Doublet vs. FODO structure: beam dynamics and layout

Mohammad ESHRAQI 3rd SPL Collaboration meeting CERN 12-11-2009

SPL layout

Source	LEBT	RFQ	MEBT	DTL	CCDTL	PIMS	HEBT	Low β	High β
		3 MeV		50	100	160	165		5000

Source: 70 mA of H^- ions at 45 keV

RFQ: 60 mA, 352.2 MHz

DTL: Three tanks (FFDD+FD)

CCDTL: 7 Tanks (FD)

PIMS: 12+1 Tanks (FD)

Elliptical: Two generations of elliptical cavities, geometric betas of 0.65 and 1. (Doublets , or singlets) 704.4MHz

SPL layout

Doublet, baseline, design:

10 low beta cryo-modules (Transition Energy 780 MeV)

5 high beta cryo-modules (Extraction Energy 1516 MeV)

Extraction to ISOLDE

6 high beta cryo-modules (Extraction Energy 2586 MeV)

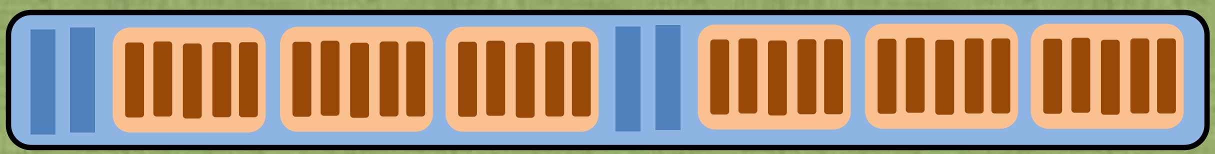
Extraction to EURISOL

12 high beta cryo-modules (Final Energy 4989 MeV)

Doublet(Baseline) Cryo-modules

sLHC

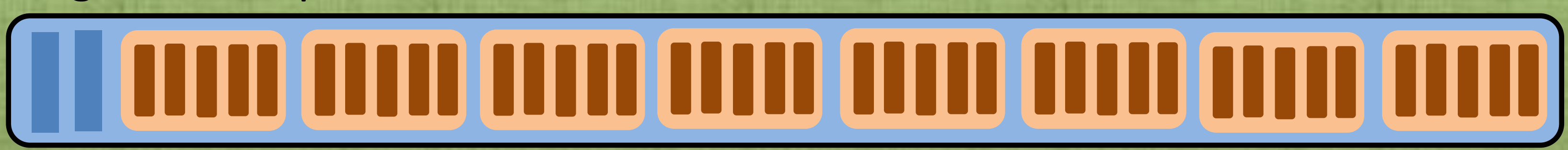
Low beta elliptical



12.3 m

Quad length 450 mm
Quad Aperture 100 mm

High beta elliptical

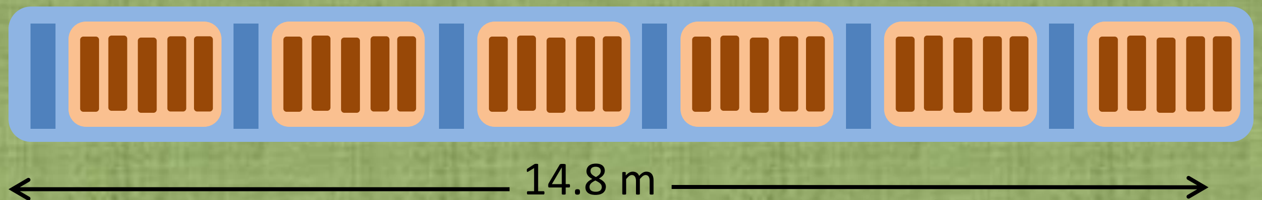


15.1 m

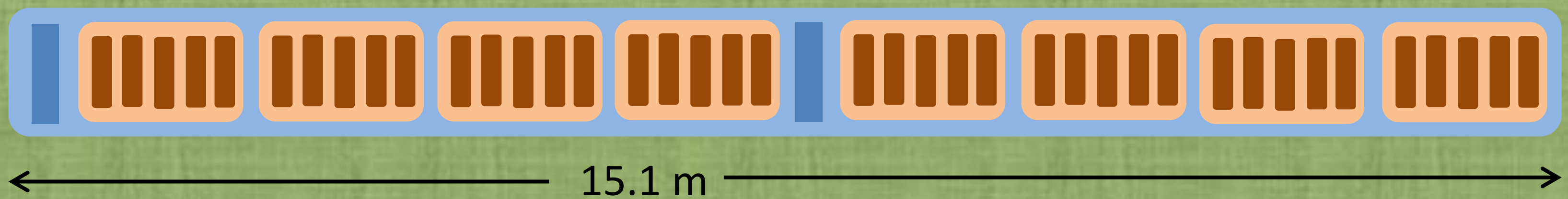
A black outline indicates the Doublet (baseline) from now on

