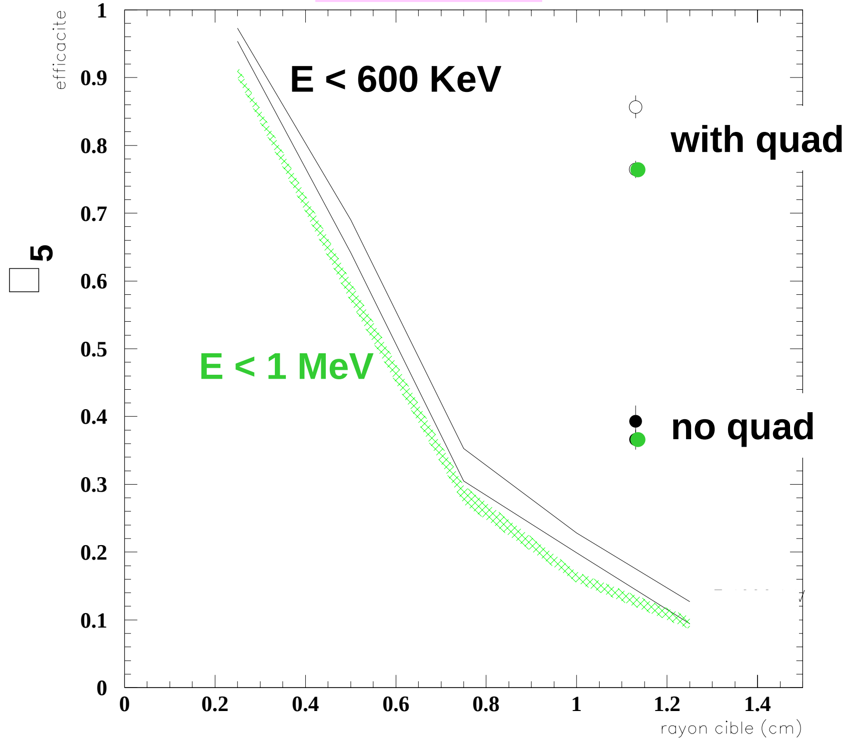
X = 200 cm

2004

Collection efficiency

Fraction of e$^+$ at exit plane inside circle of radius 5 or 2 cm centered on axis

r = 5 cm



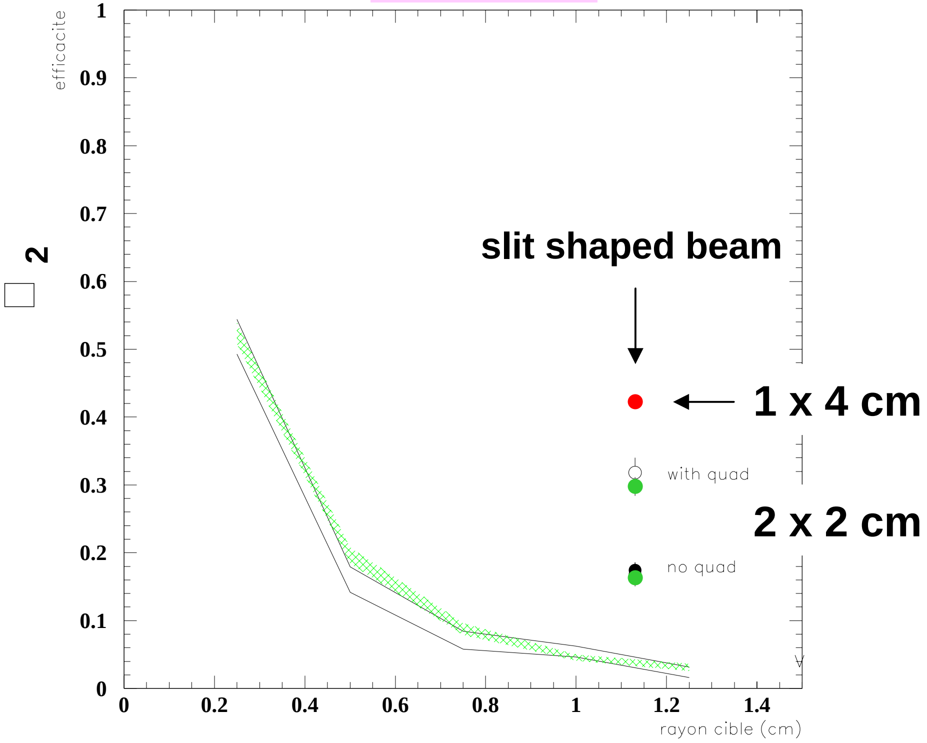
E < 600 KeV

with quad

E < 1 MeV

no quad

r = 2 cm



slit shaped beam

1 x 4 cm

2 x 2 cm

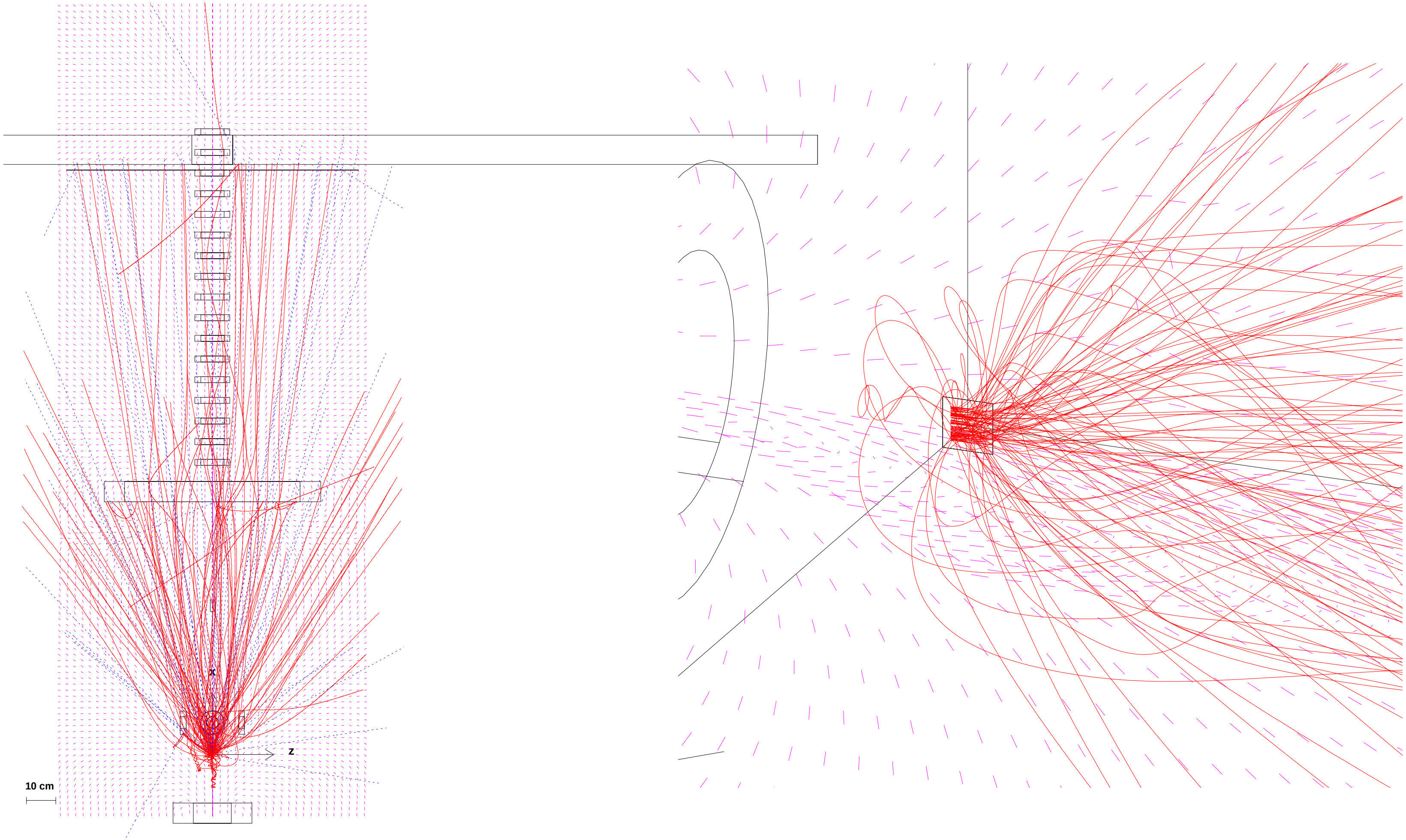
transverse radius of e$^+$ source at target level (cm)

Version 2004

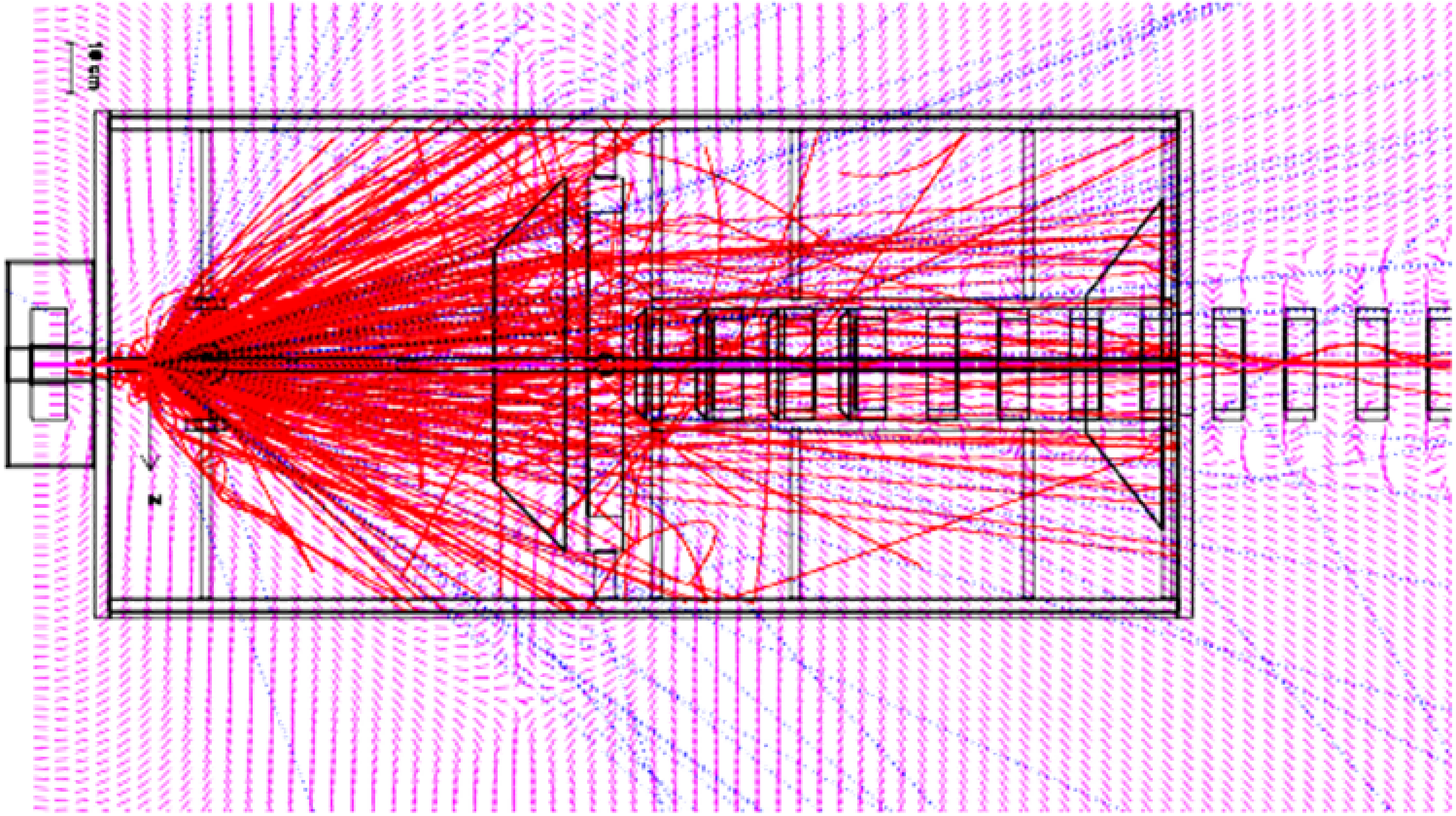
I = 2.5 mA	X = 200 cm			X = 320 cm		
R_{coll}= 5 cm	**5**	e^+ yield	e^+ rate xE12	**5**	e^+ yield	e^+ rate xE12
all	24%	5.0E-4	7.8	23%	4.87E-4	7.6
E <1 MeV	33%	2.4E-4	3.7	32%	2.37E-4	3.7
E < 600 KeV	25%	1.0E-4	1.6	23%	0.95E-4	1.5

I = 2.5 mA	X = 200 cm			X = 320 cm		
R_{coll}= 10 cm	**10**	e^+ yield	e^+ rate xE12	**10**	e^+ yield	e^+ rate xE12
all	31%	6.3E-4	9.8	29%	5.99E-4	9.3
E <1 MeV	36%	2.6E-4	4.1	35%	2.53E-4	3.9
E < 600 KeV	25%	1.0E-4	1.6	25%	1.02E-4	1.6

Electrons (2003)



