Low E e- driven e+ source

as a summary of e+ meeting on 09/01/13.

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Low E e- driven e+ source

- The low E e- driven e+ source has been proposed by MK at ILC08. It was updated by considering DR acceptance.
- Critical investigation was made by W. Liu and W. Gai (ANL group).
- Two studies are compared.

Positron Yield study (MK)

- ►Positron generation is simulated by NRC-EGS4 with various electron energy (0.25 – 6.0 GeV) as a function of the target thickness (0.5 – 8.0 X_0).
- ►Beam spot : 2.5mm radius (rms)
- ►Capture optics: AMD (B_0=7.0T, B_S=0.5T, L=220mm, μ=60.8 1/m)
- ►Positron acceptance is qualified by an analytical method .
- ►DR acceptance is accounted. The real yield is 87% of the yield at AMD + capture RF.
- ►No enhancement was assumed by Lithium lens.

Schematic layout of beamline used for tracking (ANL)

Liquid lead target:

X0=~0.5975cm

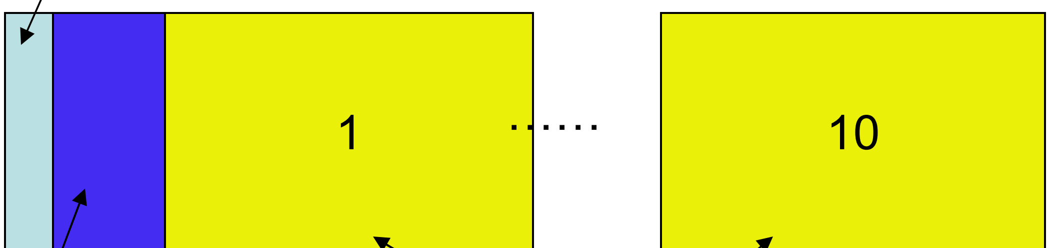
C=162.9-3.022e-2*T+8.341e-6*T^2 [J/(kg*K)]

K=9.2+0.011*T [W/(m*K)]

ρ=11367-1.1944*T [kg/m^3]

Melting point: 600K , Boiling point: 2022K

At melting point, 1 J/cm^3 can cause ~1.5K temperature change

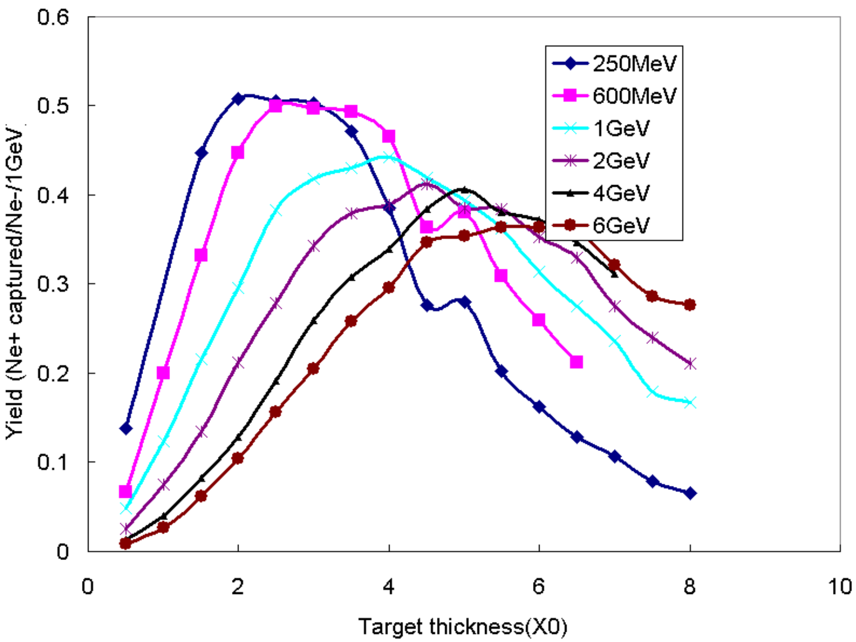


AMD (6T) or
Lithium lens

Field map of 1.3GHz RF standing wave cavities. ~1.15m long, surrounded by 0.5T solenoid, with ~12MV/m gradient

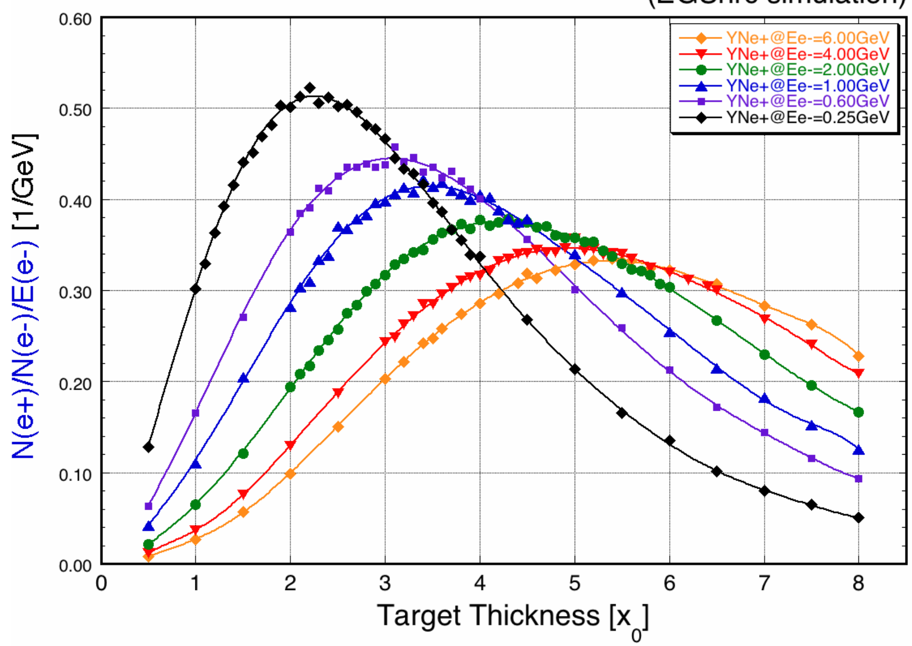
EM shower is simulated by EGS4.

