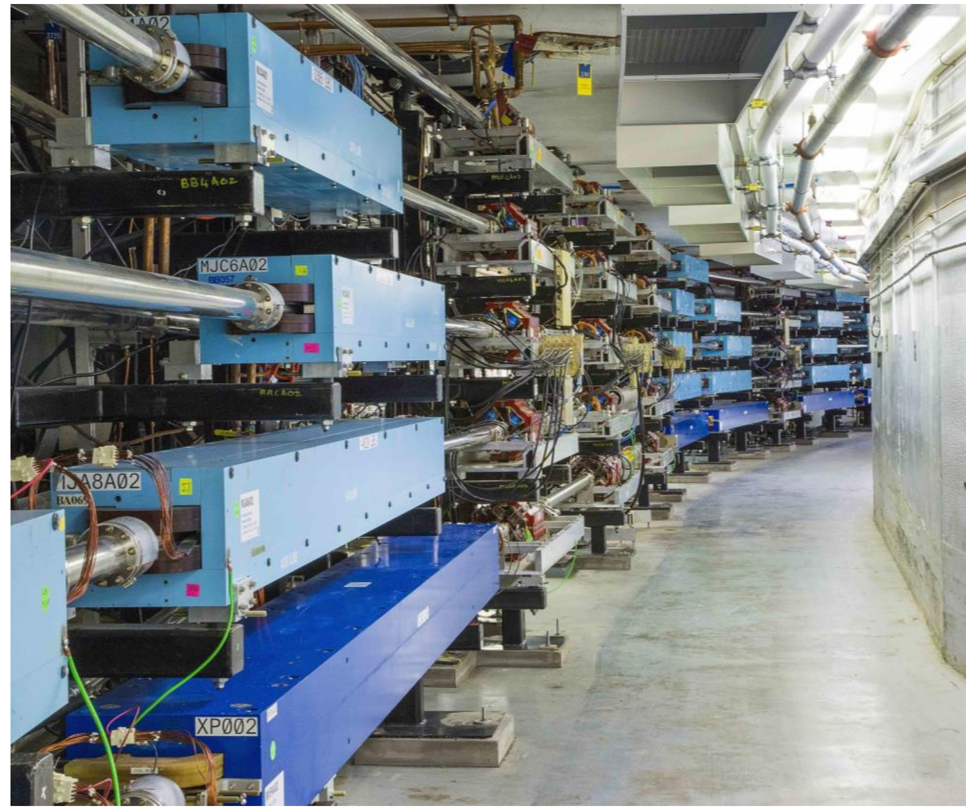
Accelerator status overview

Past performance

Near and long term plans



Yves R. Roblin

2023 Hall A Winter Collaboration Meeting

Jefferson Lab

U.S. DEPARTMENT OF ENERGY | Office of Science

JSA

Introduction - Outline

I. 2022 In Review, past performance

II. Improving reliability, reducing tune time
  I. Operational improvements/procedural developments
  II. CPP: the CEBAF Performance Plan

III. Energy reach plan

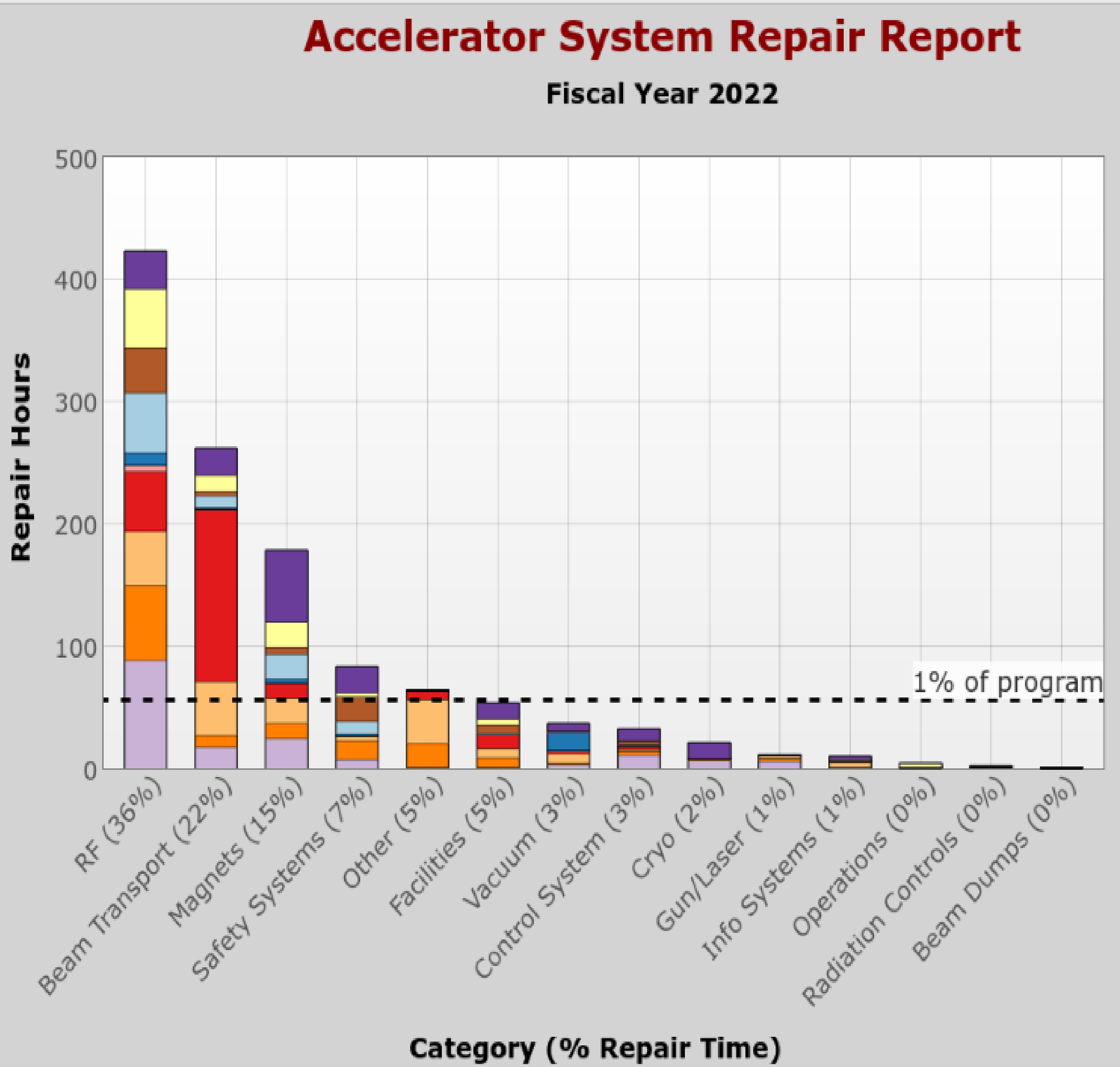
IV. Moving towards the future
  I. Injector upgrade
  II. Hall A beamline upgrade
  III. Positron Project
  IV. CEBAF at 22 GeV

V. Winter SAD schedule

VI. Upcoming physics run

Reliability at CEBAF

FY 22: 76.5 %



	Prg Hrs	Prg %
Oct '21	744	14%
Nov '21	721	13%
Dec '21	477	9%
Jan '22	625	11%
Feb '22	175	3%
Mar '22	0	0%
Apr '22	0	0%
May '22	0	0%
Jun '22	617	11%
Jul '22	744	14%
Aug '22	726	13%
Sep '22	659	12%
Total:	**5,488**	

FY	% Reliability
FY21	70.30%
FY20	68.30%
FY19	81.30%
FY18	76.00%

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Improving reliability, reducing tune time

Operational procedures are being reviewed/rewritten

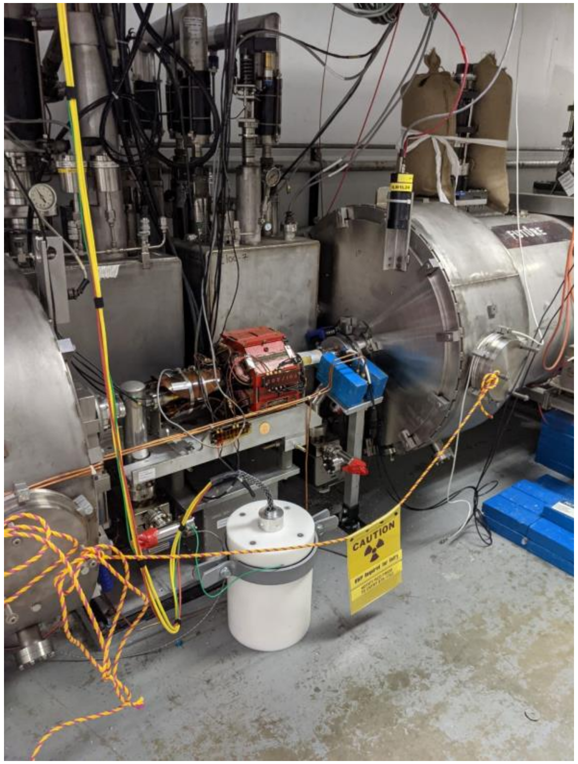
- Optics Restoration and Finalization Procedure (ORFP)
  - Systematic task driven method to restore the machine
- Energy scaling
  - New process reduced tune time from 5 to 1 calendar days
- Pass change setup improved
- Beam envelope match into the halls

In FY2022 the lab is investing $2.5M in upgrading obsolete systems and procuring spares.

See R. Michaud JLAAC talk on the CEBAF Performance Plan

rmichaud@jlab.org

Improving reliability: Optimizing for reduced radiation



Sum of SL NDX neutron signals

measured gradients of each cavity

beamline vacuum in vicinity

- NDX (neutron) detectors were installed in the accelerator enclosure.
- They inform gradient redistribution with the aim of reducing the radiation induced field emission.
- Designed and built by the Radiation Control group.

- Gradient / radiation reduction moving toward AI optimization.
  - Currently the focus of efforts from the Radiation Control group, Operations and CASA.