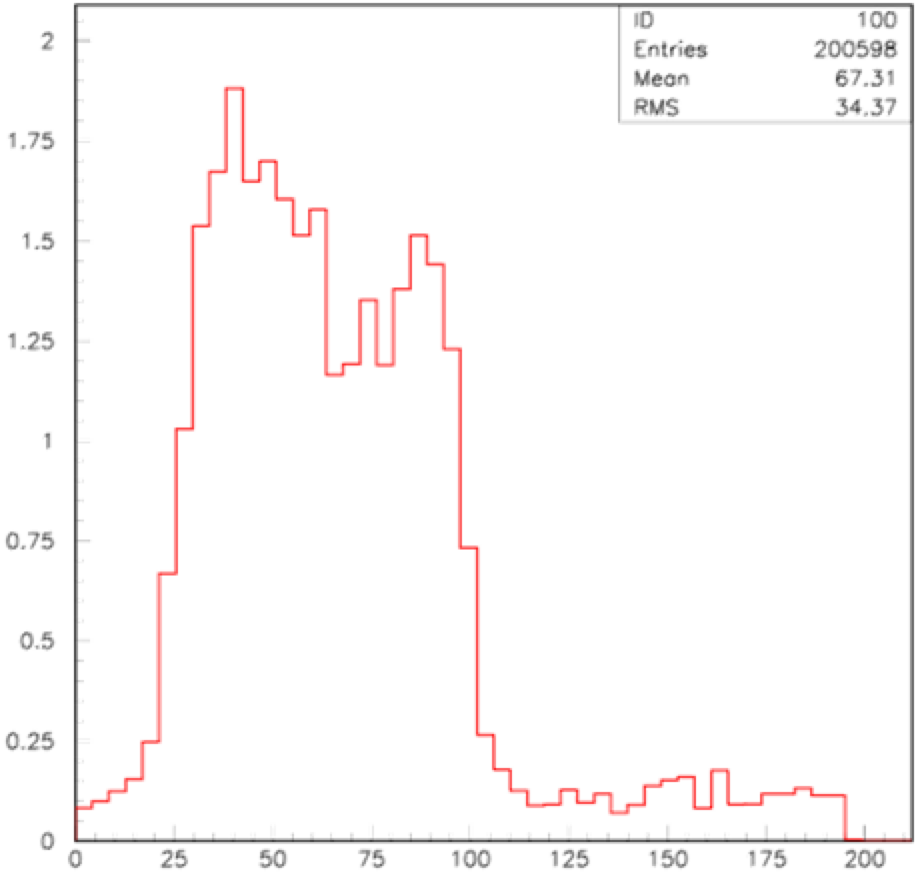
Scattered electrons



2004

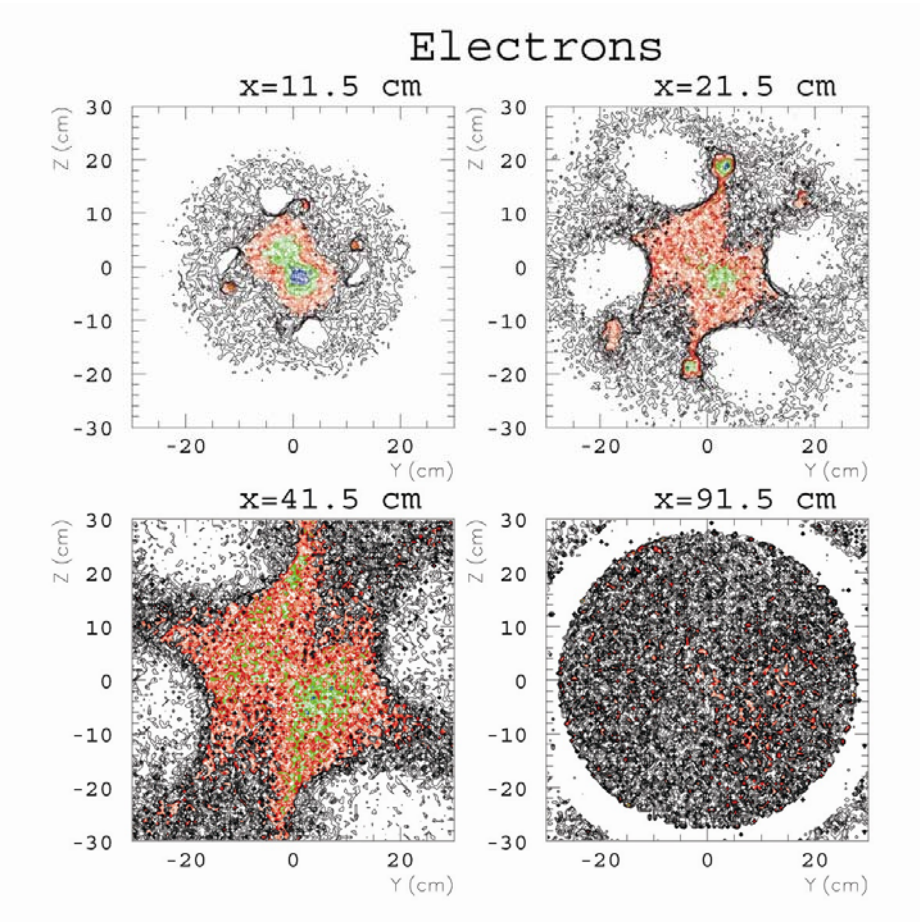
Scattered electrons

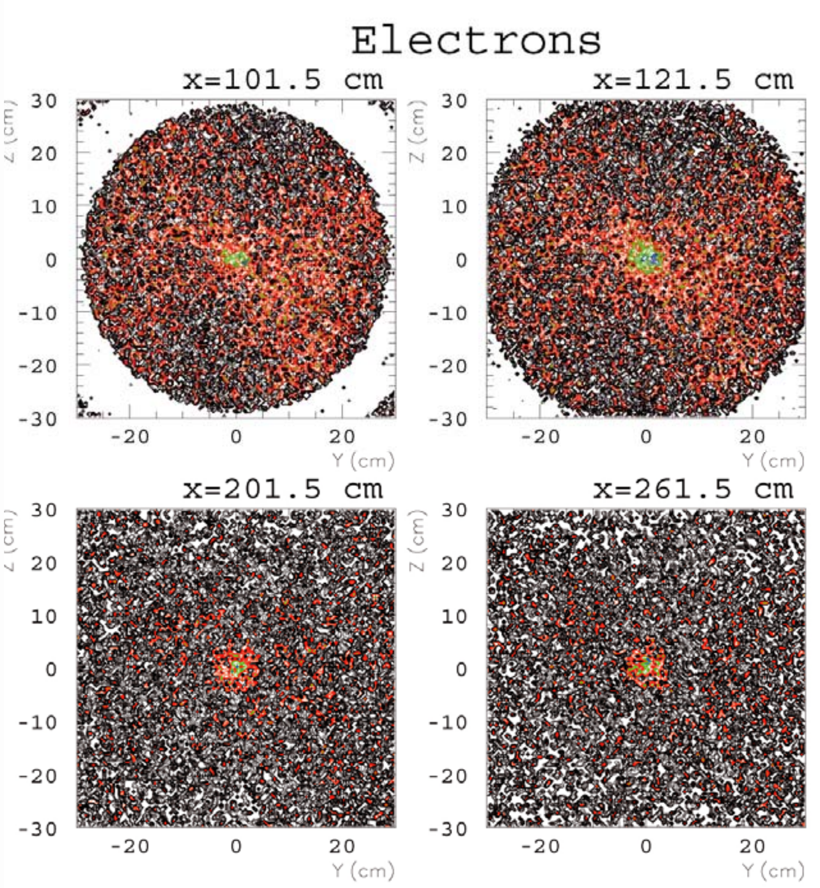
2004



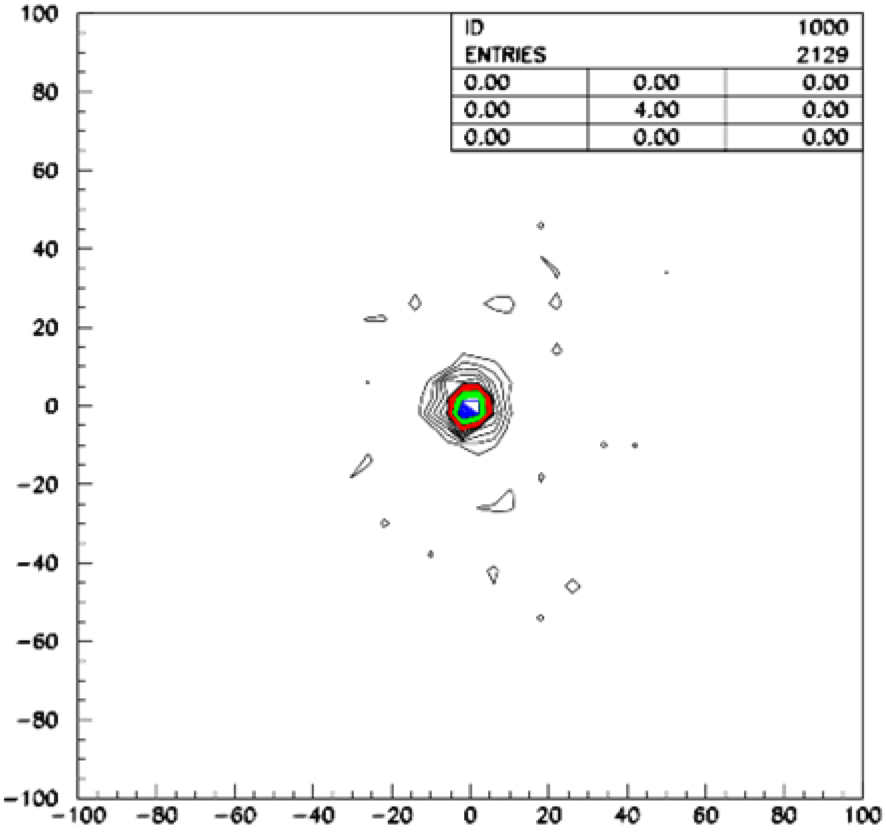
Energy deposited into SC10 from 0 to 200 cm

