Truly Conventional e^+ Source for ILC

T. Omori (KEK)

25-Oct-2011

Baseline Technical Review at DESY

Truly Conventional Collaboration

ANL, IHEP, Hiroshima U, U of Tokyo, KEK, DESY, U of Hamburg

Wei Gai, Jie Gao, Shin-ichi Kawada, Wanming Liu, Natsuki Okuda, Tsunehiko Omori, Guoxi Pei, Sabine Riemann, Tohru Takahashi, Junji Urakawa, and Andriy Ushakov

paper; arXiv:1110.1450 --> going to submit to NIM A

Special Thanks to Takahashi-san:

About half of the slides are taken from Takahash-san's talk at ALCPG11&e+meeting@IHEP

300 Hz scheme

e+ generation in 63 m sec (cf. undulator : in 1 m sec)

How?

- Total Number of bunches: 2640
- Divide into 20 triplets
  (1 Triplet = 3 Mini-Trains)
- Each triplet contains 132 bunches
- 2640 = 20 x 132
- 300 Hz creation of triplets
  triplet to triplet time space = 3.3 m sec
- Create 20 triplets : 63 m sec

→ **Stretching in time**

Conventional e+ Source for ILC

Normal Conducting Drive and Booster Linacs in 300 Hz operation

e+ creation

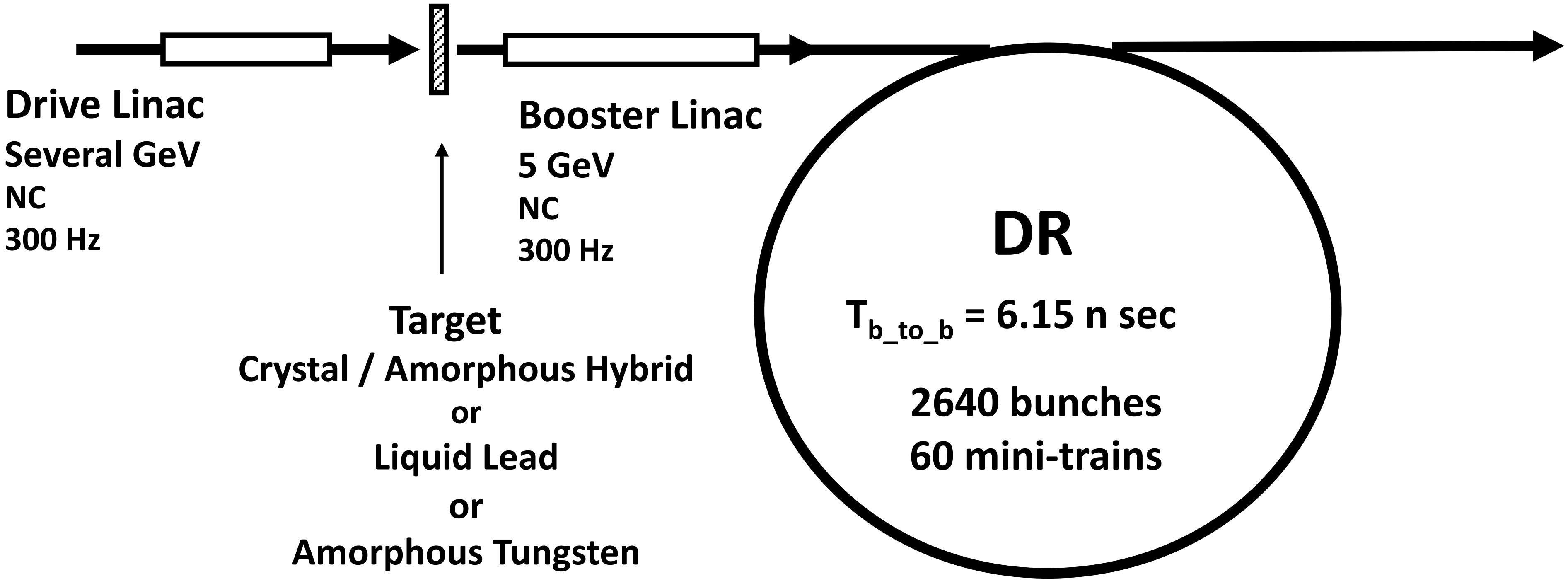
20 triplets, rep. = 300 Hz

- triplet = 3 mini-trains with gaps
- 44 bunches/mini-train, $T_{b\_to\_b}$ = 6.15 n sec

