

MICHIGAN STATE UNIVERSITY LISE++

Purpose:

2nd optics minimization of existed separators

v.9.10.156 from 07/27/15

- 1. Introduction: First order optics minimization in LISE** (links)
- 2. Modification of M-multipole blocks for 2nd order optimization
- 3. Modification of the "Fitting constraints" block for 2nd order
 - Aberrations list
- 4. Run new minimization version
 - High order truncation problem
- 5. "OptBeam" : New Beam sigma vector used only in the Optics Optimization

Acknowledgements to Drs. M.Hausmann and M.Portilio (NSCL/MSU) for fruitful discussions.

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v.9.10.100 22-05-15 Optics minimization (main part)

v.9.10.119 23-06-15 Optics minimization (update)

v.9.10.14222-07-15Using LISE++ optics minimization for the
DRAGON2000 extended configuration development



Multipole: Q2		1.00	1	? **
Magnetic Multipole Settings L_eff (effective length) mode: <keep> B (field at pole tip) Radius (half-aperture) B & S field values in Fitting Use in Fitting process Use Bounds constraints Lower bound</keep>	QUADrupole 0.333 1.96491 7.9375 V V 1	SEXTupole 85 0.1059 7.9375 V 1 1	m kG cm kG	Block settings, Information Block length 0.33385 Current (Real) Brho-value 0.49996 for the setting fragment 39Ca13+ Multipole fixed Brho-value 0.49996 corresponding to the setting fragment 1 fit will be used for scaling) Fix current value Image: Calculate 2nd order matrix elements B(I) calibration Image: Allow remote matrices recalculation Ino calibration file
if Brho-value has been chang no actions recalculate automatically recalculate automatically	ed then B (fields), keep th the matrix, keep	ne matix [Recc B (fields)	omended]	Image: Second control of the second

New feature: using sextupole fields in the Optimization process. Evidently, it has an effect only in the 2nd order optimization



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I	2	I	1	5	I	6			Þ

Opt	tics settin	gs (fast editing))	1	14.									×
Block		Given Name	Start(m)	Length(m)	B0(kG)/*U	Br(Tm)cor/*real	DriftM/*Angle	Rapp(cm)/*R(.	Leff(m)/*Ldip(m)	2 nd order	CalcMatr/*Z-Q	AngAcc,Apps,Slits	COSY Fit	SE 🔺
D	= Dipole	tuning	0.000	0.0000	+1.6665	× 0.5000	* +0.0	* 3.0000	× 0.0000	-	* 7	HV	-	S 🗌
d 🗖	drift	t-q1	0.000	1.0689			standard					HV		е
<mark>0</mark> 🔷	<quad></quad>	Q1	1.069	0.2523	-2.1576	0.5000	QUAD	5.3975	0.2523	yes	1 B	HV	fit - Q	е
d 🗖	drift	q1-q2	1.321	0.2569			standard							- E
0 🔷	<quad></quad>	Q2	1.578	0.3338	+1.9649	0.5000	MULT	7.9375	0.3338	yes	1 B	HV	fit - QS	
F 🌟	Fit	Fit 1	1.912	0.0000									R12 = 0	e
d 🗆	drift	d3-md1	1.912	0.6381			standard					HV	7 .	е
D)	= Dipole	MD1	2.550	0.8727	+4.9996	* 0.5000	* + 50.0	* 1.0000	* 0.8727	yes	* 7 B		/ .	E
d 🗖	drift	md1-slits	3.423	0.3079			standard					/		е
F 🐇	Fit	FitXT	3.731	0.0000								/	R12 = 0	е
F *	Fit	Fit 🔀	3.731	0.0000									// R11 =	no
F 🐇	Fit	Fit YP	3.731	0.0000									R34 = 0	е
F 🐇	Fit	T122	3.731	0.0000									T122 = 0	е
s I	_slits_	CHARGE slits	3.731	0.0000			SLITS							е
d 🗖	drift	slts-sm1	3.731	0.2720			standard					HV HV		е
d 🗆	drift	SM1	4.003	0.2560			standard					- HV		е
d 🗆	drift	sm1-s1	4.259	0.1862			standard					HV		е
<mark>0</mark> 🔷	<quad></quad>	S1	4.445	0.1875	+0.1372	0.5000	SEXT	7.9375	0.1875	yes	1R	HV	fit - S	е
d 🗖	drift	s1-q3	4.632	0.1614			standard					- HV		е
<mark>0</mark> 🔷	<quad></quad>	Q3	4.794	0.3338	+1.7749	0.5000	QUAD	7.9375	0.3338	yes	R	HV	fit - Q	е
d 🗆	drift	q3-q4	5.127	0.2162			standard					HV		е
<mark>0</mark> 🔷	<quad></quad>	Q4	5.344	0.3338	-2.2980	0.5000	QUAD	7.9375	0.3338	yes	1R	HV	fit - Q	е
d 🗆	drift	q4-q5	5.677	0.2162			standard			/		- HV		е 👻
Selec	cted block						Angular accepta	ince (mrad) —	Inside Aperture (mm)		Slits (mm) after thi	s BLOCK	st order Matrix B	Elements
	Drift (r	nultipole,slits)	Ier I	Block nath (m)	Selected	Block Edit		Use	min n	nax Use	min	max Use 👔	Matrix F	Plot
Bloc	k name –		0.3	33385	alla. Muster	ole Edit	Horizontal ±		×= -75 7	5 🔽	X =		····	un Diet
	Auto G	2		<u>`</u>	www.inititit		Vertical ±		Y = -75 7		Y =		Leam-sign	
	matric. I		Len this t	gthafter 🛛 🛔	👥 Cuts (Ac	ceptances)	Shape		_ Shape		Shape	6	ੇਰ∕ View	/
Us	se in the Fl	T process 🔽 (9119	Get Optica	al Matrix	Rectangle C		Rectangle C	Ellipse	Rectangle 📀	O Ellipse		
		, v i										🗠	Quit	Help
_	_		_							_				