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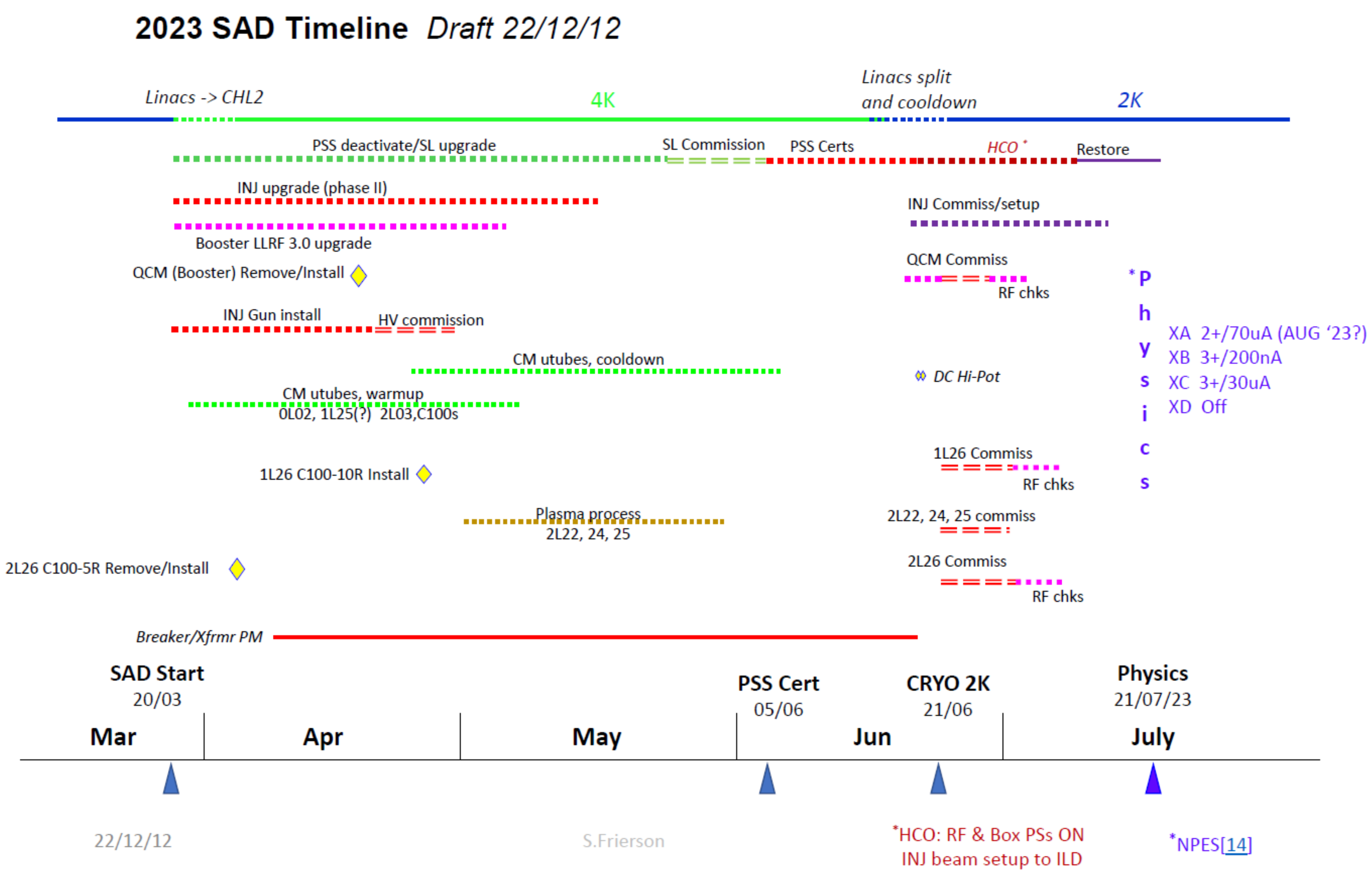
Scheduled accelerator Down timeline



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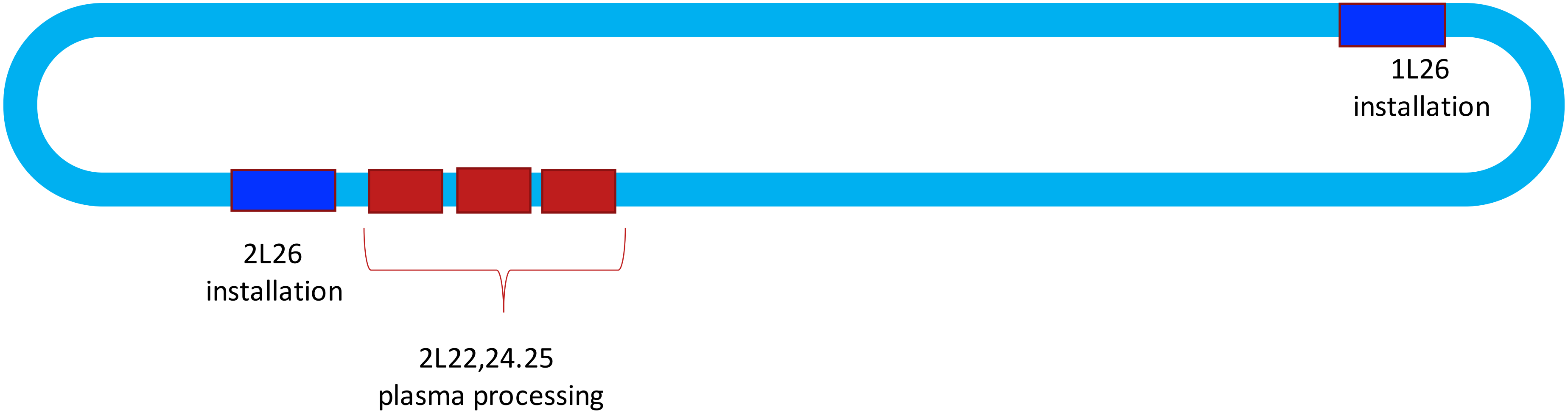
Energy reach plan for FY2023, cryomodule dance

Current reach:
NL : 1053
SL: 1056

expected reach after sad:
NL : 1103
SL: 1106

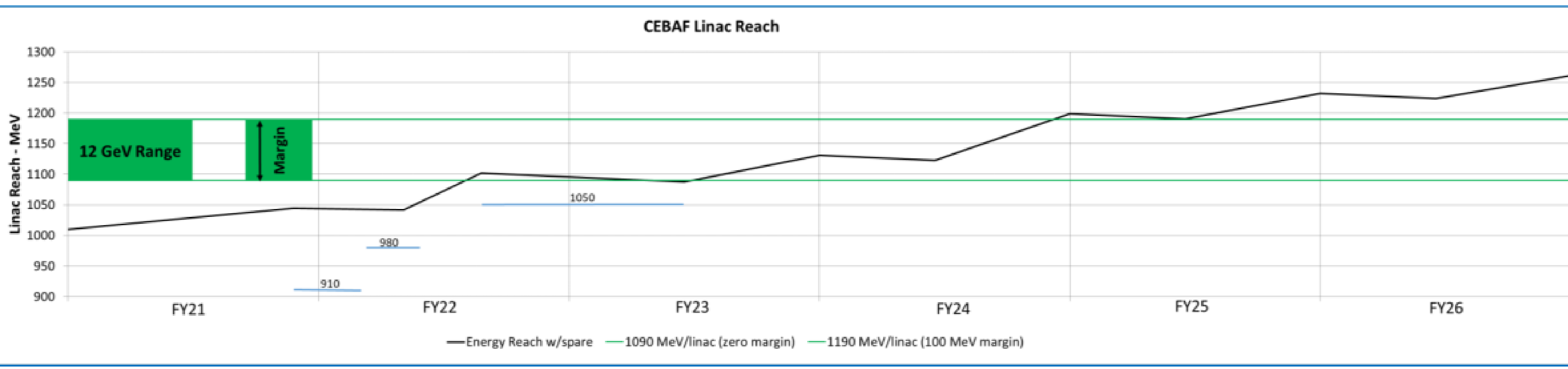


Current forecast. The situation is in flux and plan will be adjusted as one becomes aware of the SRF reach (affected by component failures,etc..), e.g 2L07 ?

CEBAF performance Plan: Energy reach FY2021-2026

	#CM assembled (previous year)	CM serial number	NL energy reach (MeV)	SL energy reach (MeV)	
FY21	2	P1 (NL), C75-01 (NL)	1038.5	1047.8	
FY22	3	C75-02(SL), C50 (SL), C100-09R(NL)	1096	1100	
FY23	3	~~C75-03(SL)~~, C100-10R (SL), C100-X1R (SL), []	1124	1123	~~remove C75-04 (SL)~~
FY24	TBD		TBD		
FY25					
FY26					

Changes from Oct 2020 plan marked in red



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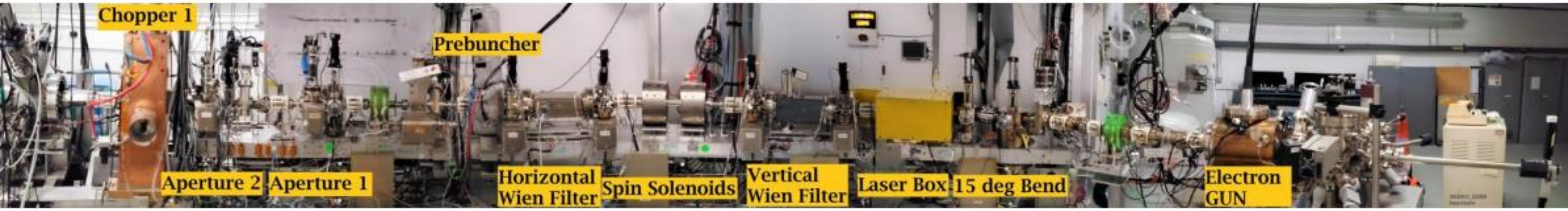
Injector upgrade



- Taking place in two phases, we have completed phase 1:
  - Gun upgraded to 200 kV
  - Relocated Wien Filters, designed matching optics
  - Replaced injector solenoids with a better design

- Phase 2 is planned for 2023 SAD, will involve installing the new booster

Why are we doing this ?

Changes are needed to reach the parity quality beam specifications in support of future experiments such as the Moller experiment.