Scattered electrons inside

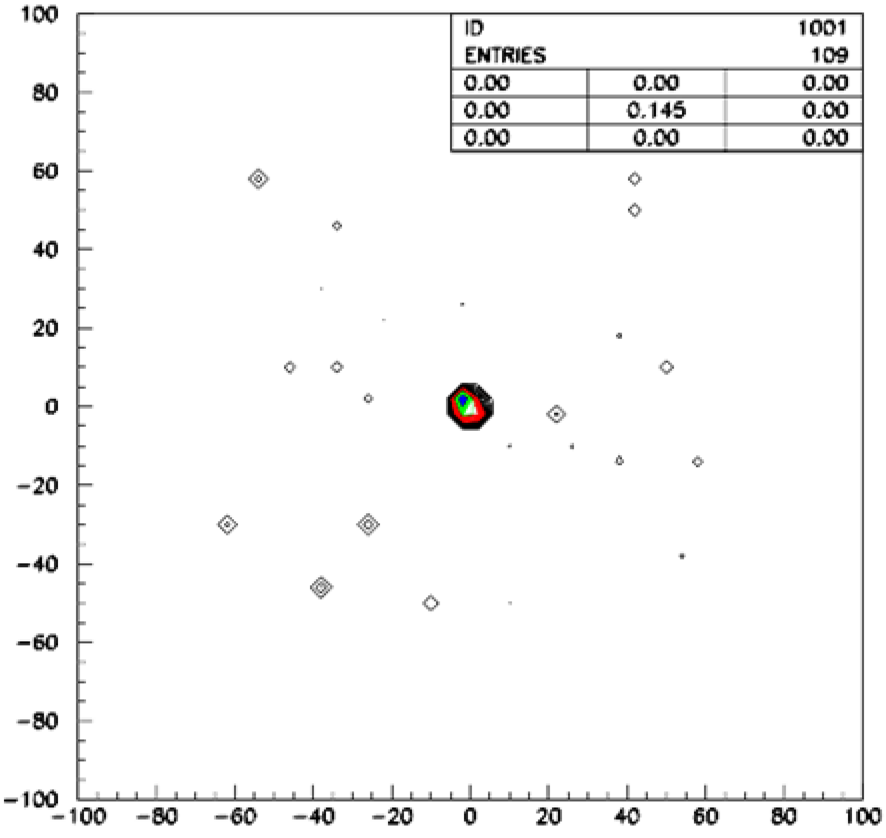




Scattered electrons



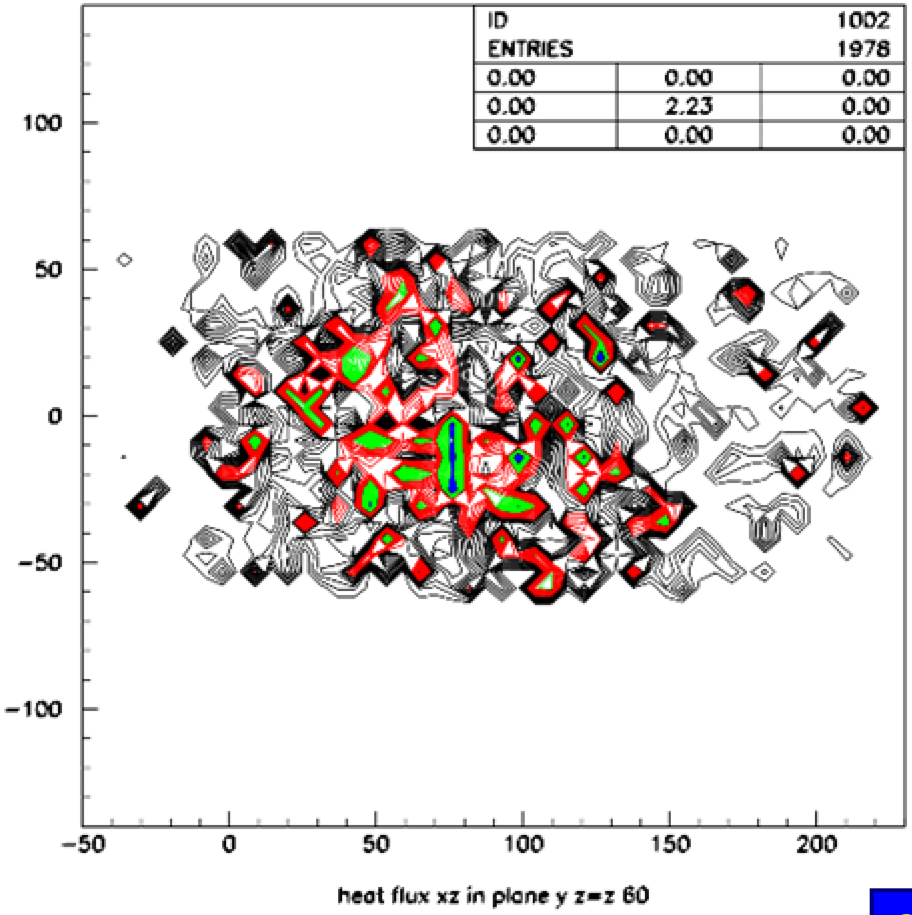
heat flux yz in plane x z=z 216

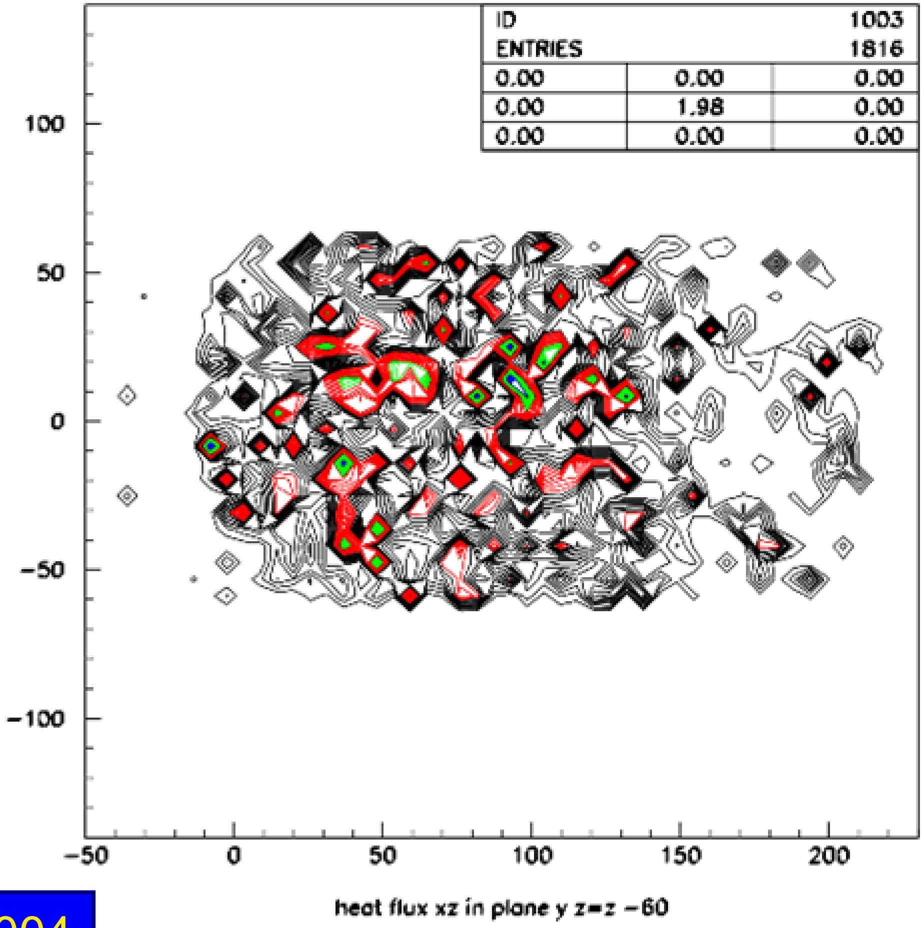


heat flux yz in plane x z=z −40

2004

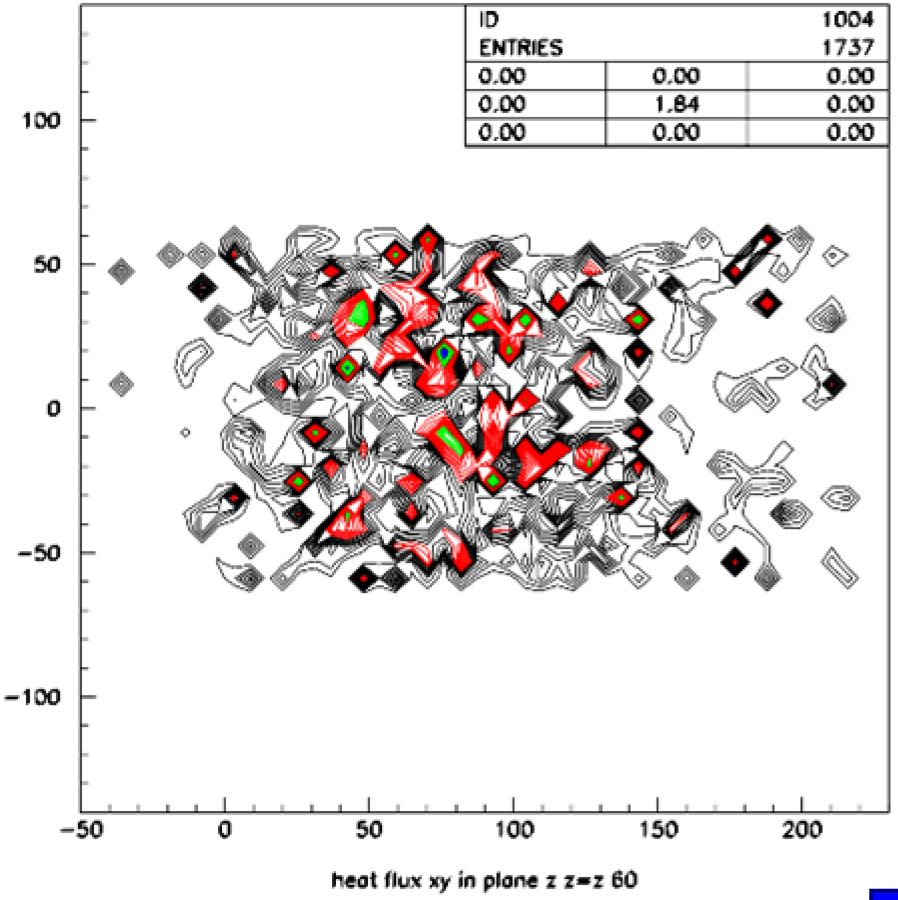
Scattered electrons

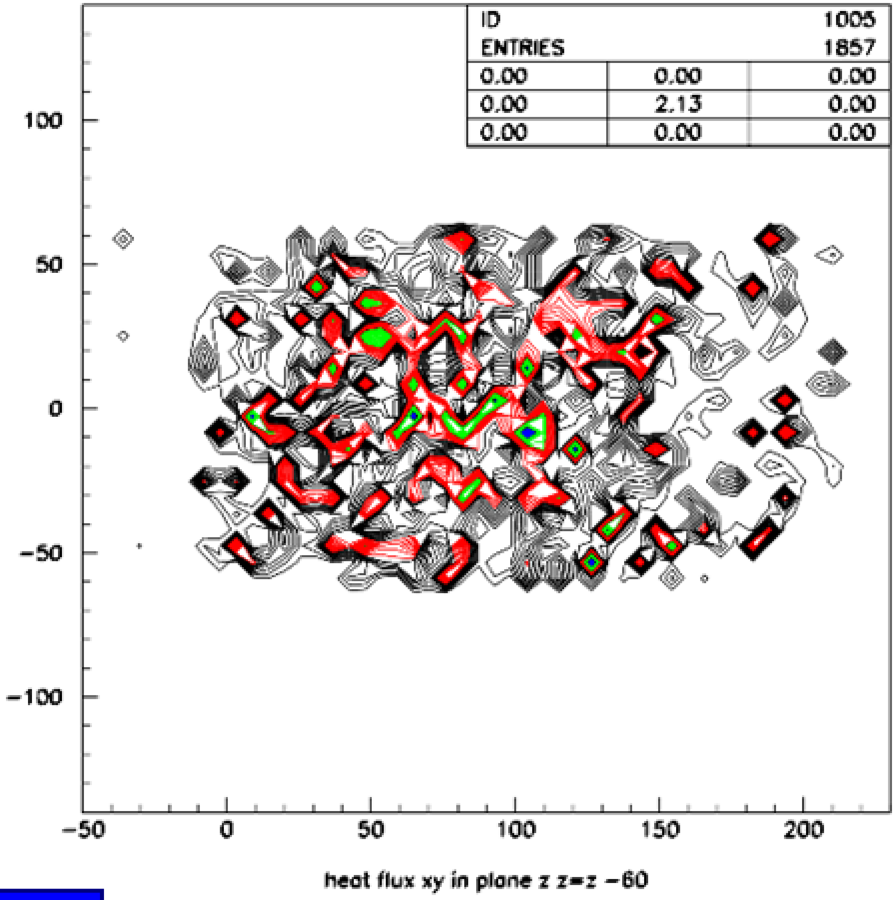




2004

Scattered electrons





2004

Energy deposited

energy in % of total deposited beam energy

dE/dx magnet H1 HLM1 = 0.000122330341
dE/dx magnet H2 HLM2 = 0.0286305789
dE/dx magnet H4 HLM4 = 0.0682362914
dE/dx dump SCR2 = 0.000255941792

dE/dx magnet H3 HLM3 I = 1 0.0091400696
dE/dx magnet H3 HLM3 I = 2 0.00750565063
dE/dx magnet H3 HLM3 I = 3 0.00405035447
dE/dx magnet H3 HLM3 I = 4 0.00288876216
dE/dx magnet H3 HLM3 I = 5 0.00254936377
dE/dx magnet H3 HLM3 I = 6 0.00162501738
dE/dx magnet H3 HLM3 I = 7 0.00172283954
dE/dx magnet H3 HLM3 I = 8 0.00202953094
dE/dx magnet H3 HLM3 I = 9 0.000685093924
dE/dx magnet H3 HLM3 I = 10 0.000578379841
dE/dx magnet H3 HLM3 I = 11 0.00041745021
dE/dx magnet H3 HLM3 I = 12 0.000419273681

dE/dx rod H3 ROD3 I = 1 0.010669956
dE/dx rod H3 ROD3 I = 4 0.00951220281
dE/dx rod H3 ROD3 I = 9 0.00702352962
dE/dx rod H3 ROD3 I = 12 0.00500533357

dE/dx SCR4 = 0.
dE/dx SCR5 = 0.
dE/dx SCR6 = 0.
dE/dx SCR7 = 0.00640179683
dE/dx SCR8 = 2.370119E-05
dE/dx SCR9 = 7.97315661E-05
dE/dx SC10 = 0.356774747
dE/dx SC11 = 0.147463262
dE/dx SC12 = 5.45780676E-05
dE/dx SC4P = 0.00213429541
dE/dx ROD2 = 0.0340836123
dE/dx RDUP = 0.00375873246
dE/dx LIK3 = 0.0216296595
dE/dx RAIL = 0.0265459437

dE/dx deflector H2 = 0.00584139721
dE/dx deflector H3 = 0.00109494338
dE/dx deflector DFDU = 0.000519398251
dE/dx deflector SC11 = 0.00316047249