FoDo Cryo-modules

Low beta elliptical



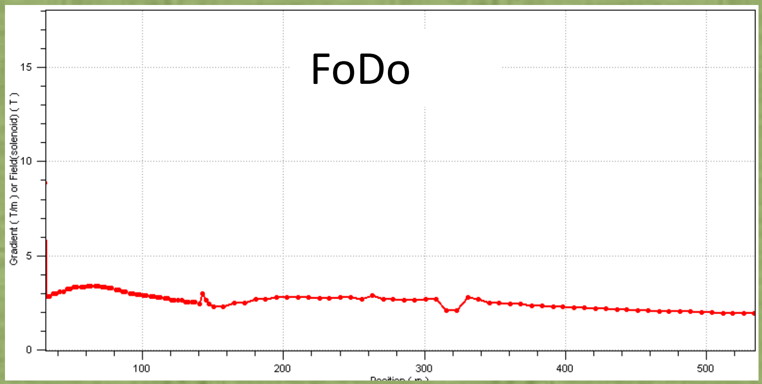
High beta elliptical



Comparison

	L (m)	E (MeV)	Periods	Cav/period	Total Cav/ Quad (PS)
Doublets	501	786 / 4989	20 / 23	3 / 8	244 / 86+4^{warm} (54)
FoDo	510	710 / 5020	24 / 24	2 / 8	240 / 96 + 4^{warm}(59)