HALL A BEAMLINE FOR FY23

- Two options were being considered (for 2022):

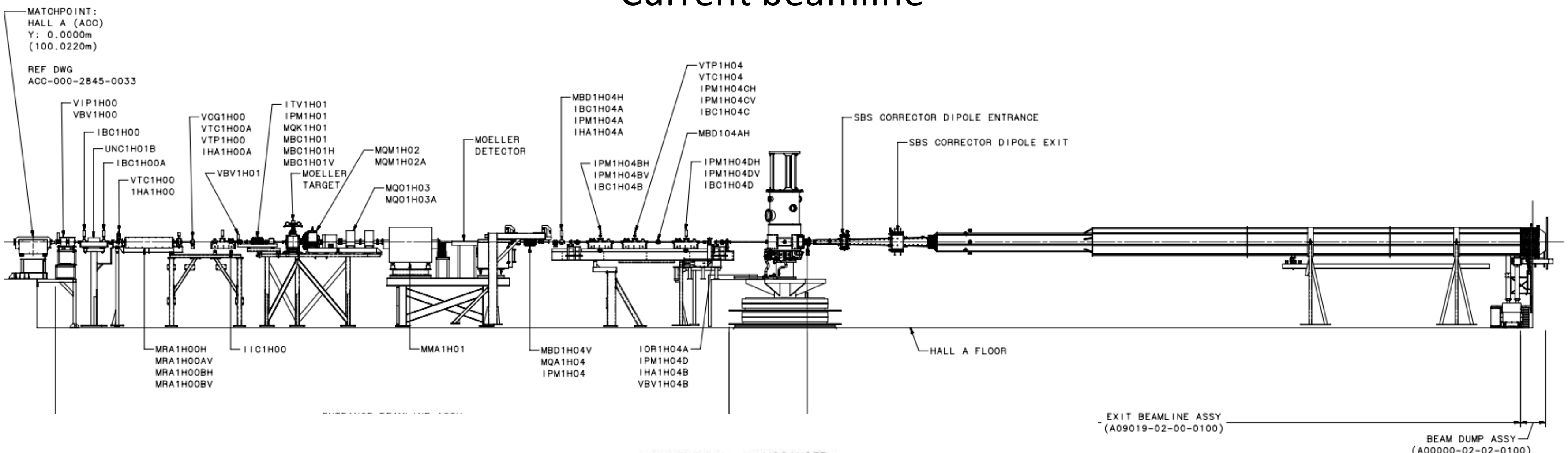
1. Phase 1 Moller beamline upgrade where one partially moves the beamline towards the final configuration for Moller. It has a number of benefits for SBS as well.

2. Current optics where the last six quads are turned off to insure a circular raster are not easy to tune. Small errors in the incoming beam in Hall A are magnified into significant variations at target requiring lengthy retunes.

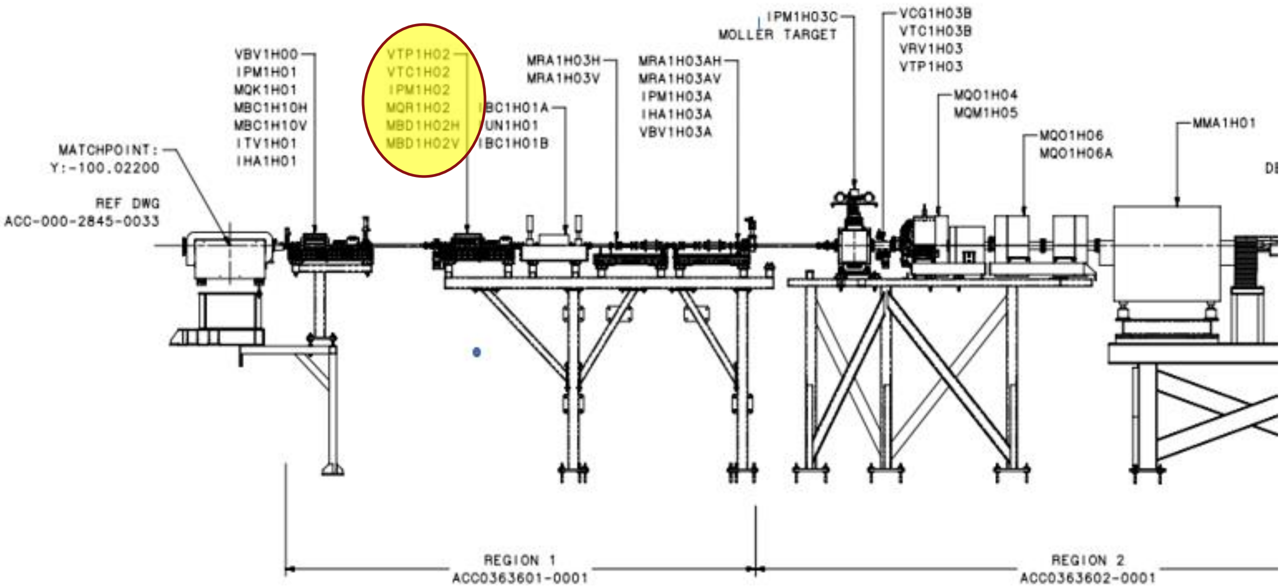
3. We are planning to do phase 1 during this SAD.

Hall A Moller phase 1 beamline install

Current beamline



New region 1



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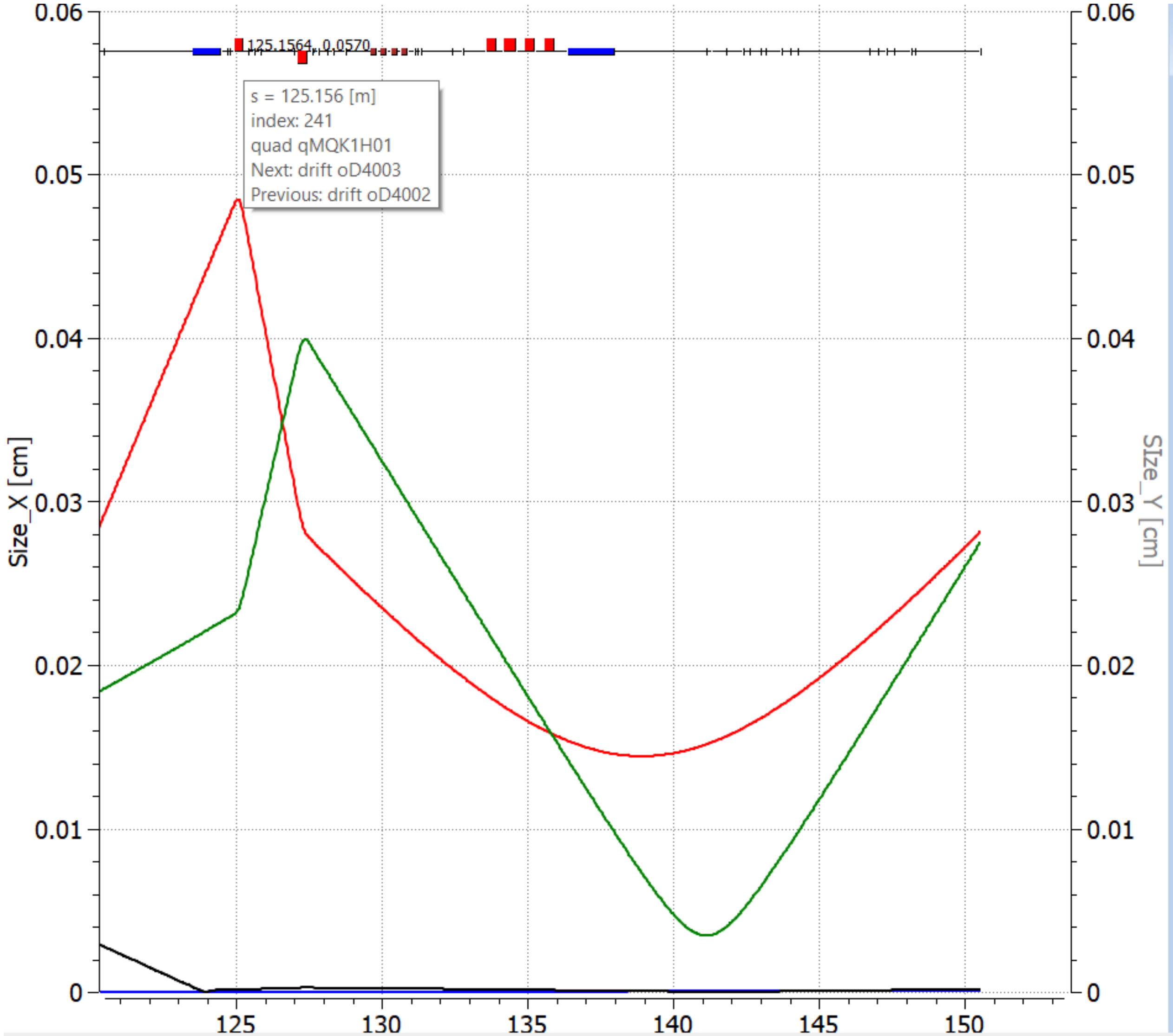
Beam Envelope Hall A phase 1 beamline



- No quads past raster
- Moller target moved 30cm upstream
- Enhanced steering capabilities
- Easily controllable raster size

Upcoming 2023 physics run

- We are restarting end of July. We are planning to go with 1047 MeV/linac .

- Next running period will have a large combination of halls/passes requiring polarization. The energy choice above provide a good compromise to maximizing it in as many halls as possible.

Config	Wien	P^2 A	P^2 B	P^2 C
a2b5c4	-36.4	0.89	0.99	0.82
a2b5c5	-26.6	0.97	0.99	0.99
a3b5c5	-20.6	0.86	0.97	0.96
b5c3	-10.4	n/a	0.88	0.88
b5c4	-46.2	n/a	0.93	0.93
b3c5	-13.3	n/a	0.89	0.89
b4c5	-47.9	n/a	0.93	0.93

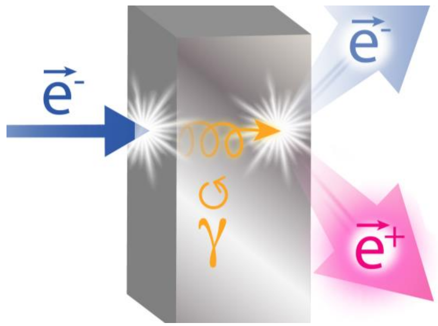
Summary

- Successfully running at 1047 per linac, albeit having issues reaching the desired linac current.
- Machine reliability is improving despite pandemic related issues in supply chain and labor.
- A robust CPP program is in place to address remaining vulnerabilities.
- There is a long term plan for the gradient ramp-up and SRF inventory is being upgraded with new cryomodules.
- We are preparing for the upcoming run period and the Moller experiment.