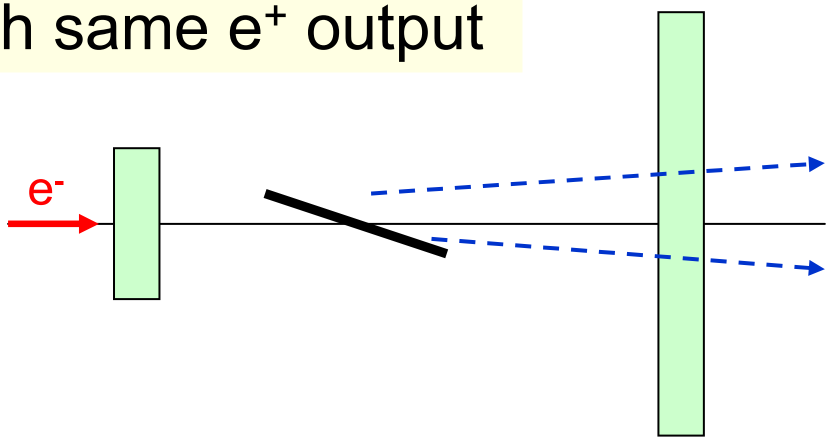
dE/dx deposited in moderator = 0.000436547067

total dE/dx inside target-selector cylinder = 0.996470451

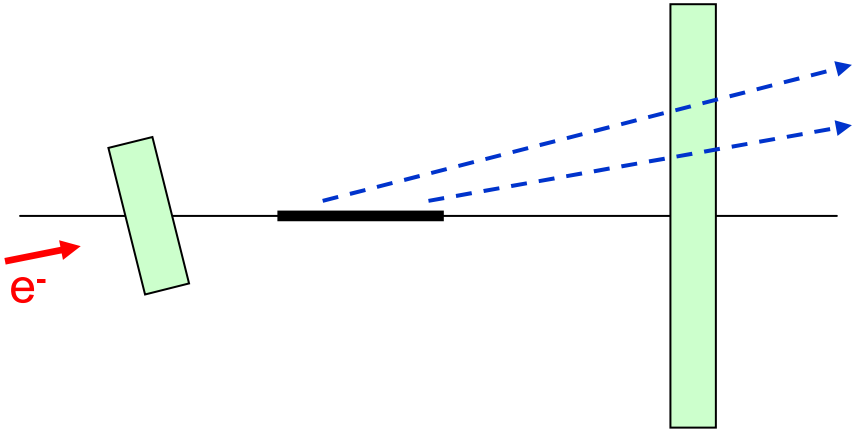
Electron and photon fluxes

Two possible setups with same e$^+$ output

- Beam and coils on same axis



- Target and downstream coils on same axis



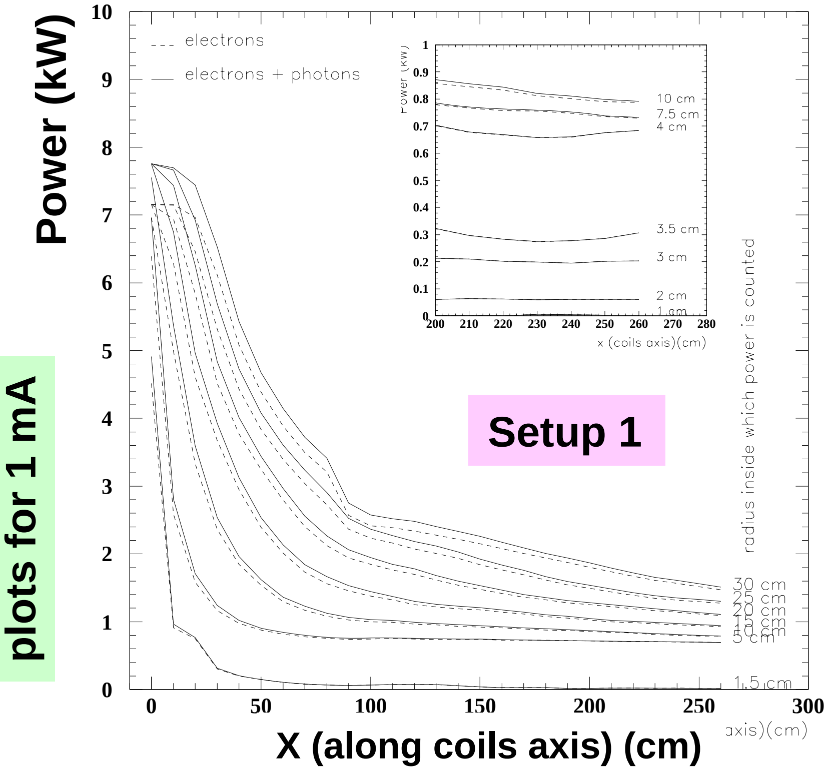
Fluxes of electrons and photons

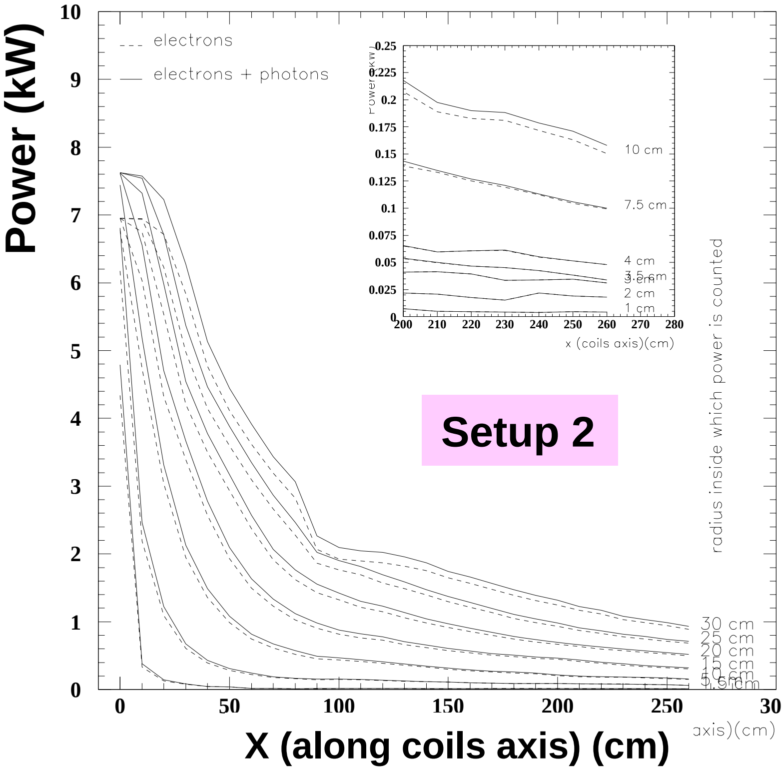
I = 2.3 mA

	R = 1 cm	R = 2 cm	R = 3 cm	R = 4 cm
Setup 1	5 W	140 W	450 W	1.5 kW
Setup 2	10 W	45 W	80 W	110 W

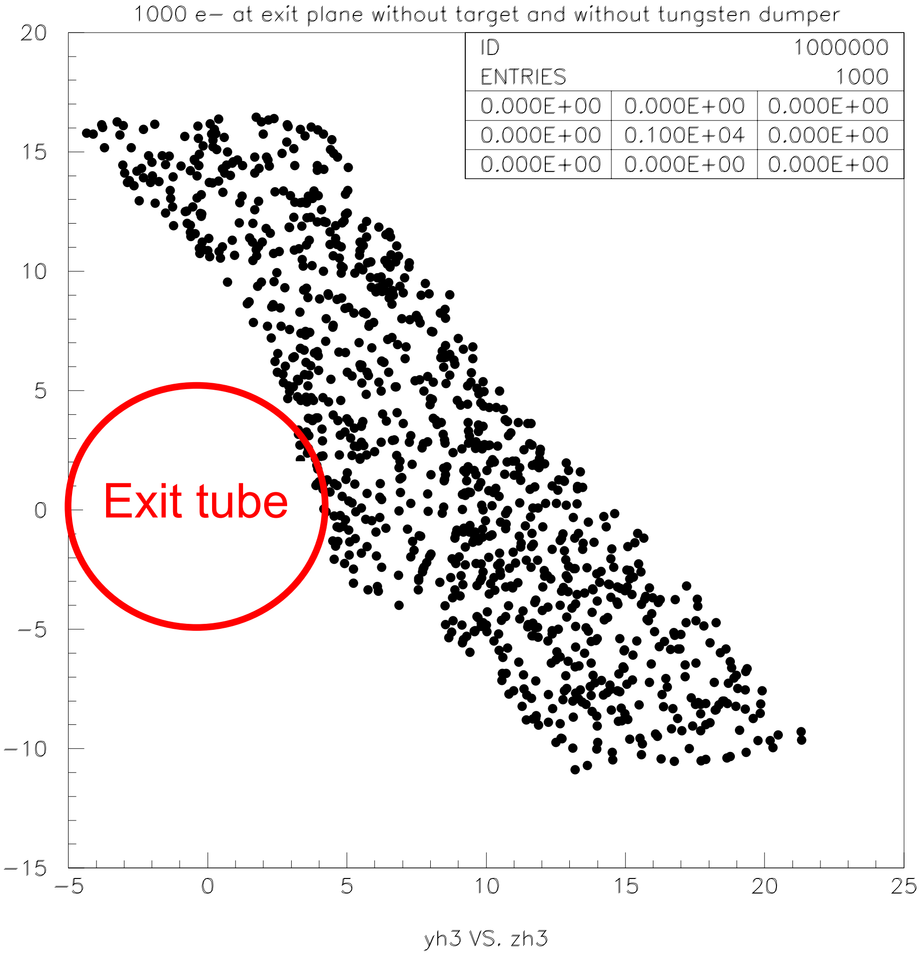
at exit plane

plots for 1 mA

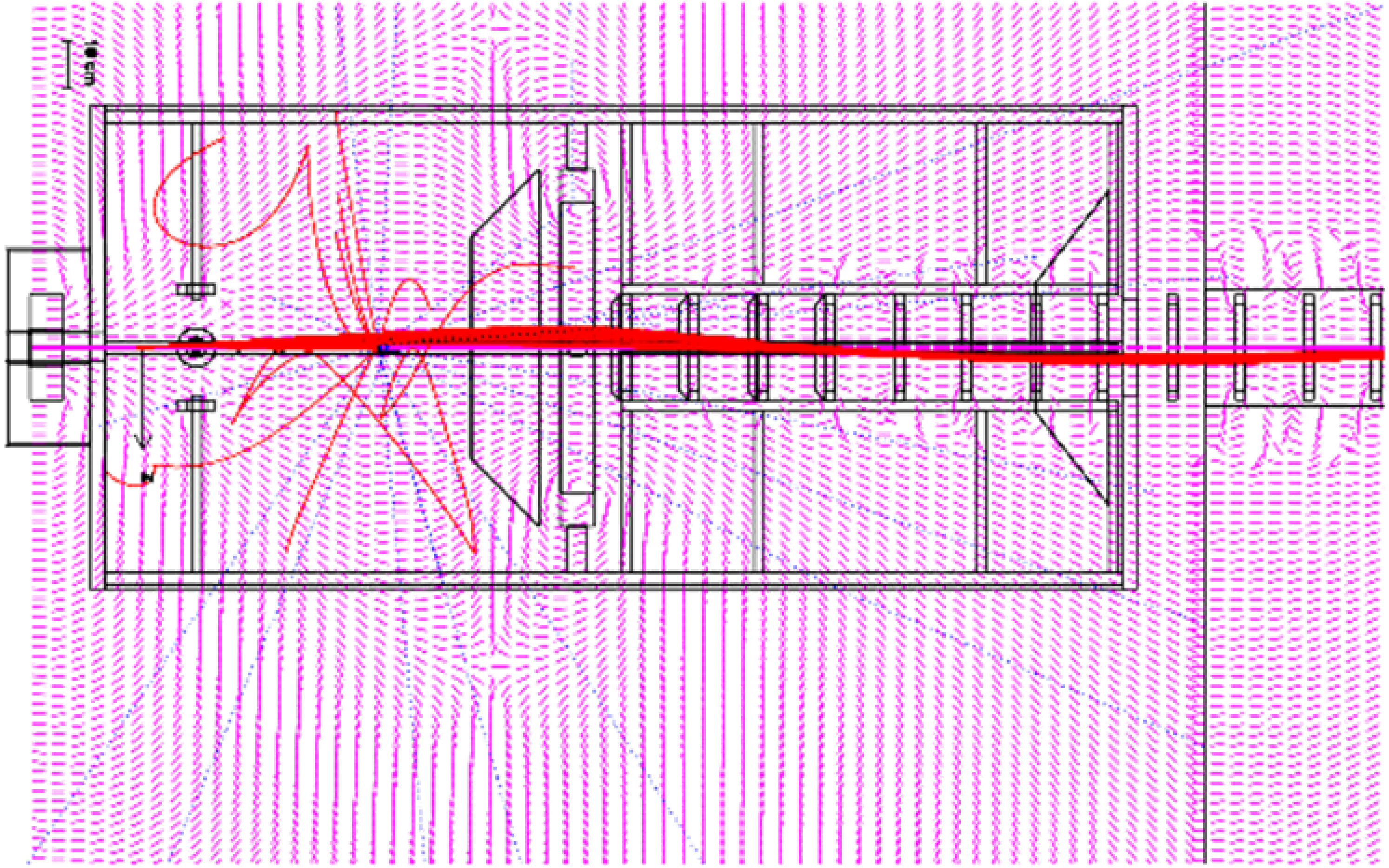




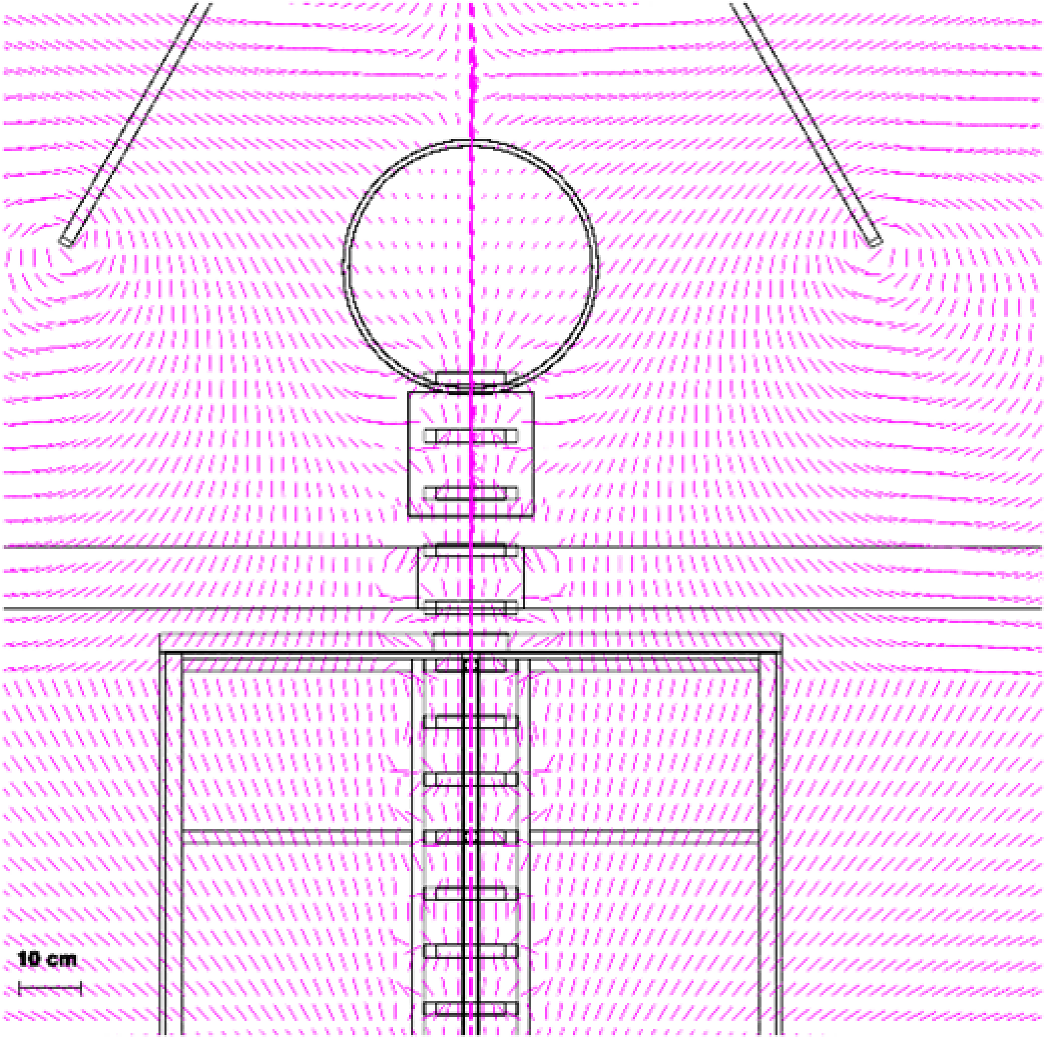
No target No dump (setup 2)



