Optimisation of the CLIC positron source

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CLIC Project meeting

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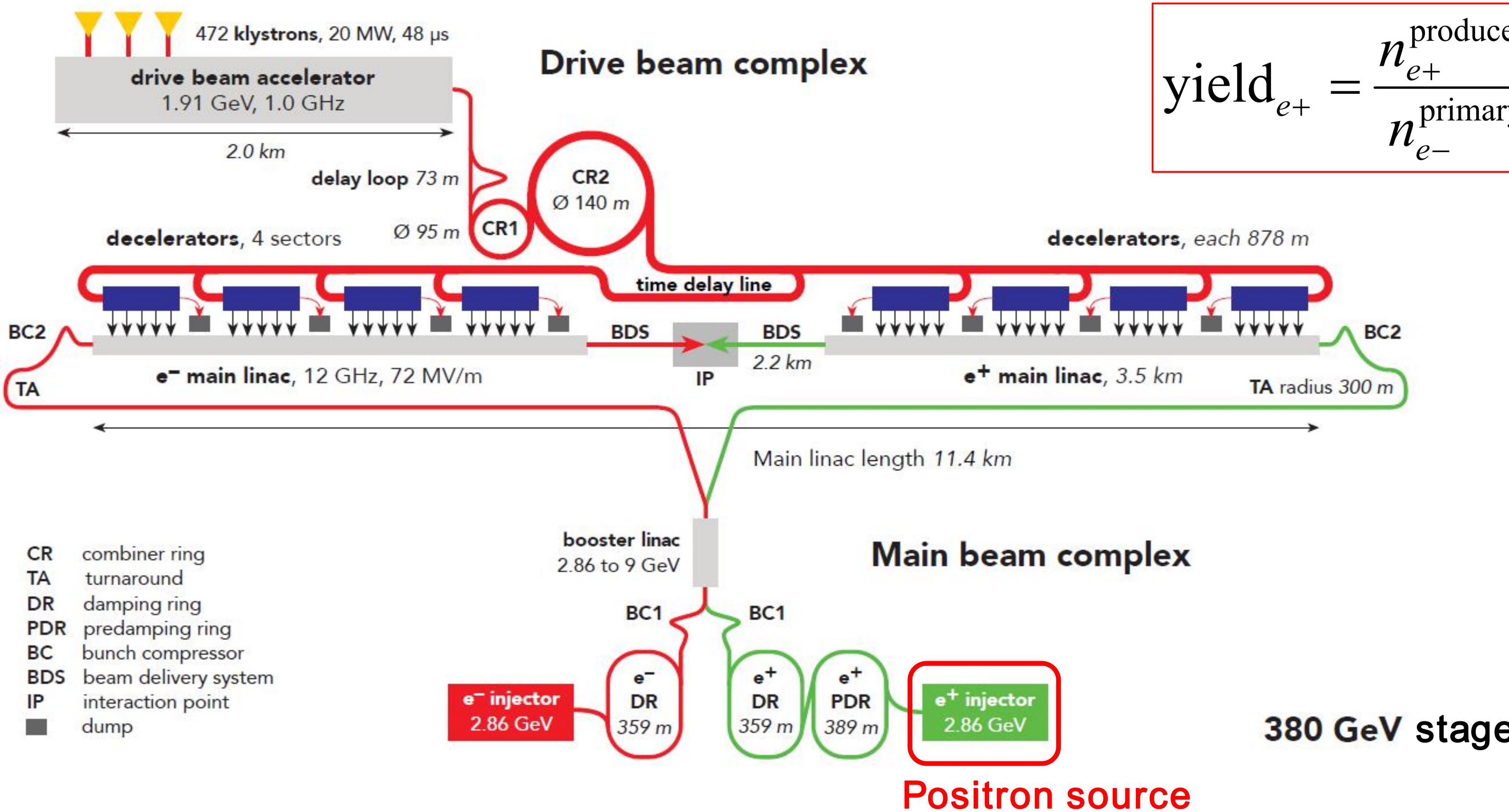
Outline

- Introduction
- Code validation
- New optimisation strategy and results
- Conclusion

Introduction

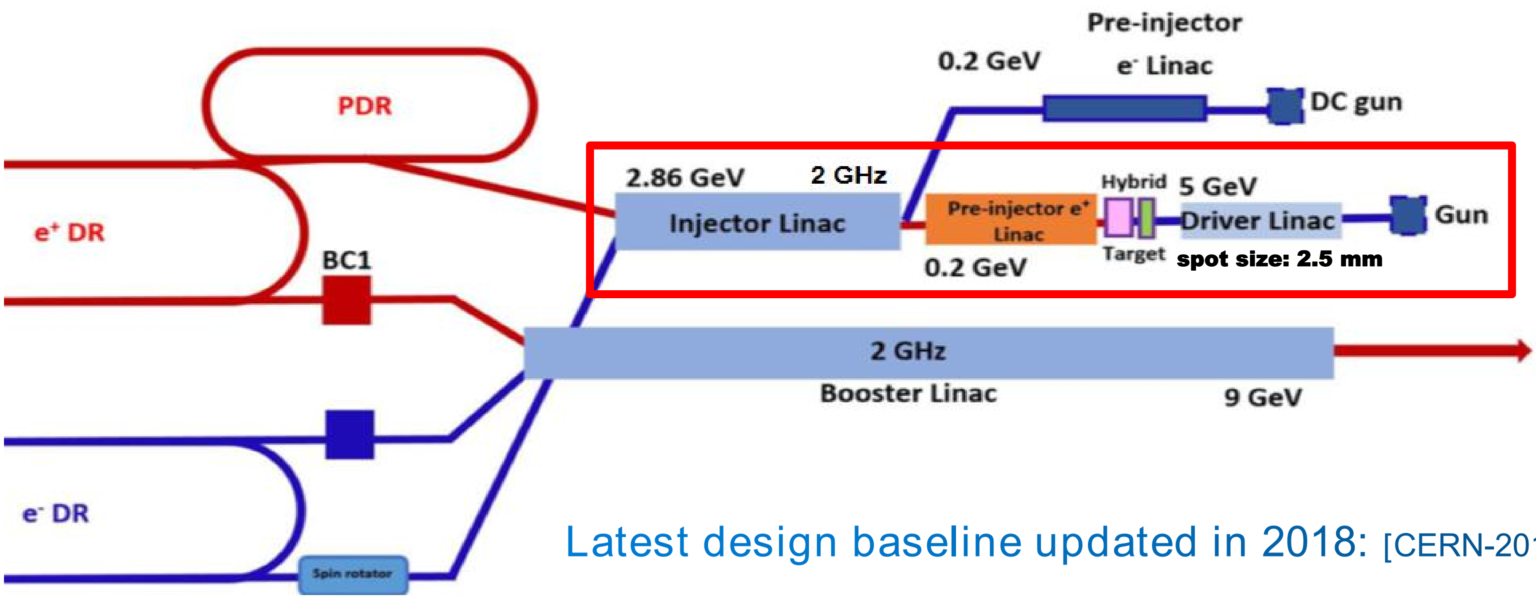
- Motivation: a well optimised positron source is essential to improve positron production efficiency and reduce the positron linac cost. In principle, a higher positron yield is always prefered

$$\text{yield}_{e+} = \frac{n_{e+}^{\text{produced}}}{n_{e-}^{\text{primary}}}$$



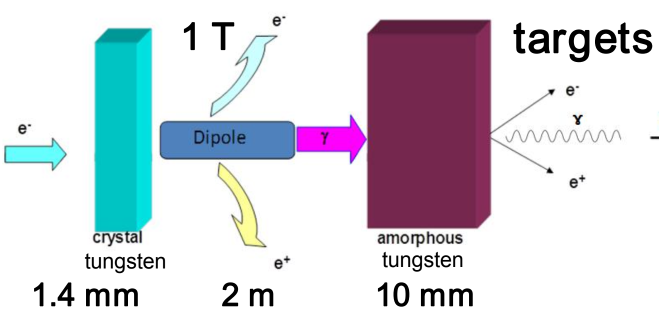
Introduction

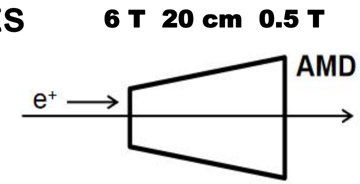
- Main components: Primary e$^-$ gun, targets, adiabatic matching device (AMD), travelling wave (TW) structures, injector linac (IL)



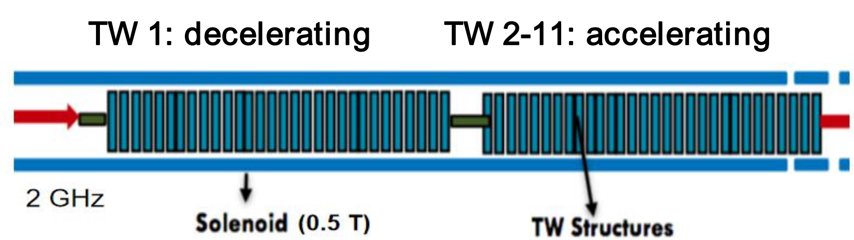
Latest design baseline updated in 2018: [CERN-2018-010-M]

- Components for optimisation: target, AMD and TW structures





$$B_z = \frac{B_0}{1+\mu \cdot z}$$



Introduction

- Same simulation tools and configurations used as **Yanliang Han** ([DOI: 10.1016/j.nima.2019.03.044]), who worked on this previously
- **Primary e$^-$** generated from **gaussian** sampling
- Tools: **FOT + Geant4** for targets, **RF_Track** for AMD and TW structures
- **Injector linac** simulated using a formula **approximation** (assuming no losses, based on previous studies [10.1016/j.nima.2017.07.010])

$$\mathrm{E} = \mathrm{E}_0 + \Delta\mathrm{E}\cdot\cos(2\pi\omega\cdot\Delta t), \quad \Delta\mathrm{E} = 2.86\,\mathrm{GeV} - 200\ \mathrm{MeV}, \quad \Delta\mathrm{t} = \mathrm{t} - \mathrm{t}_{\mathrm{ref}}$$