The gradient of the quadrupoles vs. length in two layouts



Warm-Cold transition quadrupoles

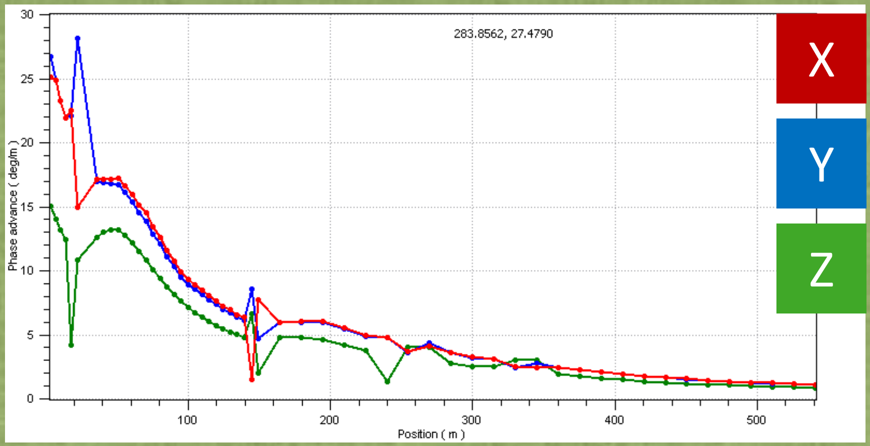
sLHC

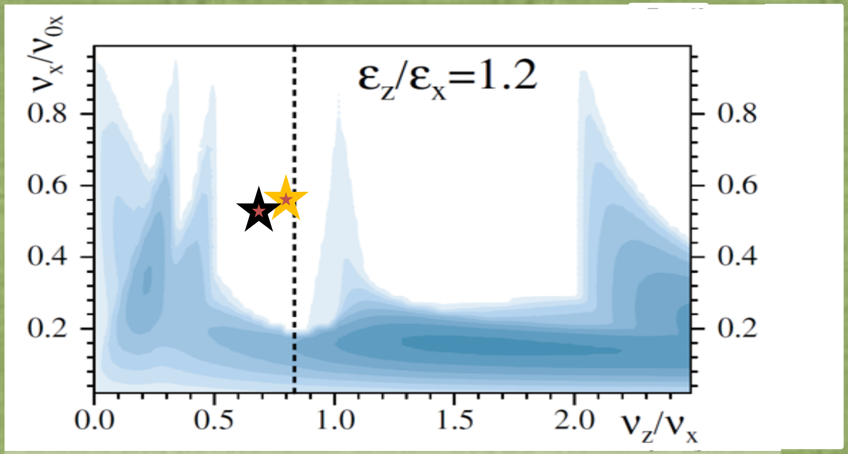
Beam dynamics - Design

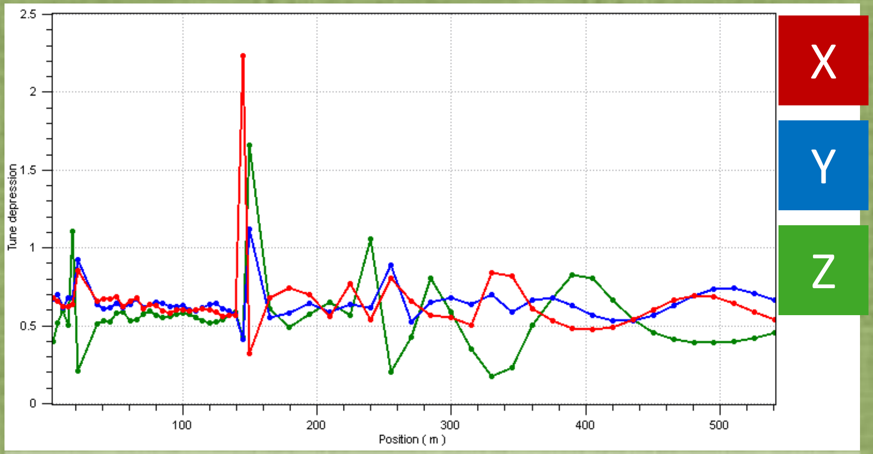
Synchronous phase ramps up from -19 to -14 in β_g = 0.65 and stays at -14 except in the extraction regions