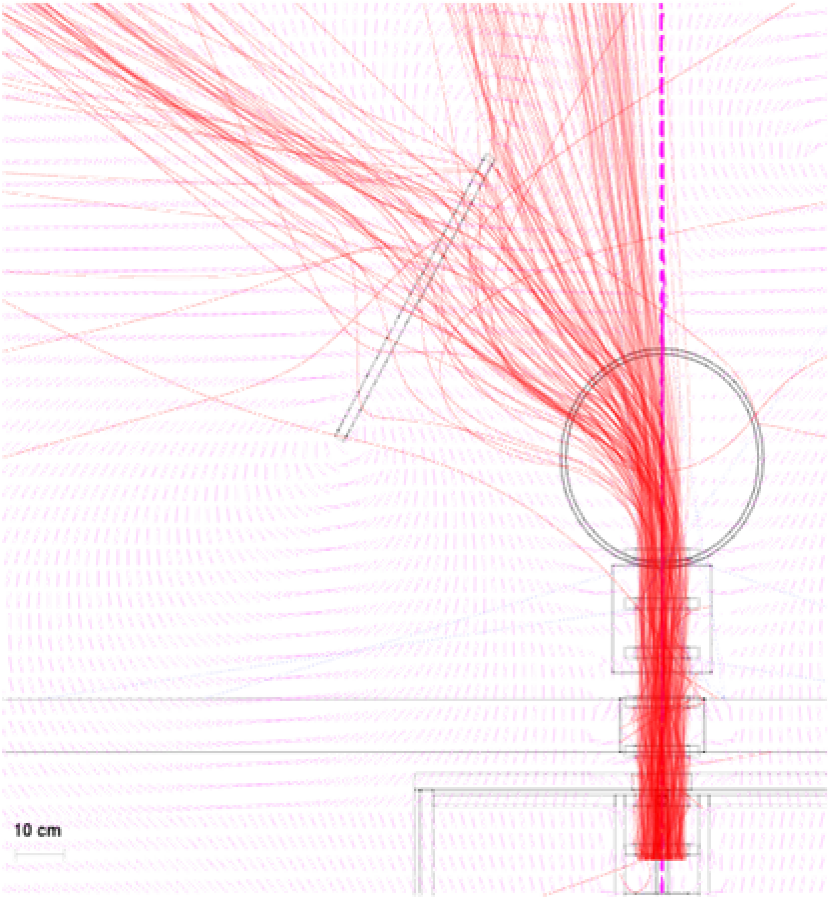
No target (2004)