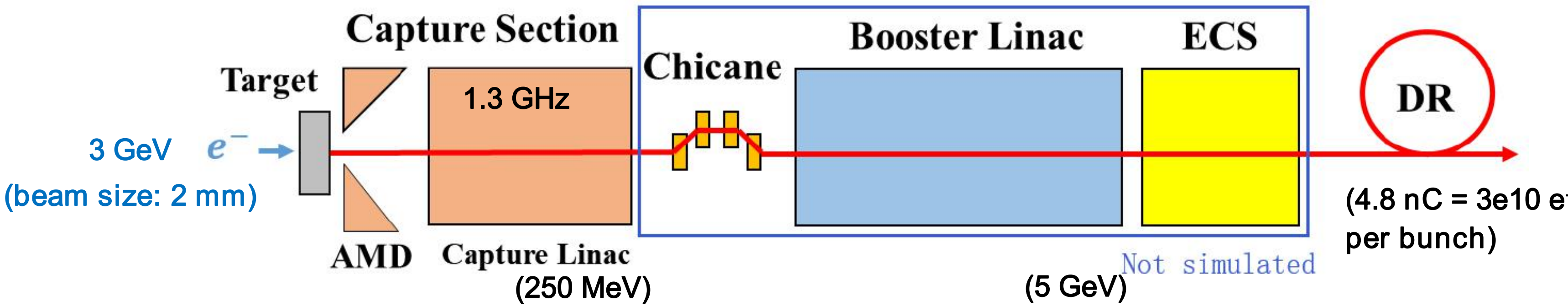
- Final **effective** positrons accepted by the pre-damping ring (PDR): **time window: 20 mm/c**, **energy window**: 2.86 GeV · (1 ± 1.2%)
- Peak energy deposition density (**PEDD**) in targets < 35 J/g

$$\mathrm{PEDD} = \frac{\max(\mathrm{E}_{\mathrm{deposited}})}{V_{\mathrm{mesh}}\cdot\rho_W\cdot n^{e^-}_{\mathrm{simulated}}}\cdot\frac{n_{\mathrm{bunch}}\cdot n^{e^+}_{\mathrm{PDR}}}{\mathrm{Yield}^{e^+}_{\mathrm{effective}}}$$

PEDD always normalised by $n^{e^+}_{\mathrm{PDR}}$, the e$^+$ bunch population at the entrance of PDR

Code validation: ILC reproduction

- ILC positron source (**e-driven**) quite similar as CLIC, which can be used to **cross-check** and **validate our code**



e^+ yield	Software	After target	After AMD	After Capt. Sect.	DR accepted
ILC	Geant4	7.13	5.09	1.94	**1.03**
Reprod.	Geant4+RF_Track	7.06	4.48	1.96	**1.09**
Diff.		1%	12% *	1%	6%

* Difference after AMD due to particle interactions in Geant4. Otherwise, it is reduced to 2%

2.4 nC e^- bunch	ILC	Reprod.	Diff.
PEDD (in target) [J/g]	22.0	23.7	8%

Good agreement!

Code validation: CLIC reproduction

- Another way to **validate our code** is to reproduce the previous CLIC results from **Yanliang Han** (et al. [DOI: 10.1016/j.nima.2019.03.044])
- The same parameters used (PEDD re-normalised to ~ 0.7 nC e^- bunch charge)

e^- energy: **5 GeV** Spot size: **2.5 mm**	Y. Han	Reprod.	Diff.
e+ yield	1.30	1.28	**2%**
PEDD [J/g]	14.0	14.0	**0%**

e^- energy: **5 GeV** Spot size: **1.25 mm**	Y. Han	Reprod.	Diff.
e+ yield	1.94	1.86	**4%**
PEDD [J/g]	23.2	24.5	**6%**

e^- energy: **3 GeV** Spot size: **2.5 mm**	Y. Han	Reprod.	Diff.
e+ yield	0.76	0.71	**7%**
PEDD [J/g]	13.6	13.0	**4%**

e^- energy: **3 GeV** Spot size: **1.25 mm**	Y. Han	Reprod.	Diff.
e+ yield	1.03	0.96	**7%**
PEDD [J/g]	21.2	22.5	**6%**

Good agreement!

A new optimisation strategy

- A new optimisation strategy based on a simultaneous scan is proposed
- **Procedure**:
  ① Provide initial values as a **starting point**, and **Scan** parameters **separately but simultaneously**, and find optimised parameters (during a scan of one parameter, the other parameters are fixed)
  ② Use **all optimised parameters** (or **best one from scan** if it's better) as a **new starting point** for the next scan
  ③ Continue the **iterations** of scan till we find **final** optimal parameters (parameters are **stable** and results can not be improved)
- Similar as previous 'start-to-end' study (Nelder-Mead algorithm used), it also does a global optimisation
- But it has some **advantages**:
  - ✓ **Simpler and faster** (jobs can be in parallel instead of sequential**!**), especially for a multi-variate optimisation
  - ✓ More **reliable and convincing** results (**visual** scan plots, not like Nelder-Mead algorithm which is a **black box**)
  - ✓ Allow us to see **individual effects** from parameters

New optimisation results (preliminary)

- Before applying the new optimisation strategy, some **updates** are needed
  - ① **AMD** simulated with **tapered inner aperture** (previously constant, 20 mm, which **over-estimated** the final yield by **at least 25%**)

$$R_{entrance} = \sqrt{\frac{B_{exit}}{B_0}} \cdot R_{exit} = \sqrt{\frac{0.5\,\mathrm{T}}{B_0}} \cdot 20\,\mathrm{mm}$$

  - ② **PDR energy window** corrected to ΔE= ± **1.2%·E** (previously is 3.6%, which **over-estimated** the final yield by **at most 13%**)
  - ③ Beam **emittance**, ε, specified to be **80 mm mrad**, and set free to be optimised (previously $\sigma_{px,py} = 0.001\% \cdot E$)

$$\varepsilon = \sigma_{XY} \cdot \frac{\sigma_{p_x,p_y}}{m_e c}$$

  - ④ PEDD normalisation

3 TeV &1.5 TeV stages	New	Previous
N_{bunch} per train	352	
e^+ population	(3.7e9*1.2 =) **4.44e9** (20% safe margin)	5.6e9 (too safe)

- As a **preliminary** study, optimisation performed only for the **3 TeV & 1.5 TeV** stages

New optimisation results (preliminary)

- Main parameters for optimisation (12 free parameters)

Parameters		Symbol	Units	Value
Primary e^- beam	Energy	E_{e^-}	GeV	5
	Spot size	σ_{xy}	mm	To be optimised
	Emittance	ε	mm·mrad	To be optimised
	Number of bunches per train	n_b		312
	Bunch spacing	Δt_b	ns	0.5
	Repetition frequency	f_{rep}	Hz	50
e^+ beam at the entrance of the PDR	Target bunch population	$n_{e^+}^{\mathrm{PDR}}$	10^9	4.44
	Target energy	$E_{\mathrm{exp}}^{\mathrm{PDR}}$	GeV	2.86
	Effective energy acceptance	$\delta_E^{e^+}$	%	1.2
Hybrid target system	Crystal target thickness	W_{crys}	mm	To be optimised
	Amorphous target thickness	W_{amor}	mm	To be optimised
	Distance between two targets	D_{targ}	m	To be optimised
	Dipole magnetic field	B_{targ}	T	To be optimised
AMD	Maximum magnetic field	B_0	T	To be optimised
	Length	L_{amd}	cm	To be optimised
TW structures	Decelerating phase	ϕ_{dec}	degree	To be optimised
	Accelerating phase	ϕ_{acc}	degree	To be optimised
	Decelerating gradient	E_{dec}	MV/m	To be optimised
	Accelerating gradient	E_{acc}	MV/m	To be optimised

✓ Injector linac (IL), as the last part, can always be optimised separately and internally in the simulation, which is super fast. Therefore not included in the common optimisation

New optimisation results (preliminary)

- Starting point of free parameters for the **1st iteration** of scan

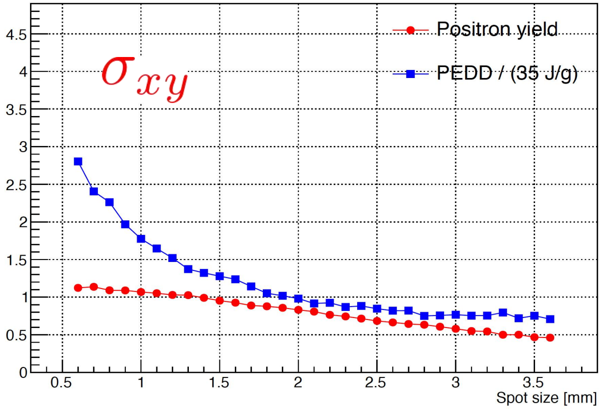
σ_{xy}	ε	W_{crys}	W_{amor}	D_{targ}	B_{targ}	B_0	L_{amd}	ϕ_{dec}	ϕ_{acc}	E_{dec}	E_{acc}	$\eta_{e^+}^{\text{eff}}$	PEDD
1.8 mm	80 mm·mrad	1.5 mm	15 mm	0.5 m	1 T	6 T	20 cm	150°	250°	15 MV/m	20 MV/m	$0.87\, e^+/e^-$	36.2 J/g

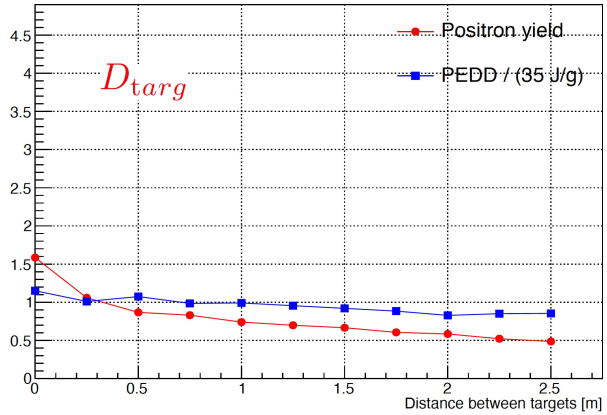
New optimisation results (preliminary)

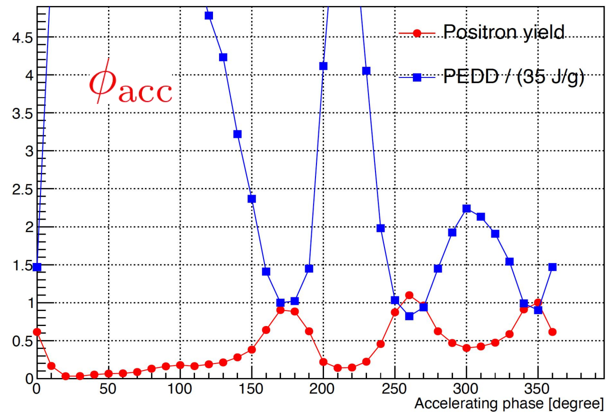
- Starting point of free parameters for the 1st iteration of scan

σ_{xy}	ε	$W_{\rm crys}$	$W_{\rm amor}$	$D_{\rm targ}$	$B_{\rm targ}$	B_0	$L_{\rm amd}$	$\phi_{\rm dec}$	$\phi_{\rm acc}$	$E_{\rm dec}$	$E_{\rm acc}$	$\eta_{e^+}^{\rm eff}$	PEDD
1.8 mm	80 mm·mrad	1.5 mm	15 mm	0.5 m	1 T	6 T	20 cm	150°	250°	15 MV/m	20 MV/m	$0.87\, e^+/e^-$	36.2 J/g