Future CEBAF

Expands the 12 GeV capability with e+

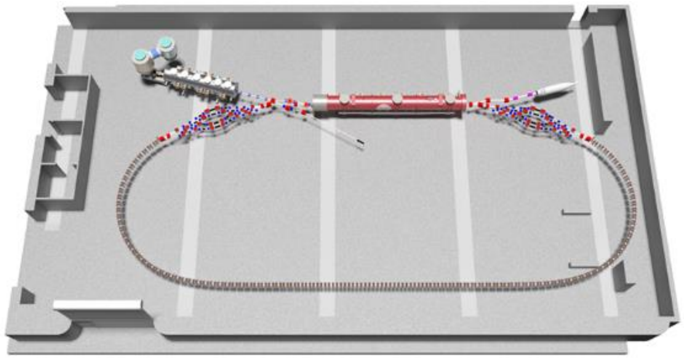
- Builds **two new polarized injectors (e+/e-)**
- Retains present polarized e- injector
- Multi-hall capability is a high priority
- Capability happens after Moller



Production of Highly Polarized Positrons Using Polarized Electrons at MeV Energies, D. Abbott et al., Phys. Rev. Lett. ***116*** *(2016) 214801*

Expands energy reach to 22 GeV with e-

- Requires **new 650 MeV polarized injector**
- Builds upon e+ infrastructure
- Adds permanent magnets (FFA) for highest energies
- Retains multi-hall capability

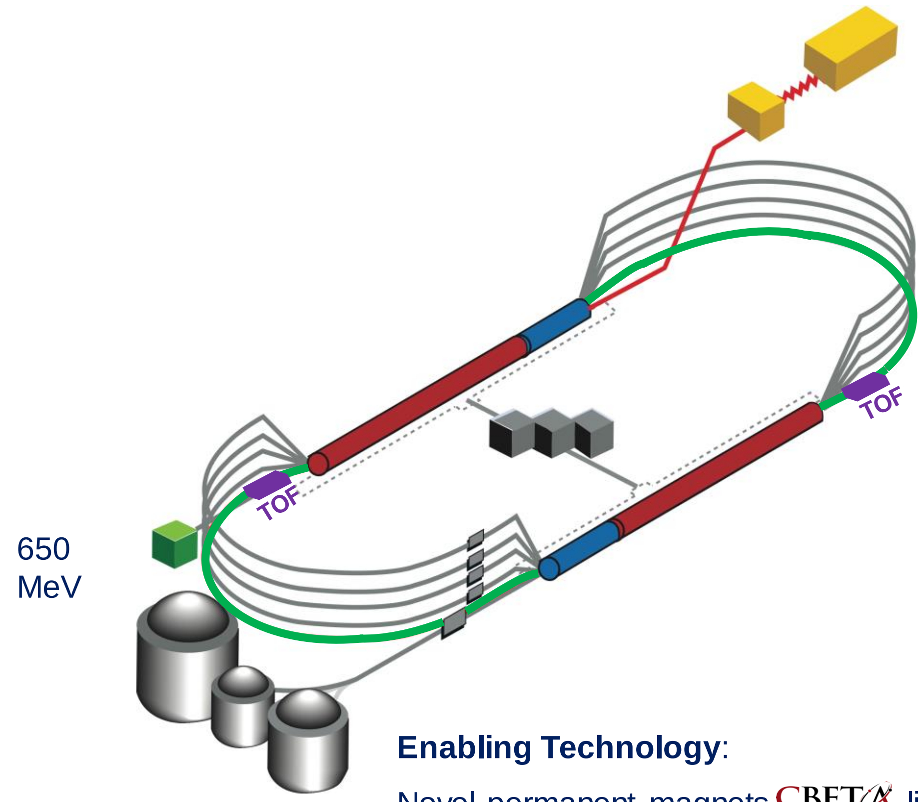


CBETA: First Multipass Superconducting Linear Accelerator with Energy Recovery, A. Bartnik, et al., Phys. Rev. Lett. ***125*** *(2020) 4, 044803*

CEBAF FFA Upgrade – Baseline under Study

- Starting with 12 GeV CEBAF
- NO new SRF (1.1 GeV per linac)
- New 650 MeV recirculating injector
- Remove the highest recirculation pass (Arc 9 & A) and replace them with two FFA arcs including time-of-flight chicanes
- Recirculate 4.5 + 6 times to get to **22 GeV**

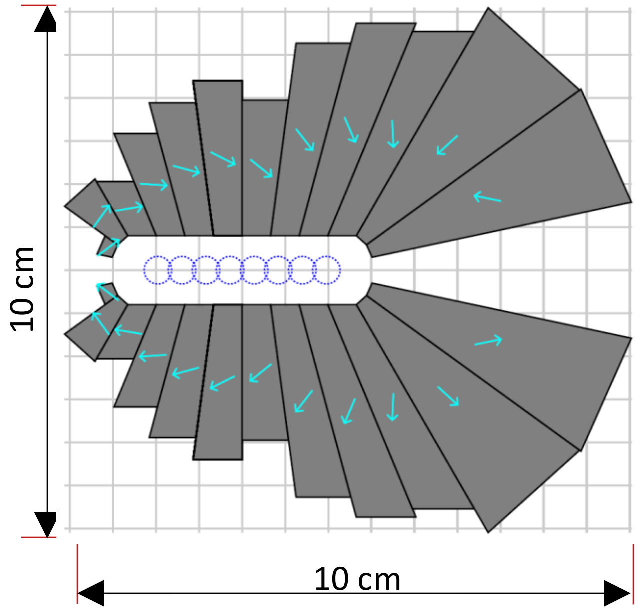
Pass Arithmetic: **5.5** -1 + **6** = **10.5**

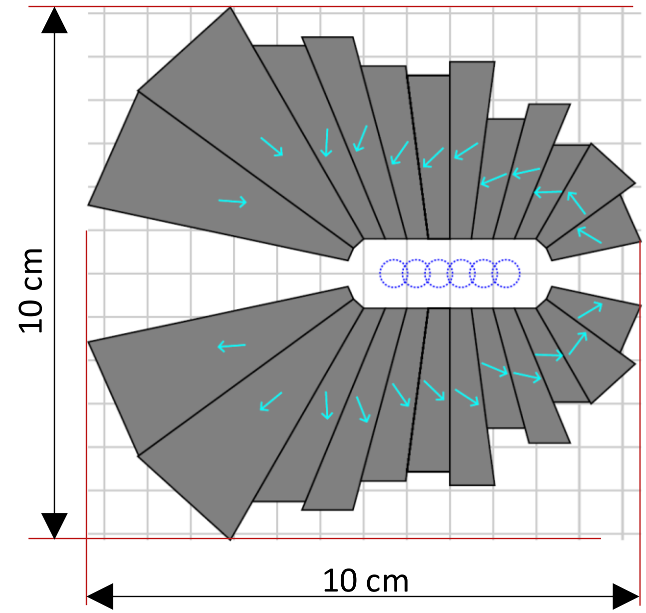


Enabling Technology:

Novel permanent magnets, CBETA-like used for power and cost savings

Permanent Magnet Design – Open Mid-plane Geometry





Focusing Magnet BF

G_F= -41.13 T/m

L_{QF}= 1.6 m

B_F= -0.812 T

Defocusing Magnet BD

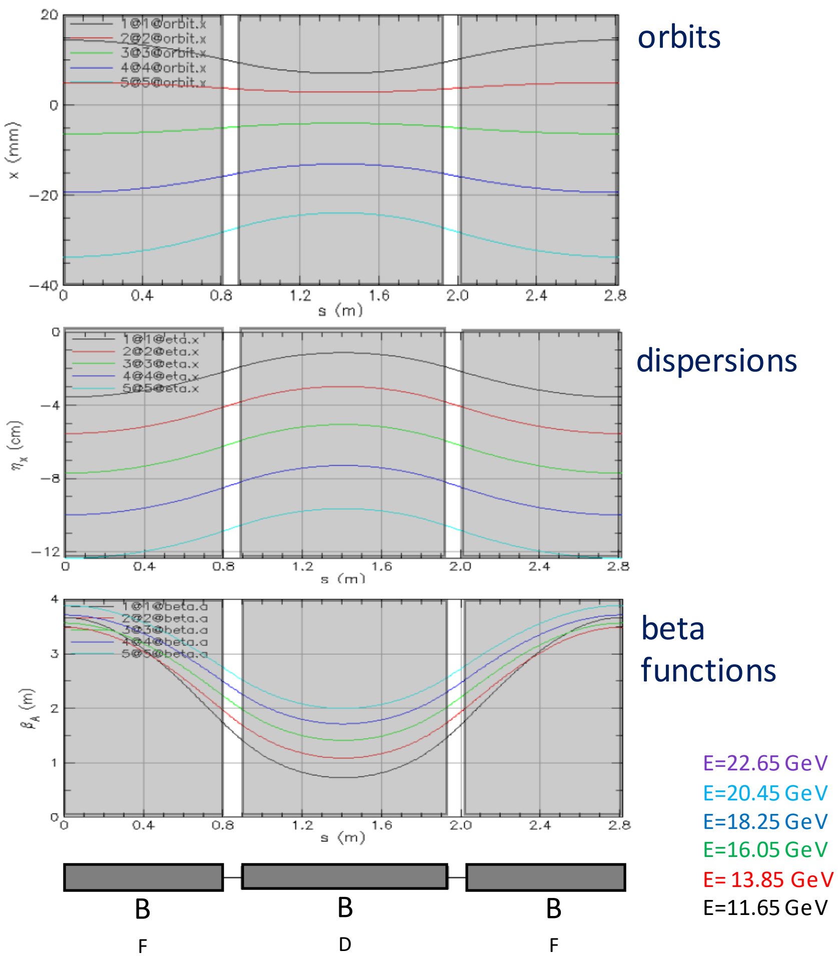
G_D= 43.44 T/m

L_{BD}= 1.0 m

B_D= -0.593 T

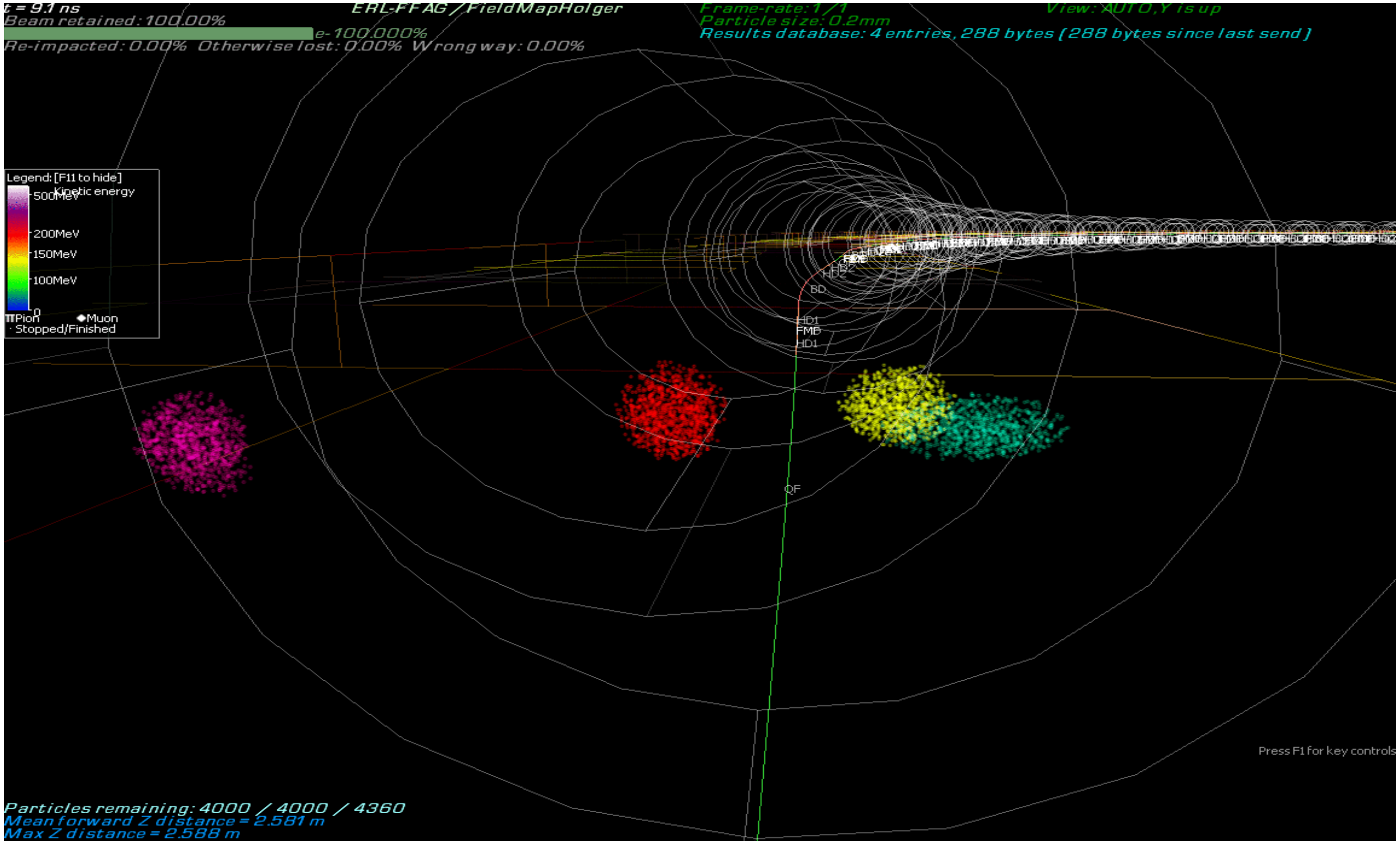
CBETA magnets: from 38cm^2 to 78cm^2

FFA Arc – Compact FODO Cell



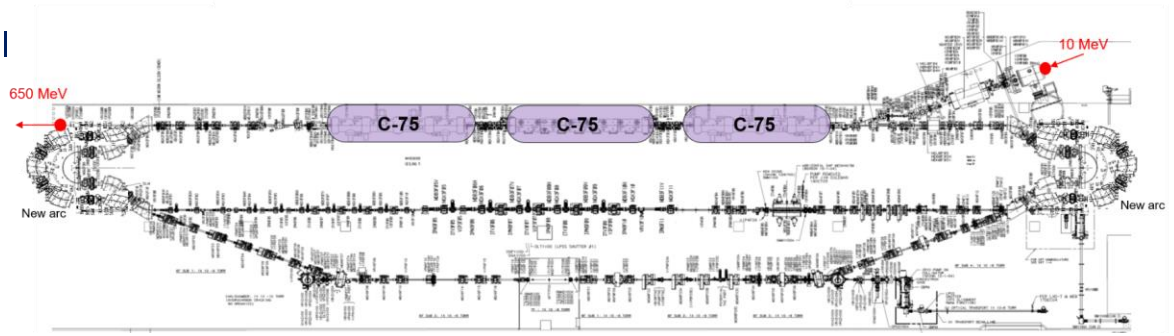
- Large momentum acceptance FFA cell, configured with combined function magnets capable of transporting six beams with energies spanning a factor of two
- Arc composed of 86 cells, $L_{cell} = 2.8$ m
- Closely spaced orbits for all six beams (~ 5 cm)
- Low betas (~ 5 m)
- Extremally low dispersions (a few cm) - Virtue of combined function FFA magnets

Multi-Bunch Dynamics in CBETA FFA Arc



Injector Upgrade - 650 MeV Recirculating Injector

With the present 123 MeV injector, the difference in the first and final pass energies in the North Linac is too large (1:175) to effectively control the beam.



650 MeV recirculating injector (3-pass) based on LERF will allow a manageable difference in energies (1:33)

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Energy loss, Emittance Dilution (6-pass FFA)

6 passes

	E [GeV]	ρ [m]	ΔE [MeV]	<H> [m]	De$_N$ [$m\ rad$]	Ds $_{DE/E}$
FFA 9	10.43	74.2	7	4.4E-03	1.9E-05	2.0E-04
FFA 10	11.51	74.2	10	4.4E-03	1.9E-05	2.3E-04
FFA 11	12.59	74.2	15	4.4E-03	2.0E-05	2.7E-04
FFA 12	13.67	74.2	21	4.4E-03	2.1E-05	3.2E-04
FFA 13	14.74	74.2	28	4.4E-03	2.2E-05	3.8E-04
FFA 14	15.80	74.2	37	4.4E-03	2.3E-05	4.5E-04
FFA 15	16.85	74.2	48	4.4E-03	2.5E-05	5.3E-04
FFA 16	17.89	74.2	61	4.4E-03	2.9E-05	6.2E-04
FFA 17	18.92	74.2	76	4.4E-03	3.3E-05	7.3E-04
FFA 18	19.94	74.2	94	4.4E-03	4.0E-05	8.5E-04
FFA 19	20.93	74.2	115	4.4E-03	4.8E-05	9.9E-04
FFA 20	21.91	74.2	137	4.4E-03	6.0E-05	1.1E-03

Geometric Arc Radius [m]	80.6

Final Energy [GeV]	22.9
Total Energy Loss [MeV]	680

$$H_x = g_x D_x^2 + 2a_x D_x D_x' + b_x D_x'^2$$

$$\Delta E = \frac{2\pi}{3} r_0\, mc^2\, \frac{\gamma^4}{\rho}$$

$$\Delta\epsilon_N = \frac{2\pi}{3} C_q r_0 < H > \frac{\gamma^6}{\rho^2},$$

$$\frac{\Delta\epsilon_E^2}{E^2} = \frac{2\pi}{3} C_q r_0\, \frac{\gamma^5}{\rho^2},$$

- Synchrotron radiation mitigation in FFAs
  - High fill factor (92% space filled with bends) increases significantly the bend radius, ρ.
  - By virtue of extremally small dispersion and betas, the horizontal emittance dispersion, **<H>**, is highly suppressed (factor of 20 lower then in a conventional CEBAF arc lattice).

What next ?

Where to stage a new e^+ injector…?

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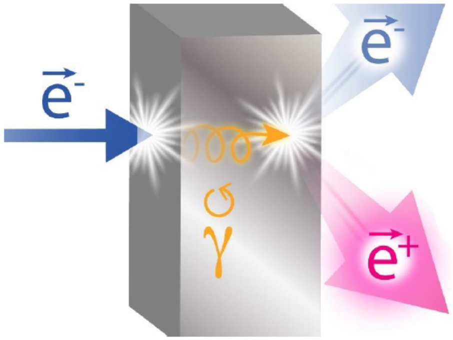
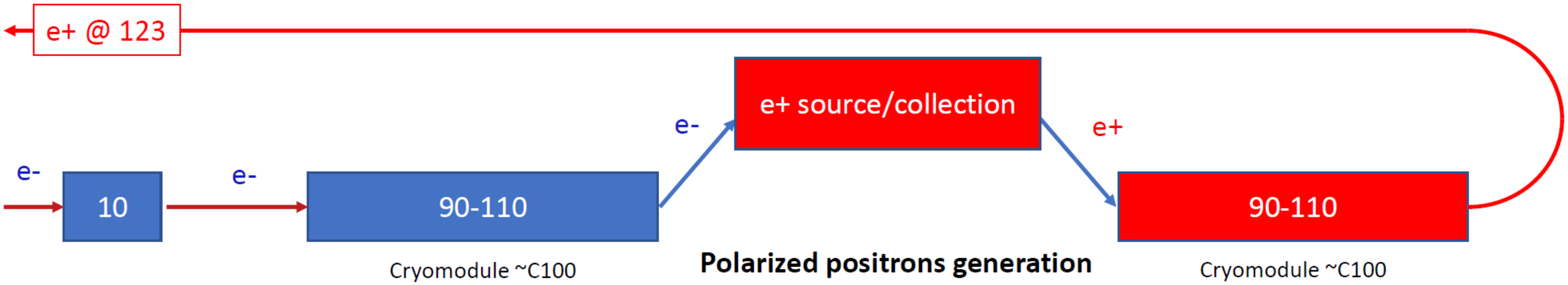
Synergy Between the Positron Source and 650 MeV Injector