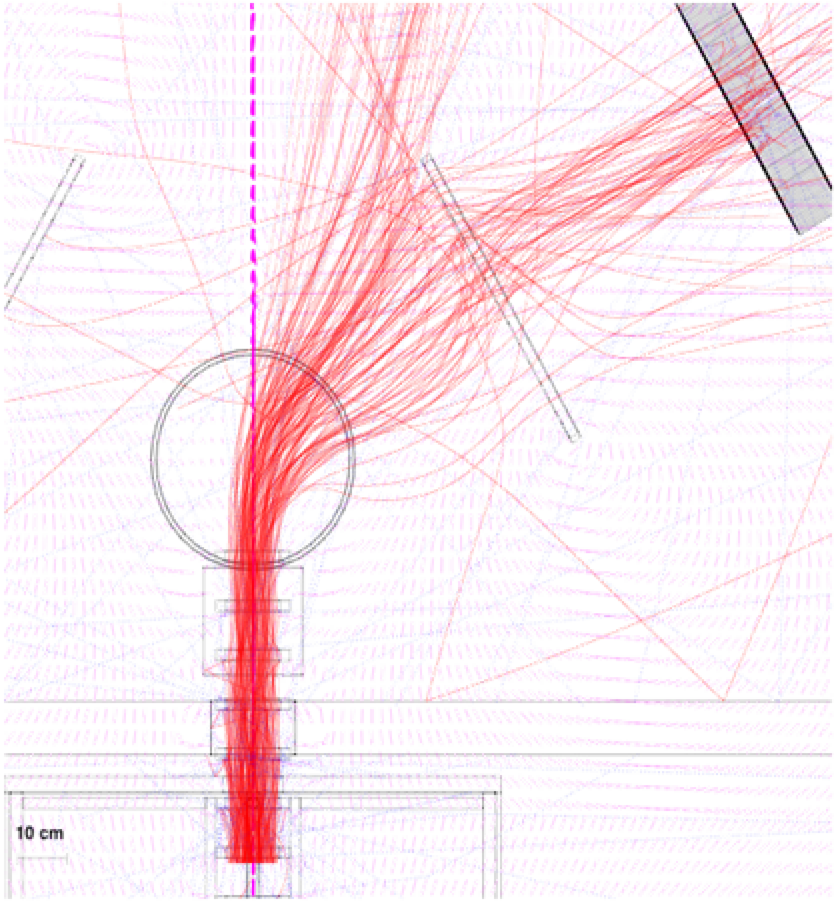


Selector field map

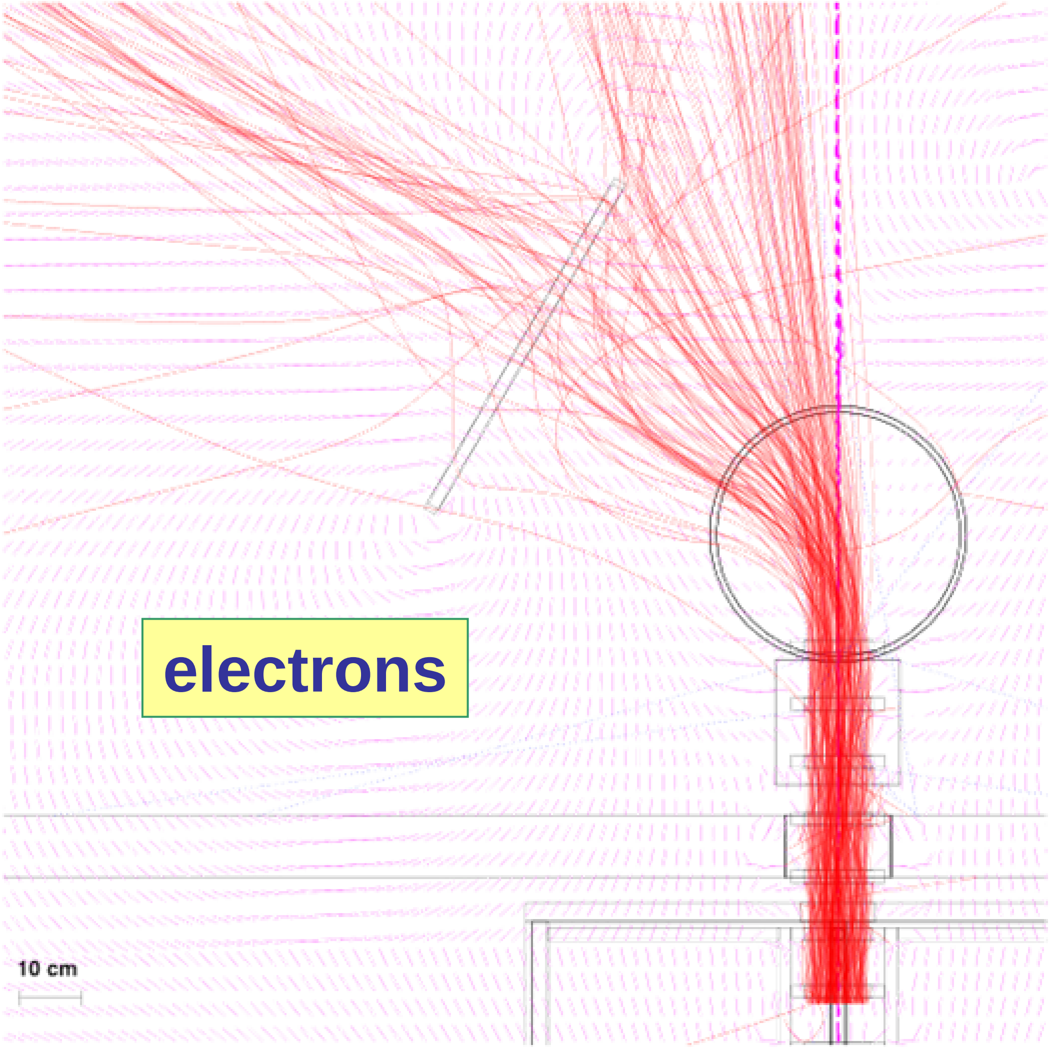


electrons positrons

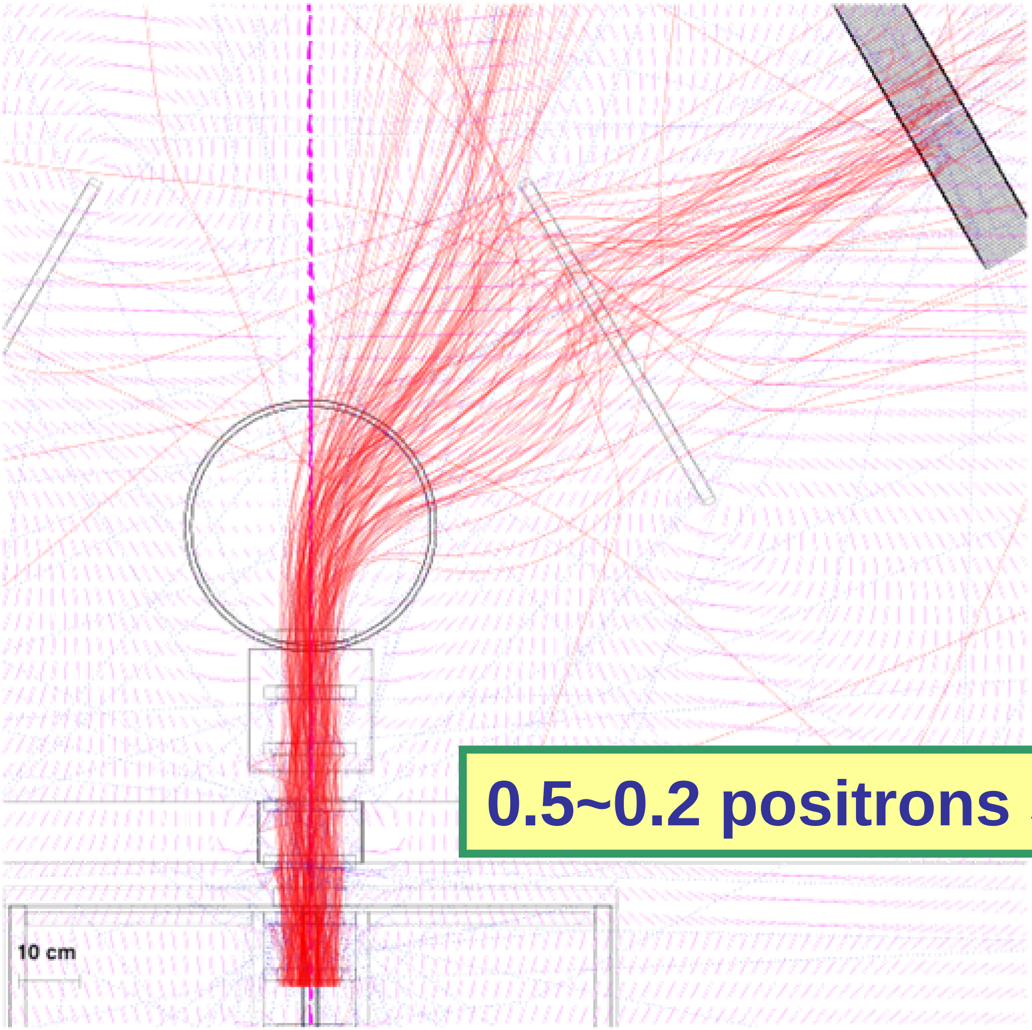




Selector: electrons

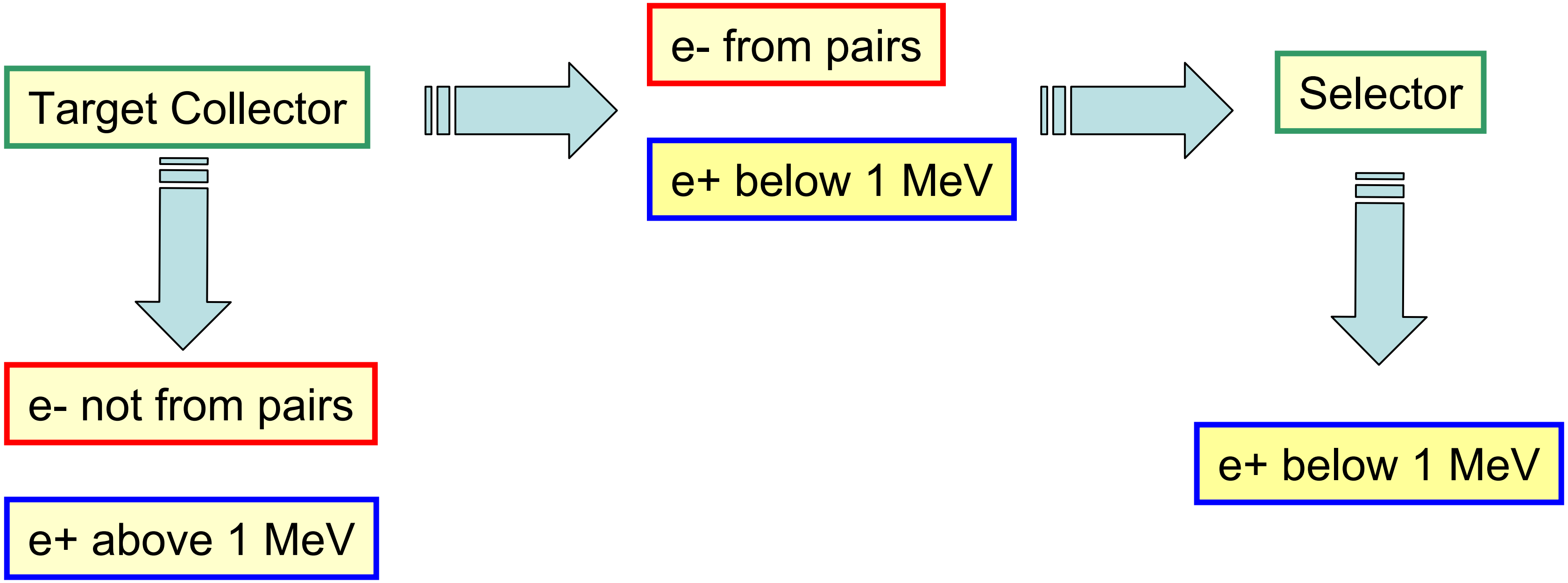


Selector: positrons



0.5~0.2 positrons selected

Separation e+ e-



Target Collector

e- from pairs

e+ below 1 MeV

Selector

e- not from pairs

e+ above 1 MeV

e+ below 1 MeV

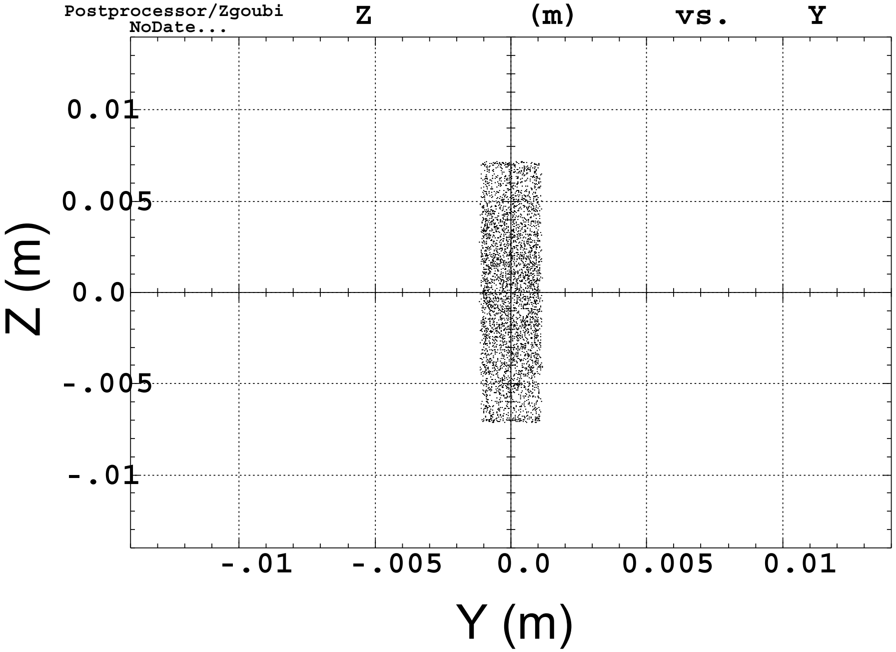
2 steps e+ isolation

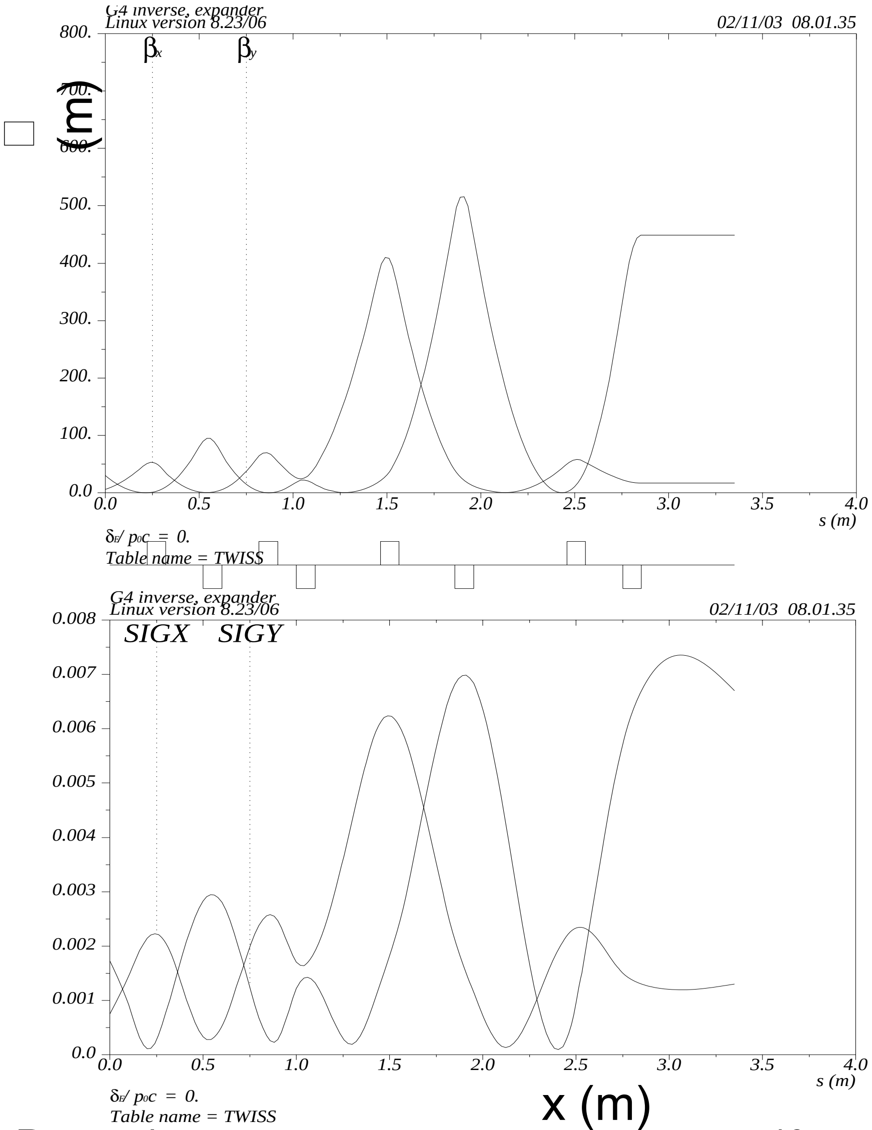
priority to e+ << 1 MeV !!!

A very first design of a 2D expander/uniformizer

F. Meot and T. Daniel,

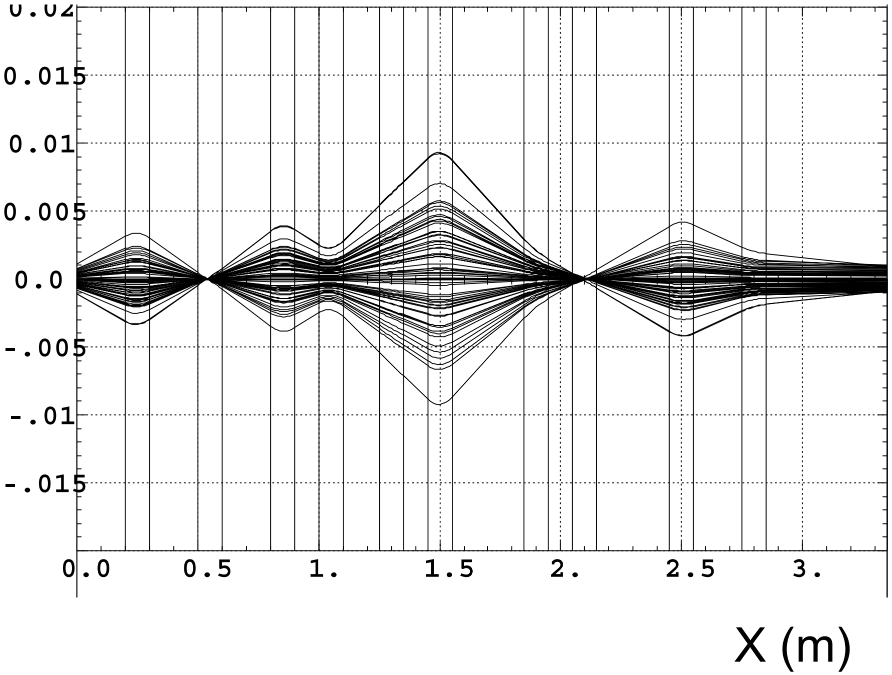
NIM, A 379 (1996) 196-205.



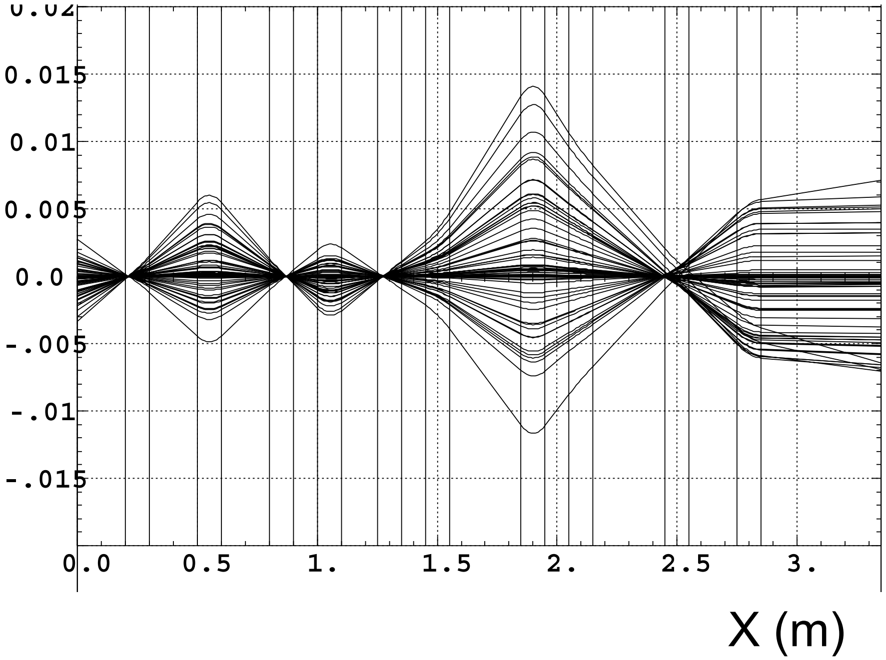


Expander (2)