- Scan results of free parameters for the 1st iteration of scan (3 examples)





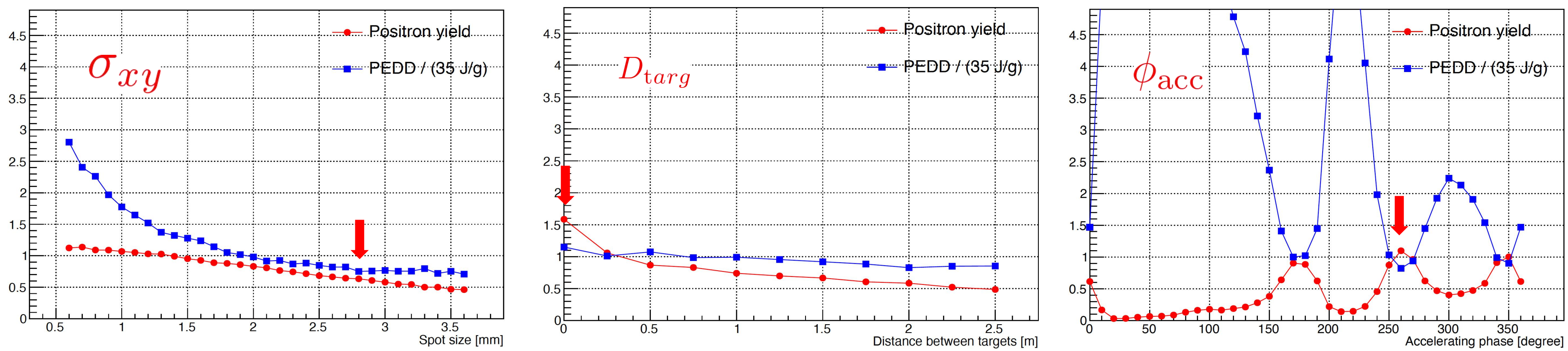


New optimisation results (preliminary)

- Starting point of free parameters for the 1st iteration of scan

σ_{xy}	ε	W_{crys}	W_{amor}	D_{targ}	B_{targ}	B_0	L_{amd}	ϕ_{dec}	ϕ_{acc}	E_{dec}	E_{acc}	η_{e+}^{eff}	PEDD
1.8 mm	80 mm·mrad	1.5 mm	15 mm	0.5 m	1 T	6 T	20 cm	150°	250°	15 MV/m	20 MV/m	0.87 e^+/e^-	36.2 J/g

- Scan results of free parameters for the 1st iteration of scan (3 examples)



- Optimised values of free parameters from the 1st iteration of scan

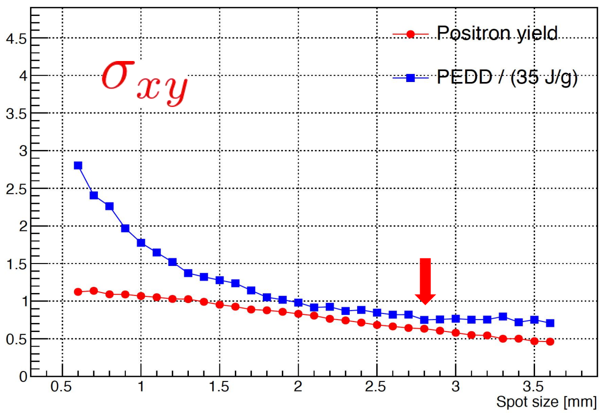
Free parameters	σ_{xy}	ε	W_{crys}	W_{amor}	D_{targ}	B_{targ}	B_0	L_{amd}	ϕ_{dec}	ϕ_{acc}	E_{dec}	E_{acc}	All used
Optimised value	**2.8 mm**	80 mm·mrad	1.5 mm	15 mm	**0**	**0**	**4 T**	**15 cm**	**140°**	**260°**	**10 MV/m**	**26 MV/m**	
η_{e+}^{eff} $[e^+/e^-]$	0.63	0.89	0.89	0.90	**1.59**	1.29	0.90	0.92	0.95	1.10	1.00	1.10	**0.54**
PEDD [J/g]	26.3	36.3	36.7	35.9	**40.2**	34.3	35.2	34.5	33.4	28.8	31.5	28.7	**56.8**

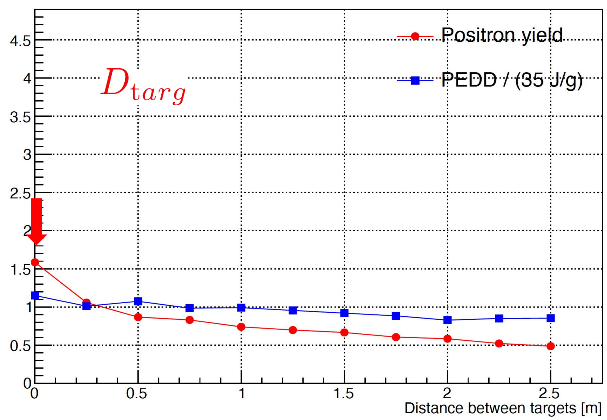
New optimisation results (preliminary)

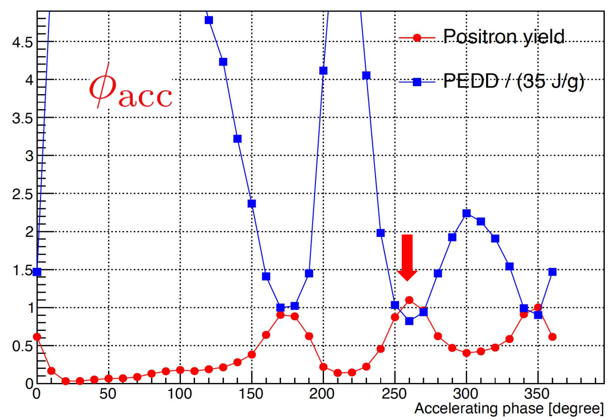
Starting point of free parameters for the 1st iteration of scan

σ_{xy}	ε	$W_{\rm crys}$	$W_{\rm amor}$	$D_{\rm targ}$	$B_{\rm targ}$	B_0	$L_{\rm amd}$	$\phi_{\rm dec}$	$\phi_{\rm acc}$	$E_{\rm dec}$	$E_{\rm acc}$	$\eta^{\rm eff}_{e+}$	PEDD
1.8 mm	80 mm·mrad	1.5 mm	15 mm	0.5 m	1 T	6 T	20 cm	150°	250°	15 MV/m	20 MV/m	0.87 e^+/e^-	36.2 J/g

Scan results of free parameters for the 1st iteration of scan (3 examples)







Optimised values of free parameters from the 1st iteration of scan

Free parameters	σ_{xy}	ε	$W_{\rm crys}$	$W_{\rm amor}$	$D_{\rm targ}$	$B_{\rm targ}$	B_0	$L_{\rm amd}$	$\phi_{\rm dec}$	$\phi_{\rm acc}$	$E_{\rm dec}$	$E_{\rm acc}$	All used
Optimised value	**2.8 mm**	80 mm·mrad	1.5 mm	15 mm	**0**	**0**	**4 T**	**15 cm**	**140°**	**260°**	**10 MV/m**	**26 MV/m**	
$\eta^{\rm eff}_{e+}$ $[e^+/e^-]$	0.63	0.89	0.89	0.90	**1.59**	1.29	0.90	0.92	0.95	1.10	1.00	1.10	**0.54**
PEDD [J/g]	26.3	36.3	36.7	35.9	**40.2**	34.3	35.2	34.5	33.4	28.8	31.5	28.7	**56.8**

Starting point of free parameters for the 2nd iteration of scan

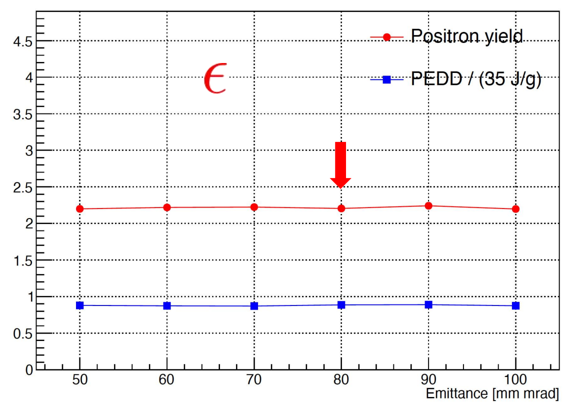
σ_{xy}	ε	$W_{\rm crys}$	$W_{\rm amor}$	$D_{\rm targ}$	$B_{\rm targ}$	B_0	$L_{\rm amd}$	$\phi_{\rm dec}$	$\phi_{\rm acc}$	$E_{\rm dec}$	$E_{\rm acc}$	$\eta^{\rm eff}_{e+}$	PEDD
2.8 mm	80 mm·mrad	1.5 mm	15 mm	**0**	0	6 T	20 cm	150°	250°	15 MV/m	20 MV/m	**1.09** e^+/e^-	**28.7 J/g**

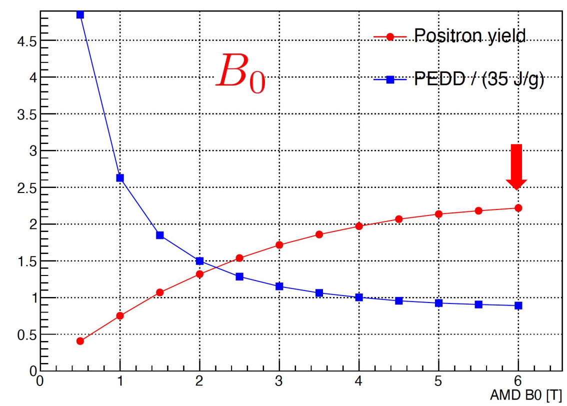
New optimisation results (preliminary)

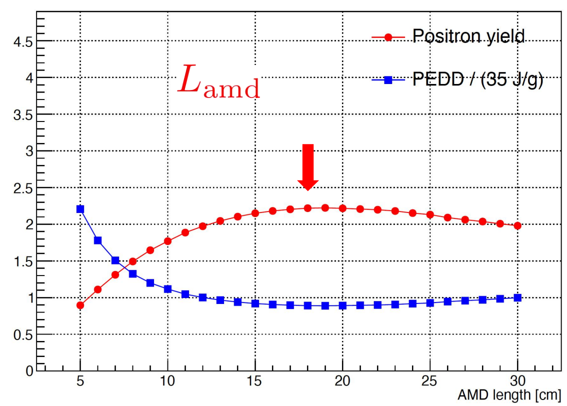
- Optimisation thought to be finished if results are stable (~ 6 iterations)
- Final optimal results (for 3 TeV & 1.5 TeV stages)