Positron Yield



by W. Liu and W. Gai

(EGSnrc simulation)



NRC EGS4 by T. Kamitani

Positron yield $\eta(N_{e+}/N_{e-}/GeV)$

- 0.6 GeV : 0.50
- 1.0 GeV : 0.45
- 2.0 GeV : 0.40

- 0.6 GeV : 0.44
- 1.0 GeV : 0.39
- 2.0 GeV : 0.37

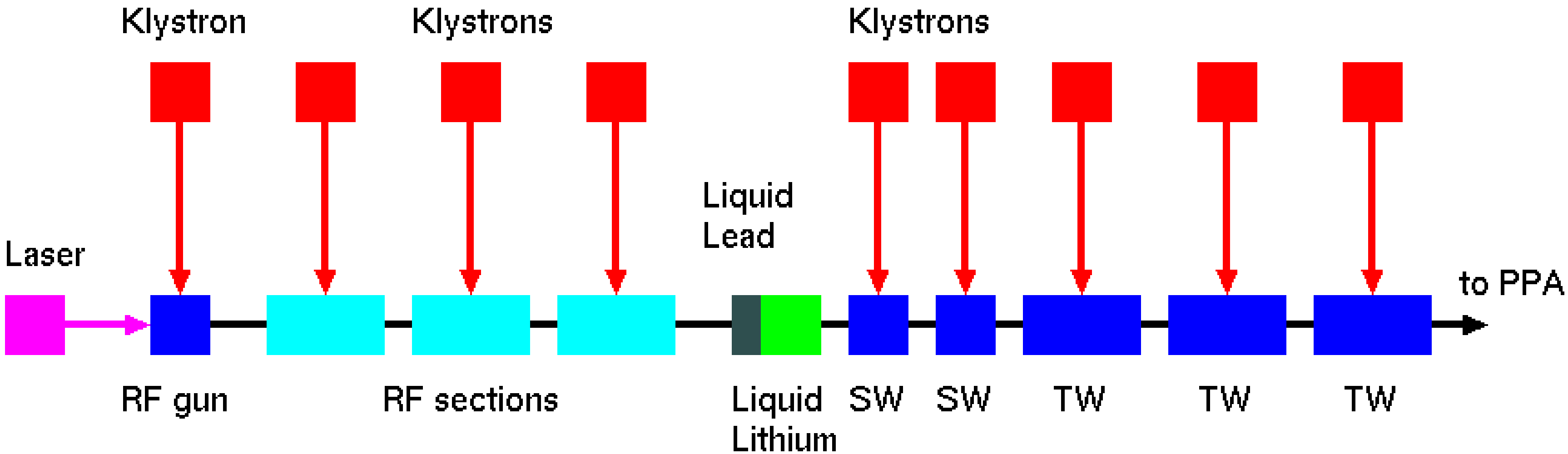
Drive Energy (MK)

- ►The positron yield at the shower max for each energy is taken from the simulation.
- ►DR acceptance is smaller than AMD acceptance. The real yield is 87%, which corresponds to 1.5σ .
- ►No Enhancement by Lithium lens is assumed.
- ►The required drive beam intensity was obtained.

Ee- (GeV)	*η*	Ne- (nC)
0.7	0.27	11.85
1.4	0.48	6.67
2.2	0.71	4.51

ILC e+ source (MK)