It is possible to change quickly the use of Quadrupole and/or Sextupole fields from the Optics settings dialog





Optics fit	
Blocks with parameters to vary	Active Constraint blocks
#01-q Position@005: Q1 #02-q Position@007: Q2 #03-s Position@007: Q2 #04-s Position@002: S1 #05-q Position@022: Q3 #06-q Position@026: Q5 #08-s Position@026: Q5 #08-s Position@028: S2 #09-q Position@044: Q6 #10-q Position@059: Q8 #12-q Position@059: Q9 #13-q Position@071: Q10	$ \begin{array}{cccccccccccccccccccccccccccccccccccc$
Niter = 1000 FIT Restore previuos values	Optics Settings (fast editting)
Shov	v initial conditions Matrix Plot
X Exit	📐 Beam-Sigma Plot
? Help	abertation_check.fit

➡ c:\program files (x86)\l	ise\results\aberration_check.fit_init		
Initial +94.1859	LISE fit reduced values		
Parano ere: 011-q: 01 012-q: 02 013-e: 02 014-e: S1 015-q: 03 015-q: 04 017-q: 05 017-q: 05 019-q: 05 019-q: 05 019-q: 05 019-q: 05 019-q: 05 01-q: 05 01-q: 05 01-q: 05 01-q: 05 01-q: 05 01-q: 05 01-q: 05 01-q: 02 01-q: 02 01-q: 02 01-q: 02 01-q: 02 02 01-q: 02 02 01-q: 02 02 02 02 02 02 02 02 02 02	$\begin{array}{llllllllllllllllllllllllllllllllllll$	RightBound -1.0+00 < +5.0+00 +1.0+00 < +5.0+00 < +1.0+00 < 1.0+00 < -1.0+00 < -1.0+00 < +5.0+00 < +0.0+00 < +5.0+00 < +5.0+000 < +5.0+0000 < +5.0+0000 < +5.0+0000 < +5.0+0000 < +5.0+0000 < +5.0+00000 < +5.0+00000 < +5.0+000000 < +5.0+0000000000000000000000000000000000	
Constraint values: 01: Fit 1 02: Fit XT 03: Fit YP 04: T122 05: Mass_XD 06: Mass_XD 06: Mass_TD 07: Mass_TD 09: M12: Charge2 YT 11: Charge2 YT 11: Charge2 YT 12: Fin XT 13: Fin XD 14: Fin YP 15: Fin TD 16: F122	$\begin{array}{c ccccc} Initial & Final \\ +2.978\pm00 \\ +1.101\pm05 \\ +2.796\pm05 \\ +2.796\pm05 \\ -5.116\pm09 \\ -4.284\pm05 \\ -2.271\pm04 \\ +4.4312\pm04 \\ +3.174\pm01 \\ +1.627\pm04 \\ +2.844\pm05 \\ -8.730\pm04 \\ -1.052\pm04 \\ -7.852\pm04 \\ +8.599\pm06 \\ -5.760\pm01 \\ -1.236\pm04 \\ \end{array}$	Precision (II 1.0e-03 +2 1.0e-03 +2 1.0e-01 +2 1.0e-03 +4 1.0e-03 +4 1.0e-03 +4 1.0e-03 +4 1.0e-03 +4 1.0e-03 +4 1.0e-03 +1 1.0e-03 +1 1.0e-03 +7 1.0e-03 +7 1.0e-03 +7 1.0e-03 +7 1.0e-03 +7 1.0e-03 +7	hit-Des)/P Desired 2.978e+03 = 0 .101e-02 = 0 .776e-03 = 0 .116e-08 = 0 .271e-01 = 0 .271e-01 = 0 .431e-03 = 0 .174e-01 = 0 .434e-02 = 0 .730e-03 = 0 .652e-01 = 0 .559e-03 = 0 .559e-03 = 0 .559e-01 = 0 .236e-01 = 0
	fitting block global optica === G L O B A L ==== matri 052e=04 0 0 0 097e+00 0 -1.146e+00 48.599 -1.525e+00 -8.724 829e-05 0 0 0 0	.1 matrix and sig Format [mm-m x 0 -7.88 le-06 0 -5.76 le-06 0 0 .e-01 0 0 1.0 -9.64 0 +1.00	ma vector rand] Beam(sigma) j2e-04 1.05e-02 j0e-01 1.10e+02 0 0 00+00 9.83e-03 j0e+00 0.83e-03