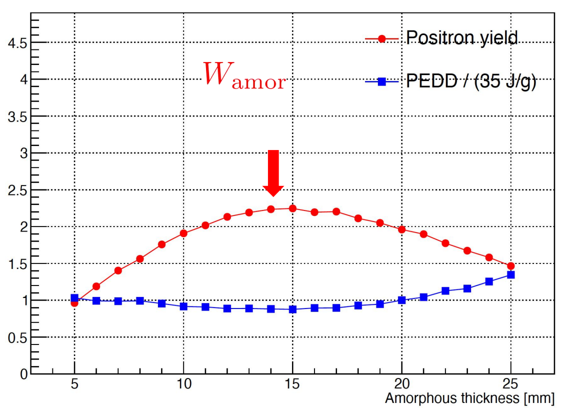
σ_{xy}	ε	$W_{\rm crys}$	$W_{\rm amor}$	$D_{\rm targ}$	$B_{\rm targ}$	B_0	$L_{\rm amd}$	$\phi_{\rm dec}$	$\phi_{\rm acc}$	$E_{\rm dec}$	$E_{\rm acc}$	$\eta^{\rm eff}_{e^+}$	PEDD
1.7 mm	80 mm·mrad	1 mm	14 mm	0	0	6 T	18 cm	150°	260°	10 MV/m	19 MV/m	2.22 e^+/e^-	31.2 J/g

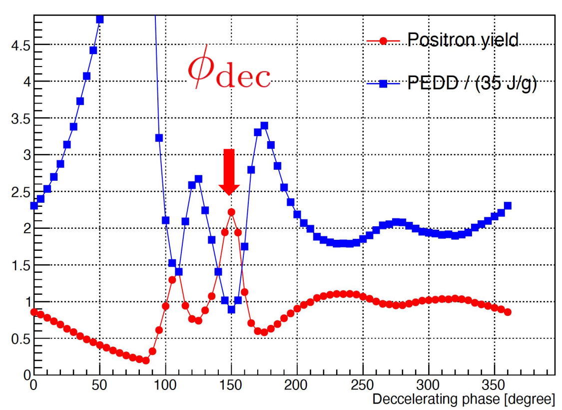
- Final scan results (a few examples)

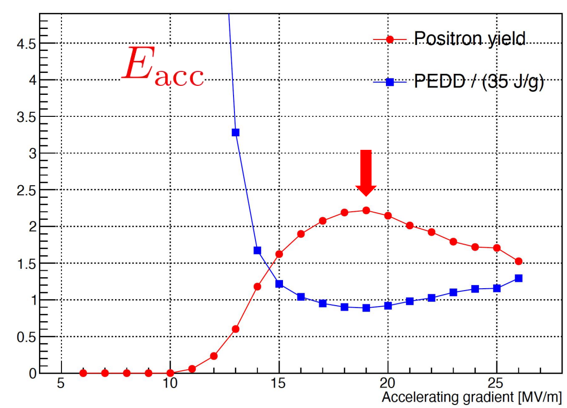












New optimisation results (preliminary)

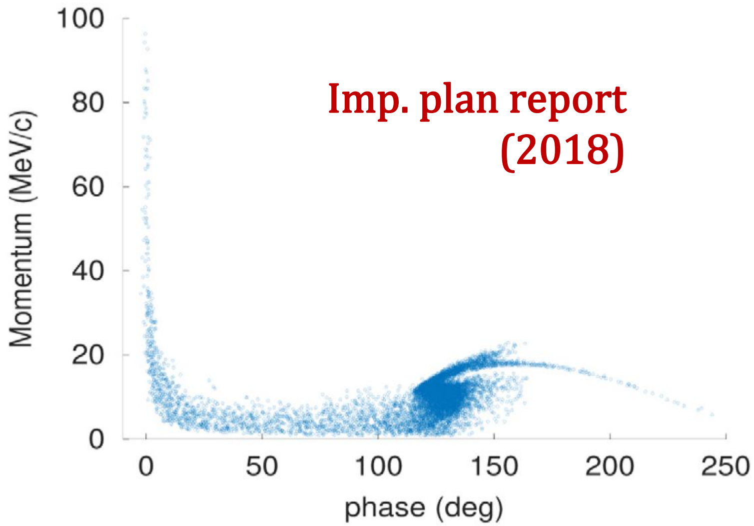
- Comparison with previous results
  - Stage: 3 TeV or 1.5 TeV   Primary e^- energy: 5 GeV
  - Previous results recalculated by removing 25% yield over-estimation due to old AMD aperture simulation
  - PEDD re-normalised according to the updates

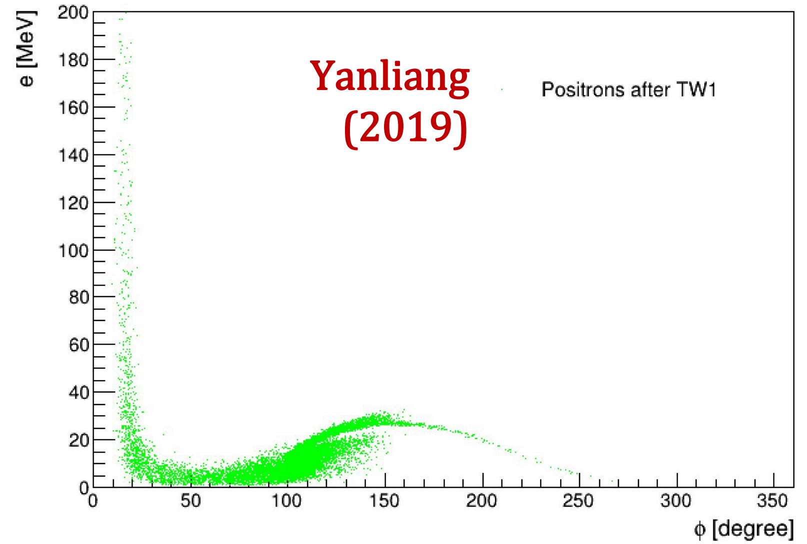
Results	Spot size	Distance betw. targets	Final eff. e^+ yield	PEDD [J/g]	Yield improv.	
CDR (2012)	2.5 mm	2 m	0.31	38.8	-	
Implementary plan report (2018)	2.5 mm	2 m	0.78	15.6	152%	
Yanliang HAN (2019)	1.25 mm	0.65 m	1.55	29.0	99%	
		0	2.78	35.0	-	(test)
Yongke (preliminary)	1.7 mm	0	2.22	31.2	43%	

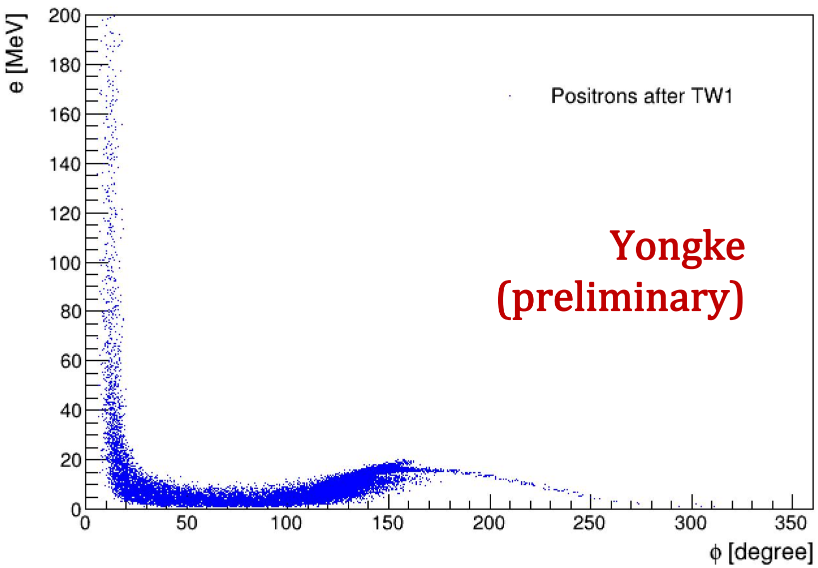
- The final e^+ yield improved (by 43%) mainly due to the constraint on the distance between targets is removed in our new optimisation (as confirmed by the test)

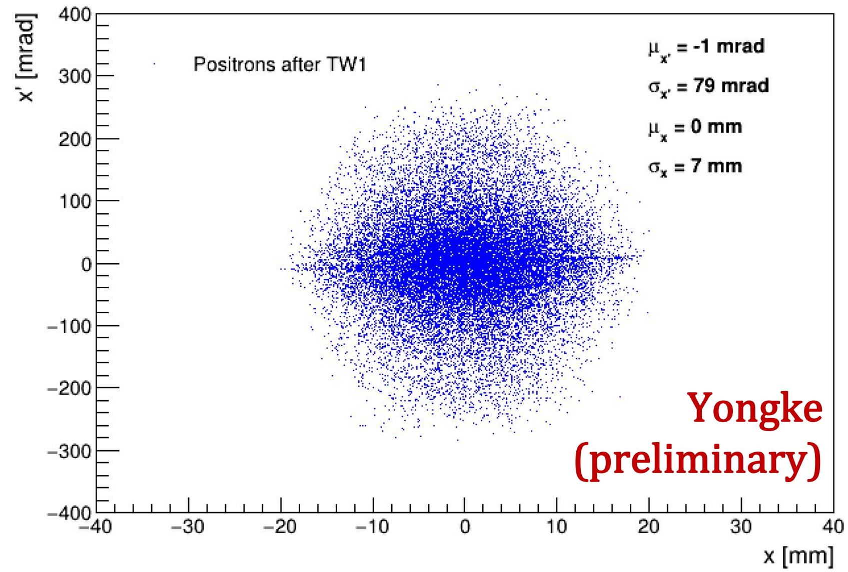
New optimisation results (Preliminary)

- Phase spaces at the end of the **first** TW structure (decelerating)