★ Doublet layout

★ FoDo layout

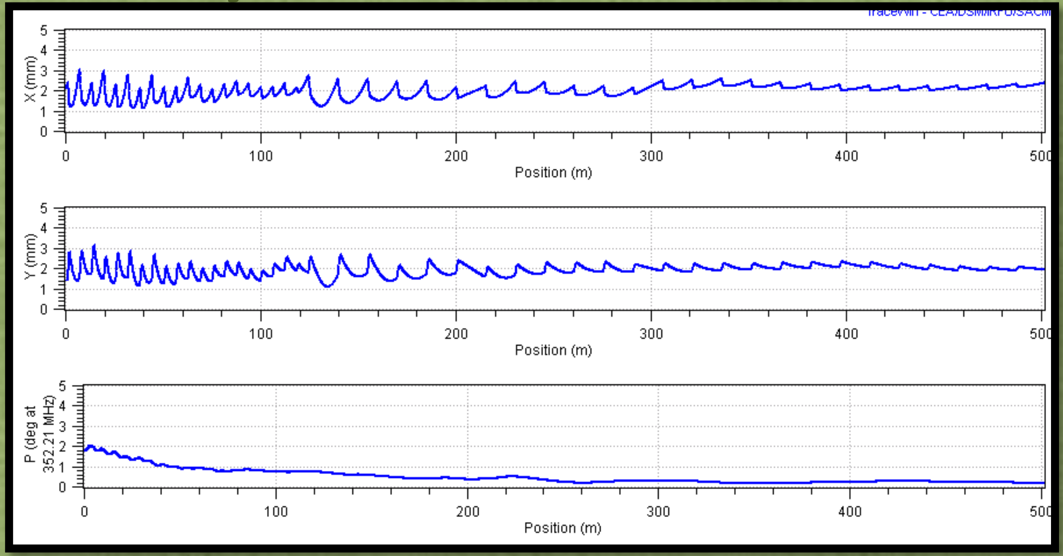




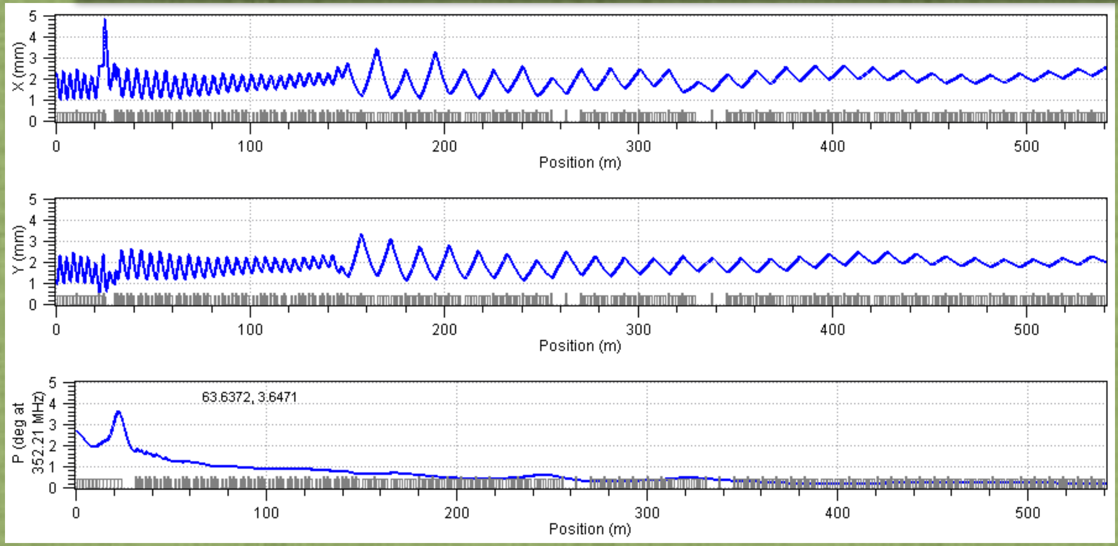


Beam dynamics - I

RMS beam envelopes for a beam generated at PIMS input for the Doublet option

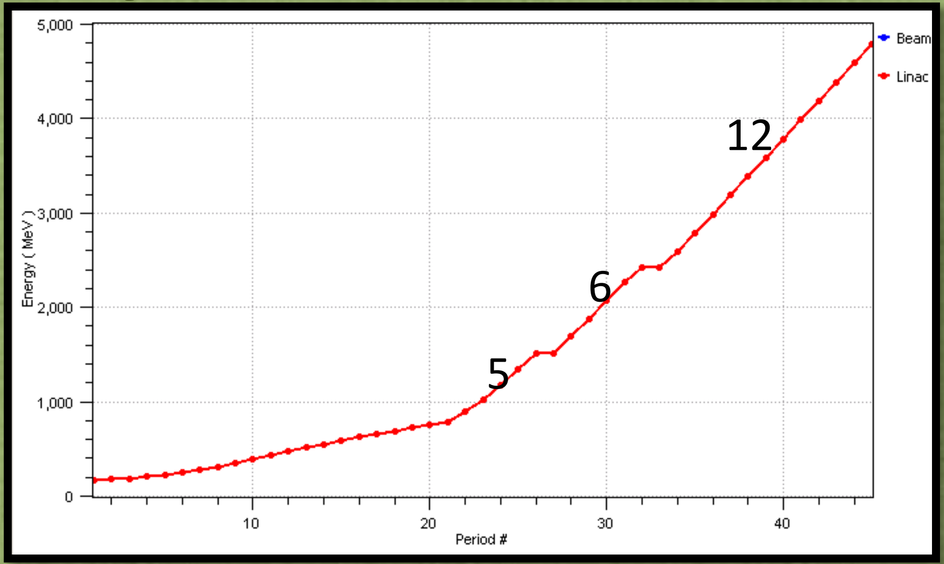


RMS beam envelopes for a beam generated at PIMS input for the FoDo (Singlet) option