go to main linac

2640 bunches/train, rep. = 5 Hz

- $T_{b\_to\_b}$ = 369 n sec

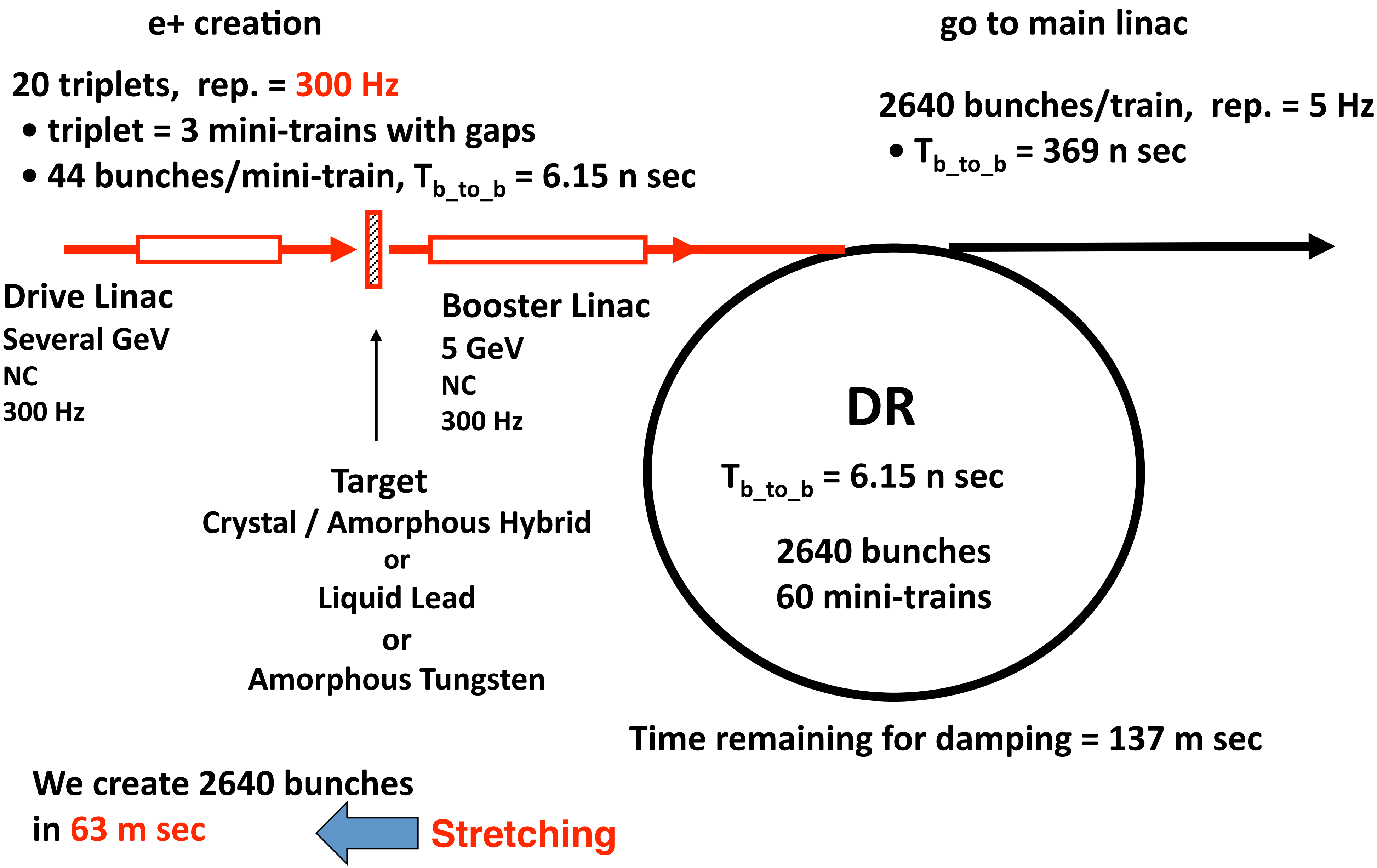


Time remaining for damping = 137 m sec

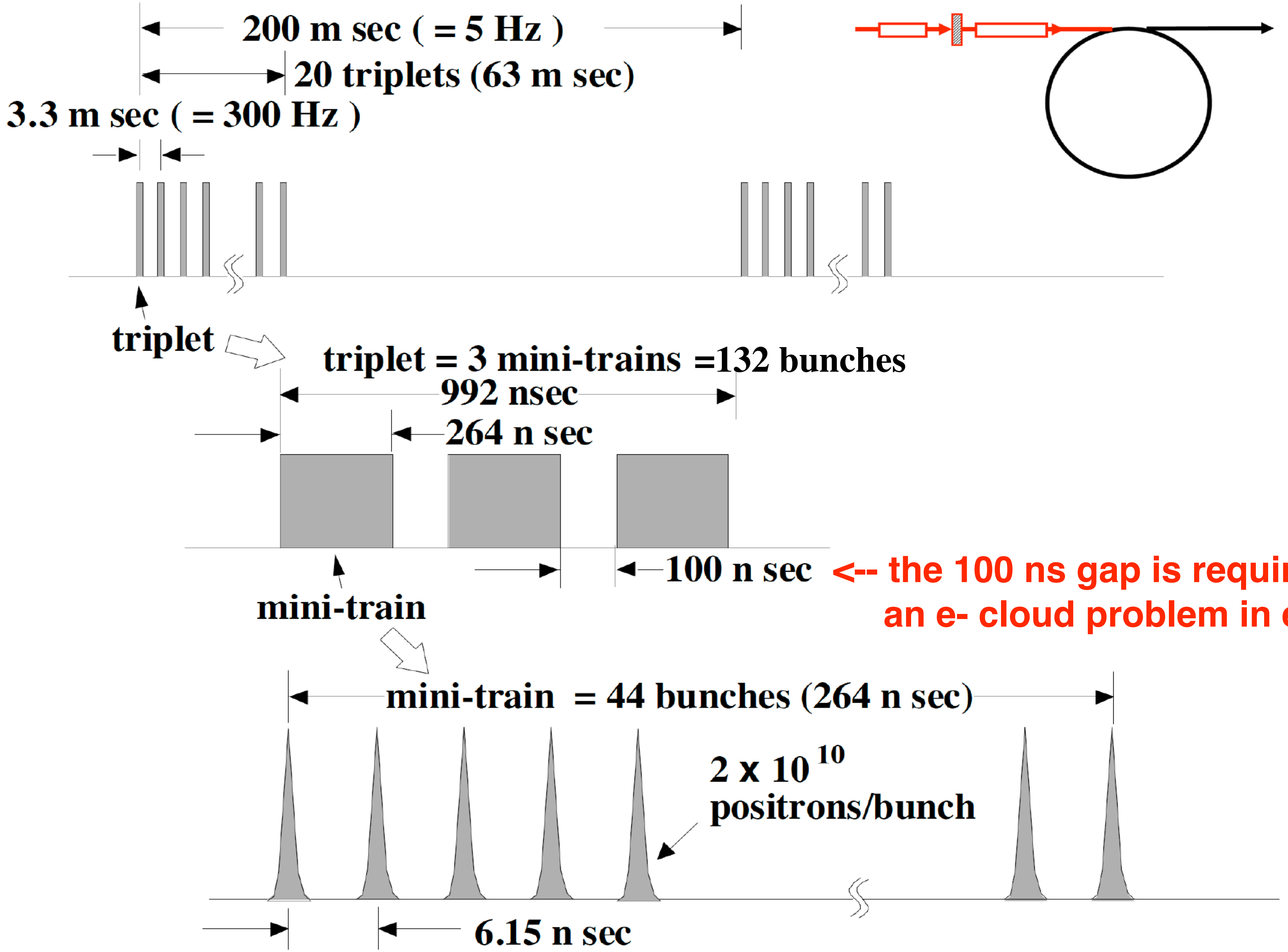
We create 2640 bunches in 63 m sec

Conventional e+ Source for ILC

Normal Conducting Drive and Booster Linacs in 300 Hz operation

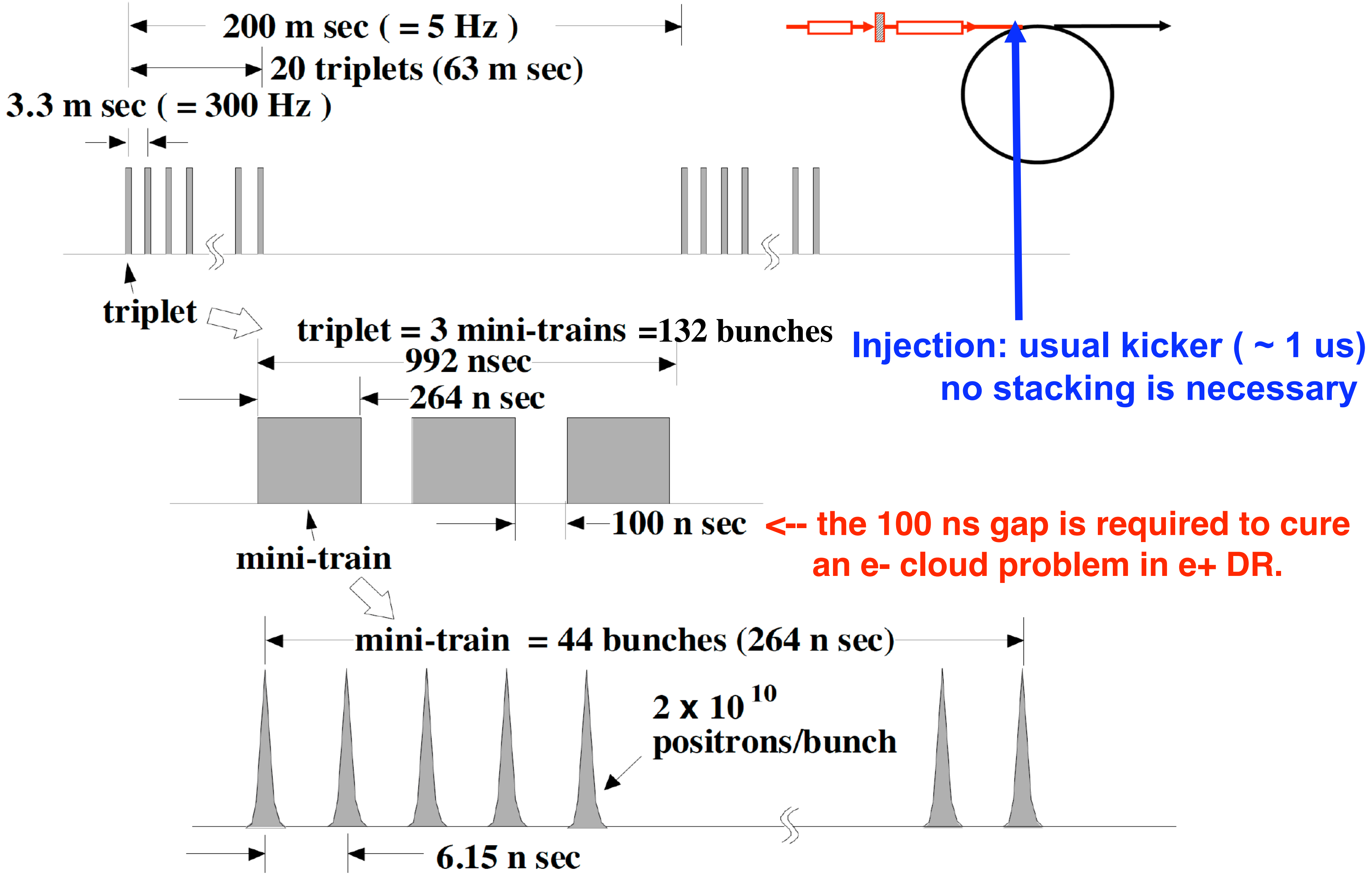


Beam before DR



<-- the 100 ns gap is required to cure an e- cloud problem in e+ DR.

Beam before DR



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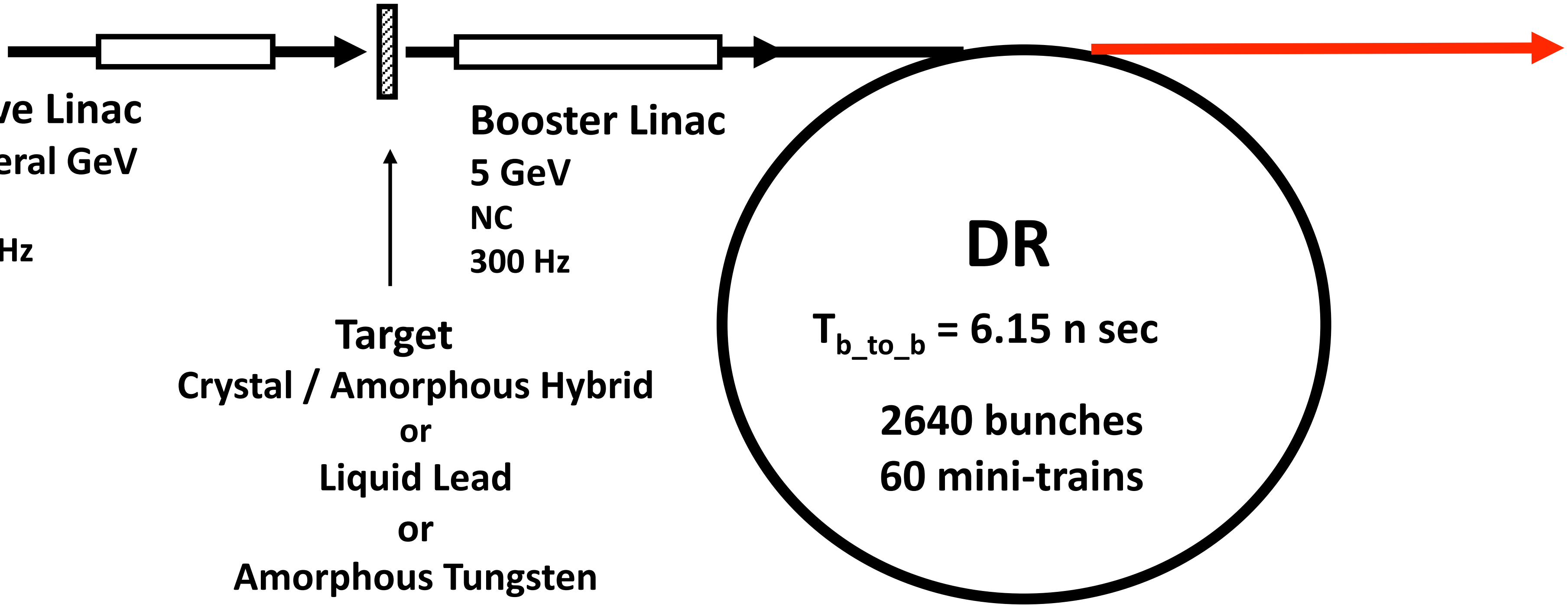

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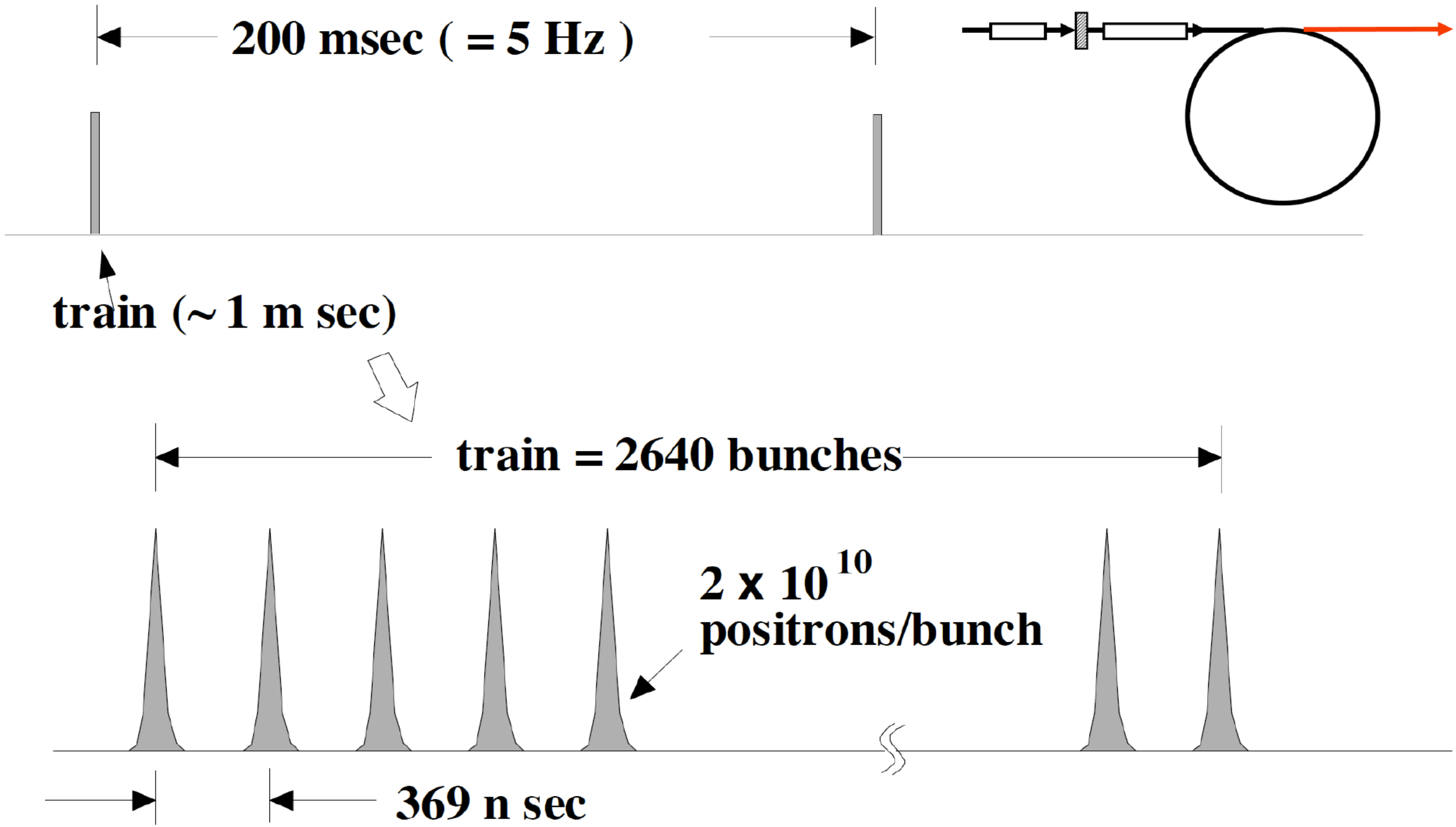
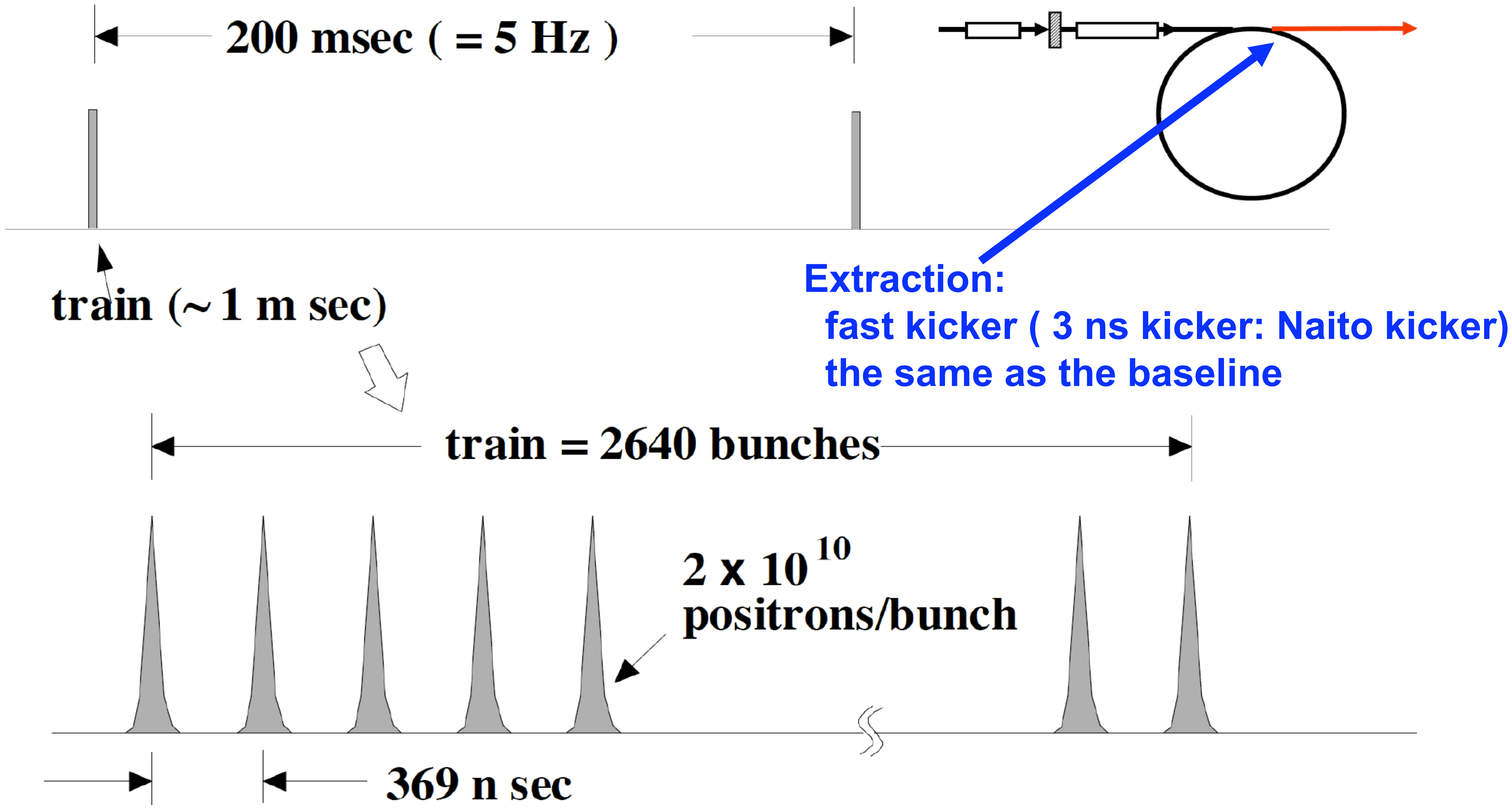