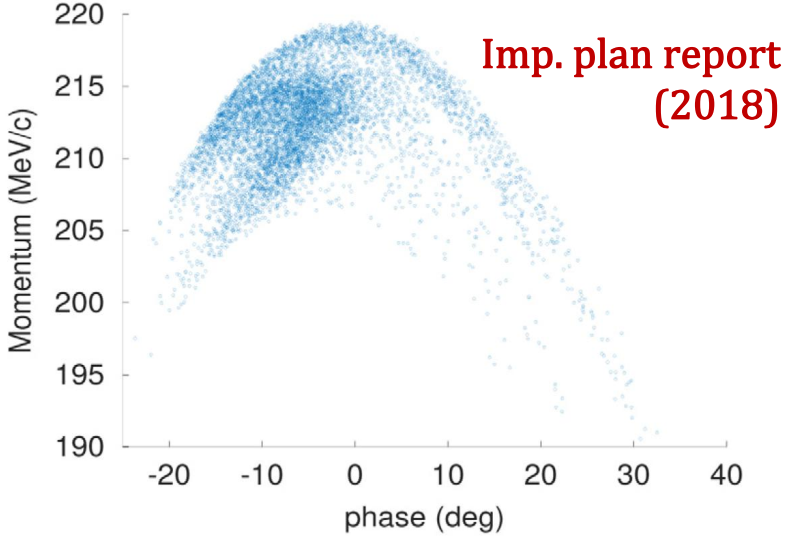


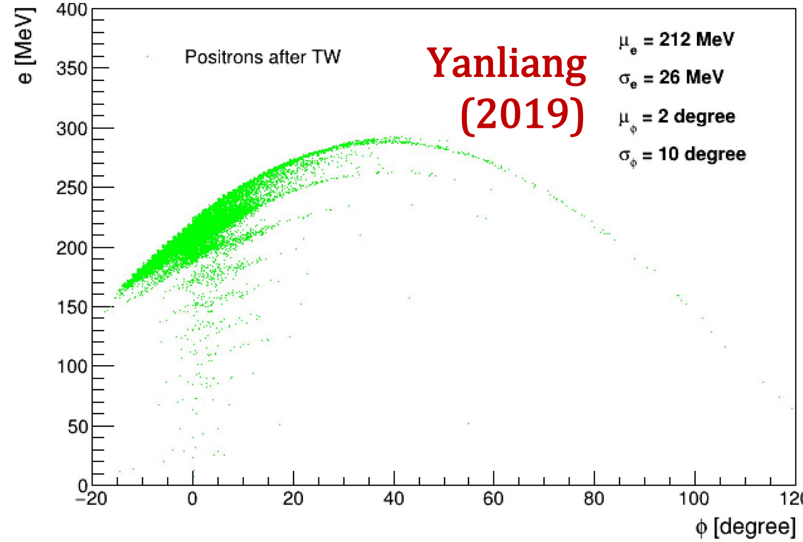


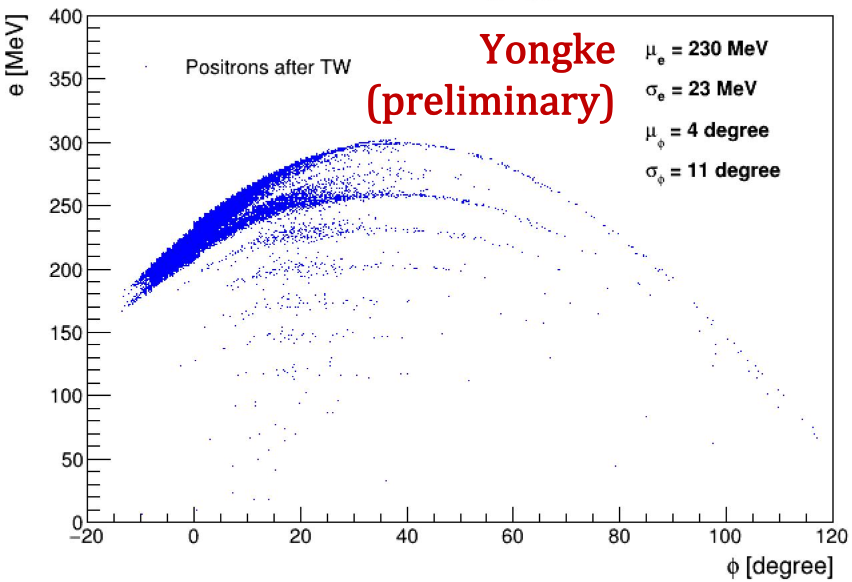


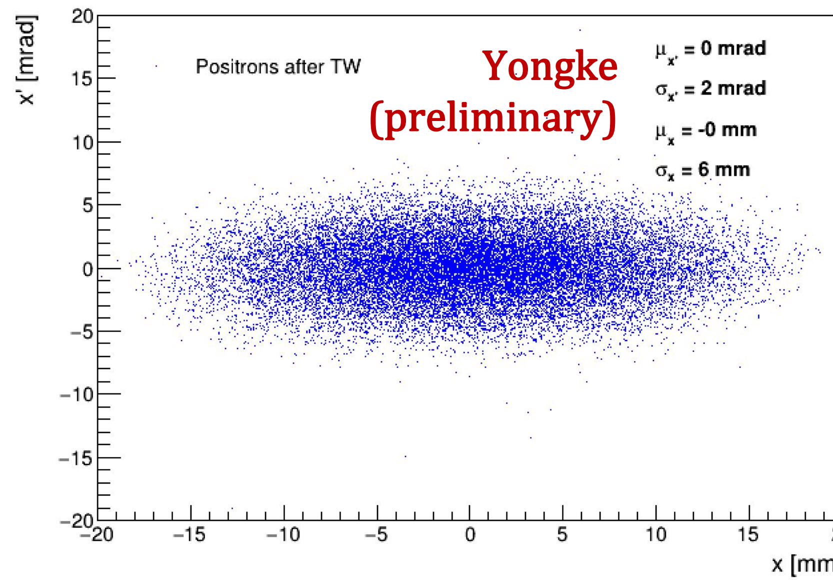
New optimisation results (Preliminary)

- Phase spaces at the end of all TW structures (at the end of pre-injector linac)



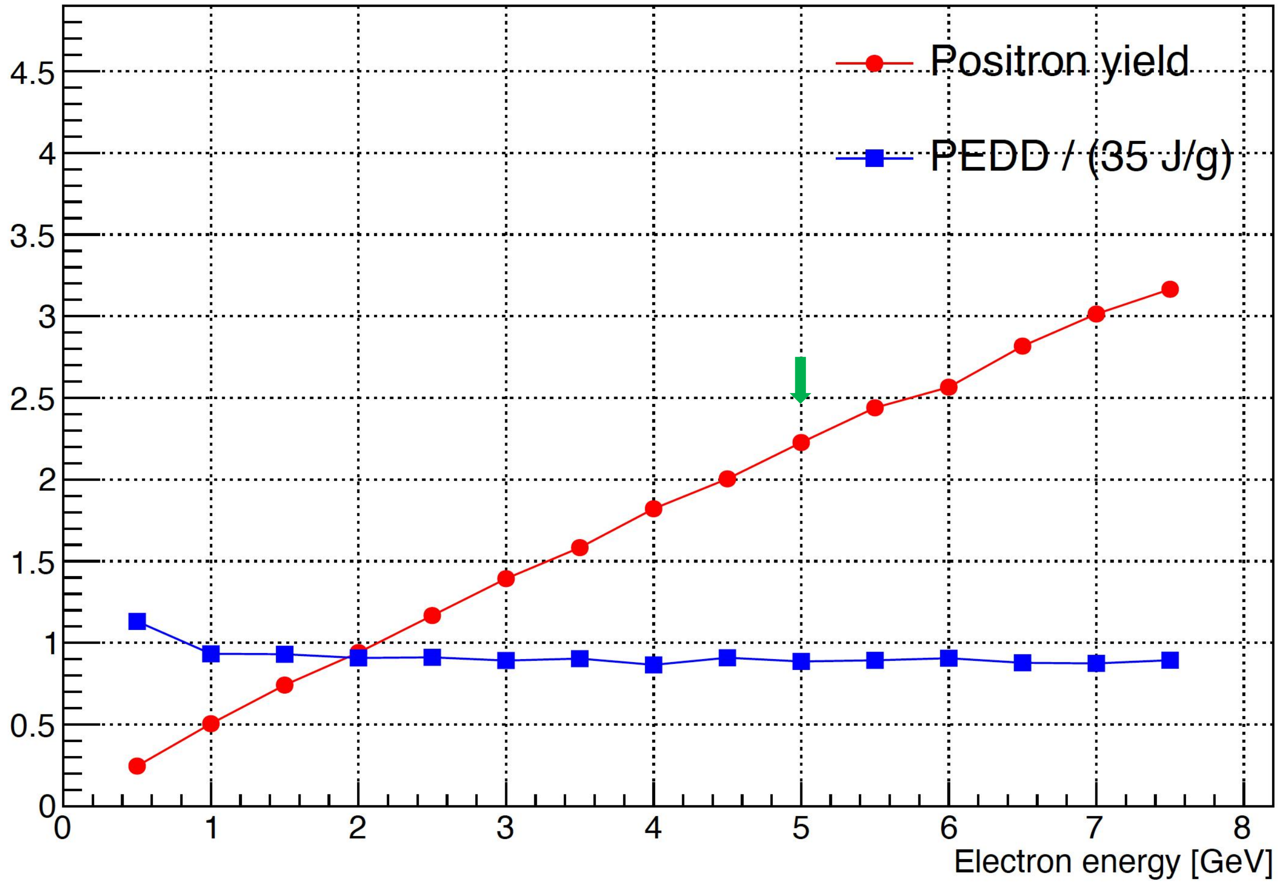






Additional studies

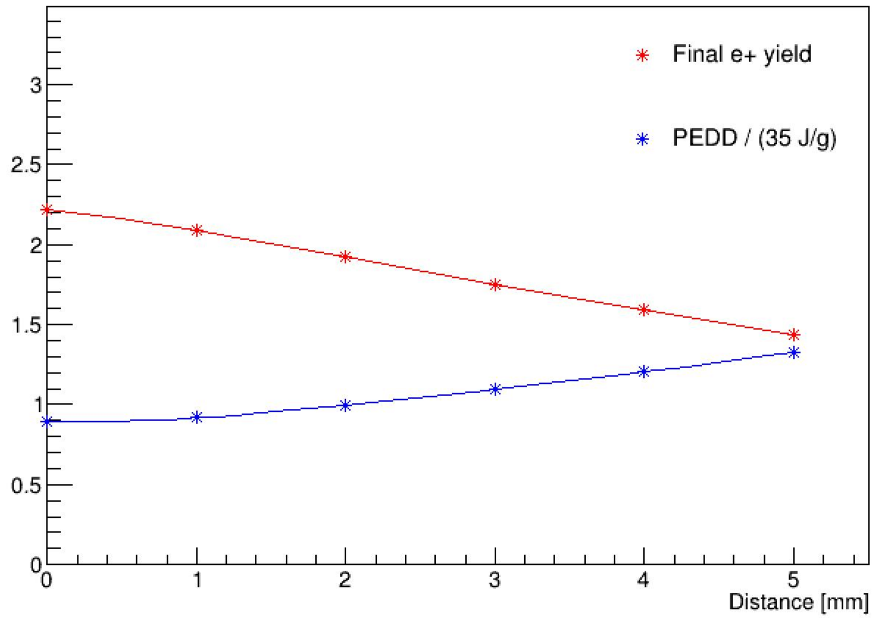
- Primary e- energy scan (with optimal parameters for 3 TeV)