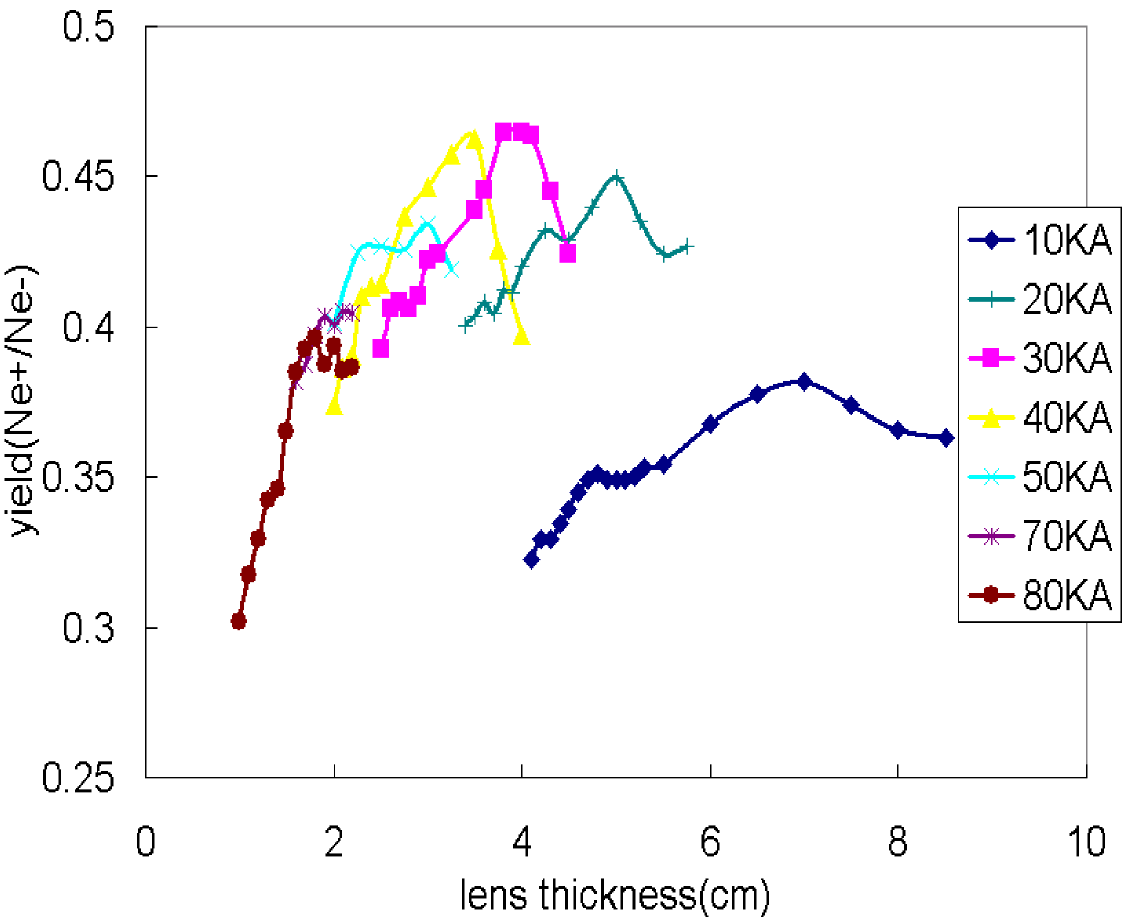
- L-band RF gun (FLASH type) generates ILC format beam with 4.5nC bunch intensity.
- Three RF sections (2 klystron + 3 cryomodules, 24 cavities) accelerate it up to 2.2 GeV.
- Liquid lead target + Liquid Lithium lens.



Target vitality (MK)

- Operation is limited by BN isolation window.
  - **10×10^{12} GeV/mm^2 in 100ns duration**
  - **180kW average power**
- 2.2GeV, 4.5nC bunch with 369ns spacing, 2625 bunches, 5Hz
  - **3.1×10^{9} GeV/mm^2 (spot size 20mm^2)**
  - **2.2x4.5x2625x5=130kW**
- Both limits are cleared. The average power would be half for LowP.
- The spot size can be smaller; The acceptance may be improved.
- Those limits should be confirmed by experiments.

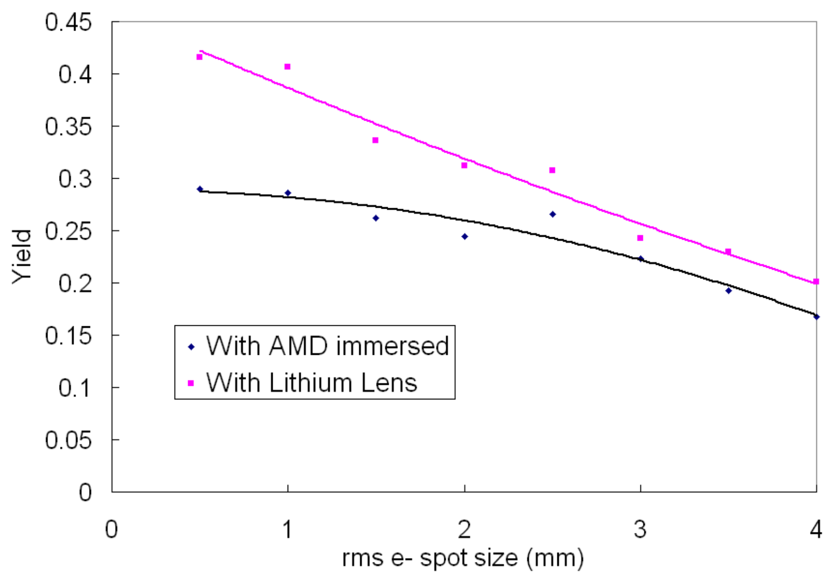
Lithium lens, 700MeV, $3X_0$ liquid Pb (ANL)