Beam after DR



300 Hz scheme

- Stretching in time

300 Hz scheme

- Stretching in time

- The Same as Warm colliders

  NLC 120 Hz
  GLC 150 Hz
  CLIC 50 Hz

Conventional e+ Source for ILC

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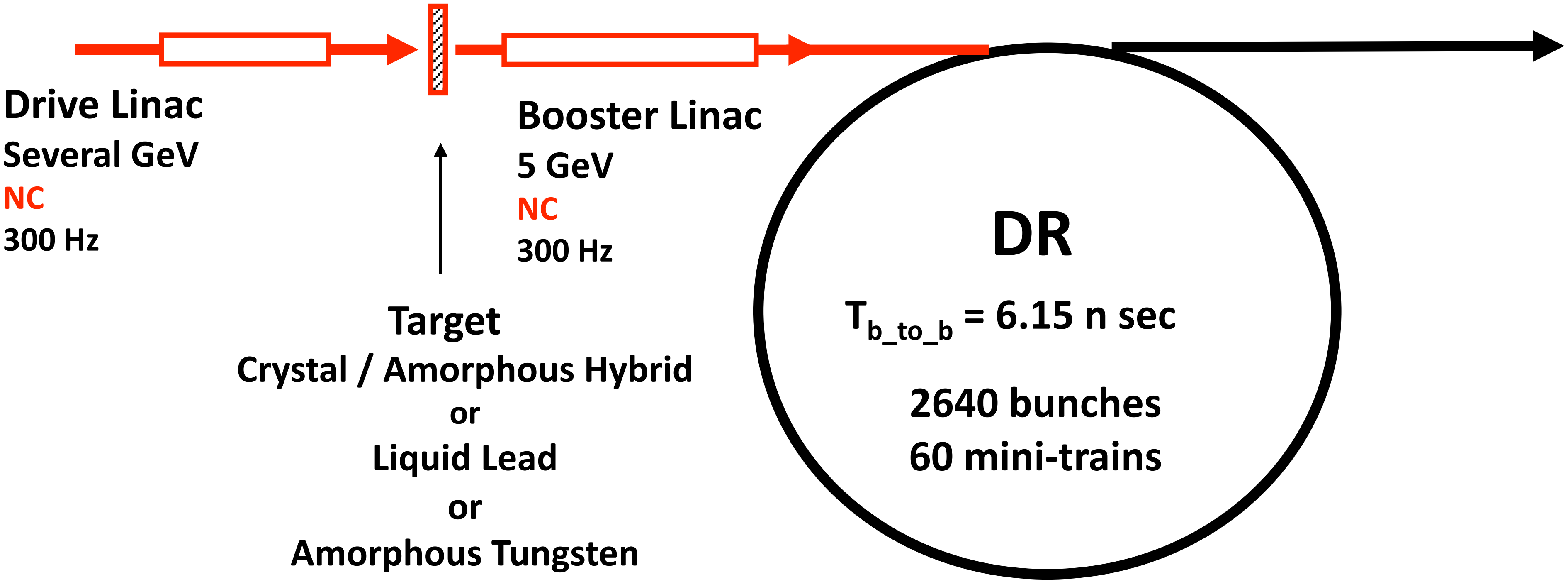

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Stretching

300 Hz scheme

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NLC 120 Hz
GLC 150 Hz
CLIC 50 Hz

Employs 3-4 targets (NLC, GLC)
Thermal Shockwave

300 Hz scheme

- Stretching in time

- The Same as the Warm colliders

  NLC 120 Hz
  GLC 150 Hz
  CLIC 50 Hz

  (NLC and GLC) → Employs 3-4 targets
  Thermal Shockwave

- We try to employ single target.

  Crystal / Amorphous Hybrid
  or
  Liquid Lead
  or
  Amorphous Tungsten

300 Hz scheme

- Stretching in time

- The Same as the Warm colliders

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  GLC 150 Hz
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  ← Employs 3-4 targets
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  Just solid tungsten target is OK
  with slow rotation.

  Truly Conventional

Conventional e+ Source for ILC

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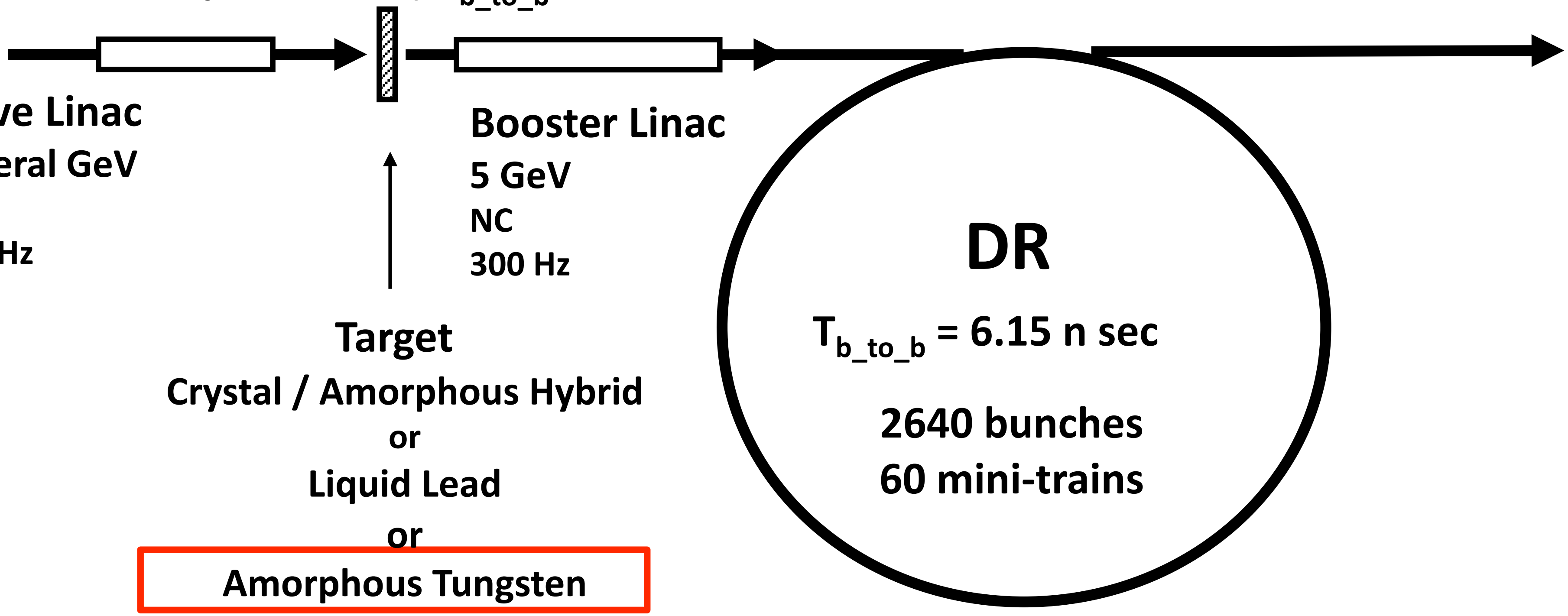