Chars "q" and "s" show what component ("q"uadrupole or "s"extupole) of multipole is used in the Optimization process



Modification of the "Fit constraint" block for 2^{nd} order optimization







"Fit constraint" block for 2nd order optimization : Aberrations List





The Aberration list purpose : show a 2nd element to pay attention. Aberration value is:

1st order : 2nd order : $V_1 = (a|b)^*s(b)$ $V_2 = (a|bc)^*s(b)^*s(c)$



Comparison of absolute largest 1st and 2nd orders aberrations

Status messages					
$V_1 < 3 V_2$	attention				
$V_1 < V_2$	Critical				
$V_1 < V_2/3$	VERY critica				



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The 1st part of DRAGON2000 : Target – Charge Slits



- 11			[
		QUADrupole	SEXTupole	
	L_eff (effective length) mode: <keep></keep>	0.25	23	m
	B (field at pole tip)	-2.1576	0	kG
	Radius (half-aperture)	5.3975	5.3975	cm
	- B & S field values in Fitting-			
	Use in Fitting process	V		
	Use Bounds constraints	~		
	Lower bound	-5	-100	kG
	Upper bound	-1	100	kG
l	Upper bound	-1	100	kG
	Upper bound Magnetic Multipole Settings			kG
	Upper bound	QUADrupole	SEXTupole	kG
	Upper bound Magnetic Multipole Settings L_eff (effective length) mode: <keep></keep>	-1	SEXTupole	kG m
ļ	Upper bound Magnetic Multipole Settings L_eff (effective length) mode: <keep> B (field at pole tip)</keep>	-1	100 SEXTupole 385 0.106	m kG
	Upper bound Magnetic Multipole Settings – L_eff (effective length) mode: <keep> B (field at pole tip) Radius (half-aperture)</keep>	-1 QUADrupole 0.33 1.96503 7.9375	100 SEXTupole 385 0.106 7.9375	m kG cm
	Upper bound Magnetic Multipole Settings L_eff (effective length) mode: <keep> B (field at pole tip) Radius (half-aperture) B & S field values in Fitting-</keep>	QUADrupole	100 SEXTupole 385 0.106 7.9375	m kG cm
	Upper bound Magnetic Multipole Settings L_eff (effective length) mode: <keep> B (field at pole tip) Radius (half-aperture) B & S field values in Fitting Use in Fitting process</keep>	QUADrupole 0.33 1.96503 7.9375	100 SEXTupole 385 0.106 7.9375	m kG cm
	Upper bound Magnetic Multipole Settings L_eff (effective length) mode: <keep> B (field at pole tip) Radius (half-aperture) B & S field values in Fitting Use in Fitting process Use Bounds constraints</keep>	-1 QUADrupole 0.33 1.96503 7.9375 V	100 SEXTupole 385 0.106 7.9375	kG m kG cm
	Upper bound Magnetic Multipole Settings L_eff (effective length) mode: <keep> B (field at pole tip) Radius (half-aperture) B & S field values in Fitting Use in Fitting process Use Bounds constraints Lower bound</keep>	-1 QUADrupole 0.33 1.96503 7.9375 V 1 1 1	100 SEXTupole 385 0.106 7.9375	kG m kG cm kG

? X Beam vector used for Optical Optimization "Opt.Beam" • mm 1. X 2 mm C cm 20 2. T mrad 3. Y mm 4. P 20 mrad Ok 5. L mm % 6. D 2 🗶 Cancel

Initial settings

Aberration list @ Charge Slits

Block: "Fit YP" Aberrations (Elements normalized on Phase Space)



transport format [mm-mrad]

C







Let's try to neglect the element T144 in the optimization using Q1 & Q2 multipoles!