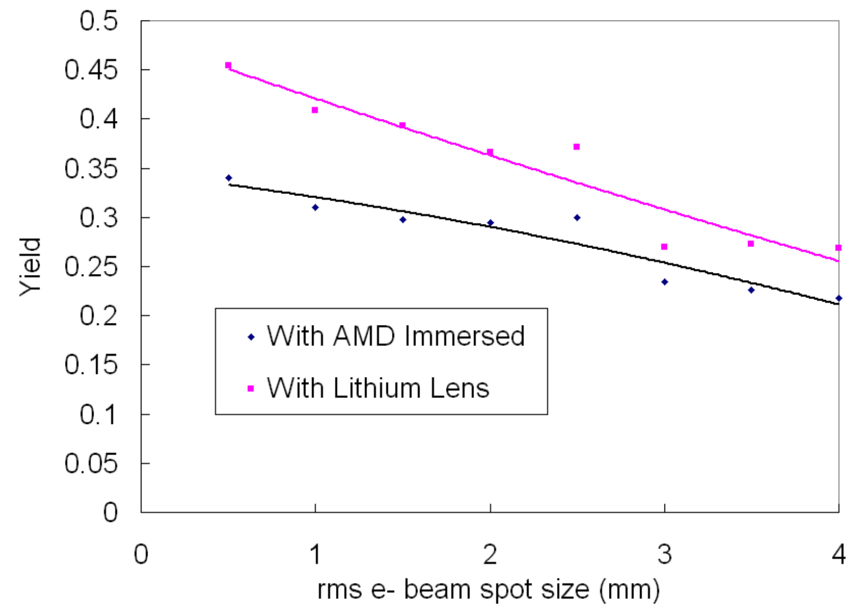
As showing in this figure, the maximum yield is about 0.46 when lithium lens is about 4cm thick and driven by 30KA current.

Comparing with yield of~0.33 achieved by using AMD and immersed liquid lead target, using lithium lens only enhanced the capture by ~40%.

e+ Yield for different rms spot size of drive e- beam (ANL)



600MeV e- drive beam

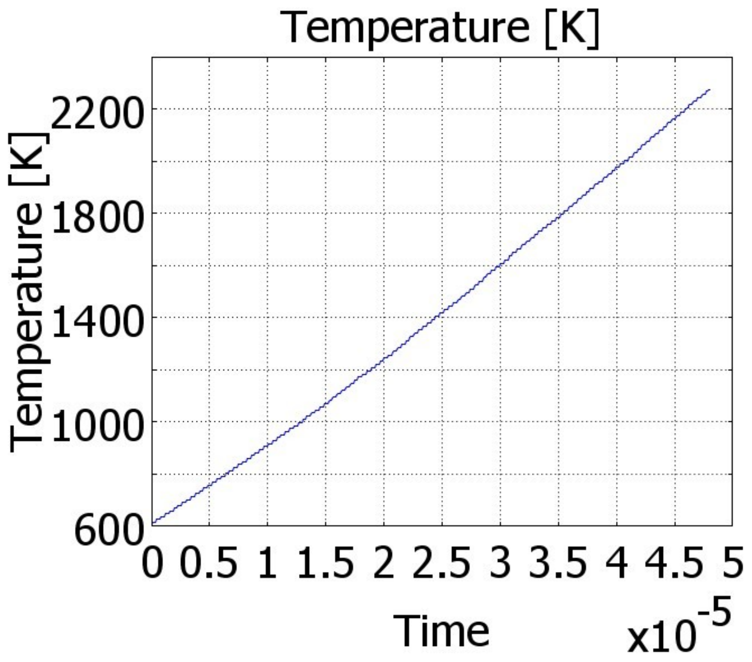


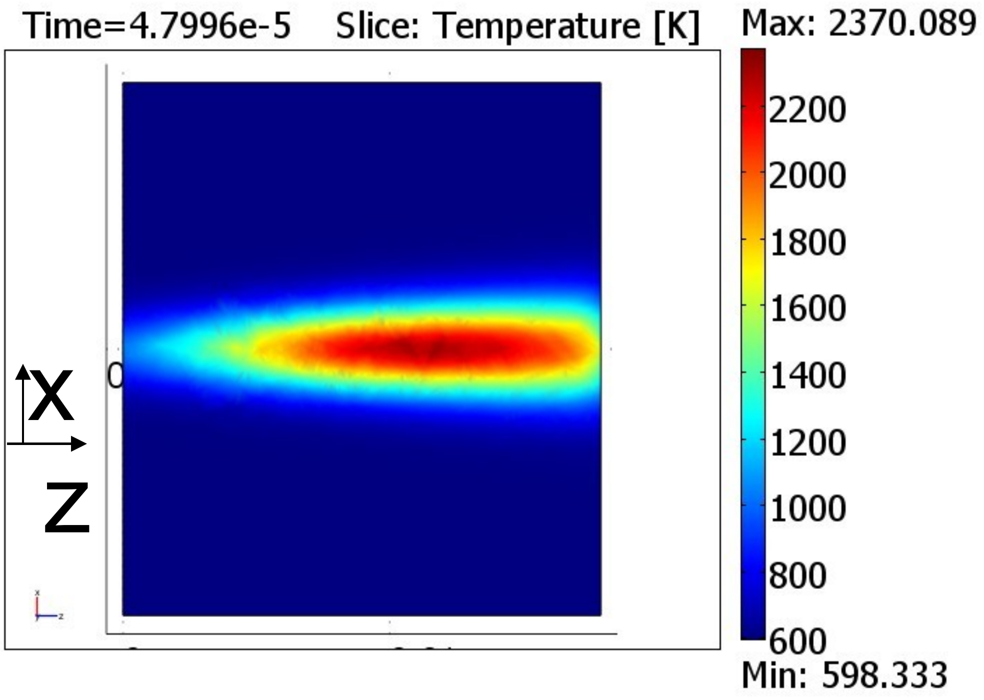
700MeV e- drive beam

AMD is 6T to 0.5 T in 14 cm for all data points.
Lithium lens parameters are optimized for each case. We optimized both the thickness and the driving current density. The current is assumed to be uniform in the lens.