Truly Conventional

Time remaining for damping = 137 m sec

We create 2640 bunches
in 63 m sec

Target and Drive_Beam Optimization for Truly Conventional e+ Source

Method

EM shower simulation

e+ yields
Peak Energy Deposit Density (PEDD)
total energy deposit

e+ capture efficiency

of e+ in the Damping Ring

Geant 4

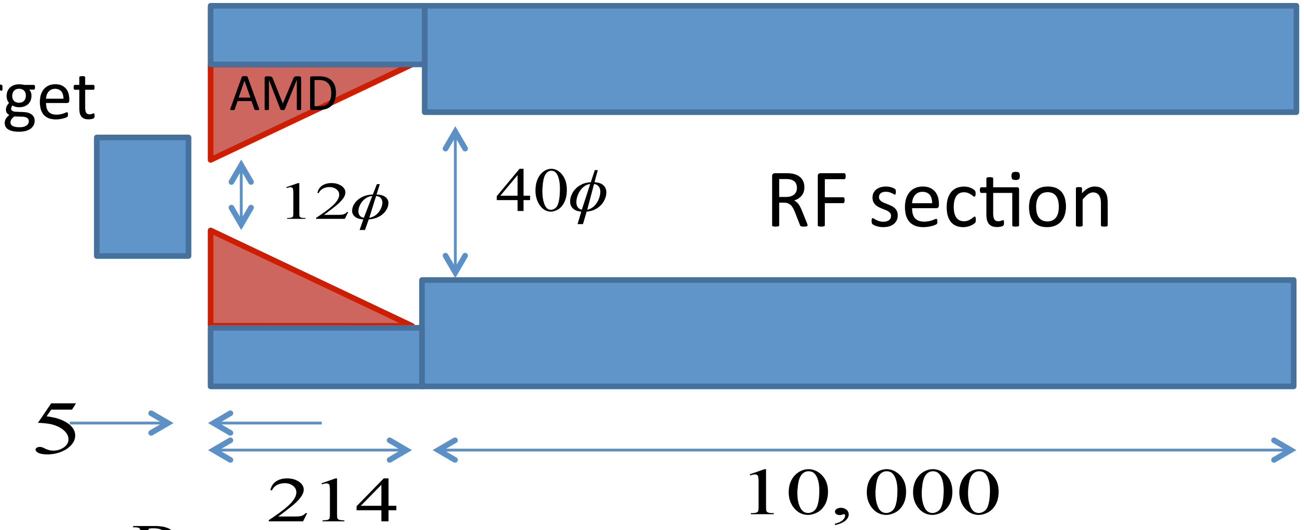
+

Empirical formula by CLIC note 465

EM shower and particle tracking w/ Geant 4

Parameters in capture section

300Hz scheme w/ slow rotation target ～ CLIC



$$Bz(z) = \frac{B_0}{1+\mu z} + B_{sol}$$

$$E_z = E_0 \cos(kz - \omega t + \varphi)$$

$$E_0 = 25MV/m$$

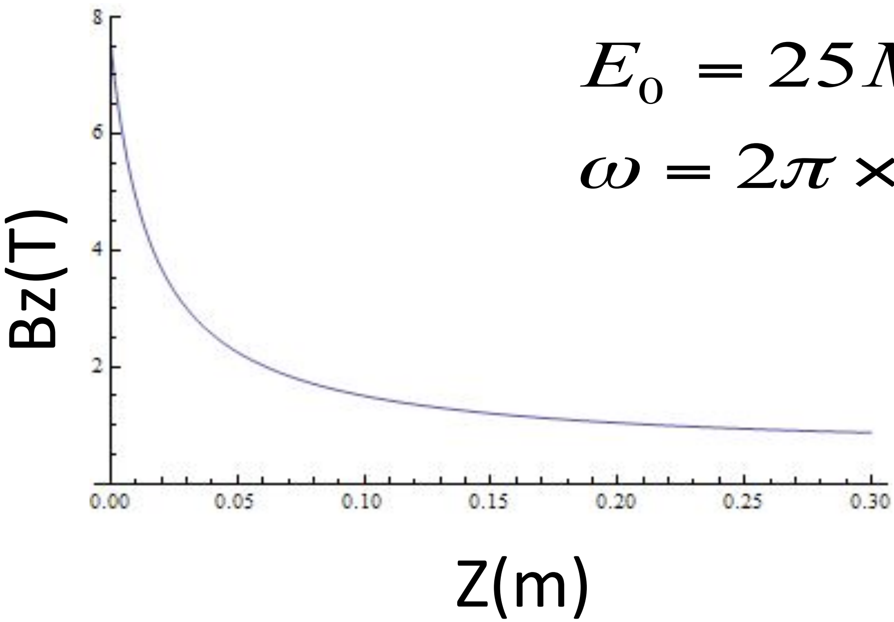
$$\omega = 2\pi \times 1.3GHz$$

$$B_0 = 7T$$

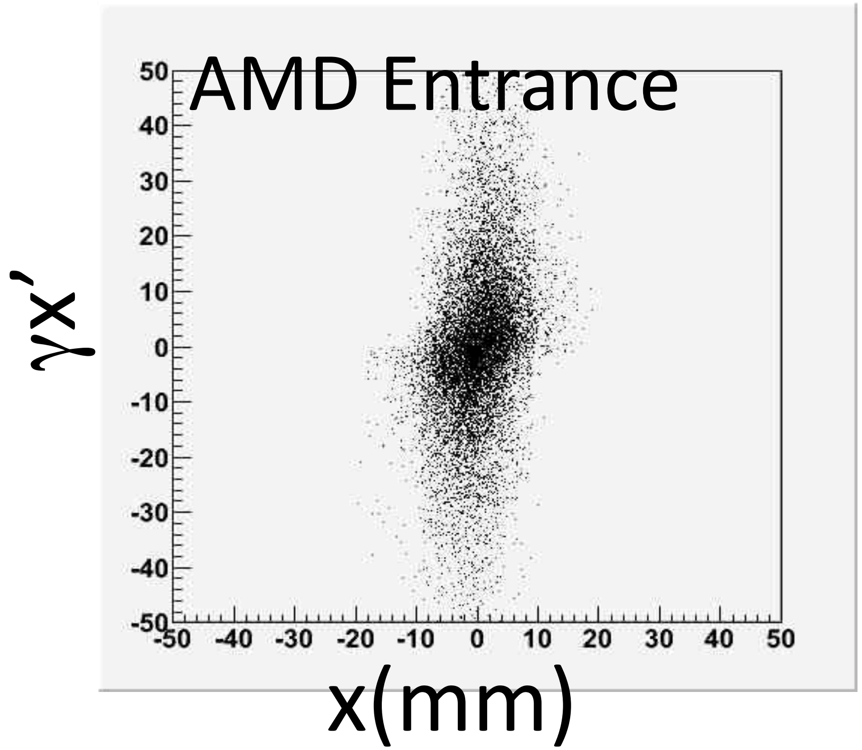
$$\mu = 60.1m^{-1}$$

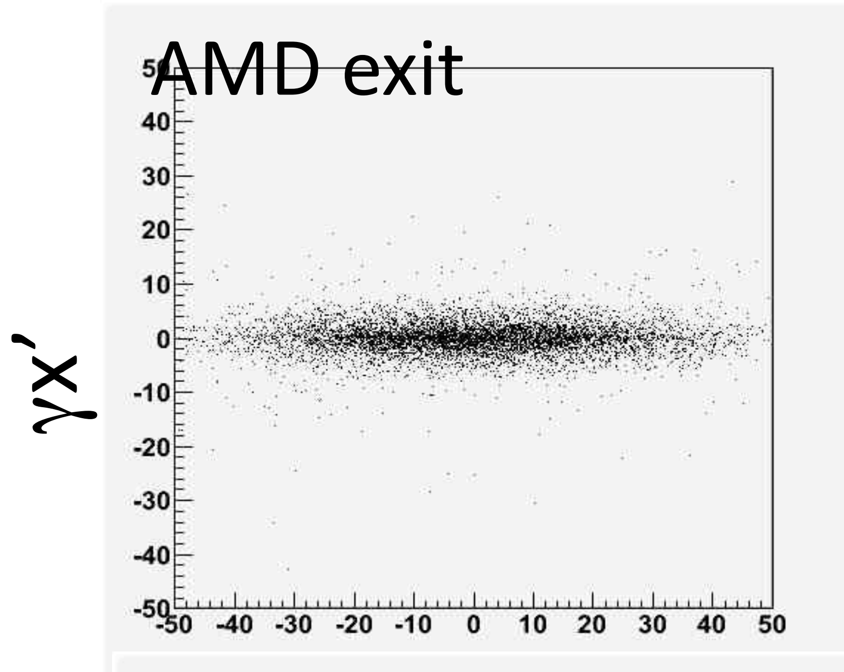
$$B_{sol} = 0.5T$$

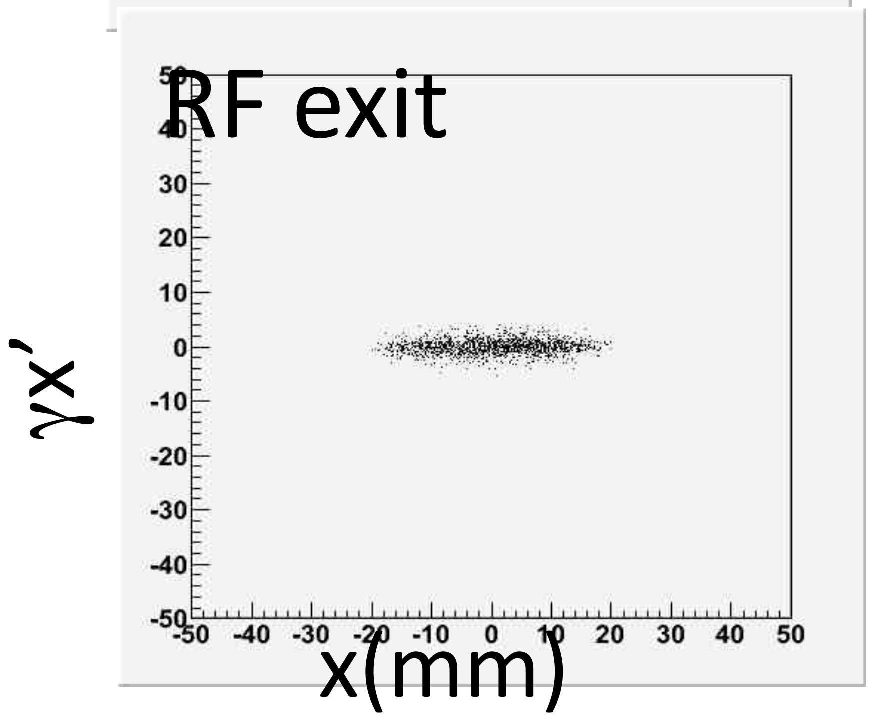
$$Br(r,z) = -\frac{1}{2} r \frac{\partial B_z(z)}{\partial z} + \frac{1}{16} r^3 \frac{\partial^3 B_z(z)}{\partial z^3}$$