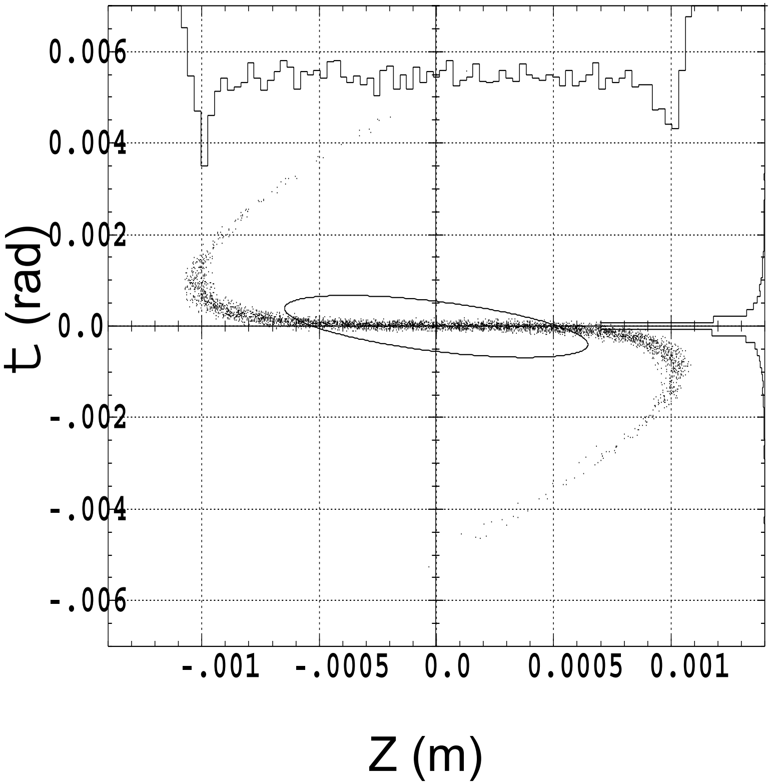
Z (m) vs X



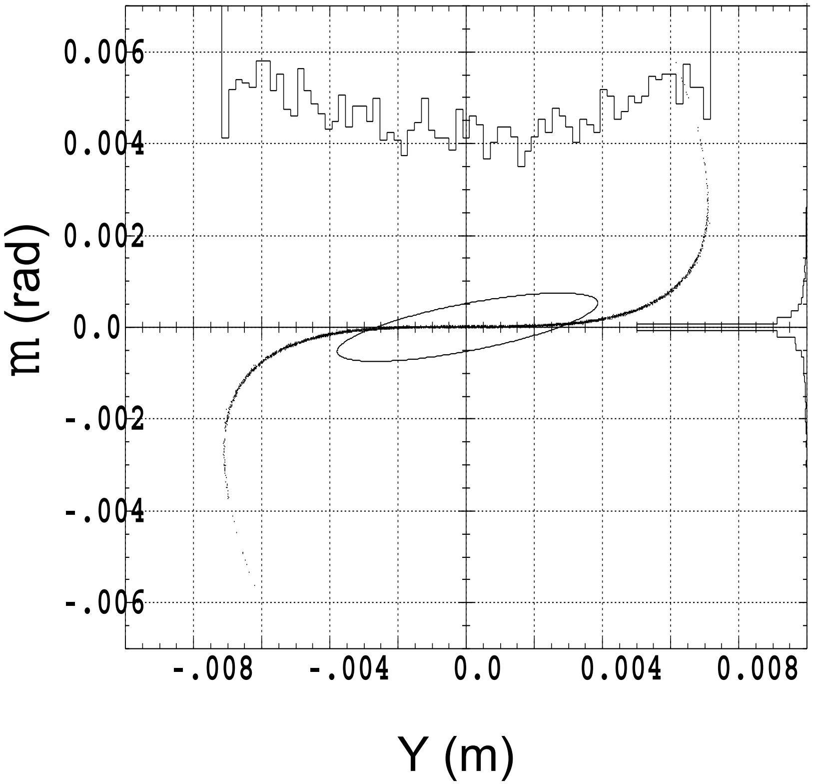
Y (m) vs X



Expander (3)



t (rad)
0.006
0.004
0.002
0.0
-.002
-.004
-.006
-.001
-.0005
0.0
0.0005
0.001
Z (m)



m (rad)
0.006
0.004
0.002
0.0
-.002
-.004
-.006
-.008
-.004
0.0
0.004
0.008
Y (m)

Optimal Production Rates (E_{e+} <1 MeV)

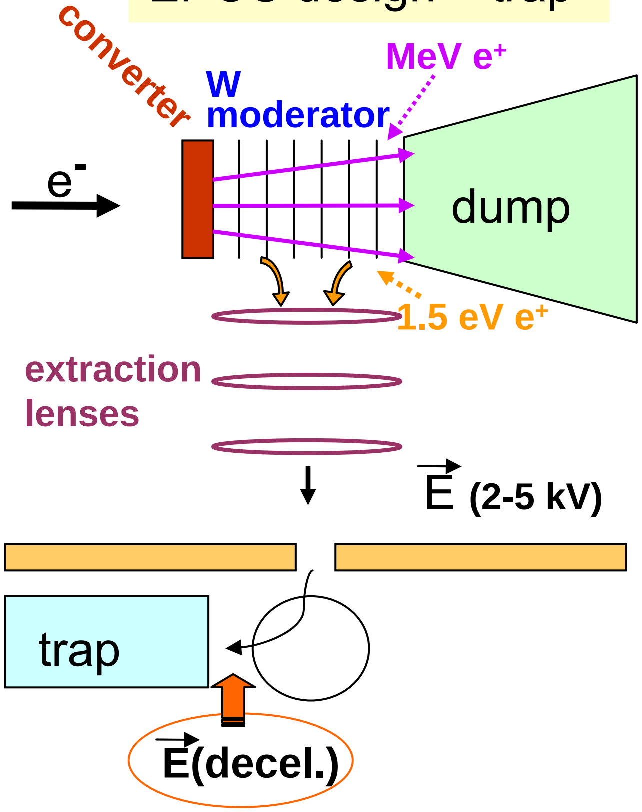
What next

- Finalize injection scheme (F. Meot/Saclay)
- Finalize engineering of collection system (SACM/Saclay)
- Shielding scheme: depends on location
- Study moderation “a la DELFT “ hot or cold before trap

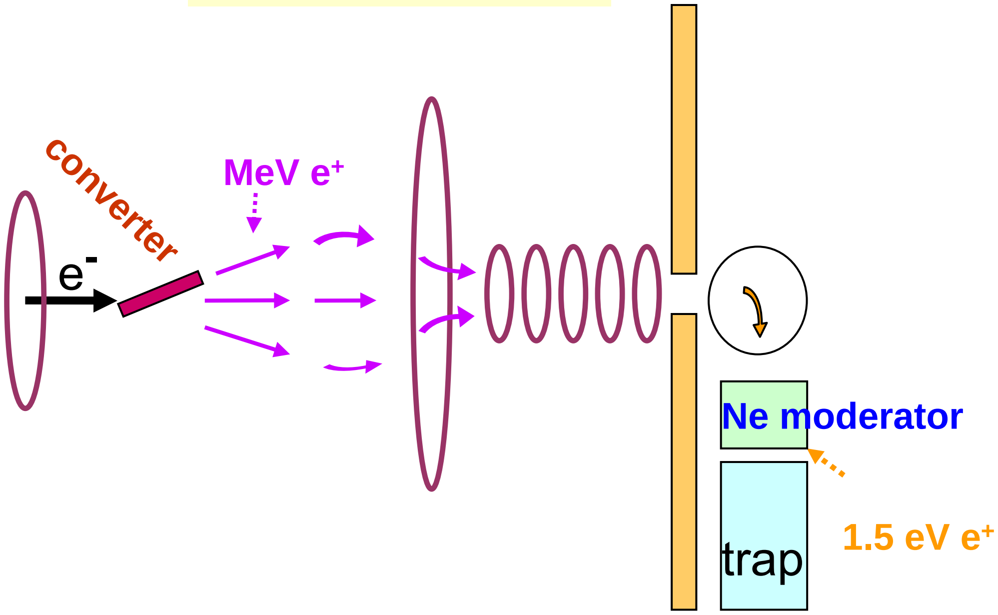
Design differences (1)

Rossendorf / Aarhus

EPOS design + trap



Proposed design



	efficiency	temperature
Tungsten	10^{-4}	room
Neon	10^{-2}	7K

Design differences (2)

Original EPOS design:

40 MeV, 0.25 mA, ~CW Linac

Pt or W moderator, 3.5 mm Pt target

Neutron activation

Collection efficiency before trap 20%

Expected Rate before trap 1.6 10^{8} s^{-1}

At 10 MeV, 2.5 mA

1mm target = 0.8 10^{8} s^{-1}

Proposed design:

10 MeV, 2.5 mA, CW

Ne Moderator, thin W target

Collection efficiency before trap 20%

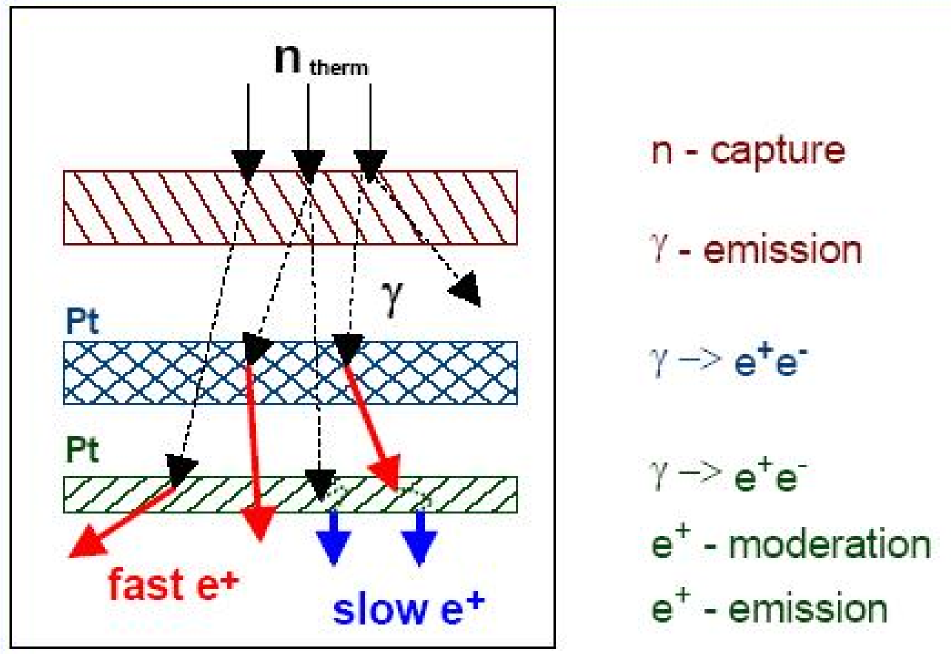
Expected rate before trap 1.1 10^{10} s^{-1}

E (MeV)	I(mA)	Mod.	Activ.	L	wall	Rate
40	0.25	Pt	yes	30m	3m	1.6 10^{8}
10	2.5	W	no	3m	2m	0.8 10^{8}
10	2.5	Ne	no	3m	2m	10^{10}

Other designs

Thermal neutron capture: ^{113}Cd(n,□)^{114}Cd □ = 26000 barn !!

By nuclear research reactor FRM2 in Munich (Germany) can reach $10^{10}s^{-1}$



NEPOMUC

NEutron induced POsitron Source MUniCh

& Positron physics

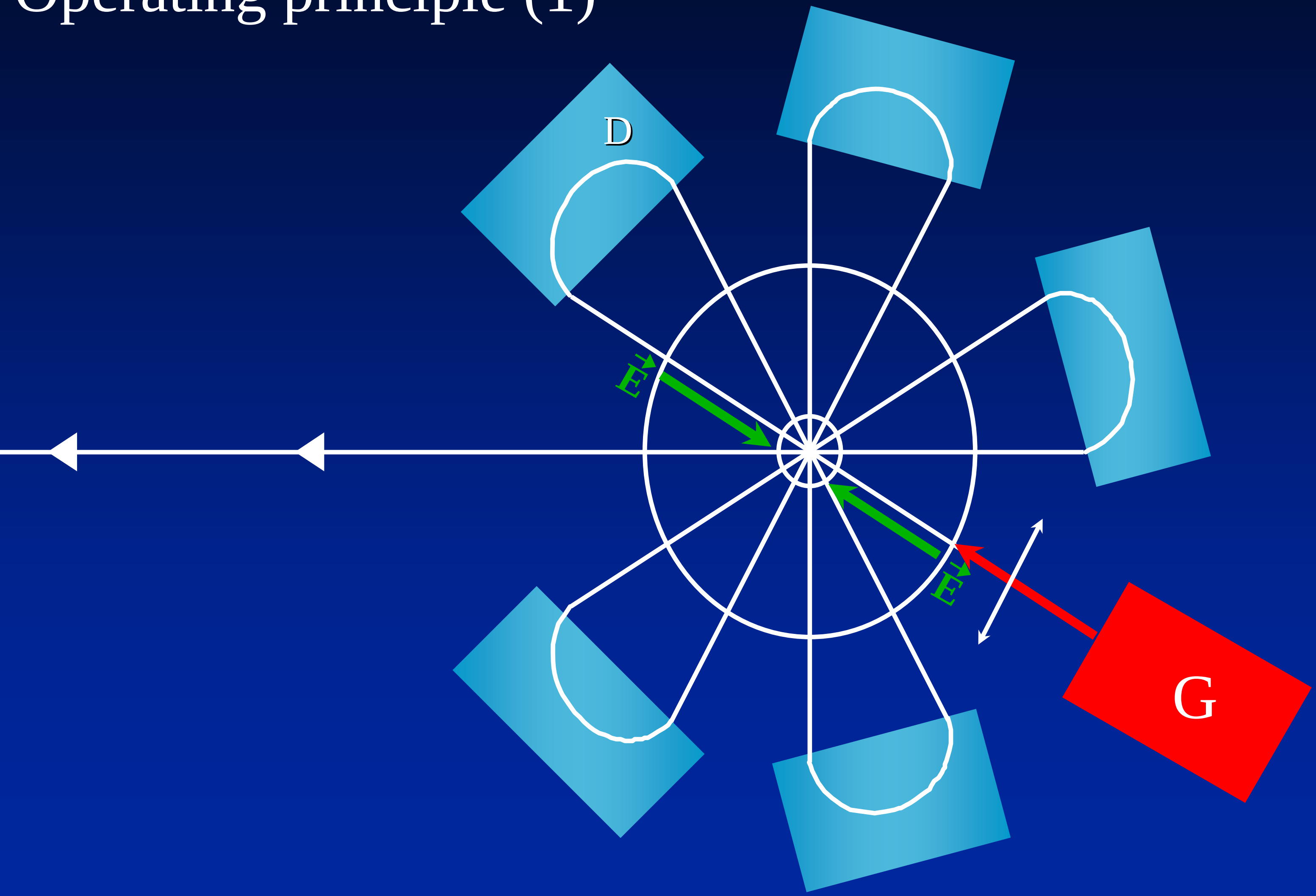
Building size:

40 m x 40 m x 30 m

IBA

RHODOTRON®

Operating principle (1)



IBA

Rhodotron Models - Basic Specifications

	TT100	TT200	TT300
Energy (MeV)	3-10	3-10	3-10
Power range at 10 MeV (kW)	1-35	1-80	1-150
Design value (kW)*	45	100	> 200
Full (cavity) diameter (m)	1.60 (1.05)	3.00 (2.00)	3.00 (2.00)
Full (cavity) height (m)	1.75 (0.75)	2.40 (1.80)	2.40 (1.80)
Weight (T)	2.5	11	11
MeV/pass	0.833	1.0	1.0
Number of passes	12	10	10
Stand-by kW used	<15	<15	<15
Full beam kW used	<210	<260	<370

Our bias …….