Increasing of the drive e- beam spot size will lower the yield enhancement from lithium lens.

Heat transfer simulation up to 130 bunches, 700MeV drive beam, 1mm spot size, AMD immersed target (ANL)





The difference between 700MeV and 600MeV drive e- is very small at this point.

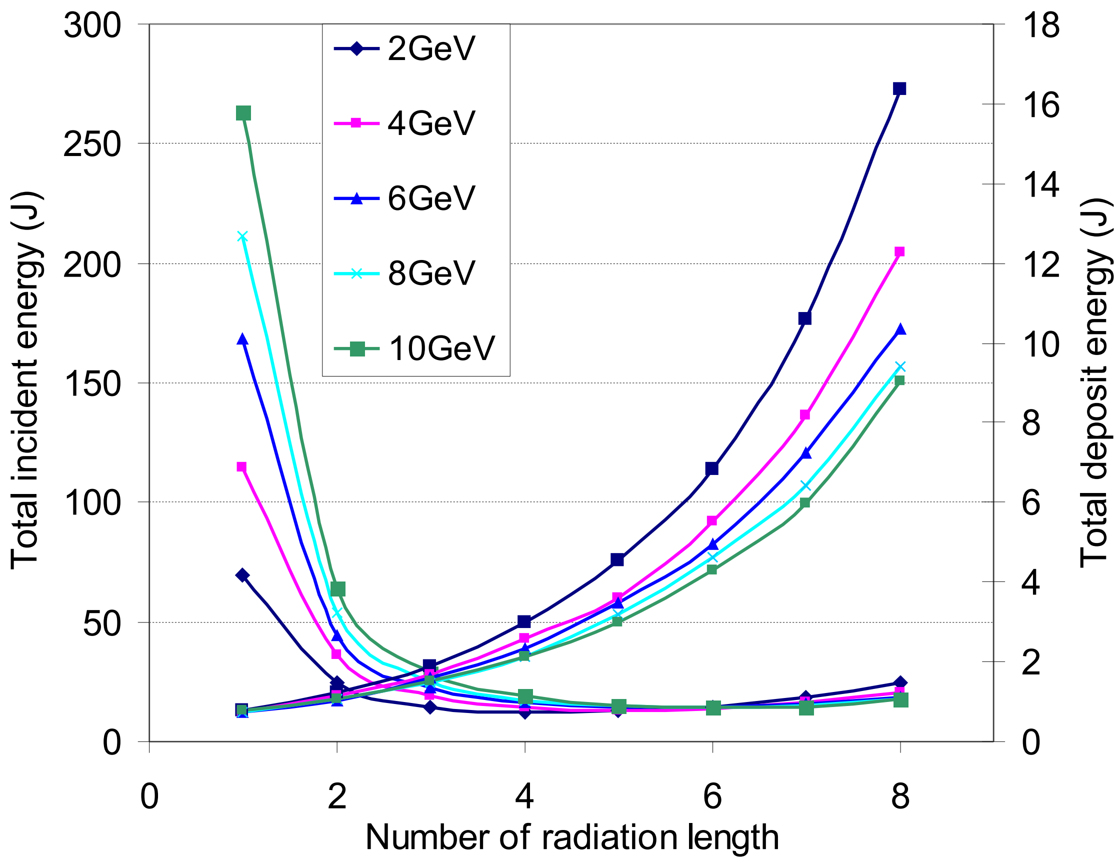
Summary of the studies

Name	e- (GeV)	Spot (mm)	Pb flow (m/s)	Yield e+/e-	Ne- (nC)	NB limit
MK1	0.7	2.5	-	0.27	11.85	-
MK2	1.4	2.5	-	0.48	6.67	-
MK3	2.2	2.5	-	0.71	4.51	-
ANL1	0.7	1.0	10	0.45	7.11	182
ANL2	0.7	3.0	10	0.27	11.85	1200
ANL3	0.7	3.0	30	0.27	11.85	Saturated at 1973K
ANL4	0.7	4.0	30	0.27	11.85	Saturated at 1600K

- MK proposed 2.2 GeV drive beam.
- Boiling of Liquid Pb (2200K) is a serious problem according to ANL's study.
- High speed flow (20-30m/s) and larger spot size (2-3mm) help to avoid the boiling.