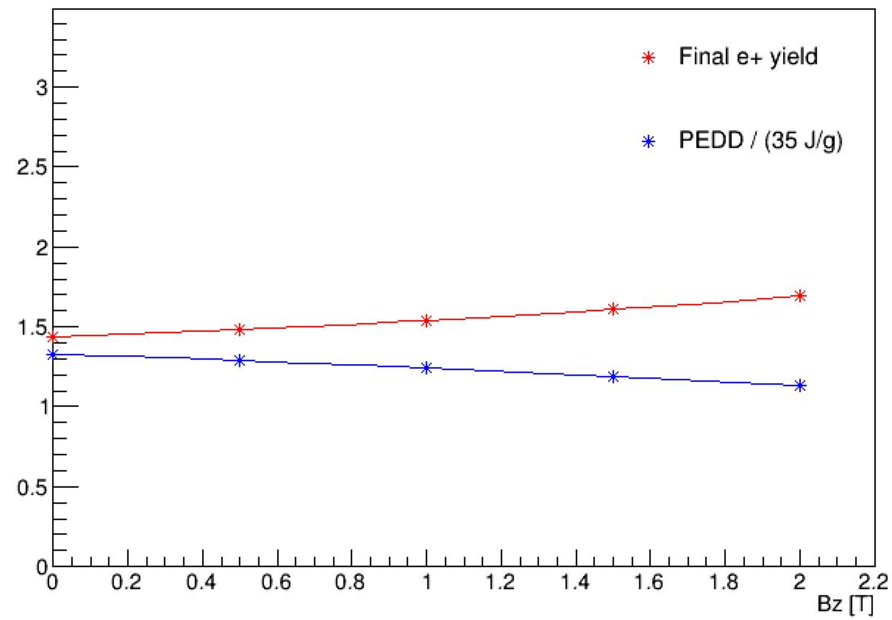
Linear effect from e- energy $(\text{e.g. } \eta_{e^+}^{\text{eff}} \approx 0.2 + 0.4 \cdot (E_{e^-}/\text{GeV}) e^+/e^-, \text{ when } 3\,\text{GeV} < E_{e^-} < 5\,\text{GeV})$ which shows the possibility to further increase the yield, or derease the energy

Additional studies

- Increase distance between target and AMD (default: 0)



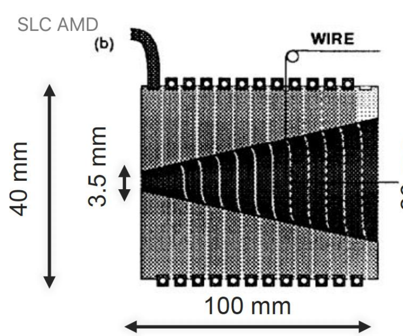
- Magnetic field (const.) between target and AMD (default: 0)
  - for a distance of **5 mm**

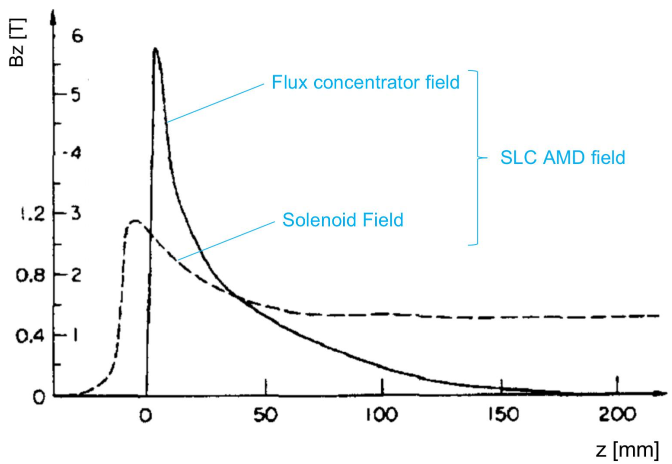


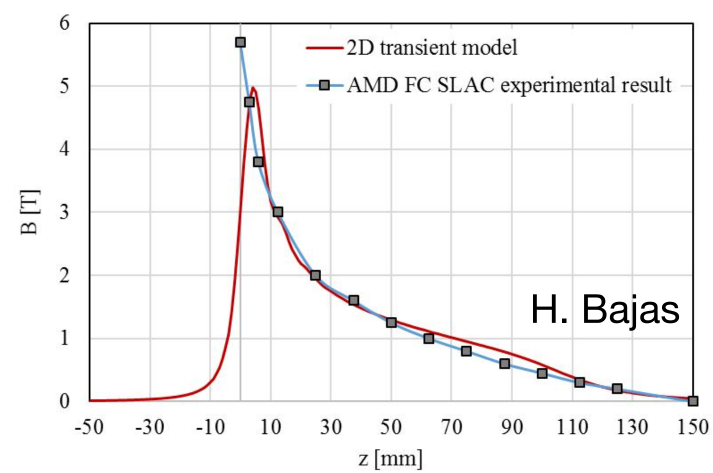
- Distance between target and AMD has a **big** negative effect
- Magnetic field would help to reduce the effect, but not so much

Conclusion & outlook

- A new optimisation strategy proposed (faster, simpler). **Preliminary** results showing an improvement compared with previous results
- Outlook:
- A more realistic AMD modelling, tuning and design with Opera-3D on-going (so far analytical field used)
- **Preliminary** simulation results from **Hugo Bajas** (magnet group):
  - SLAC SLC AMD simulation & field reproduction
  - More tests and re-optimisation needed





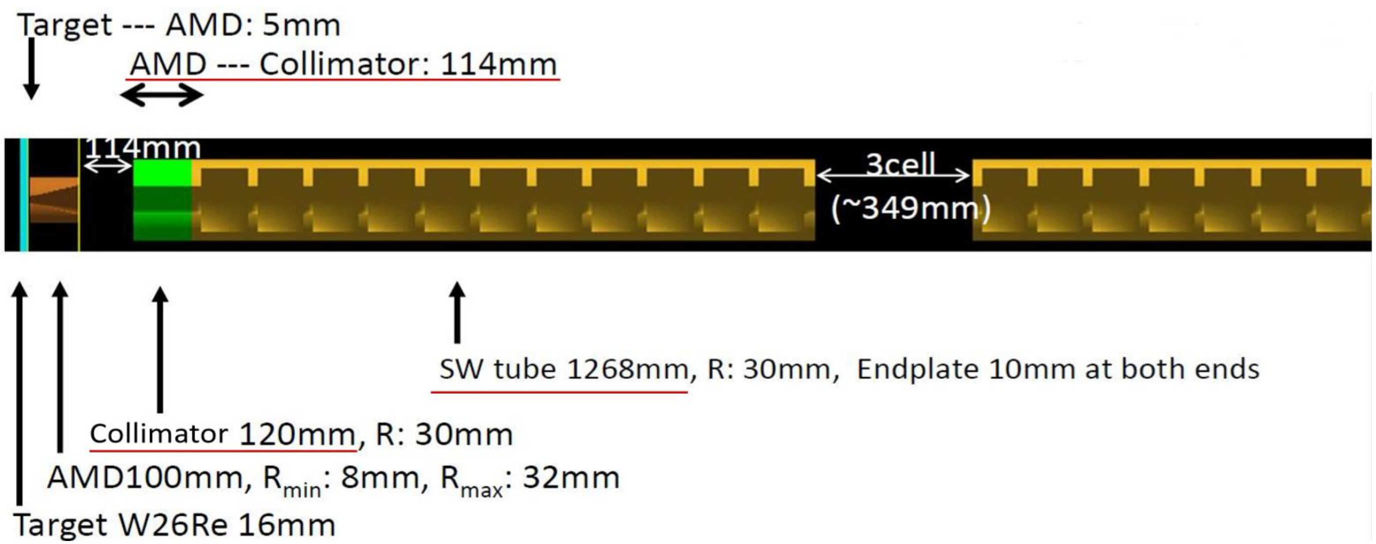


BACKUP

Code validation: ILC reproduction

- Simulation tools that are used

	Nagoshi-san	Fukuda-san	Yongke
Targets	Geant4	Geant4	Geant4
AMD & SW tubes	General Particle Tracker (GPT)	Geant4	RF-Track



(Totally 36 SW tubes)

- Number of bunches assumed in **mini-trains** contributed to PEDD: **66** (in ~500 ns, as a conservative estimate for the rotating target)
- Energy and momentum spread not considered in simulation

Code validation: ILC reproduction

[redacted]

- Study based on **LCWS2018&2019** talks and discussions with the team

[redacted]

- Main **difference** from CLIC: rotating single target; standing wave (SW) structures used after AMD instead of TW; injector linac replaced by a booster linac in ILC.
- But **booster linac is not simulated**, a **time window ± 7 mm/c** used for damping ring (DR) acceptance instead

(Totally 36 SW tubes)

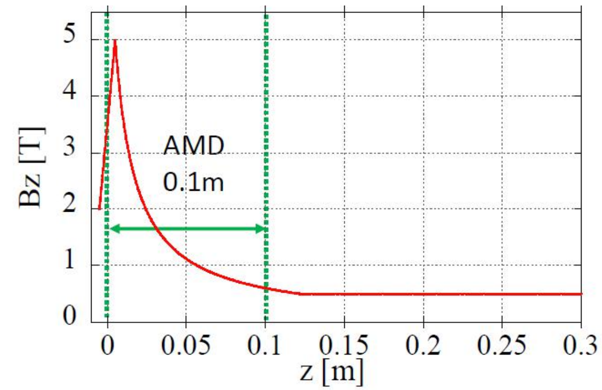
Code validation: ILC reproduction

- Analytical field used for AMD

Similar as CLIC AMD field, except for peak not at 0

$$B(z) = \frac{B_{peak}}{1 + \mu(z - 0.005)}$$

$$B_{peak} = 5\ [T]$$
$$\mu = 77\ [1/m]$$



- Pillbox (TM010) field approximation used for SW tubes

An improved field also studied, but not much difference observed (BACKUP slides)

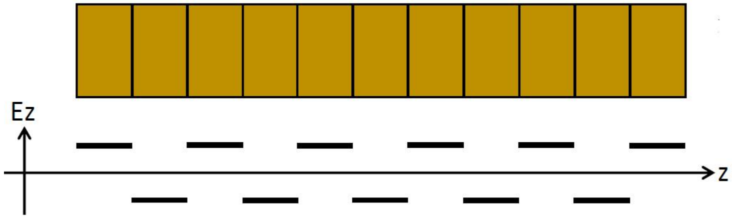
$$f = 1.3\ \text{GHz (L-band)}$$
$$\lambda = \frac{c}{f} \approx 230.61\ \text{mm}$$
$$\varphi = 20°$$