Polarized e+, big picture

- Hardware needed:
  - High current polarized e- source
  - A cryomodule to accelerate e-
  - An e+ target-source and collection system
  - A cryomodule to accelerate e+

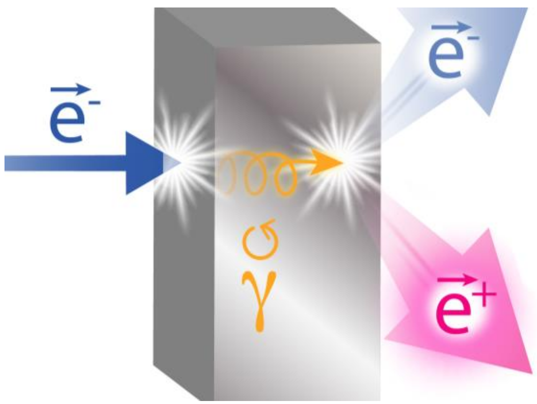




- Most of hardware from e+ stage can be re-used in the 22 GeV program – synergy with energy upgrade
- Space requirements for e+ source are similar to what is needed for ~600 MeV injector for 22 GeV program

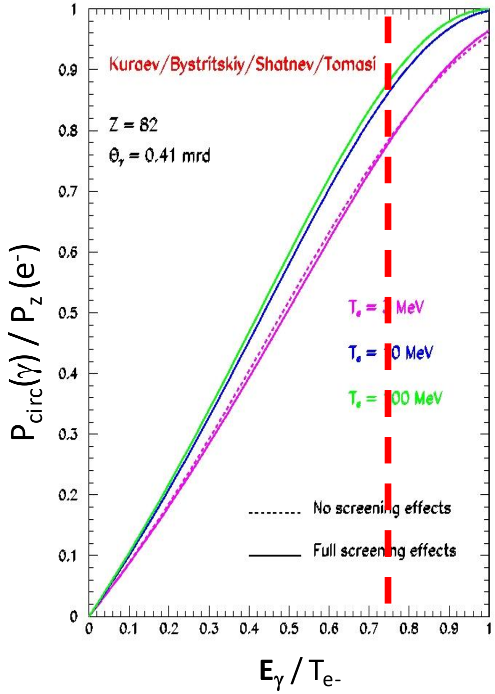
Exploit electron spin polarization to produce polarized positrons

When a longitudinally polarized e^- beam strikes matter, e^+ produced in the shower carrying ***>50% of the e^- beam energy*** *are significantly longitudinally* ***spin polarized****…*

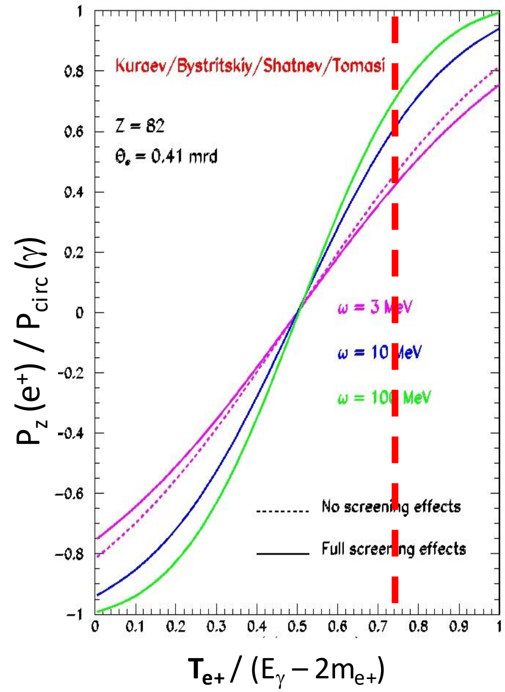


…so why not take advantage of this?

Polarized Bremsstrahlung



Polarized Pair Creation



E.A. Kuraev, Y.M. Bystritskiy, M. Shatnev, E.Tomasi-Gustafsson, PRC 81 (2010) 055208

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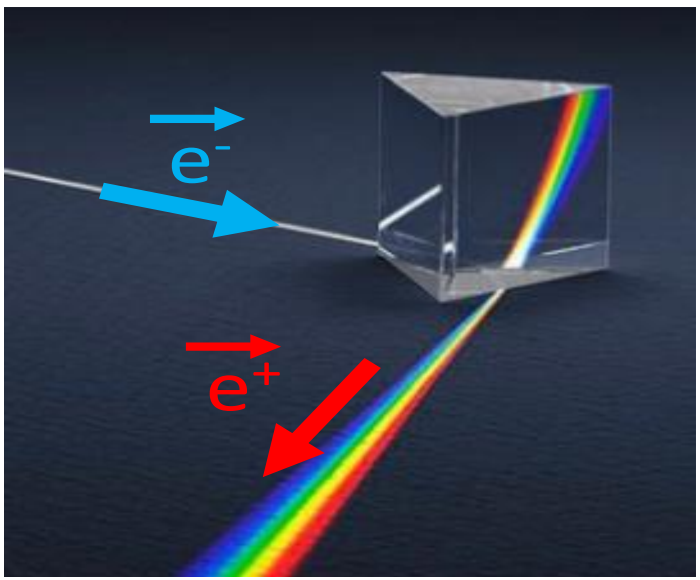
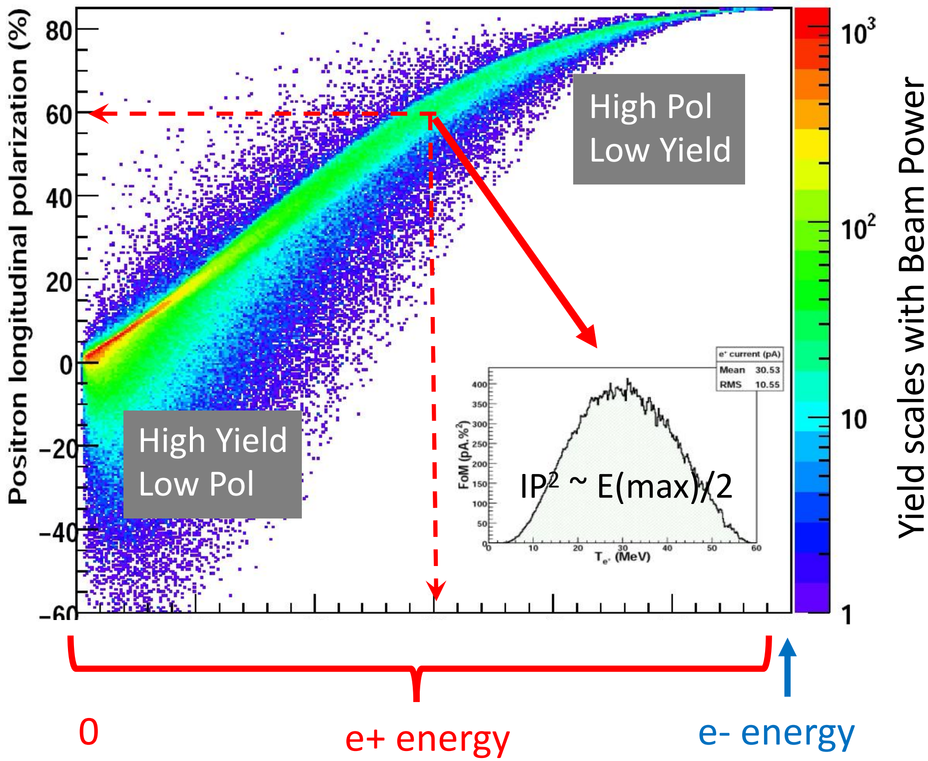
PEPPo : Polarization and Intensity Trade Off

Positron polarization & intensity is characteristically ***independent*** *of the e^- beam energy*





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Volume of EPJA on e+ program for CEBAF 12 GeV

20 contributions** from the PWG Working Group of (at last count) **230 scientists** from **75 institutions

An Experimental Program with Positron Beams at Jefferson Lab

Regular Article - Experimental Physics

Eur. Phys. J. A (2021) **57**: 261

https://doi.org/10.1140/epja/s10050-021-00564-y

Regular Article - Experimental Physics

An experimental program with high duty-cycle polarized and unpolarized positron beams at Jefferson Lab