Run 2nd order optics minimization









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Let's create the Beam vector for optimization

Aberration list @ Charge Slits

Aberration analysis
 * (Absolute largest value)

:	lst order	2nd	order	
: in	ndex value	index	value	status
1 [X]: 1	1 -4.45e-01	112	-8.23e-02	
2 [T]: 2	2 -2.25e+02	222	-4.35e+00	
3 [Y]: 0	10 +0.00e+00	000	+0.00e+00	
4 [F]: 0	10 +0.00e+00	000	+0.00e+00	
5 [L]: 5	2 -1.36e+02	522	+1.64e+00	
6 [D]: 0	10 +0.00e+00	000	+0.00e+00	

No large aberrations with using <u>GLOBAL</u> matrices!

OT, 28-July-2015, East Lansing



High order truncation problem



But Let's run Monte Carlo calculation the similar beam emittance

1. X	mm	1	Rectangle uniform 📃 💌	
2. T	mrad	100	Rectangle uniform 📃 💌]
3. Y	mm	0	Rectangle uniform 📃 💌]
4. P	mrad	0	Rectangle uniform 📃 💌]
5. L	mm	0	Gaussian 💌]
6. D	%	0	Rectangle uniform 📃 💌]

³⁹Ca : Monte Carlo Transmission Plot







High order truncation problem

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- We did not observe large values in the Aberration list calculated with the Global matrices
- Large aberrations have been observed in Monte Carlo calculations where local 2nd order matrices are used
- It is happen due to truncation of high order values with matrices multiplication
- Recommendation: not to use large Beam sigma values for optimization. 2nd order optic optimization operates with small emittances
- For large emittance the LISE⁺⁺ optimization should be updated to work with Monte Carlo results.

³⁹Ca : MC Transmission Plot - Envelope (only pass





Length [m]

³⁹Ca : MC Transmission Plot - Envelope (only passed)





"Main" Beam emittance is used for transmission calculations in both ("Distribution" and MC) modes, for matrices in Optical Block dialogs and so on.

"Beam" dialog

Beam			? ×
A Element q+	Beam energy MeV/u Energy • 79.55705 MeV/u TKE 18935.619 MeV Brho 4.52331 Tm P 93.5677 GeV/c U 2.744e+5 KV Beam intensity C 0.003403 enA C 4.941e-5 pnA	Emittance Beam CARD (Distribution method) 2D (Monte Carlo with half-width) 1.X mm 5 Rectangle uniform 2.T mrad 15 Gaussian 4.P mrad 15 Gaussian 5.L mm 0 Gaussian 6.D % 0.1 Gaussian	mm C cm beam respect to spectrometer dX 0 mm dX 0 mm d dY 0 mm d dY 0 mm d dY 0 mm d dP 0 mrad d dT 0 degrees d dP 0 degrees d
Cancel	0 9.356e-7 KW	Energy Loss in life 9.23e-8 RF frequency 20 MHz target box [KW] 9.23e-8 Bunch length 1 ns	Beam Sigma Vector used for Optics Optimization ("Opt.Beam")

New Beam sigma vector ("OptBeam") used only for optics optimization in the Fit Constraint block dialog and the Optics Fit dialog.

Access to the dialog to this bema vector modification can be done through the Beam or Fit Constraint block dialogs

"Opt.Beam			
1.× [1	mm	• mm
2. T	100	mrad	⊂ cm
3. Y	0	mm	
4. P	0	mrad	
5. L	0	mm	VK UK
6. D	0	%	🗙 Cancel

This new beam vector for optimization has been created to avoid additional beam emittance editing due to switching between fragment transmission calculations and the optimization mode, which done for the primary beam

"Fit constraint" dialog

T144	11.00	×			
This constraint is ACTIVE (will be used in the minimization process)	Select Element to Fit Global Block matrix : 1 st order	"Opt.Beam" at this point			
Desired parameters of element to fit Constraint : Equal to	1. X C 0.445 C 0.0004 C 0 C 0 C 0 C 6.0425 2. T C 1.5279 C 2.2488 C 0 C 0 C 0 C 8.0233	1. X C 0.447 [mm]			
Desired Value = 0	3. Y C 0 C 3.6333 C 0.0003 C 0 C 0	3. Y C 0 [mm] 4. P C 0 [mrad]			
Desired Accuracy = 0.001 Constraint name = T144	5. L C 0.6266 C 1.3585 C O C O C 1 C 1.0662 6. D C O C O C O C O C O C 1	5. L C 135.855 [mm] 6. D C 0 [%]			
TRANSPORT notation	/[mm] /[mrad] /[mm] /[mrad] /[mm] /[%]	7 B C 0.447 [mm]			
Typical TRANSPORT constraints Global Block matrix : 2nd order Matrix Element Value R.Aberration 2nd order maps mm @ C cm					
V OK X Cancel ? Help	Aberrations list				