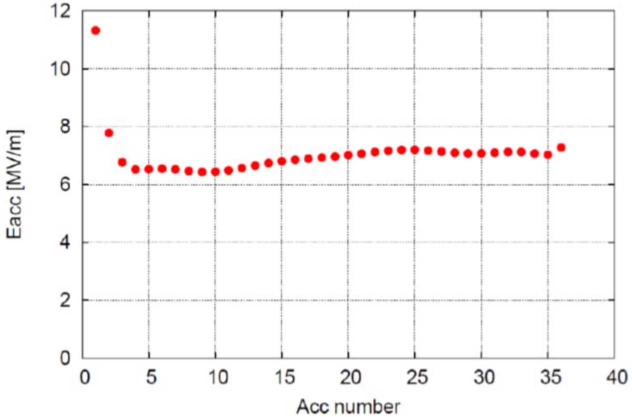
$$E_z = \frac{\pi}{2} E_{acc} \cdot J_0\left(\frac{2\pi}{\lambda} r\right) \cdot \sin(\omega t + \varphi)$$

$$E_x = E_y = 0,\ B_z = 0.5\ \text{T}$$

$$B_\emptyset = \frac{\pi}{2} E_{acc} \cdot J_1\left(\frac{2\pi}{\lambda} r\right) \cdot \cos(\omega t + \varphi) \cdot \frac{1}{c}$$

$$B_x = -\frac{y}{r} \cdot B_\emptyset,\ B_y = \frac{x}{r} \cdot B_\emptyset$$





Code validation: ILC reproduction

Improved field:

Quantity	Value
q_n	$\sqrt{\left\lvert\left(\frac{\omega}{c}\right)^2-\left(\frac{n\pi}{L}\right)^2\right\rvert}$
$\boldsymbol{E_z}(r,z,t)$	$\sum_{n=1}^{\infty} a_n Sin\left[\frac{n\pi(z+L/2)}{L}\right] Sin[\omega t+\phi_0]\times\begin{cases}J_0(q_n r) & \frac{\omega}{c}\geq\frac{n\pi}{L}\\ I_0(q_n r) & \frac{\omega}{c}<\frac{n\pi}{L}\end{cases}$
$\boldsymbol{E_r}(r,z,t)$	$-\sum_{n=1}^{\infty} a_n \frac{n\pi}{Lq_n} Cos\left[\frac{n\pi(z+L/2)}{L}\right] Sin[\omega t+\phi_0]\times\begin{cases}J_1(q_n r) & \frac{\omega}{c}\geq\frac{n\pi}{L}\\ I_1(q_n r) & \frac{\omega}{c}<\frac{n\pi}{L}\end{cases}$
$\boldsymbol{B_\phi}(r,z,t)$	$\sum_{n=1}^{\infty} a_n \frac{q_n{}^2+\left(\frac{n\pi}{L}\right)^2}{\omega q_n} Sin\left[\frac{n\pi(z+L/2)}{L}\right] Cos[\omega t+\phi_0]\times\begin{cases}J_1(q_n r) & \frac{\omega}{c}\geq\frac{n\pi}{L}\\ I_1(q_n r) & \frac{\omega}{c}<\frac{n\pi}{L}\end{cases}$

Results	After SW 1st tube	After 36 SW tubes	Within ±7 mm from z_peak
CLIC code (pillbox approximation)	2.03	1.96	1.09
CLIC code (improved SW field)	2.04	1.97	1.09

Code validation: ILC reproduction

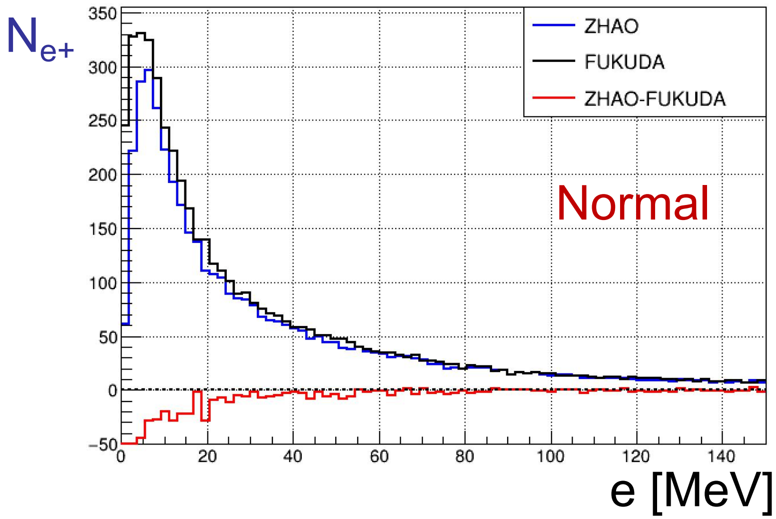
- Positron yield comparison

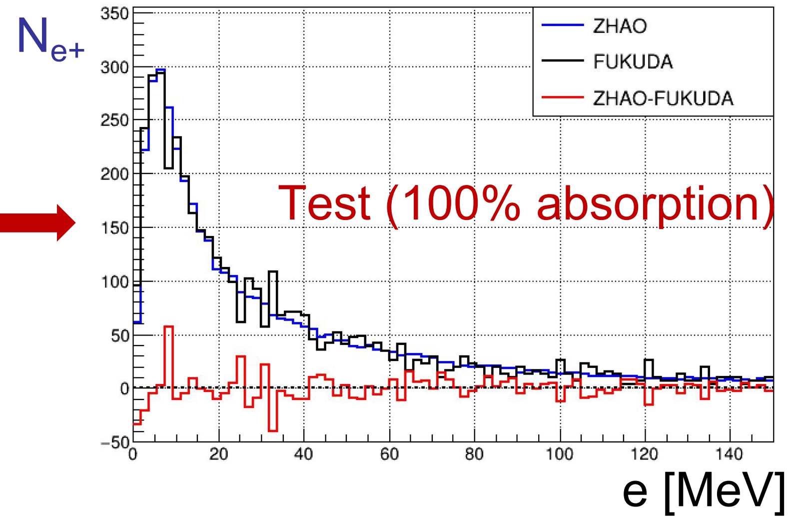
e+ Yield	Software	After target	After AMD	After 1st SW tube	After all SW tubes	Matched to DR acceptance
Nagoshi-san (ILC code)	Geant4+GPT 1,000 events	7.29	4.48	2.14	1.90	**1.00**
Fukuda-san (ILC code)	Geant4 10,000 events	7.13	5.09	2.58	1.94	**1.03**
	100% absorption in AMD & SW material (**test**)		4.57	2.24	1.84	**0.95**
Yongke (CLIC code)	Geant4+RF_Track 10,000 events	7.06	4.48	2.03	1.96	**1.09**
Difference (N.-san)		3%	0	5%	3%	**9%**
Difference (F.-san)		1%	**12%**	**21%**	1%	**6%**

- Visible **differences** found in the middle. But difference **eliminated** at the end after a long distance travel
- A test shows that **difference mainly from interactions with the linac pipe**
- **Nevertheless, a good agreement observed in the final yield**

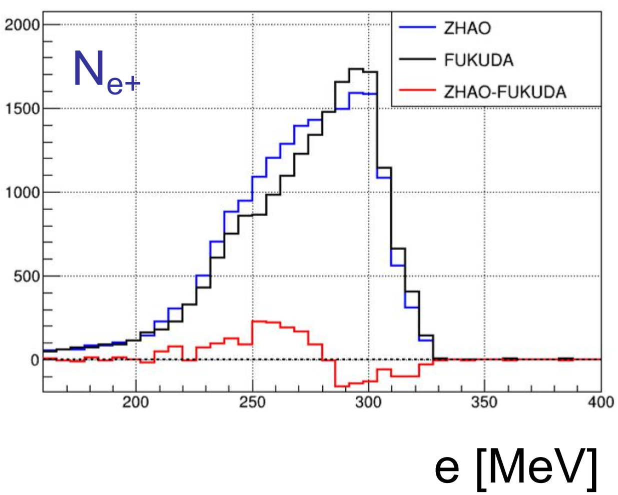
Code validation: ILC reproduction

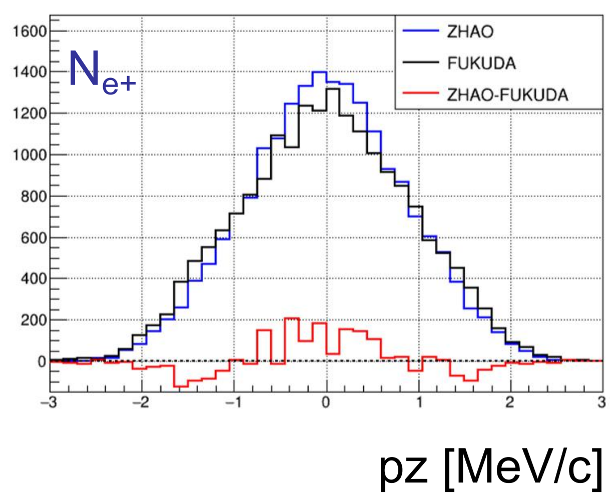
- Comparison plots between Fukuda-san's results and my results (after AMD)

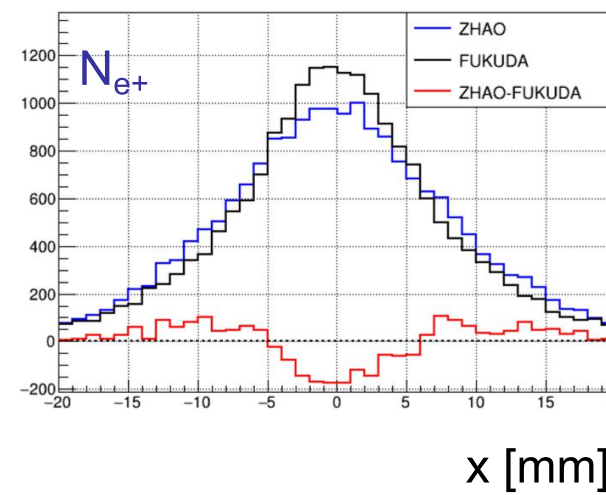




- Comparison plots between Fukuda-san's results and my results (after all SW tubes)

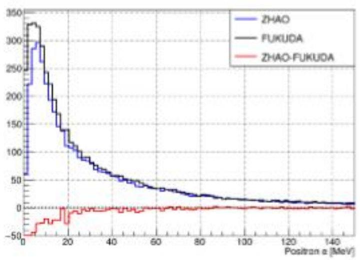




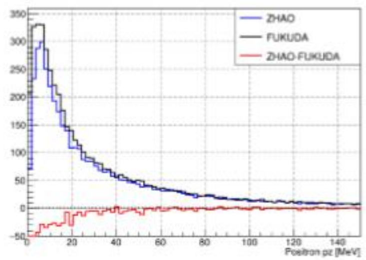


Code validation: ILC reproduction

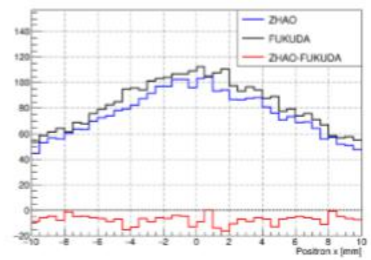
Positrons after ILC AMD



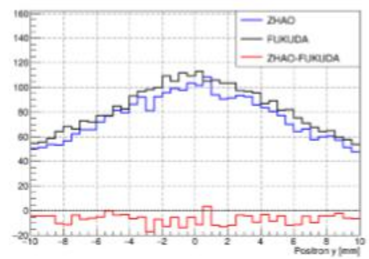
energy [MeV]