- ***Idea for e+ use since 10 ~ 20 years ….. but***
- ***10 largest US Univ: how many have a source ?***

- ***off the shelves components***
- ***No neutron safety required***
- ***low maintnance : 1 engineer***
- ***low running costs : < 500 kWatts***

Compact e+ factory

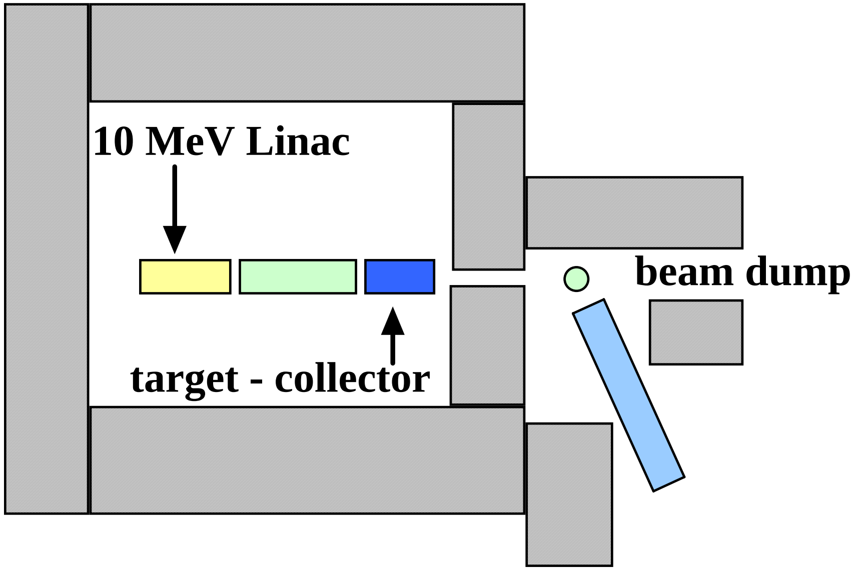
- Ne^{+} below 1 MeV > 10^{13} s^{-1}

  → Ne^{+} at 1 eV > 10^{10} s^{-1}

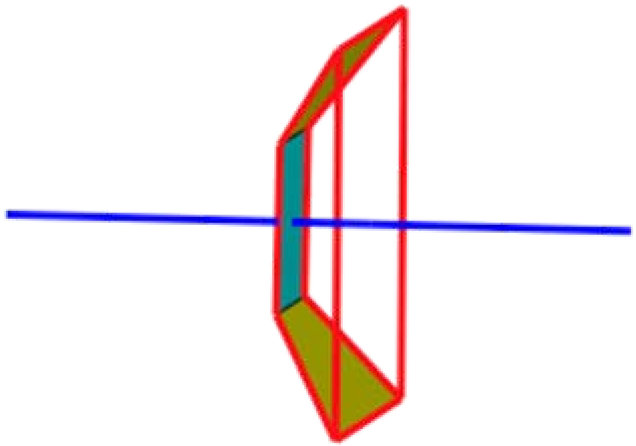
- Beam energy/intensity :

  10 MeV ~2.5 mA

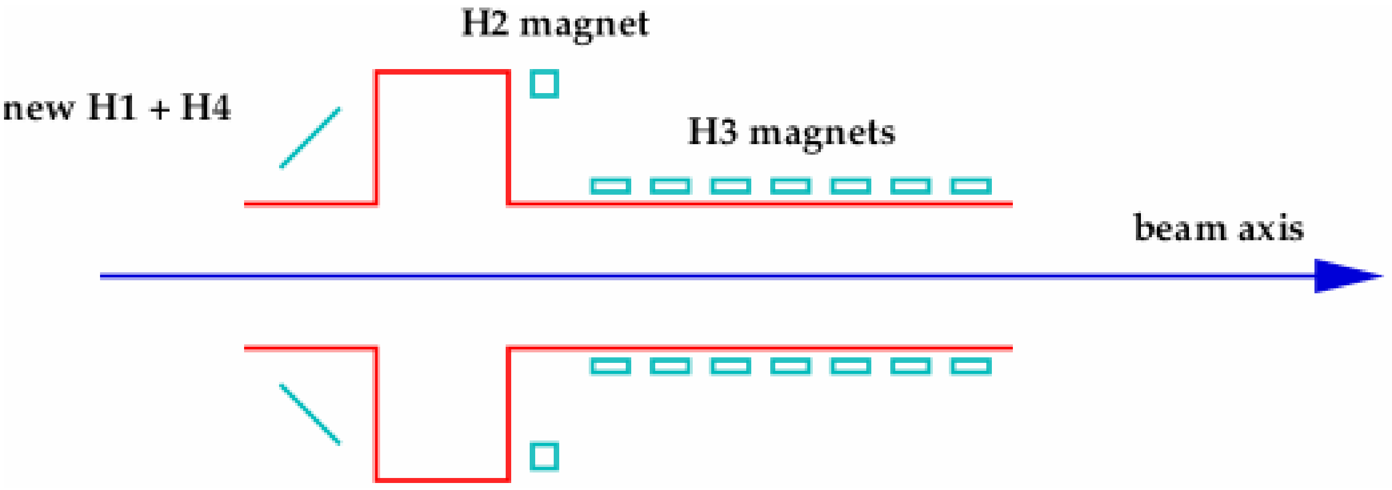
- Interdisciplinary lab:
  - HEP
  - Plasma
  - Condensed Matter
- SR radiation control and infrastructure



Engineering improvements



- Replace H1 and the 4-poles
- Use hight Tc supraconductor
- No field on the beam axis: stable injection
- New vaccum chamber with magnets outside



Version 2004

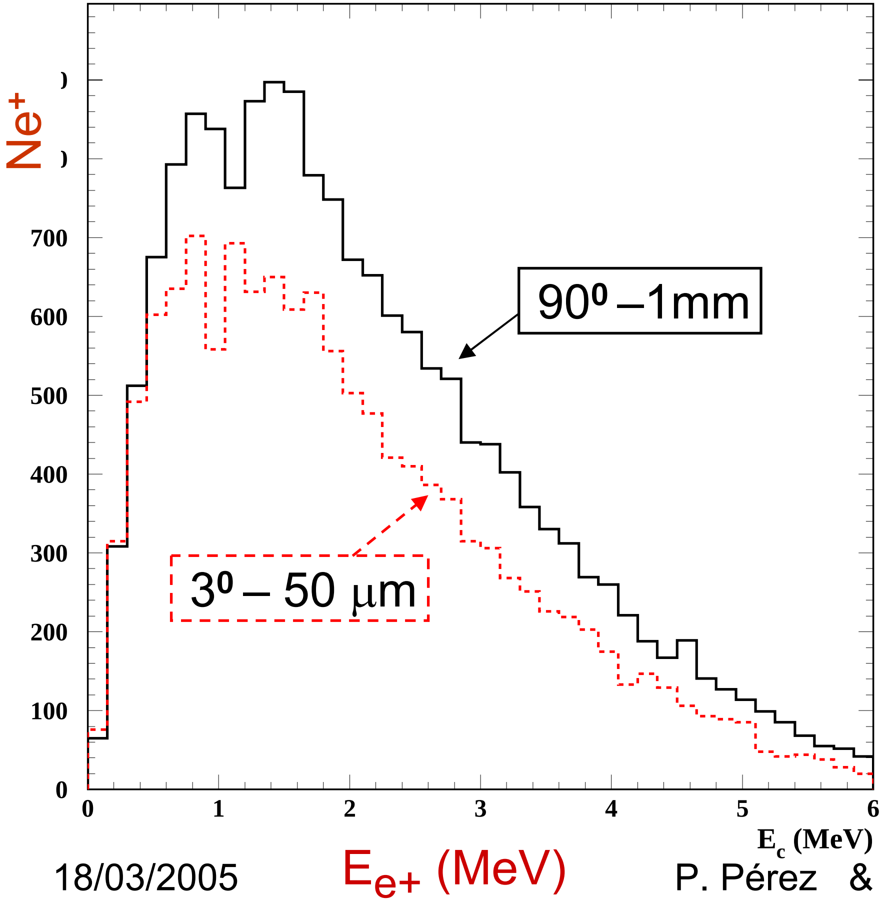
I = 2.5 mA	X = 200 cm			X = 320 cm		
R_{coll}= 5 cm	**5**	e^+ yield	e^+ rate xE12	**5**	e^+ yield	e^+ rate xE12
all	24%	5.0E-4	7.8	23%	4.87E-4	7.6
E <1 MeV	33%	2.4E-4	3.7	32%	2.37E-4	3.7
E < 600 KeV	25%	1.0E-4	1.6	23%	0.95E-4	1.5

I = 2.5 mA	X = 200 cm			X = 320 cm		
R_{coll}= 10 cm	**10**	e^+ yield	e^+ rate xE12	**10**	e^+ yield	e^+ rate xE12
all	31%	6.3E-4	9.8	29%	5.99E-4	9.3
E <1 MeV	36%	2.6E-4	4.1	35%	2.53E-4	3.9
E < 600 KeV	25%	1.0E-4	1.6	25%	1.02E-4	1.6

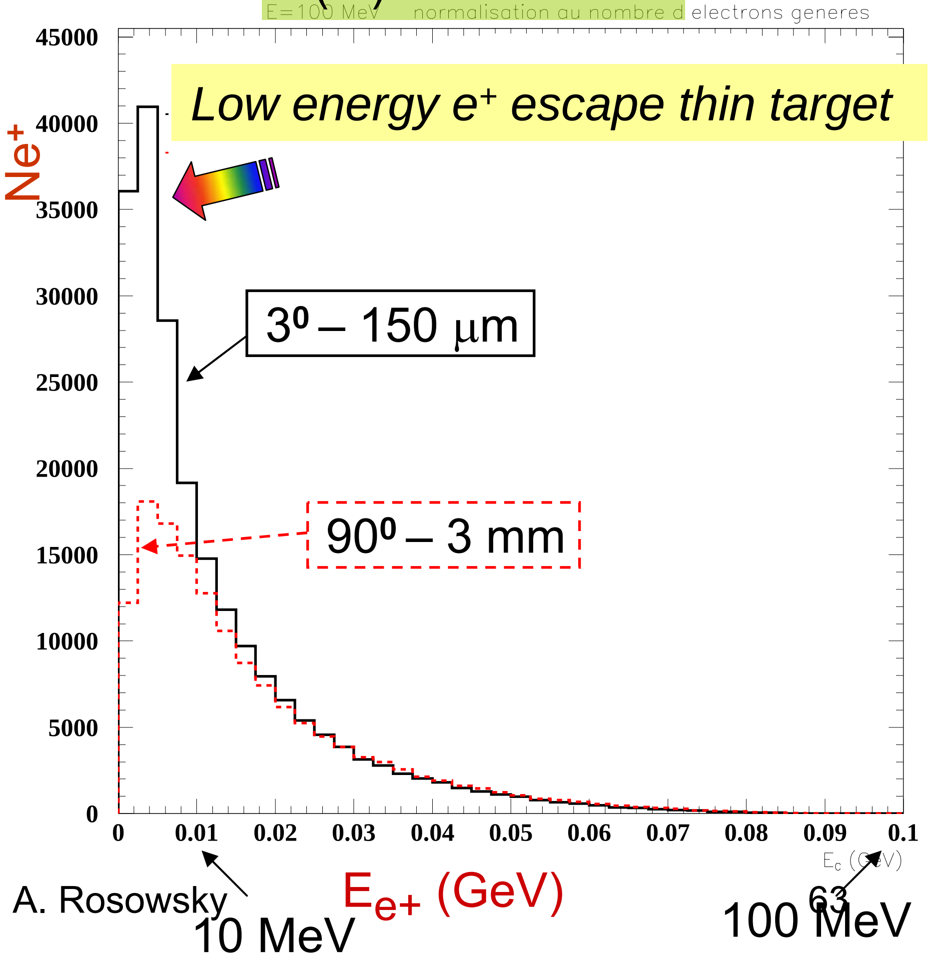
Positron energy spectrum

Same number of electrons on target

E(e$^-$) = 10 MeV



E(e$^-$) = 100 MeV



Low energy e$^+$ escape thin target