Simulation: Transeverse phase space





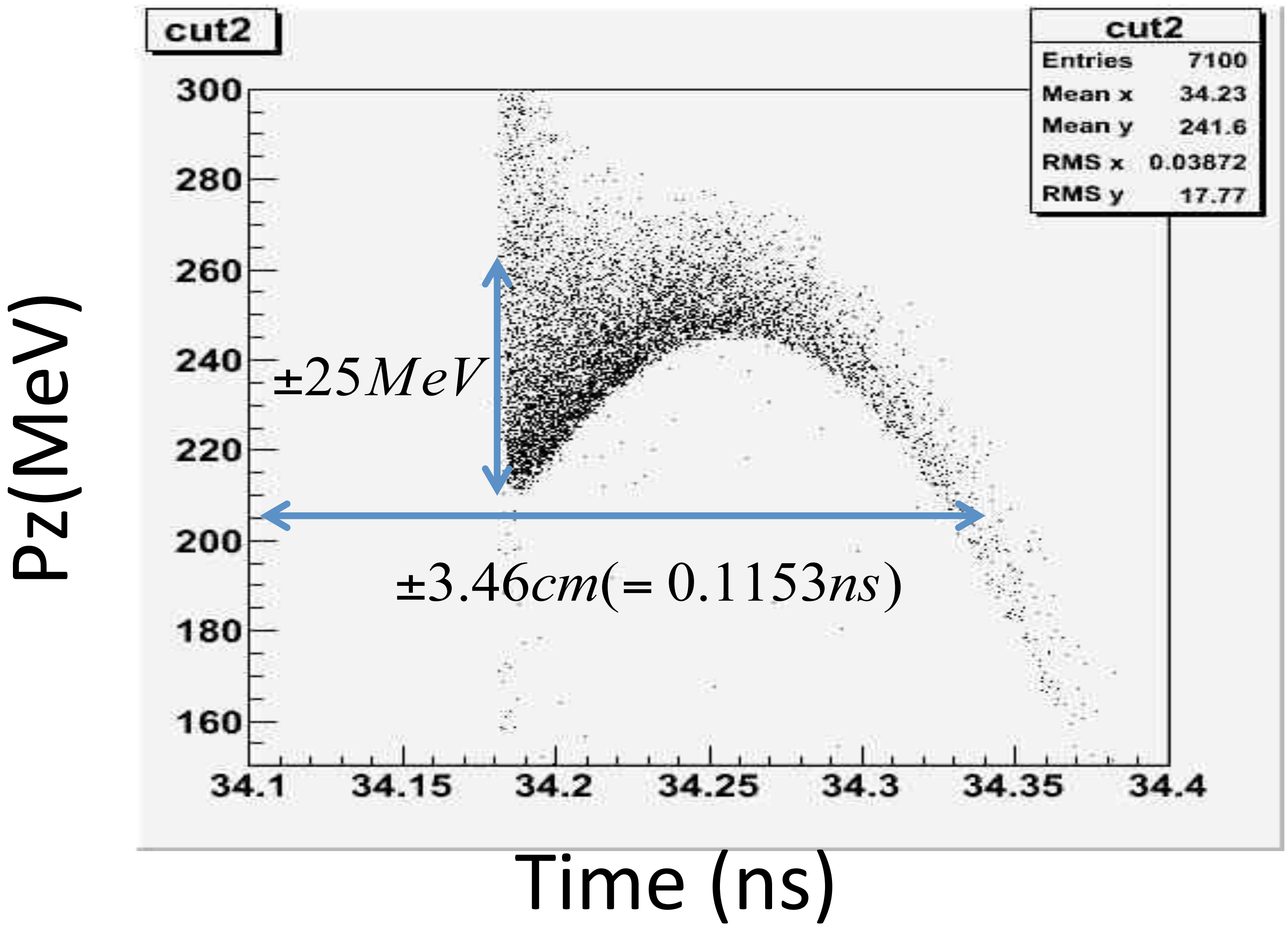


$$A_x = \gamma_x x + 2\alpha_x x(\gamma x') + \beta_x(\gamma x')^2$$

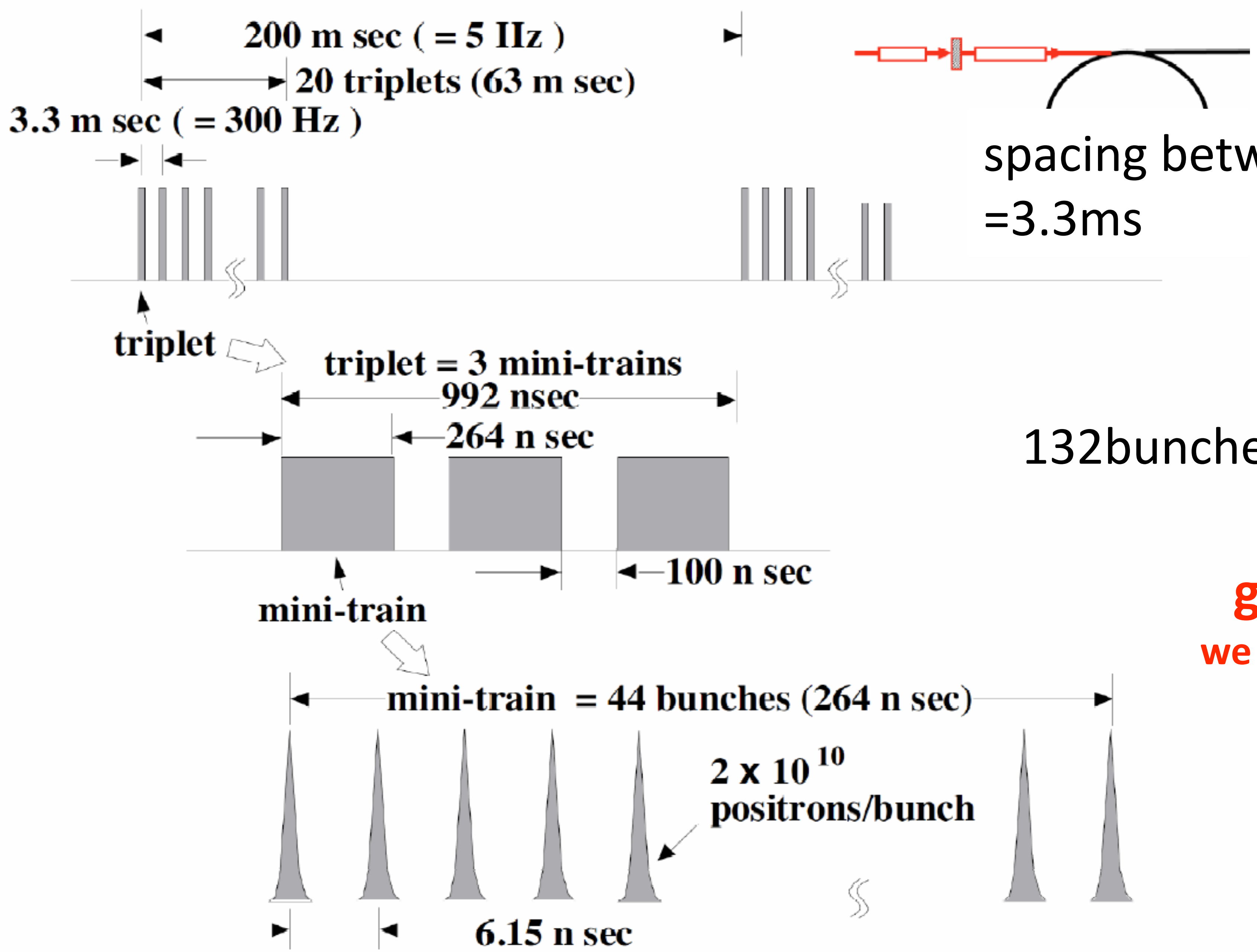
DR transverse acceptance :
fron RDR

$$A_x + A_y < 90 mm \cdot rad$$

Longitudinal phase space



In the case of 300Hz scheme



spacing between triplets
=3.3ms

132bunches in 992ns

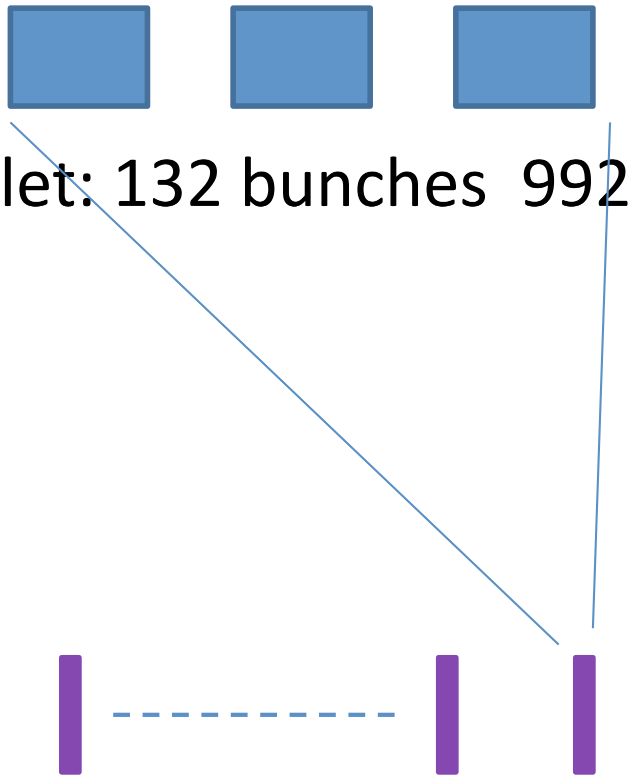
good for a FC

we can use existing FC technology

Assumptions

drive electrons

2×10^{10}/bunch

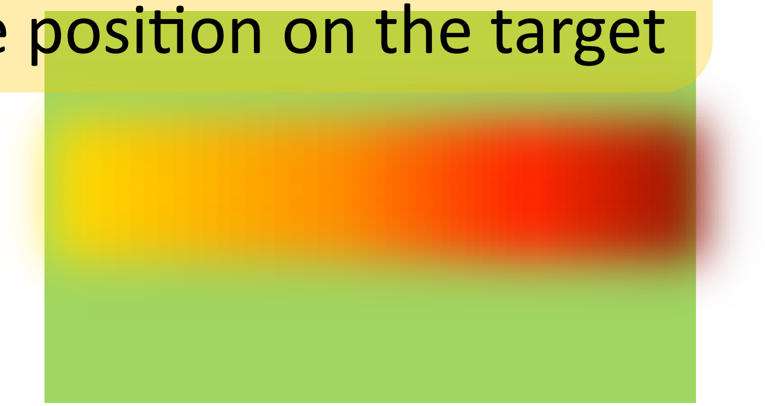


a triplet: 132 bunches 992ns

3.3ms

a train: 20 triplet
= 2640 bunches 63ms

132 bunches
make a shock wave
heat same position on the target



each triplet hits
different position on the target

slow rotation target

Parameter Plots for 300 Hz scheme

e- directly on to Tungsten

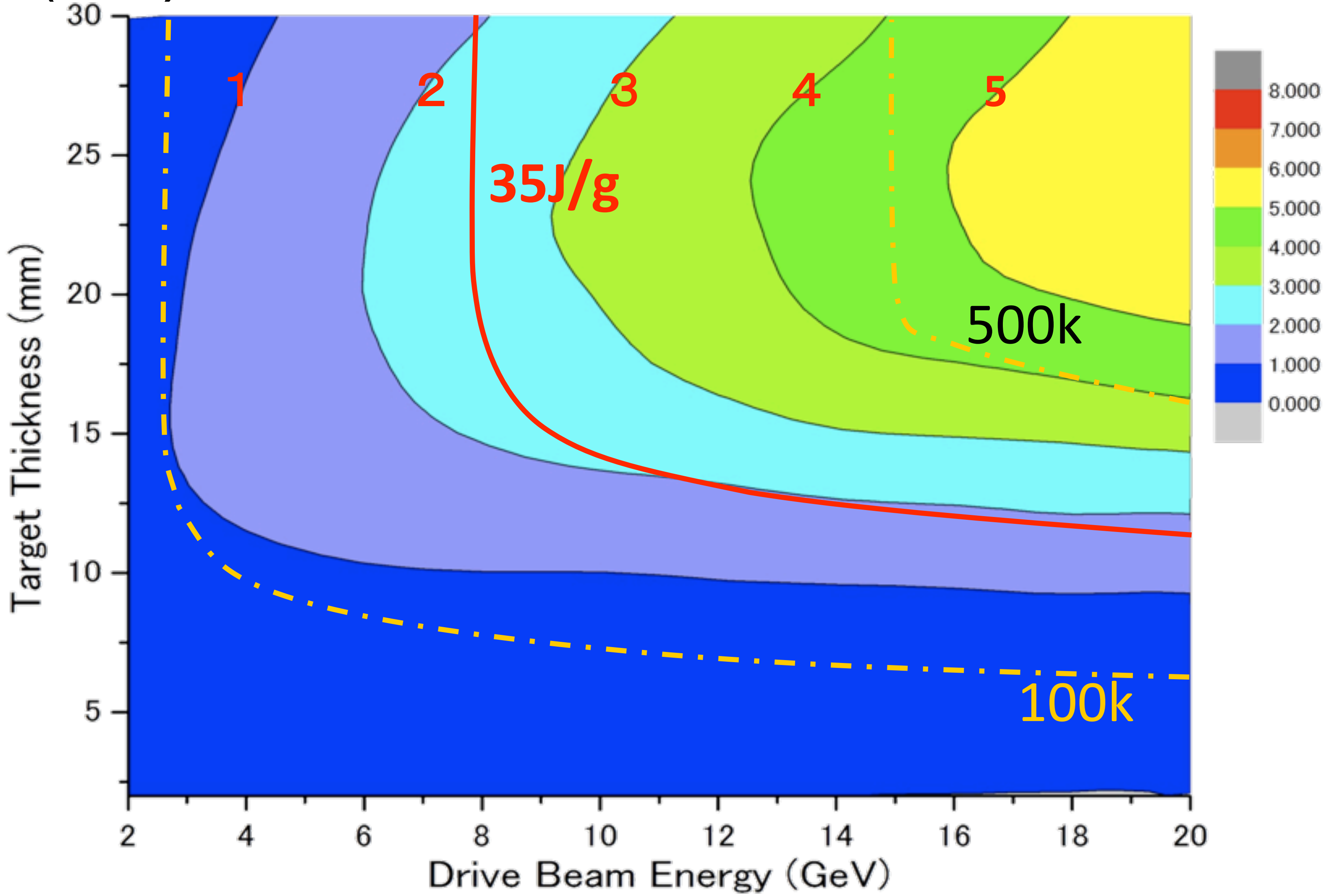
σ=4.0mm

Ne⁻(drive) = 2x10^{10} /bunch

colored band — accepted e+/e-

PEDD J/g

dT max by a triplet



Parameter Plots for 300 Hz scheme

e- directly on to Tungsten

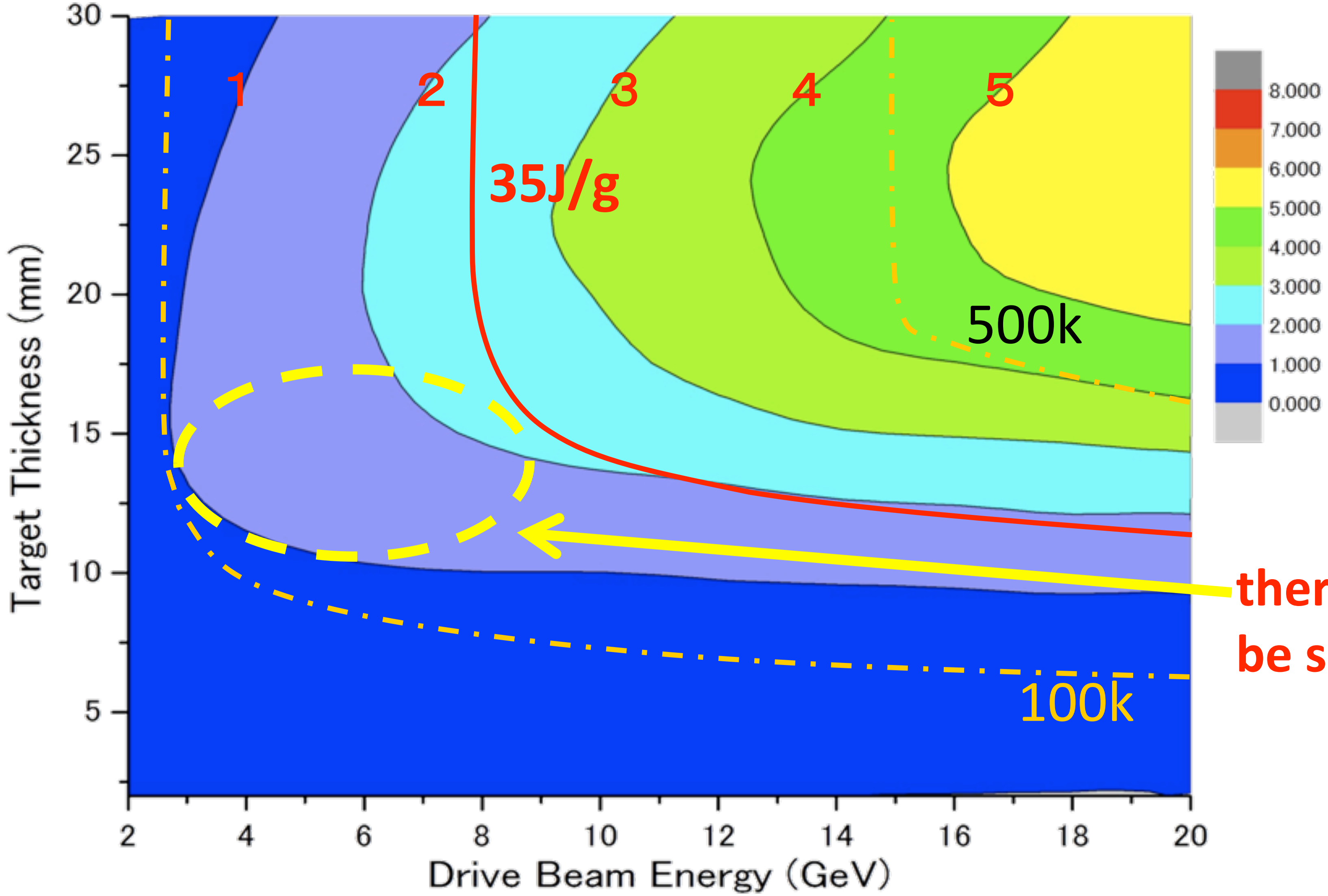
σ=4.0mm

Ne⁻(drive) = 2x10¹⁰ /bunch

colored band — accepted e+/e-

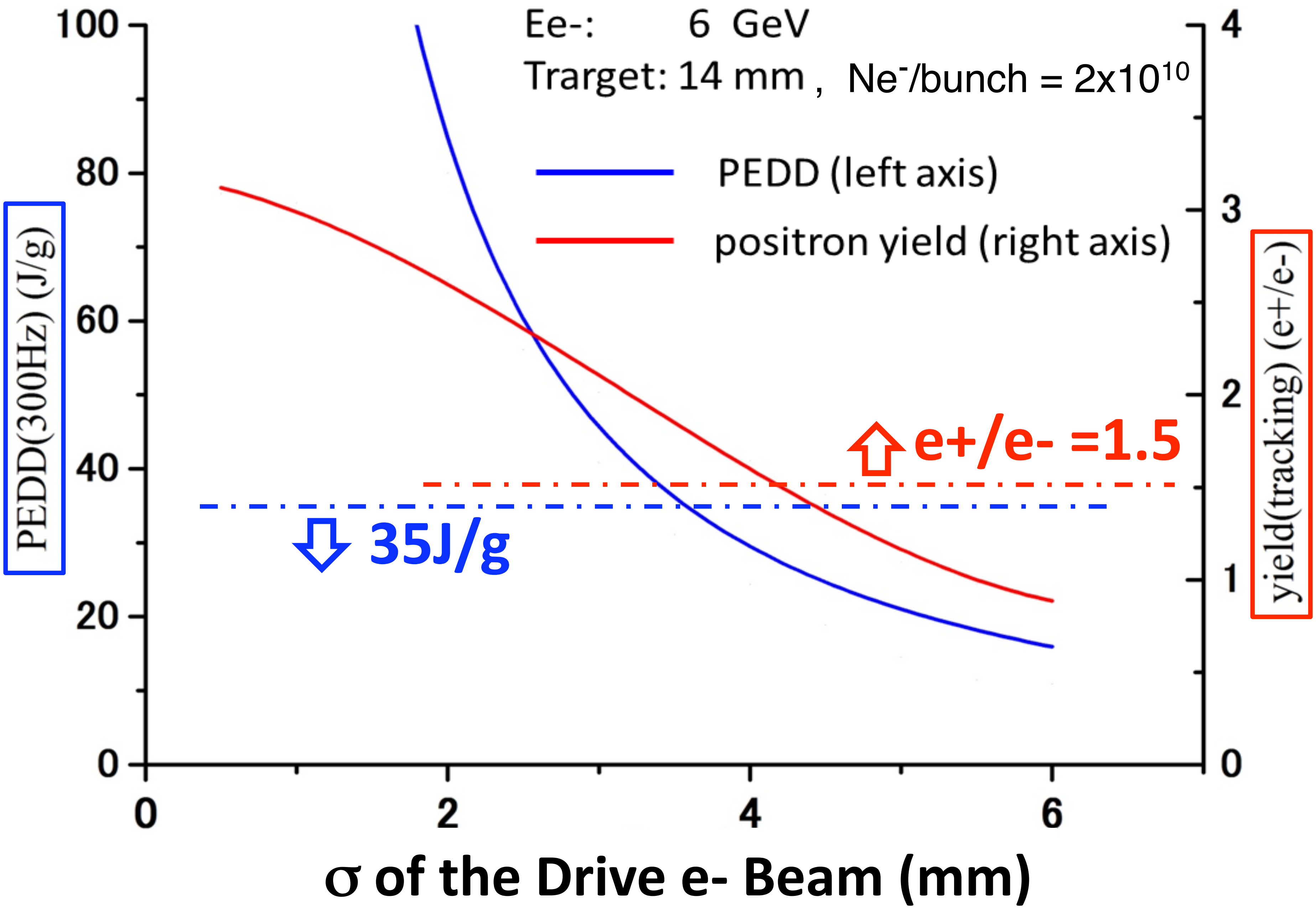
red line — PEDD J/g

dashed line — dT max by a triplet



there seems to be solutions

Dependence on Drive beam size



Numbers for a Reference Point

Parameters for target and captures		Parameters for 300Hz scheme	
Drive beam energy	6 GeV	# drive e- /bunch	2×10^{10}
Beam size	4.0 mm (RMS)	# bunches/triplet	132 (in 996ns)
Target material	Tungsten	# bunches/train	2640 (in 63 ms)
Target thickness	14 mm	repetition	5 Hz
Max AMD field	7 T	Results numbers in () are for 300Hz operation	
Taper parameter	60.1/mm	e+ yield	1.6 /e-
AMD length	214 mm	PEDD in the target	1.04 GeV/cm^3/e- (22.7 J/g)
Const. field	0.5 T	E. deposit in the target	823 MeV/e- (35kW)
Max. RF field	25 MV/m	E. deposit in the AMD	780 MeV/e- (33kW)
RF frequency	1.3 GHz	E. deposit in the RF section	470 MeV/e- (20kW)

Target Rotation Speed (Tangential)

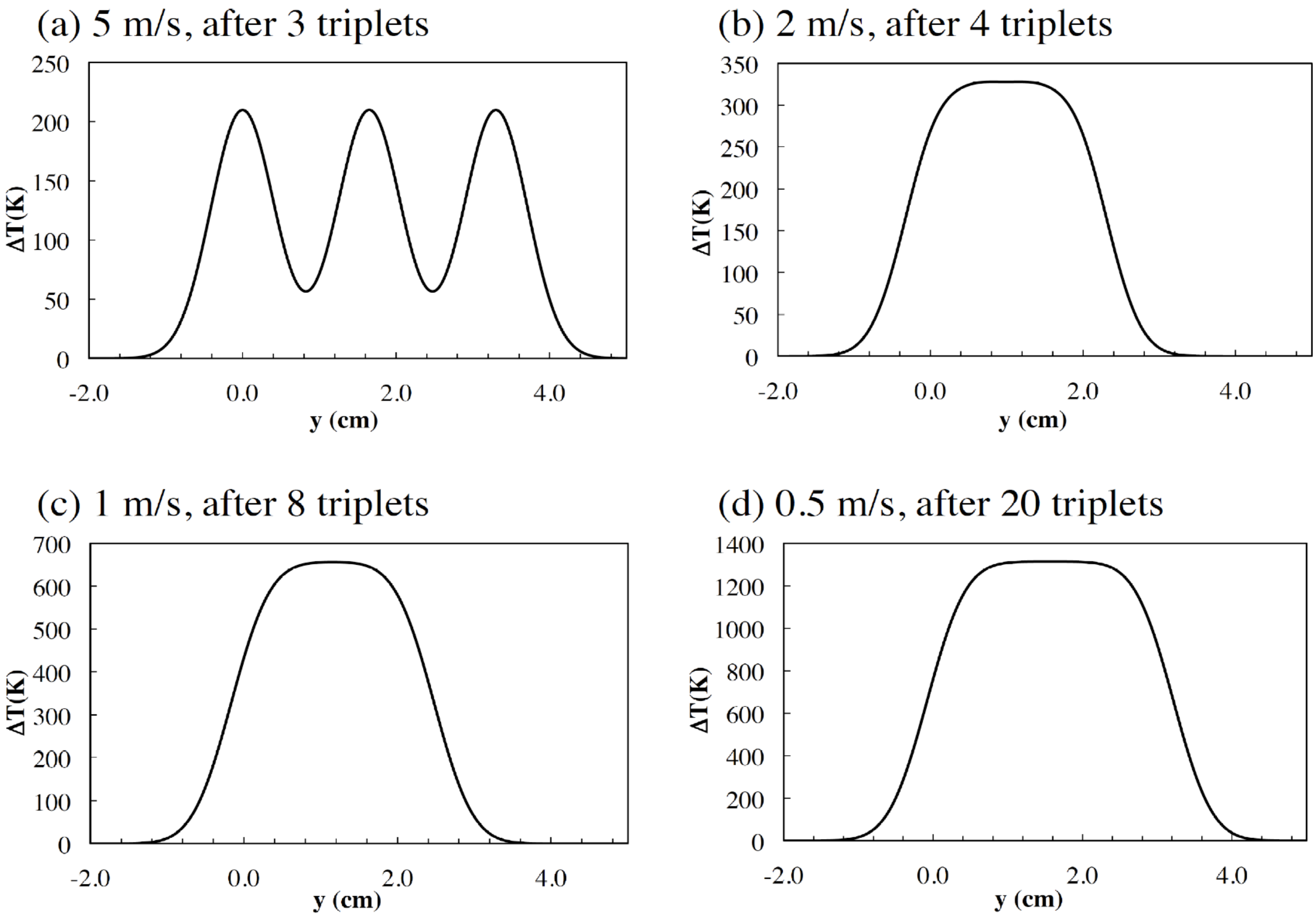
- SLC (actual achievement) :
  0.1 m/s (Swinging/Troll target: Not really rotating)

- ILC baseline (design: test is ongoing):
  100 m/s

- Truly Conventional (assumption) :
  5 m/s
  triplet and triplet are fully separated on target (spatial separation).

  0.5 m/s
  large spatial overlap between triplets --> But OK in temperature.
  Design study with cooling <-- NOT yet
  shockwave : OK because triplet to triplet separation 3.3 ms in time.
  Probably 0.5 m/s is OK.

Target Heat Simulation



300 Hz scheme

- Stretching in time

- The Same as the Warm colliders

  NLC 120 Hz
  GLC 150 Hz
  CLIC 50 Hz

  Employs 3-4 targets
  Thermal Shockwave

- We try to employ single target.

  Crystal / Amorphous Hybrid
  or
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  or
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Today's talk
Just soild tungsten target is OK with slow rotation.