A. Accardi[2,31], A. Afanasev[4], I. Albayrak[35], S. F. Ali[63], M. Amaryan[42], J. R. M. Annand[29], J. Arrington[8], A. Asaturyan[65], H. Atac[48], H. Avakian[2], T. Averett[75], C. Ayerbe Gayoso[40], X. Bai[14], L. Barion[23], M. Battaglieri[2,3], V. Bellini[13], R. Beminiwattha[74], F. Benmokhtar[72], V. V. Berdnikov[63], J. C. Bernauer[55,61], V. Bertone[28], A. Bianconi[10,44], A. Biselli[68], P. Bisio[26], P. Blunden[64], M. Boer[21], M. Bondi[3], K.-T. Brinkmann[27], W. J. Briscoe[4], V. Burkert[2], T. Cao[31], A. Camsonne[2], R. Capobianco[57], L. Cardman[2], M. Carmignotto[2], M. Caudron[1], L. Causse[1], A. Celentano[3], P. Chatagnon[1], J.-P. Chen[2], T. Chetry[40], G. Ciullo[23,24], E. Cline[55], P. L. Cole[7], M. Contalbrigo[23], G. Costantini[10,44], A. D'Angelo[51,53], L. Darmé[25], D. Day[14], M. Defurne[28], M. De Napoli[13], A. Deur[2], R. De Vita[3], N. D'Hose[28], S. Diehl[27,57], M. Diefenthaler[2], B. Dongwi[31], R. Dupré[1], H. Dutrieux[28], D. Dutta[40], M. Ehrhart[1], L. El Fassi[40], L. Elouadrhiri[2], R. Ent[2], J. Erler[36], I. P. Fernando[14], A. Filippi[60], D. Flay[2], T. Forest[49], E. Fuchey[57], S. Fucini[46,47], Y. Furletova[2], H. Gao[19], D. Gaskell[2], A. Gasparian[30], T. Gautam[31], F.-X. Girod[57], K. Gnanvo[14], J. Grames[2], G. N. Grauvogel[4], P. Gueye[22], M. Guidal[1], S. Habet[1], T. J. Hague[30], D. J. Hamilton[29], O. Hansen[2], D. Hasell[12], M. Hattawy[42], D. W. Higinbotham[2], A. Hobart[1], T. Horn[63], C. E. Hyde[42], H. Ibrahim[69], A. Ilyichev[39], A. Italiano[13], K. Joo[57], S. J. Joosten[71], V. Khachatryan[19,20], N. Kalantarians[73], G. Kalicy[63], B. Karky[19], D. Keller[14], C. Keppel[2], M. Kerver[42], M. Khandaker[18], A. Kim[57], J. Kim[71], P. M. King[5], E. Kinney[9], V. Klimenko[57], H.-S. Ko[1], M. Kohl[31], V. Kozhuharov[25,54], B. T. Kriesten[14], G. Krnjaic[6,15], V. Kubarovsky[2], T. Kutz[4,12], L. Lanza[51,53], M. Leali[10,44], P. Lenisa[23,24], N. Liyanage[14], Q. Liu[37], S. Liuti[14], J. Mammei[64], S. Mantry[17], D. Marchand[1], P. Markowitz[38], L. Marsicano[3,26], V. Mascagna[16,44], M. Mazouz[41], M. McCaughan[2], B. McKinnon[29], D. McNulty[49], W. Melnitchouk[2], A. Metz[48], Z.-E. Meziani[71], S. Migliorati[10,44], M. Mihovilovič[34], R. Milner[12], A. Mkrtchyan[65], H. Mkrtchyan[65], A. Movsisyan[23], H. Moutarde[28], M. Muhoza[63], C. Muñoz Camacho[1], J. Murphy[5], P. Nadel-Turoński[56], E. Nardi[25], J. Nazeer[31], S. Niccolai[1], G. Niculescu[32], R. Novotny[27], J. F. Owens[59], M. Paolone[70], L. Pappalardo[23,24], R. Paremuzyan[21], B. Pasquini[43,44], E. Pasyuk[2], T. Patel[31], I. Pegg[63], C. Peng[71], D. Perera[14], M. Poelker[2], K. Price[1], A. J. R. Puckett[57], M. Raggi[50,52], N. Randazzo[13], M. N. H. Rashad[42], M. Rathnayake[31], B. Raue[38], P. E. Reimer[71], M. Rinaldi[46,47], A. Rizzo[51,53], Y. Roblin[2], J. Roche[5], O. Rondon-Aramayo[14], F. Sabatié[28], G. Salmè[50], E. Santopinto[3], R. Santos Estrada[57], B. Sawatzky[2], A. Schmidt[4], P. Schweitzer[57], S. Scopetta[46,47], V. Sergeyeva[1], M. Shabestari[45], A. Shahinyan[65], Y. Sharabian[2], S. Širca[34], E. S. Smith[2], D. Sokhan[29], A. Somov[2], N. Sparveris[48], M. Spata[2], H. Spiesberger[37], M. Spreafico[26], S. Stepanyan[2], P. Stoler[57], I. Strakovsky[4], R. Suleiman[2], M. Suresh[31], P. Sznajder[62], H. Szumila-Vance[2], V. Tadevosyan[65], A. S. Tadepalli[2], A. W. Thomas[66], M. Tiefenback[2], R. Trotta[63], M. Ungaro[2], P. Valente[50], M. Vanderhaeghen[36], L. Venturelli[10,44], H. Voskanyan[65], E. Voutier[1,g], B. Wojtsekhowski[2], M. H. Wood[11], S. Wood[2], J. Xie[71], W. Xiong[58], Z. Ye[67], M. Yurov[33], H.-G. Zaunick[27], S. Zhamkochyan[65], J. Zhang[14], S. Zhang[2], S. Zhao[1], Z. W. Zhao[19], X. Zheng[14], J. Zhou[19,20] and C. Zorn[2]

[1] Université Paris-Saclay, CNRS/IN2P3, IJCLab, 91405, Orsay, France
[2] Thomas Jefferson National Accelerator Facility, 23606, Newport News, VA, USA
[3] INFN, Sezione di Genova, 16146, Genova, Italy

Positron Partial Program Summary

Experiment Label (EPJ A)	Experiment Short Name	Hall	Detector	Target	Polarity	p (GeV/c)	P (%)	I (μA)	Time (d)	PAC Grade
Two Photon Exchange Physics										
57:144	$H(e,e'p)$	B	CLAS12$^+$	H_2	$+/-_s$	2.2/3.3/4.4/6.6	0	0.060	53	
57:188	$H(\vec{e},e'\vec{p})$	A	ECAL/SBS	H_2	$+/-_p$	2.2/4.4	60	0.200	121	
57:199	r_p	B	PRad-II	H_2	$+$	0.7/1.4/2.1	0	0.070	40	
	r_d			D_2		1.1/2.2		0.010	39	
57:213	$\vec{H}(e,e'p)$	A	BB/SBS	$N\vec{H}_3$	$+/-_s$	2.2/4.4/6.6	0	0.100	20	
57:290	$H(e,e'p)$	A	HRS/BB/SBS	H_2	$+/-_s$	2.2/4.4	0	1.000	14	
57:319	SupRos	A	HRS	H_2	$+/-_p$	0.6−11.0	0	2.000	35	
58:36	$A(e,e')A$	A	HRS	He	$+/-_p$	2.2	0	1.000	38	
Nuclear Structure Physics										
57:186	p-DVCS	B	CLAS12	H_2	$+/-_s$	2.2/10.6	60	0.045	100	C2
57:226	n-DVCS	B	CLAS12	D_2	$+/-_s$	11.0	60	0.060	80	
57:240	p-DDVCS	A	SoLID$^\mu$	H_2	$+/-_s$	11.0	(30)	3.000	100	
57:273	He-DVCS	B	CLAS12/ALERT	^{4}He	$+/-_s$	11.0	60			
57:300	p-DVCS	C	SHMS/NPS	H_2	$+$	6.6/8.8/11.0	0	5.000	77	C2
57:311	DIS	A/C	HRS/HMS/SHMS		$+/-_s$	11.0				
57:316	VCS	C	HMS/SHMS	H_2	$+/-_s$		60			
Beyond the Standard Model Physics										
57:173	C_{3q}	A	SoLID	D_2	$+/-_s$	6.6/11.0	(30)	3.000	104	D
57:253	LDM	B	PADME	C	$+$	11.0	0	0.100	180	
			ECAL/HCAL	$PbW0_4$					120	
57:315	CLFV	A	SoLID$^\mu$	H_2	$+$	11.0				
								Total (d)	**1121**	

Includes two conditionally approved PAC proposals
Hall B ~ **100 nA** with polarization **>60%**
Hall C ~ **3 µA** with low or no polarization

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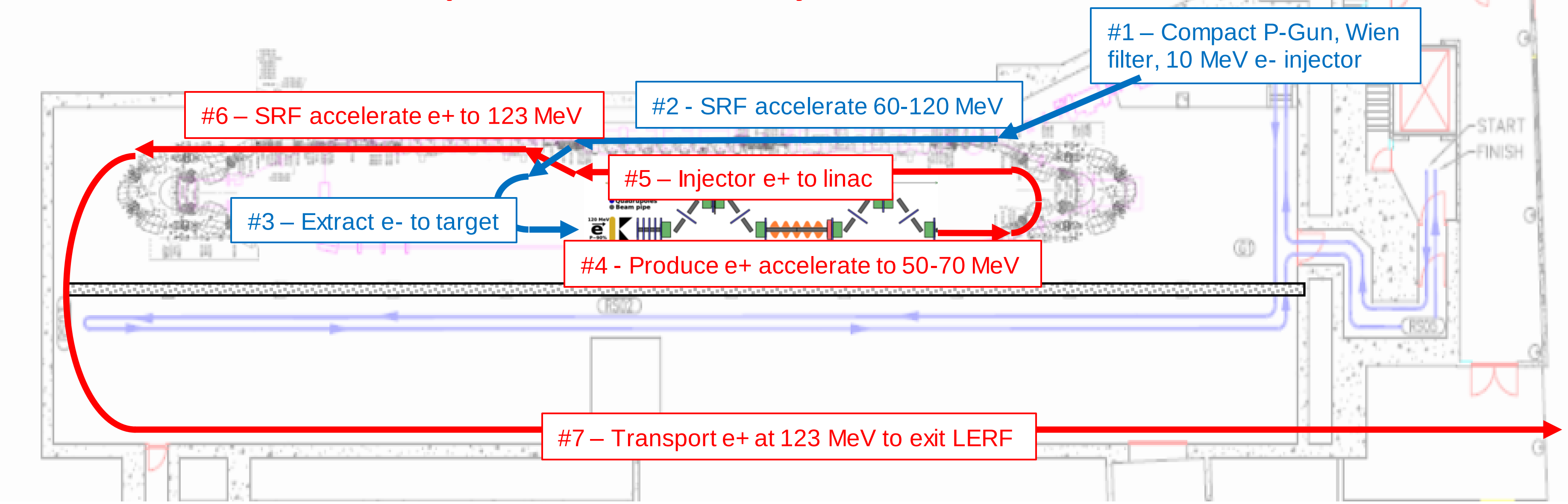
PEPPo II : Polarized e^+ Prototype Experiment

First, we need to build two injectors …

- **100 MeV** polarized e- source that **sustains milliamps** for weeks
- **123 MeV** conventional bremsstrahlung source that is both **continuous-wave** and **polarization-intensity tunable**