Total incident energy and deposit energy (ANL)

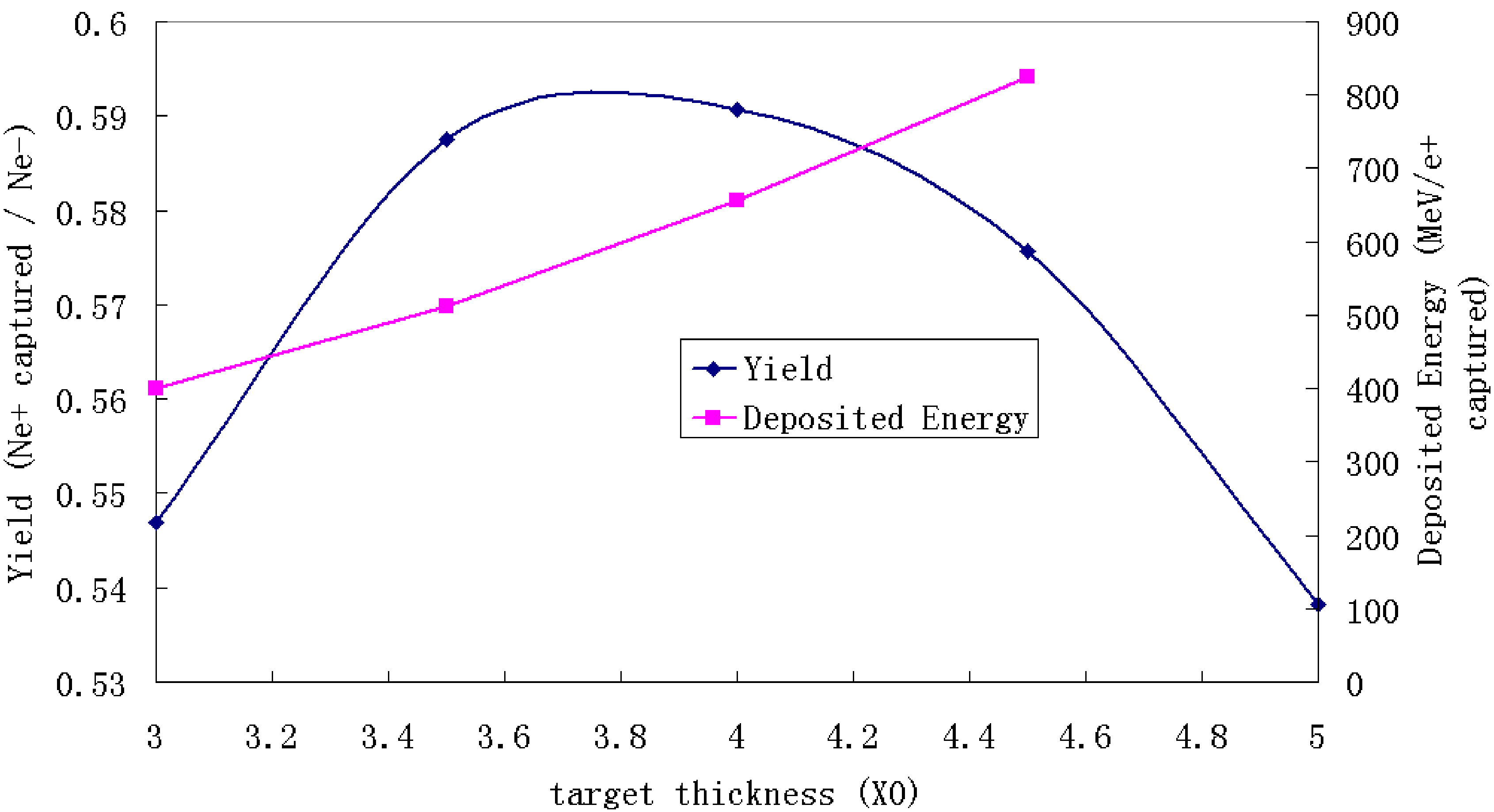
Assuming 3nC e+ are captured



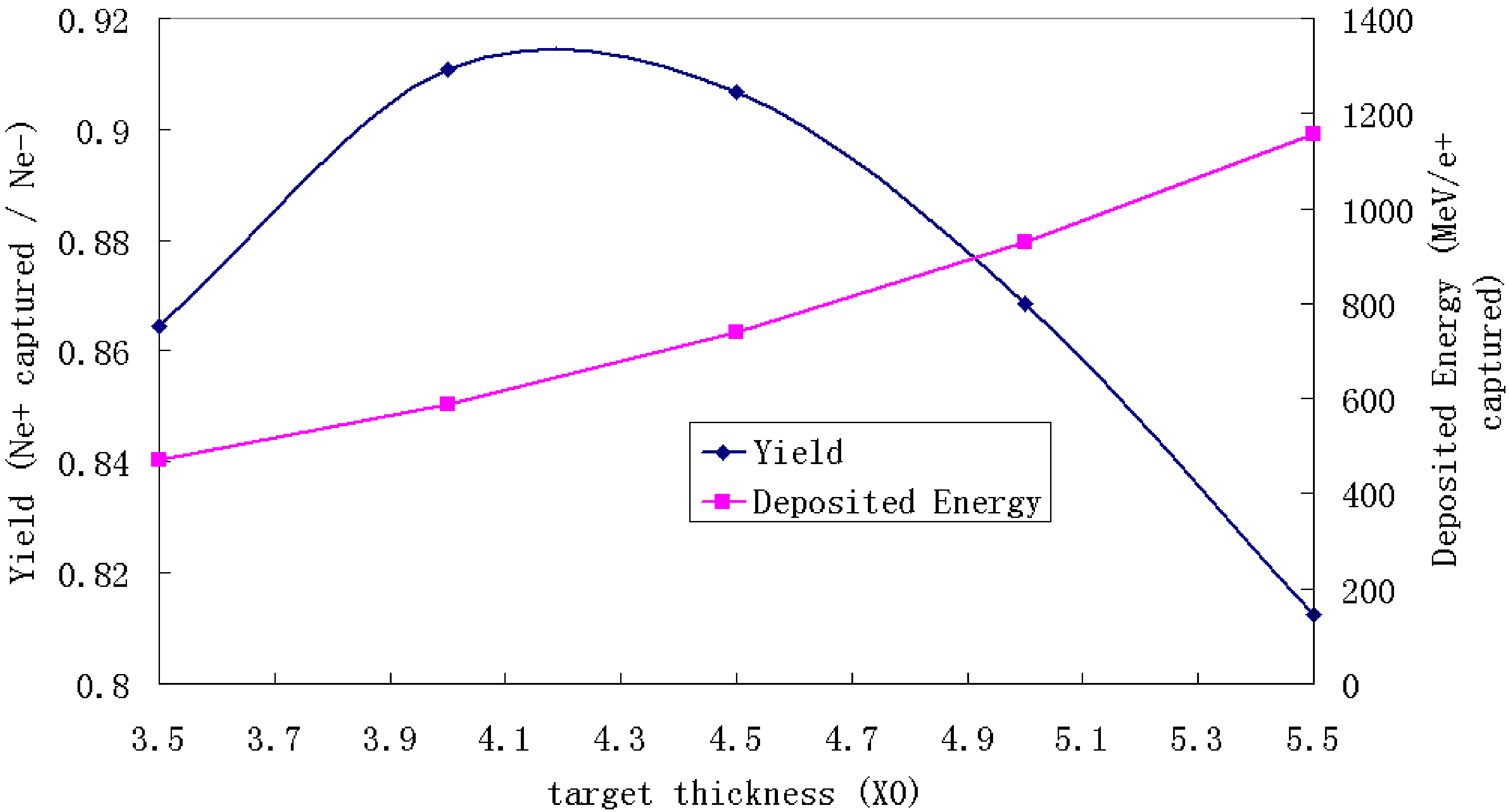
This figure from our previous conventional e+ source study shows that lower drive beam energy will result in a higher energy deposition in target.

Energy deposition per captured e+ strongly depends on X_0. (Comment by MK)

1440MeV Drive beam, Yield and energy deposition (ANL)



2200MeV drive beam, Yield and energy deposition (ANL)