Truly Conventional

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Today's talk
Just soild tungsten target is OK with slow rotation.

Why just single solid target is OK in ILC ?

Truly Conventional

What is the difference wrt GLC/NLC design

Old GLC/NLC design employed 3 targets.

Why single target can survive in ILC 300 Hz.

What is the difference wrt GLC/NLC design

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Why single target can survive in ILC 300 Hz.

Because, improved optimization in ILC 300 Hz.

What is the difference wrt GLC/NLC design

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Why single target can survive in ILC 300 Hz.

Because, improved optimization in ILC 300 Hz.

	ILC 300 Hz	GLC(JLC) 3 targets (for each)	NLC 3/4 targets (for each)
Eb	6 GeV	10 GeV	6.2 GeV
Ne-/bunch	2×10^{10}	1×10^{10}	1.5×10^{10}
N of bunches	132 (triplet)	64 (192/3)	63 (190/3)
t_target	14 mm	21 mm	14 mm
spot (σ) on target	4 mm	2.5 mm	1.6 mm
DR/preDR accpt	$\Delta E<25$ MeV	$\Delta E<19.8$ MeV	$\Delta E<10$MeV
	$\Delta T<115$ps	$\Delta T<?$	$\Delta T<30$ ps
	$\gamma A_x+\gamma A_y=0.09$ m	$\gamma A_x \& \gamma A_x<0.03$ m	$\gamma A_x \& \gamma A_x<0.03$ m
PEDD	23 J/g	35 J/g	35 J/g
e+/e-	1.5	1	1.8

Comparison of ILC 300Hz w/ JLC and NLC studies

Parameters	ILC 300Hz	JLC 3 targets (for each target)	NLC 3 × 4targets (for each target)
Drive Beam			
energy	6 GeV	10 GeV	6.22 GeV
# e- /bunch	2.0×10^{10}	1.0×10^{10}	1.5×10^{10}
# bunches	132 (triplet)	64 (=192/3)	63(=190/3)
Beam size	4.0 mm	2.5mm	1.6mm
Target			
material	~W~	W75Re25	W75Re25
Thickness	4X0 (14mm)	6X0(21mm)	4X0
PEDD	22.7 J/g	35J/g	35J/g
Energy deposit	35kW		16kW
Capture Section			
Max FC field	7 T	7T	5.8T
FC aperture(diameter)	12mm	?	9mm
Max. RF field	25 MV/m	25MV/m	25MV/m
RF frequency	1.3 GHz	1.428GHz	1.428
Positron yield/e			
DR/ PDR acceptance	dE <25 MeV, dT<115ps, γAx+γAy < 0.09m	dE <1%, dT<?, γAx, γAy < 0.027m	dE <10 MeV, dT<30ps, γAx, γAy < 0.03m
e+/e-	1.5	0.99	1.8

Summary

Summary

- **Conventional e+ source can be a solution for ILC, with 300Hz scheme and optimized beam/target/DR parameters.**

- **to go forward**
  - **heating has to be studied including cooling system.**
  - **shock wave tolerance ?**
    - **better than GLC/NLC design.**
    - **PEDD = 23 J/g (< 35 J/g)**
    - **But is it really OK?**

backups

Target Issues

Two Issues

- Heat Load (by beam): Time Scale ~ 1 m sec.
- Thermal shock wave: Time scale ~ sub micro sec.

- **Undulator Scheme (base line)**
  - In order to create e+s, it uses e- beam in the main linac.
  - It creates 2600 bunches of e+s in 1 m sec.
  - Heat load is a serious problem.
  - It requires a challenging rotation target (100 m/s).
    (spreads 2600 bunches in 100 mm length)

- **300 Hz Truly Conventional**
  - It creates 2600 bunches of e+s in 63 m sec. (stretching)
  - Heat load is not a problem.
  - Do we have a solution? **Issue : shock wave**