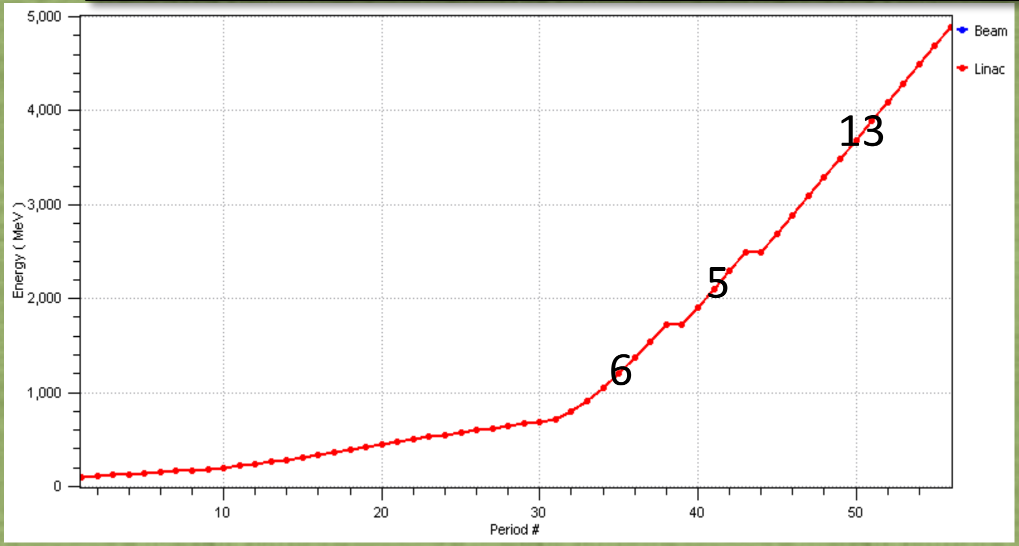


Beam dynamics - II

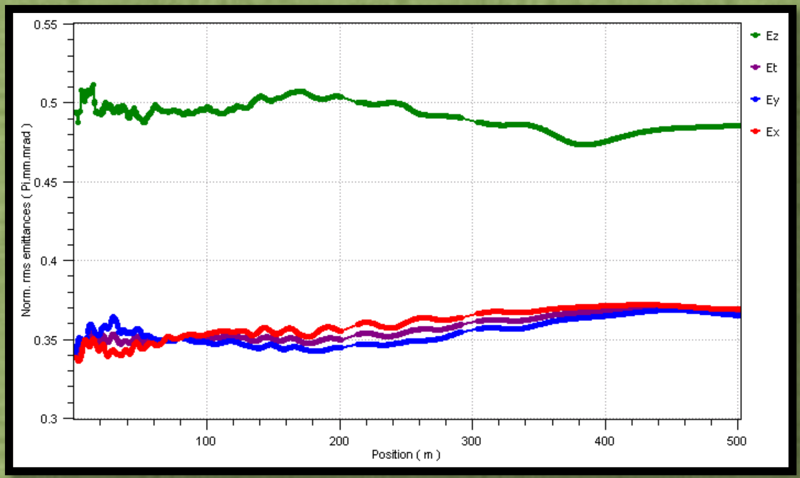
Beam energy along the machine, in the doublet layout, 1516, 2586.