Optimization (MK)

- ►The positron yield as a function of X_0 has an optimum point, but the dependence is not strong.
- ►On the other hand, the energy deposition per captured positron is simply increased as a function of X_0.
- ►By considering both facts, another optimum is lower side of the extremum of the yield.

For 2.0 GeV drive beam

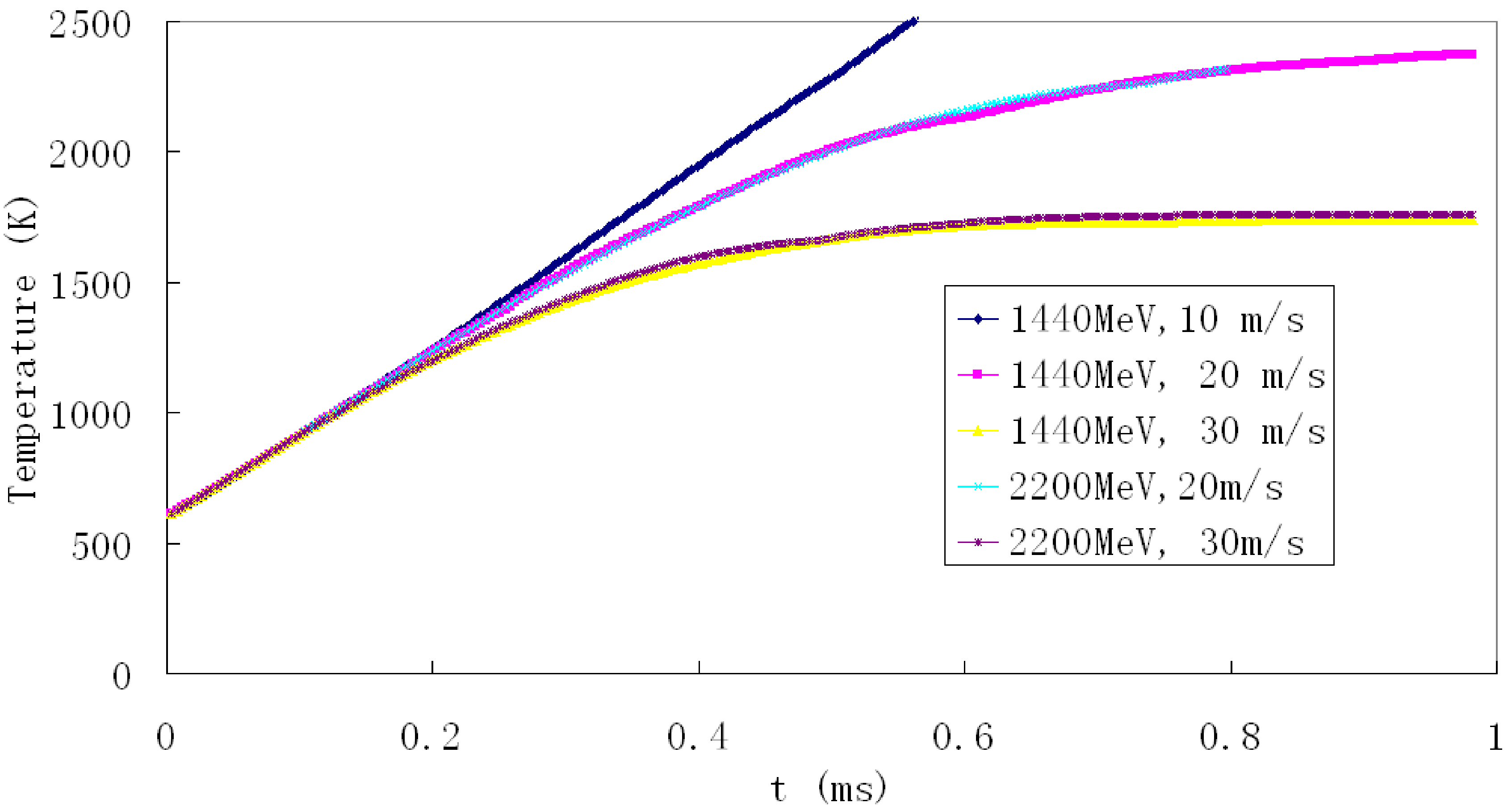
X0	Yield (Ne+/Ne-/GeV)	Energy Deposit per e+ (J/3nC)
2	0.2	1.54
3	0.32	1.88
4	0.37	3
5	0.35	4.52