Parameter Plots for 300 Hz scheme

e- directly on to Tungsten

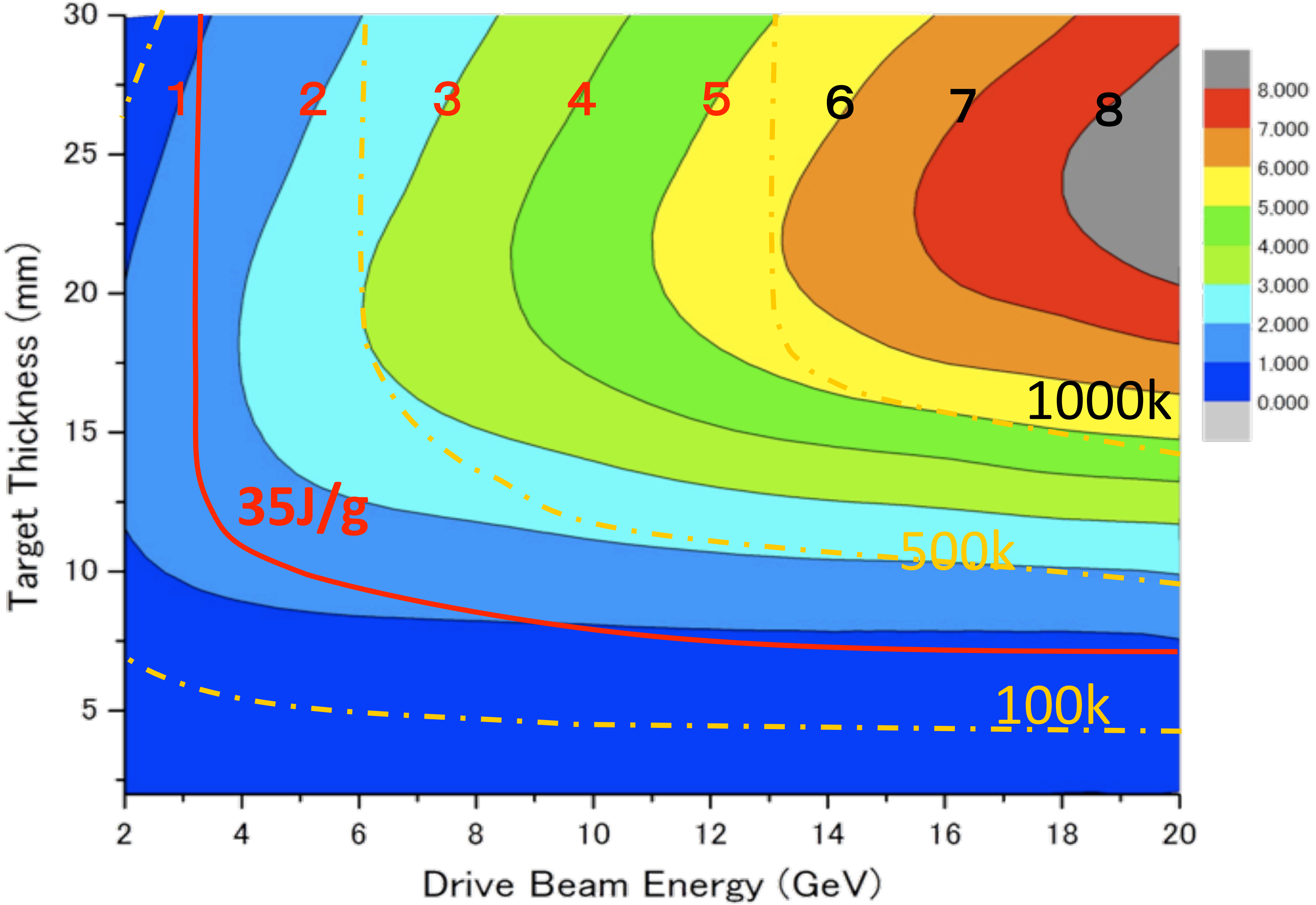
σ=2.5mm

Ne⁻(drive) = 2x10¹⁰ /bunch

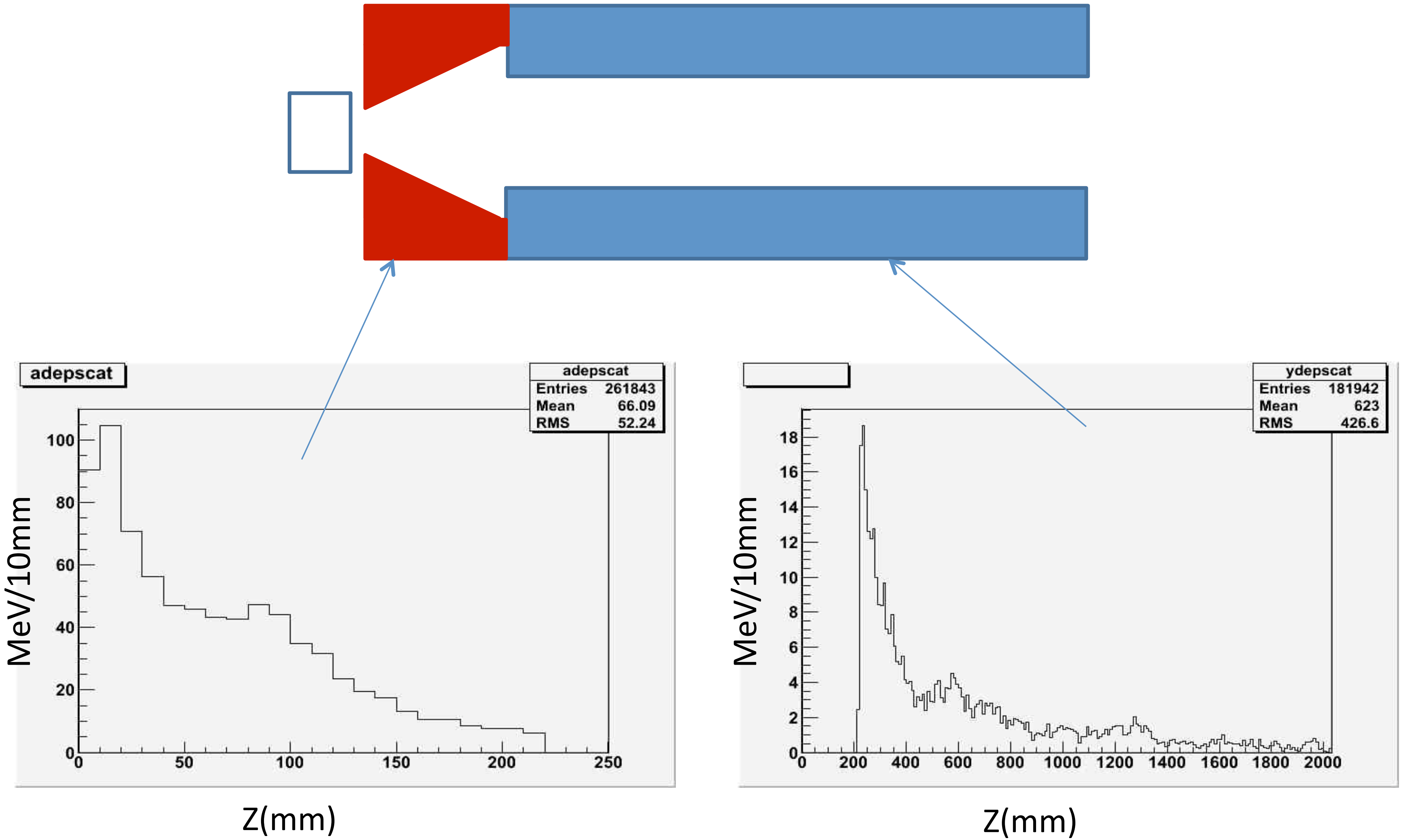
colored band — accepted e+/e-

PEDD J/g

dT max by a triplet

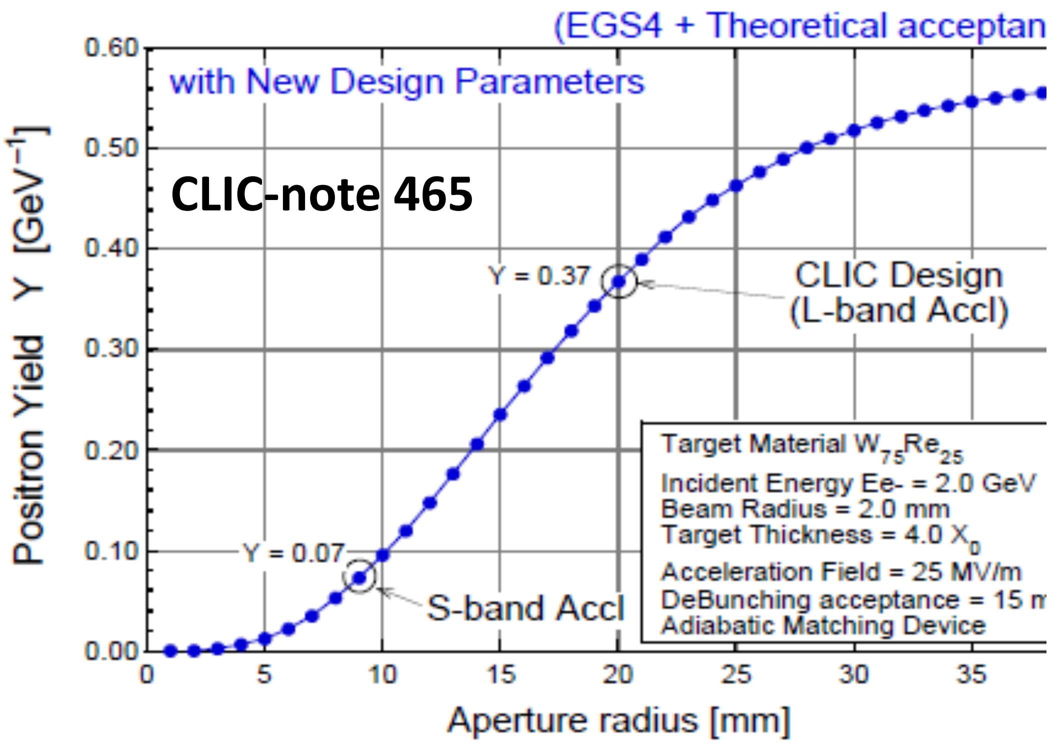


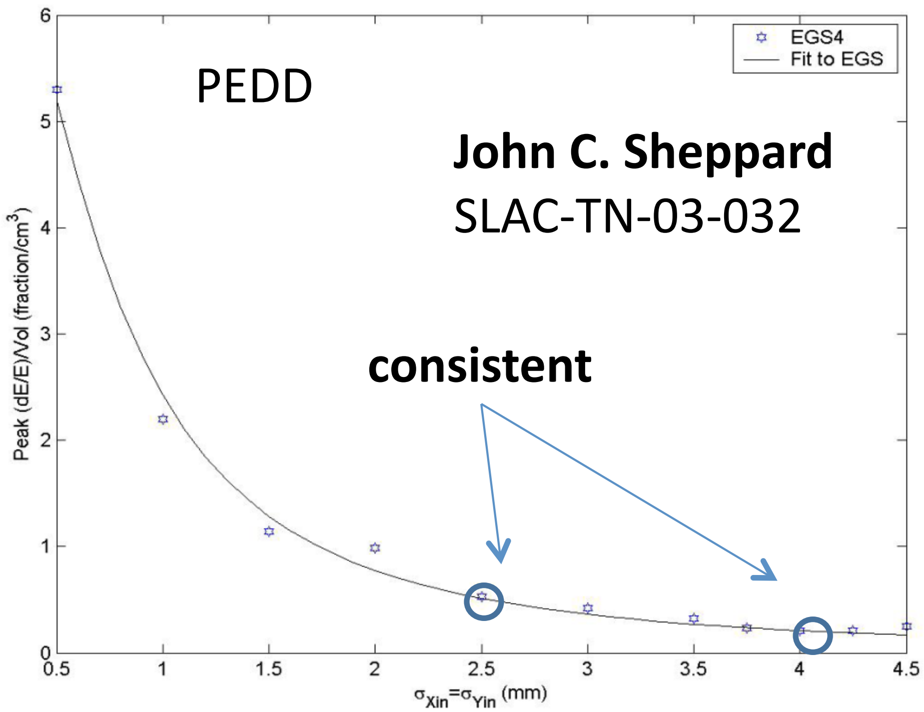
Energy deposit in capture section



a few comments

- numbers shown here are consistent w/
  - independent calculation by a colleague in KEK and French colleague for Hybrid
- comparison w/ SLC study
  - both assumed AMD but acceptance for linac is;
    - SLC S-band linac ←→ this study (CLIC) L-band