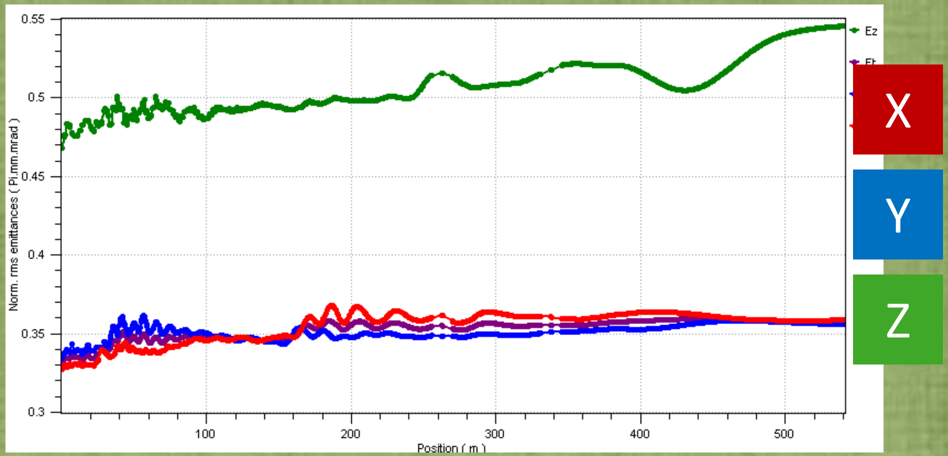


Beam energy along the machine, in the FoDo layout, 1542, 2491,



Beam dynamics - III



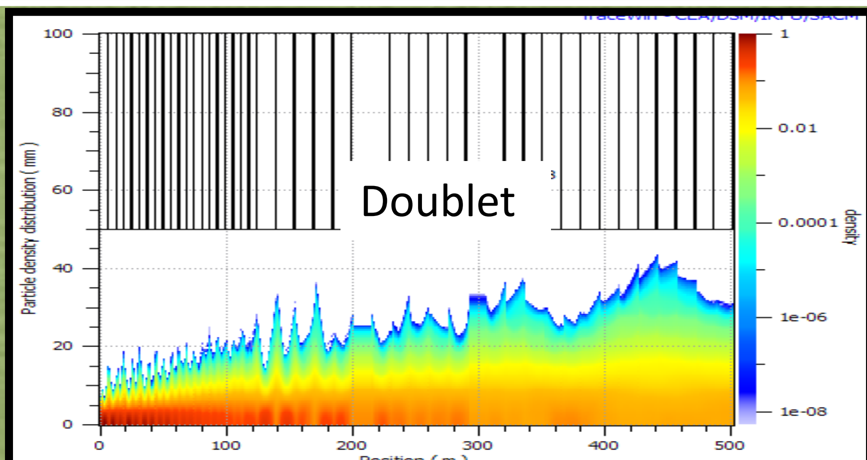


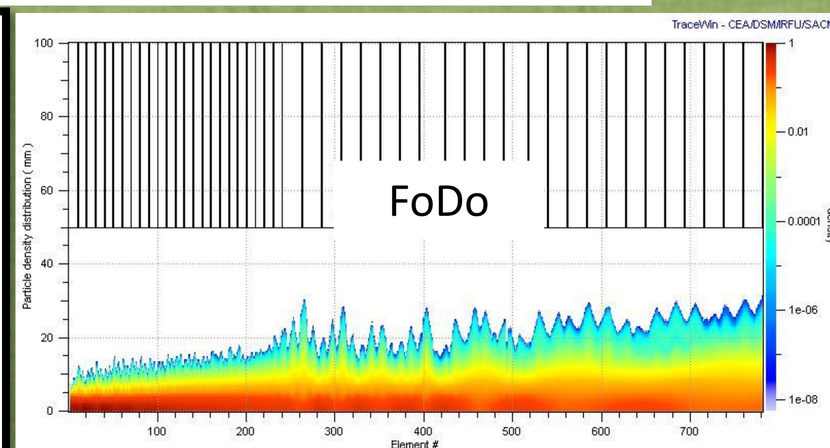
Doublet	x	y	z
Initial ε	0.328	0.334	0.468
Final ε	0.369	0.365	0.486
Δε%	12.5	9.4	3.8

FoDo	x	y	z
Initial ε	0.328	0.334	0.468
Final ε	0.359	0.356	0.546
Δε%	9.5	6.5	16.6

Erpør Studies

±0.2mm (Gaussian), ±0.5%Grad on Quads ±0.3mm, 0.3mrad (Uniform) on input beam	**Without Correction**		**With Correction**	
	Doublet	FoDo	Doublet	FoDo
$\Delta\varepsilon_x/\varepsilon_x$ (Ave ± 3 × σ)	14.77% ± 18.29%	10.51% ± 14.85%	1.05% ± 2.99%	0.44% ± 3.6%
$\Delta\varepsilon_y/\varepsilon_y$ (Ave ± 3 × σ)	12.64% ± 17.09%	13.91% ± 15.97%	0.55% ± 2.41%	0.76% ± 1.89%
$\Delta\varepsilon_z/\varepsilon_z$ (Ave ± 3 × σ)	25.49% ± 30.1%	23.62% ± 20.68%	1.2% ± 4.66%	0.77% ± 3.74%
Transmission	100% ± 0.02%	100% ± 0.00%	100% ± 0.00%	100% ± 0.00%





Piero will give a comprehensive talk on this subject in "3rd combined session WG3 & WG4"

Conclusion

A FoDo architecture (in contrary to a doublet architecture) has been designed and studied, this FoDo layout has some pros and cons as listed:

Pros: Number of low beta cavities reduces by 12
Quadrupole fields are reduced by a factor of ~2

Cons: 8 more quadrupoles are needed in low beta region
In high beta region one more cryo-module (2 Quads + 8 cavities) is needed
Less flexible for cryo distribution

Nominal beam dynamics results of the FoDo and doublet are comparable, but error studies favor the FoDo option