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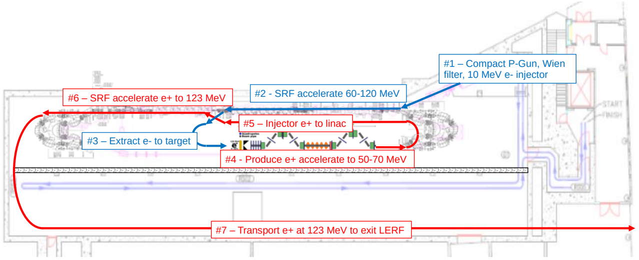
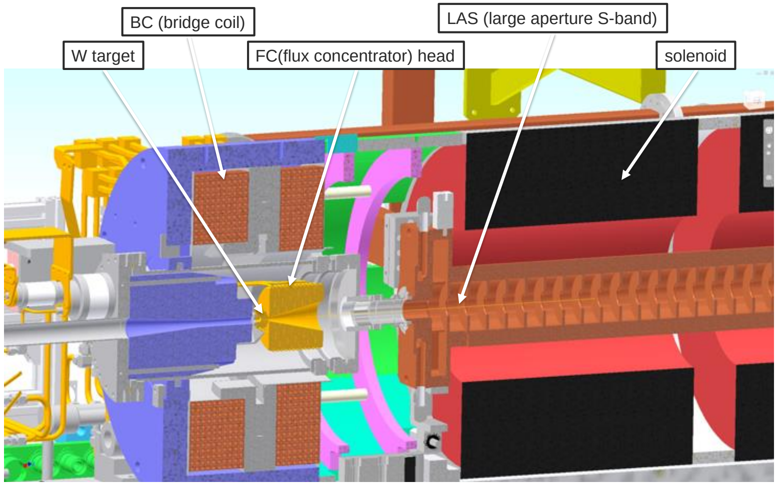
Growing an e+ injector group at JLab (S. Habet, U. of Paris)

Positron injector at LERF is a composite of systems,

- *"source" is integrated set of technologies; high power target, high field solenoid, RF capture*
- ***CW operation will be unique**, developing strategy for collection – capture - compression*



SuperKEKB Pulsed e+ Source



PhD work of S. Habet (U. Paris)

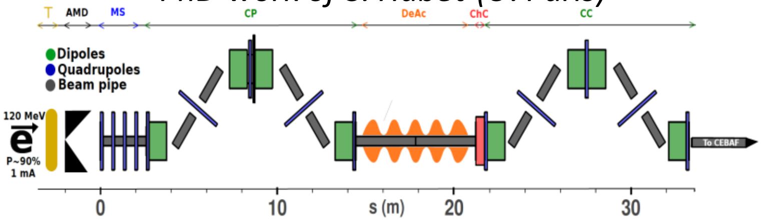


Figure: Conceptual layout of the positron injector for CEBAF.

T : Tungsten target
AMD : Adiabatic Matching Device
MS : Matching Section
CP : Magnetic Chicane
DeAc : Decelerating/Accelerating cavity
ChC : Chirping cavity
CC : Compression Chicane

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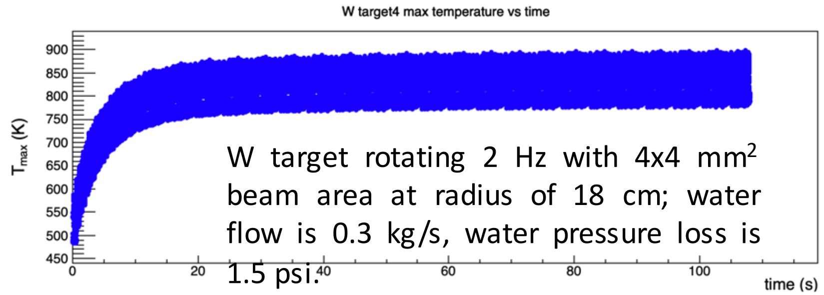
LERF e+ production target design (S. Covrig, Physics)

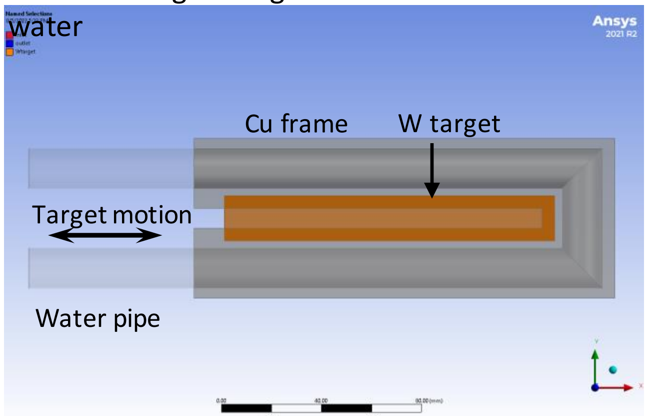
Building up ***team of target experts*** *to study various target materials & geometries*

- *prototype/proof-of-principle (3-4 kW)*
- *full power design (17-20 kW)*

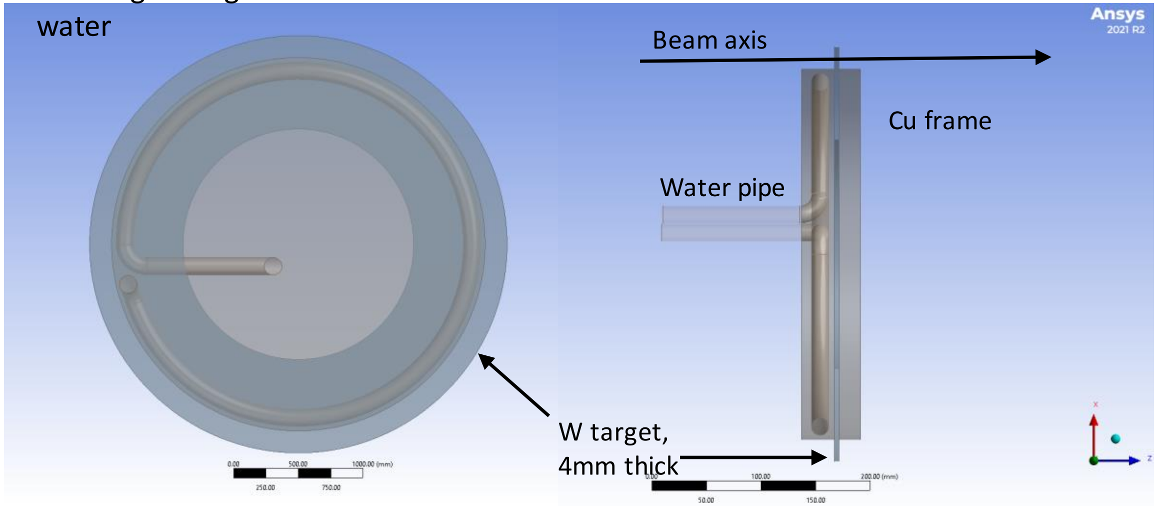


W target rotating 2 Hz with 4x4 mm^2 beam area at radius of 18 cm; water flow is 0.3 kg/s, water pressure loss is 1.5 psi.

Linear moving W target in Cu frame with RT water



Rotating W target in a Cu frame cooled with RT water



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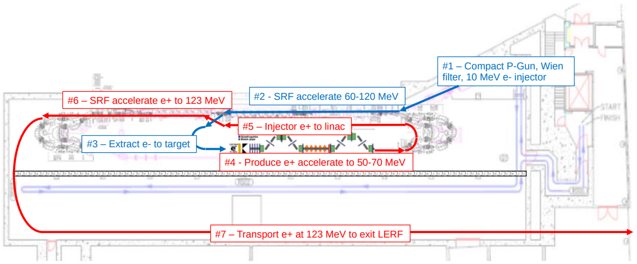
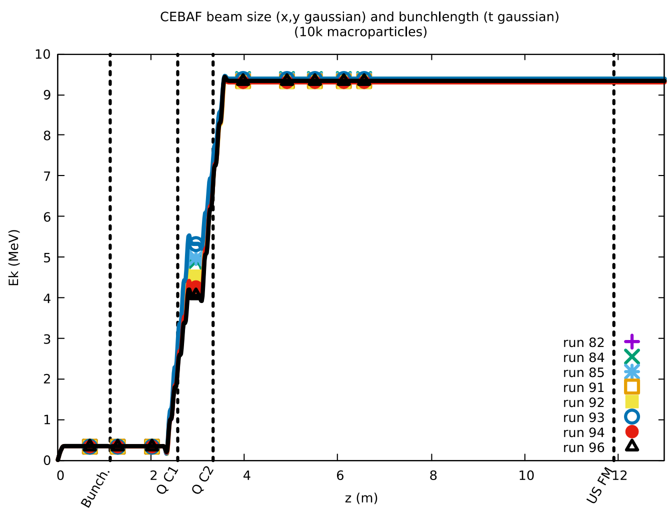
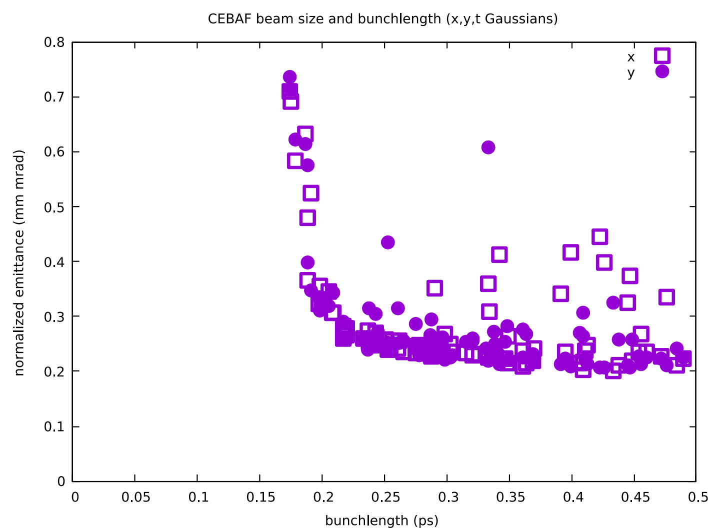
High bunch charge electron injector (A. Hofler & R. Kazimi, INJ OPS)

LERF pre-injector is critical bridge between HV Gun and first SRF acceleration

- *studies are for 3 milliamps (2 pC/bunch)*
- *goal (<0.5 psec bunch, < 1mm-mrad emittance)*
- *next add Wien filter, bridge to C75 cryomodule*







HV DC GaAs photogun (C. Hernandez-Garcia, CIS)

LERF photo-gun will likely need to operate at a voltage greater than the CEBAF 200 kV Upgrade Gun.

- *studies are evaluating* ***new ceramic/receptacle >350 kV***
- *vacuum must be in the 10^{-12} Torr range (like CEBAF)*
- *and no Field Emission (like CEBAF)*