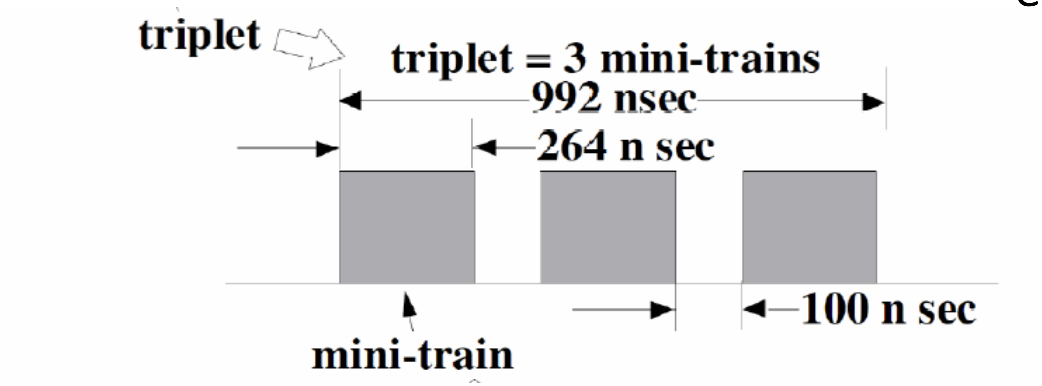


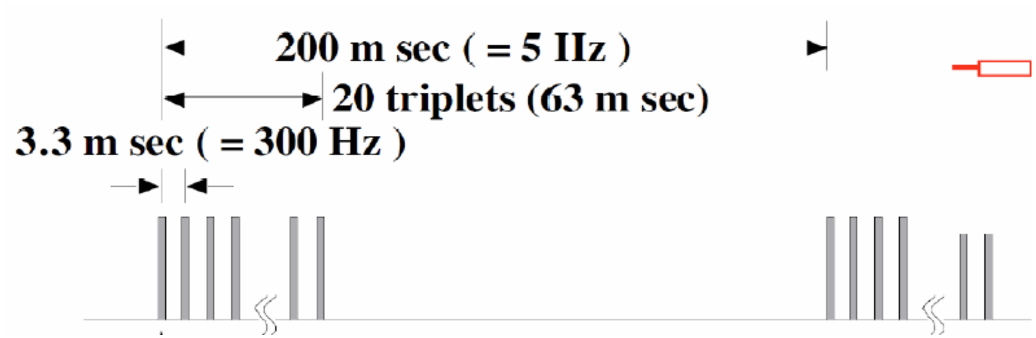


Assumption

each triplet hits different position on the target

elatively low (1~2m/s)rotational target





duration of a triplet ~ dumping time of shock wave

shoter than time scale of thermal dissusion

132 bunches in a triplet contributes both shock wave and thermal damage

Target & Drive_Beam Optimization

Conventional e+ sources

Well established

used to be → ~~thermal load, shock wave~~

300Hz scheme

e+ gen. in 60ms rather than 1ms

relax thermal problem for

targets

increase survivability w/ slow rotation targets

Capture section

larger aperture for RF section

larger acc. gradient

worth while looking into feasibility again

Acceptance estimate

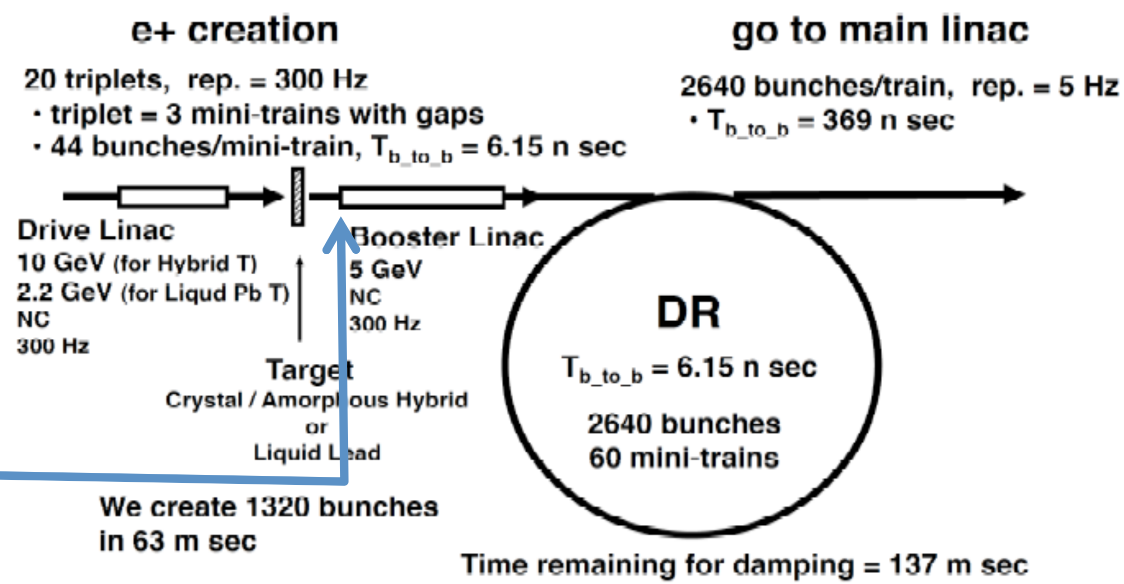
CLIC note 465

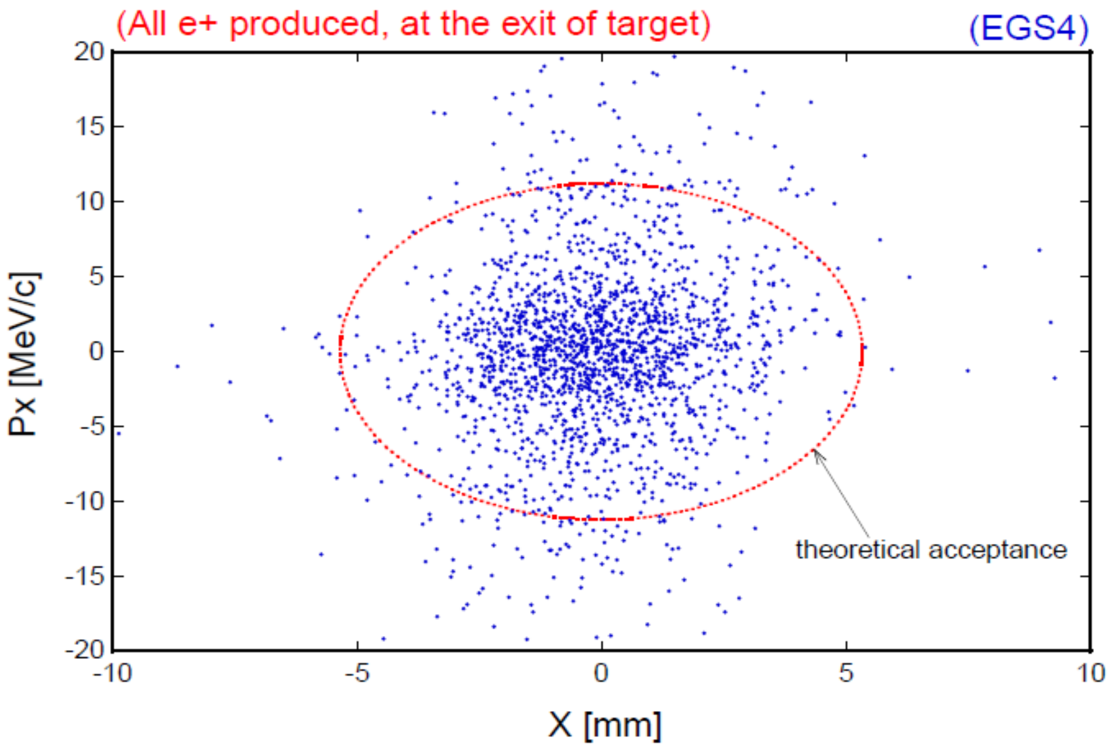
$[r/5.3[mm]]^2 + [pT[MeV]/11]^2 =< 1$

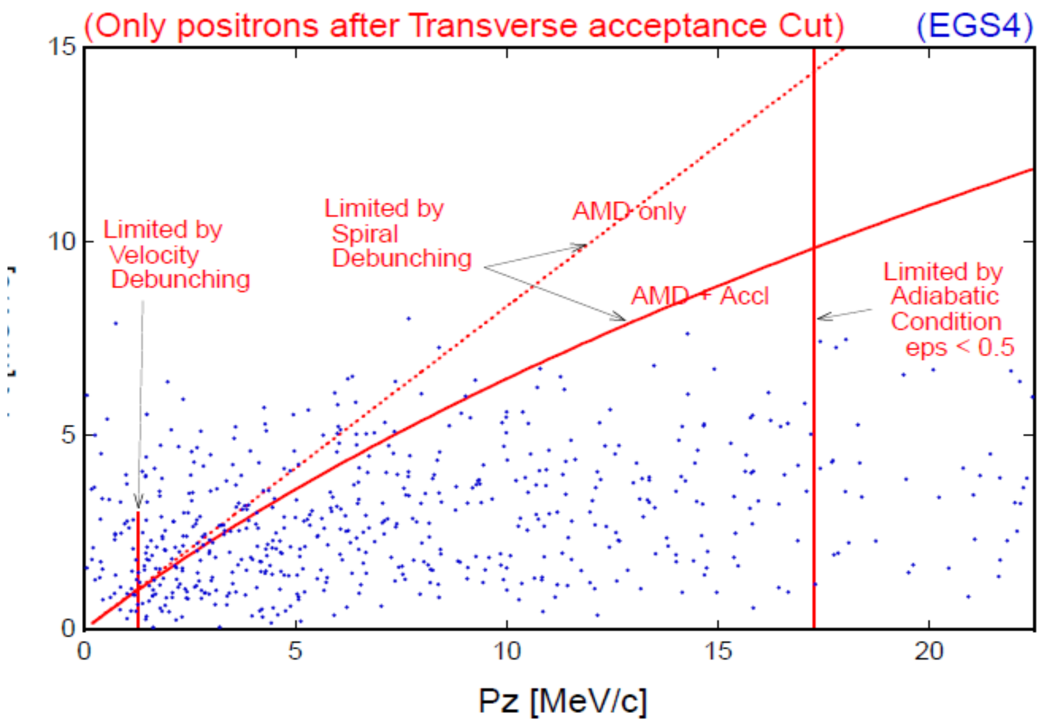
pT < 0.1875 MeV/c + 0.625 pL

1.5 MeV/c < pL < 17.5 MeV/c

～# of e+ in DR (or booter linac)







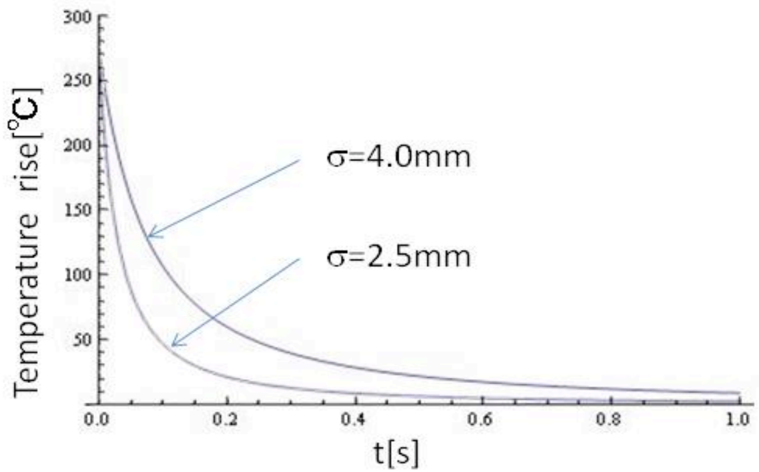
Thermal diffusion

$$T(t) \sim T_0 e^{\alpha t} \qquad \lambda = 174 \mathrm{W/m \cdot K}$$

$$\alpha = -\frac{\lambda}{C_V}\beta^2 \qquad C_V = 2.5 \times 10^6 \mathrm{J/m^3 \cdot K}$$

time constant of the diffusion depends on beam spot size ~1/ß

numerical calculation of
thermal diffusion shows



	1D	2D	3D
time constant σ=2.5mm σ=4.0mm	280ms 750ms	80ms 200ms	40ms 100ms

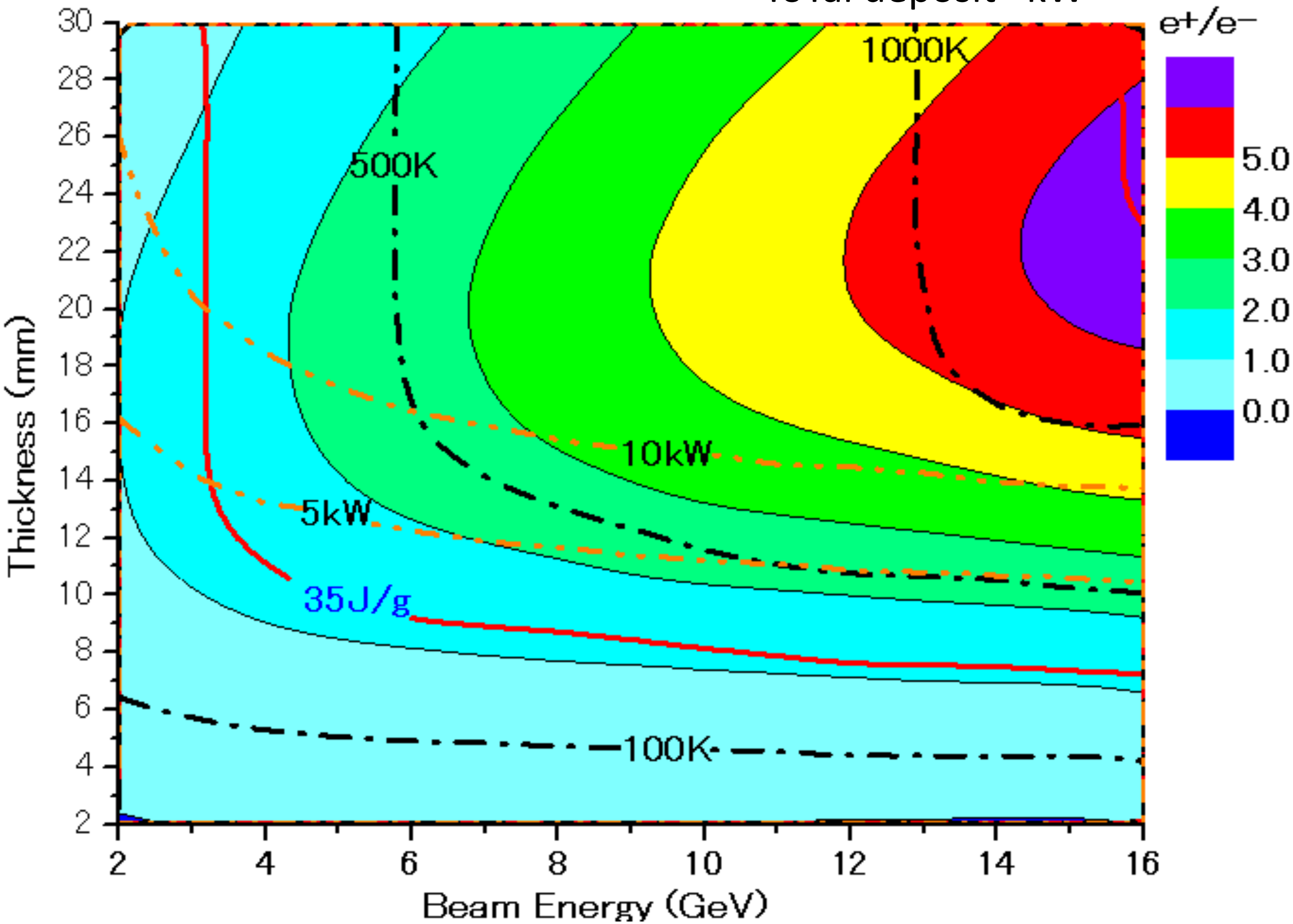
time constant is order of 100ms >> Ttriplet ~1μs

Parameter Plots for 300 Hz scheme w/ clic note formula

e- directly on to Tungsten

σ=2.5mm

colored band	accepted e+/e-
red solid line	PEDD J/g
dash-dot line	dT/triplet (132 bunc)
dash-dot-dot line	ToTal deposit kW



Parameter Plots for 300 Hz scheme w/ CLIC note formula

e- directly on to Tungsten

σ=4.0mm