Optimization(2)

- Let me assumed 3 X_0 operation, rather than $4X_0$ for 2.2GeV drive beam.
- The positron yield (N_{e+}/N_{e-}) for 2.2GeV drive beam is 0.32x2.2=0.70.
- Taking account the DR acceptance and enhancement by lithium lens (30%), the yield becomes 0.70x0.87x1.3=0.80.
- The drive beam intensity giving 3.2nC e+ bunch is 3.2/0.8=4.0nC.

X0	Yield (Ne+/Ne-/GeV)	Energy Deposit per e+ (J/3nC)
2	0.2	1.54
3	0.32	1.88
4	0.37	3
5	0.35	4.52

Evolution of Temperature(ANL)



Drive beam spot size: rms 3mm for both 1440MeV and 2200MeV.
Target thickness: 3X0 for 1440MeV, 3.5X0 for 2200MeV

Pb boiling extrapolation

- 2.2GeV, 4.0nC drive beam cause 1.65 J energy deposition per bunch.
- ANL's Pb boiling study was made with 2.30 J energy deposition per bunch.
- If the temperature rise is scaled as the energy deposition, the expected results are

Name	e- (GeV)	Thickness (X_0)	Spot (mm)	Pb flow (m/s)	Yield e+/e-	Ne- (nC)	NB limit
MKV1	2.2	3	1.0	10	0.80	4.00	250
MKV2	2.2	3	3.0	10	0.80	4.00	1670
MKV3	2.2	3	3.0	30	0.80	4.00	Saturated at 1590K
MKV4	2.2	3	4.0	30	0.80	4.00	Saturated at 1300K
ANLV1	1.4	3	3.0	20	0.55	5.82	1600
ANLV2	2.2	3.5	3.0	30	0.86	3.7	Saturated at 1800K

Pb boiling extrapolation (2)

Name	e- (GeV)	Thickness (X_0)	Spot (mm)	Pb flow (m/s)	Yield e+/e-	Ne- (nC)	NB limit
MKV1	2.2	3	1.0	10	0.80	4.00	250
MKV2	2.2	3	3.0	10	0.80	4.00	1670
MKV3	2.2	3	3.0	30	0.80	4.00	Saturated at 1590K
MKV4	2.2	3	4.0	30	0.80	4.00	Saturated at 1300K
ANLV1	1.4	3	3.0	20	0.55	5.82	1600
ANLV2	2.2	3.5	3.0	30	0.86	3.7	Saturated at 1800K

- MKV1: no way?
- MKV2, ANLV1: Acceptable for LowP set.
- MKV3, MKV4, ANLV1: Acceptable for Nominal set.
- Still Big “?” on the window: BN, Be, Ti, ...

Summary

- Two independent studies on the e- driven positron source were compared.
- The positron yield calculations were consistent to each other.
- Yield enhancement by Lithium lens comparing to AMD was shown by ANL's study.
- MK's study shows 2.2 GeV drive beam is a solution, but no enhancement by LL is assumed.
- ANL's study shows that Pb boiling is a serious issue. Larger spot size and higher flow speed avoid the boiling.

Summary (cont.)

- Accounting both yield and energy deposition, low X_0 point is another optimum.
- By assuming 2.2GeV drive beam, 30 m/s flow speed is required to avoid the boiling.
- 10 m/s speed is acceptable for LowP set.
- According the newest result of ANL party, to avoid the Pb boiling, 1.4 and 2.2 GeV driver requires 20 and 30 m/s flow speed for LowP and nominal sets, respectively.