

FFAG 2019 WORKSHOP

PSI, Villigen, Confédération des Helvètes

Zgoubi Workshop

Boulder, CO

26 – 30 August 2019

An overview

F. Méot / BNL C-AD

- The workshop was actually more of a tutorial
- Each day addressing a particular topic:
 - Mo: proton synchrotrons + spin; FFAG
 - Tue: Synchrotron radiation at ESRF;
US EIC: synchrotron radiation and spin
 - Wed: CBETA FFAG ERL
 - Thu: ExB systems, including
 - GANIL mass separator;
 - A nanoprobe;
 - A Wien filter spin rotator
- Each day essentially in two parts:
 - 1/ early morning: general introduction(s) to the accelerator field(s) of concern
 - 2/ rest of the day: simulation exercises

Many of the simulations/machines/beam lines
shown here available there:

<https://www.sirepo.com/zgoubi#/simulations>

Monday, 26 August — Introduction to Zgoubi. Proton rings.

Introduction talks: F. Méot (BNL), D. Abell (Radiasoft), K. Hock / V. Ranjbar (BNL), D. Kelliher (RAL)

Tutorial leaders: D. Abell, K. Hock, D. Kelliher

Machines: Los Alamos PSR, AGS, eRHIC, Radial Sector FFA

09:00 – 10:30 Talks

Mo1: Overview of Zgoubi — François Méot [20 min]

Mo2: Los Alamos PSR for Code Benchmarking — Dan Abell [15 min]

Mo3: AGS Booster for eRHIC, BNL EIC — Kiel Hock / Vahid Ranjbar [15 min]

Mo4: FFA Renaissance — David Kelliher [20 min]

10:30 – 12:30 Tutorial TutMo1

13:30 – 14:30 Tutorial TutMo1 (cont.)

14:30 – 15:00 Coffee Break

15:00 – 17:30 Tutorial TutMo2

TutMo1: Intro to Zgoubi with the Los Alamos PSR — D. Abell & K. Hock

<https://www.sirepo.com/zgoubi#/lattice/t2ijgRBF>

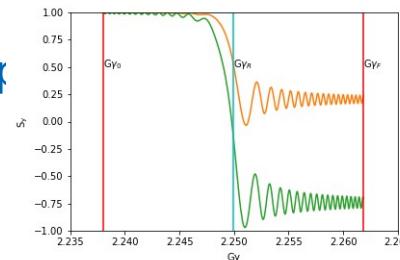
Alex Dragt's 1982 Paper Provides Useful Benchmarks

This tutorial is built around the ten-cell, 797 MeV Los Alamos PSR.

The initial exercise illustrates the basic Zgoubi files for input and output, and it demonstrates how to choose an appropriate step size.

The following two exercises introduce the standard linear and nonlinear analyses — including tune, chromaticity, and Twiss functions.

In the final exercise, we add both spin and acceleration, and simulate the crossing of a spin resonance.



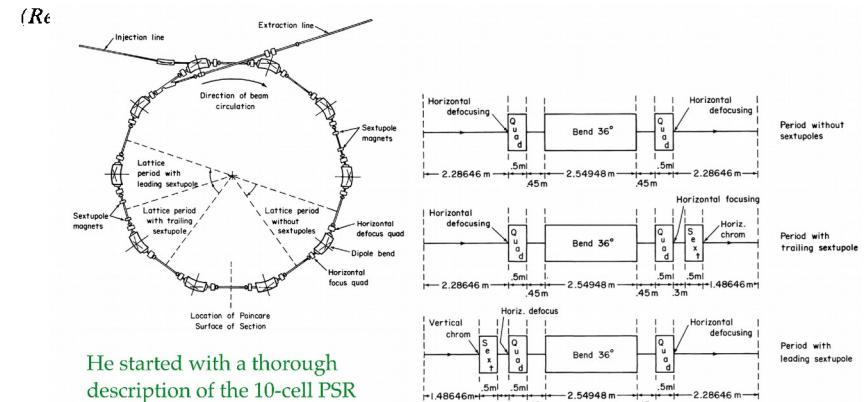
Particle Accelerators
1982 Vol.12 pp. 205-218
0031-2460/82/1204/0205\$06.50/0

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EXACT NUMERICAL CALCULATION OF CHROMATICITY IN SMALL RINGS

ALEX J. DRAGT

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He started with a thorough description of the 10-cell PSR lattice, with an excessive number of significant digits (useful for benchmarking).