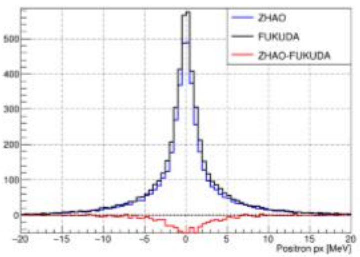
pz [MeV]



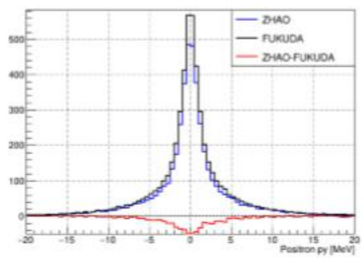
x [mm]



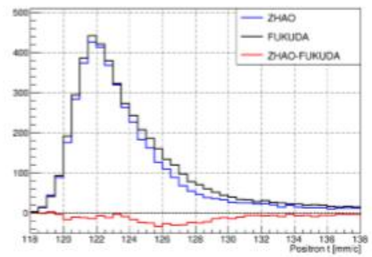
y [mm]



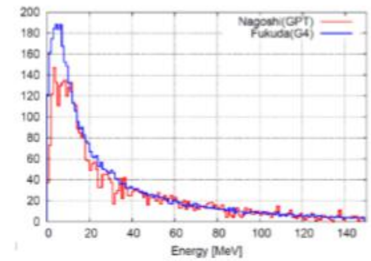
px [MeV]



py [MeV]



t [mm/c]

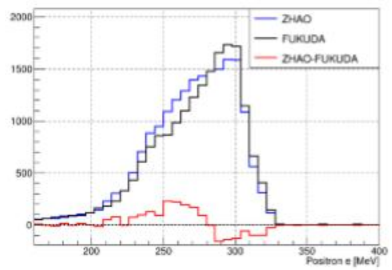


energy [MeV]

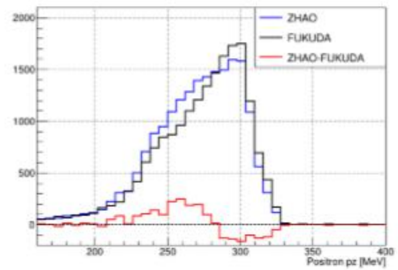
- ❑ Difference mainly distributed at **very low four-momentum** range
- ❑ An internal comparison from ILC (the last plot) shows even larger difference

Code validation: ILC reproduction

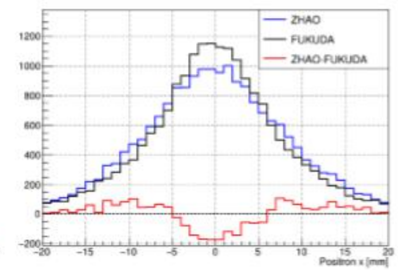
Positrons after all the 36 SW tubes



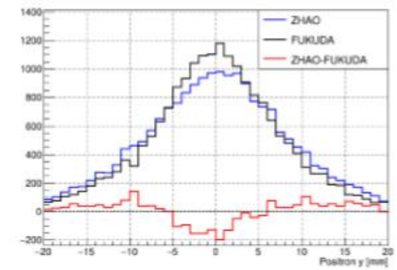
energy [MeV]



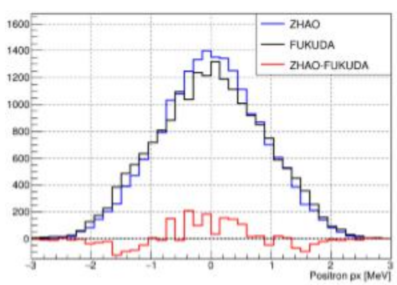
pz [MeV]



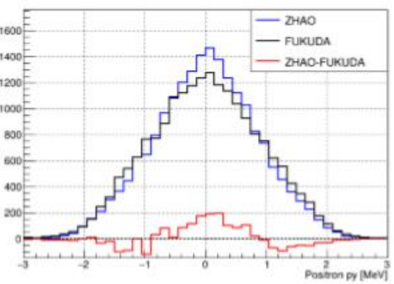
x [mm]



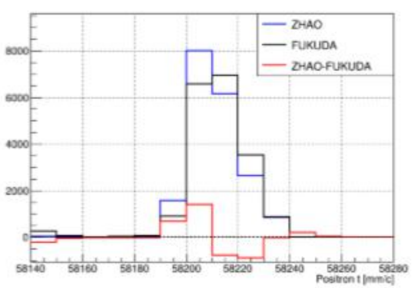
y [mm]



px [MeV]



py [MeV]

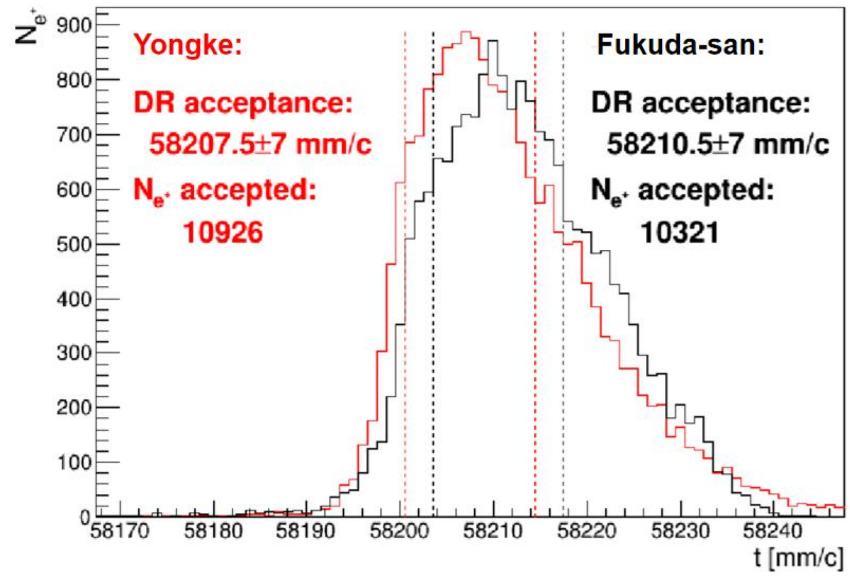


t [mm/c]

- ❑ **Small differences:** our results have a bit larger **energy and momentum spread** and **beam size**

Code validation: ILC reproduction

- Positrons with the DR acceptance (± 7 mm/c)



More comparison plots in BACKUP slides

Code validation: ILC reproduction

Target PEDD comparison

- for **2.4 nC** e$^-$ bunch (equivalent to a final e$^+$ **yield** of **2**)

Target PEDD	Ne- simulated	PEDD for 2.4 nC e- bunch / [J/g]
Nagoshi-san	1,000	**19.20**
Takahashi-san (previous)	10,000	**18.75**
Takahashi-san (latest*)	1,000	**22.00**
Yongke	10,000	**23.73**

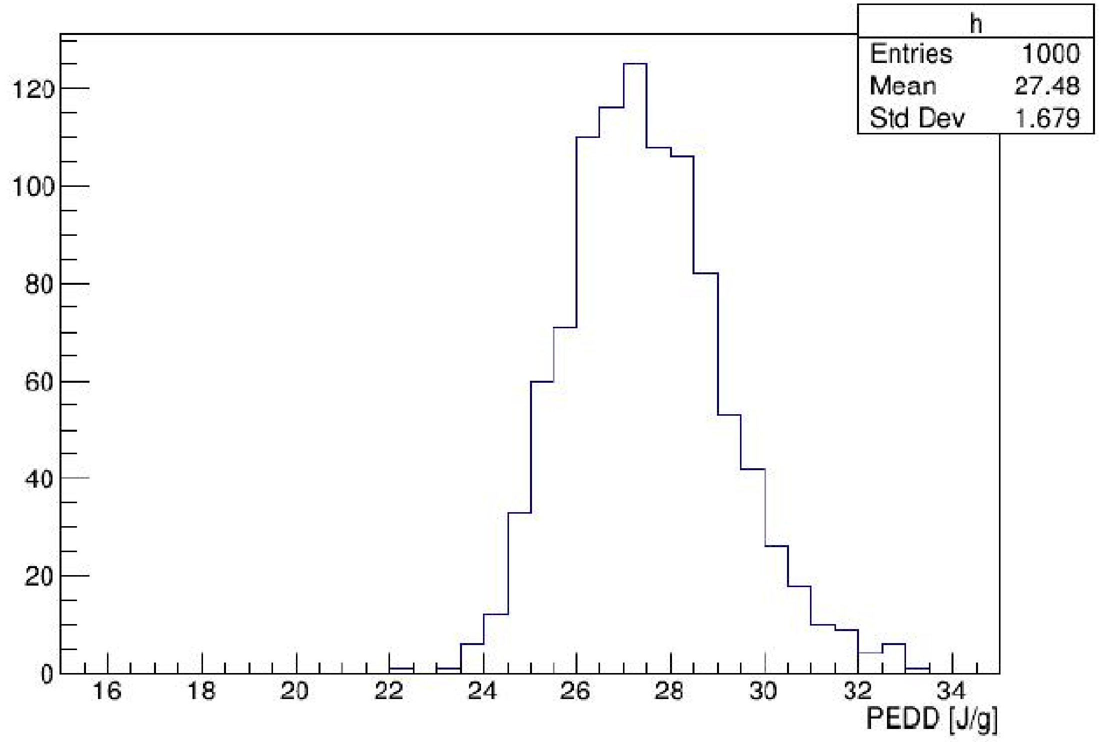
* In previous ILC result, PEDD **underestimated** compared to CLIC. **In the latest ILC result, this is improved.** However still some differences in the estimation between ILC and CLIC, e.g. ILC **mesh volume** size 2 times larger than CLIC

- Finally a **difference** of **8%** is found
- We think CLIC PEDD calculation **more conservative** and will **stick to it**
- Nevertheless, the **agreement is good**, given that our PEDD **statistical uncertainty** is **6%**

Code validation: ILC reproduction

PEDD uncertainty for cross-check with ILC

- PEDD uncertainty for 1000 events: 6.1% (1 sigma, 1000 electrons simulated also, and 1000 times of simulation with different random seed).



Code validation: CLIC reproduction

- PEDD re-normalised to the same **e^+ bunch population:** 4.44e9 (~ **0.7 nC** bunch charge)
- The same PDR energy acceptance window used as in the publication: E ± **3.6%·E.** Though it should be 1.2%·E
- **Nevertheless, a good agreement (difference < 10%)** observed in both yeild and PEDD

New optimisation results (Preliminary)

- Phase spaces

Yongke (preliminary)