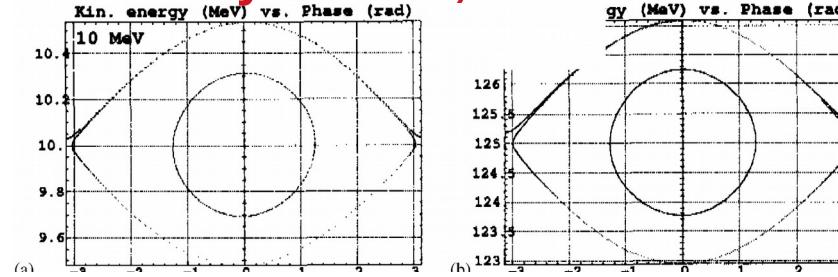
TutMo2: FFA Tutorial — David Kelliher

We simulate a 150 MeV, zero-chromaticity radial-sector FFA.

This includes synchrocyclotron like spiraling accelerated orbit, ~50,000 turns.

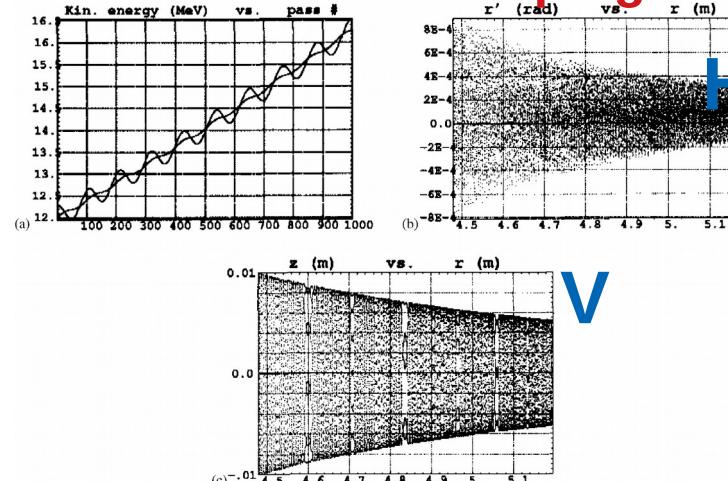
If time allows, include multi-turn injection, and/or RF capture, and/or dynamic aperture computation.

Stationary bucket, 10 and 125 MeV



$$\pm \frac{\Delta p}{p} = \pm \frac{1}{\beta_s} \left(\frac{2q\hat{V}}{\pi h\eta E_s} \right)^{1/2}, \quad v_s = \frac{2\pi}{\beta_s} \left(\frac{h\eta \cos \phi_s q\hat{V}}{2\pi E_s} \right)^{1/2}$$

Betatron damping



Tuesday, 27 August — Synchrotron radiation - Electron Ion Colliders

Talks: B. Nash (Radiasoft), V. Morozov (JLab)

Tutorial leaders: F. Lin (JLab), B. Nash

Machines: ESRF, JLEIC

09:00 – 09:45 Talks

Tu1: Physics of Electron Rings — Boaz Nash [15 min]

Tu2: Polarized Electrons in Designs for JLEIC — Vasiliy Morozov
[15min]

10:10 – 12:30 Tutorial TutTu1

13:30 – 15:00 Tutorial TutTu1 (cont.)

15:30 – 17:30 Tutorial TutTu2

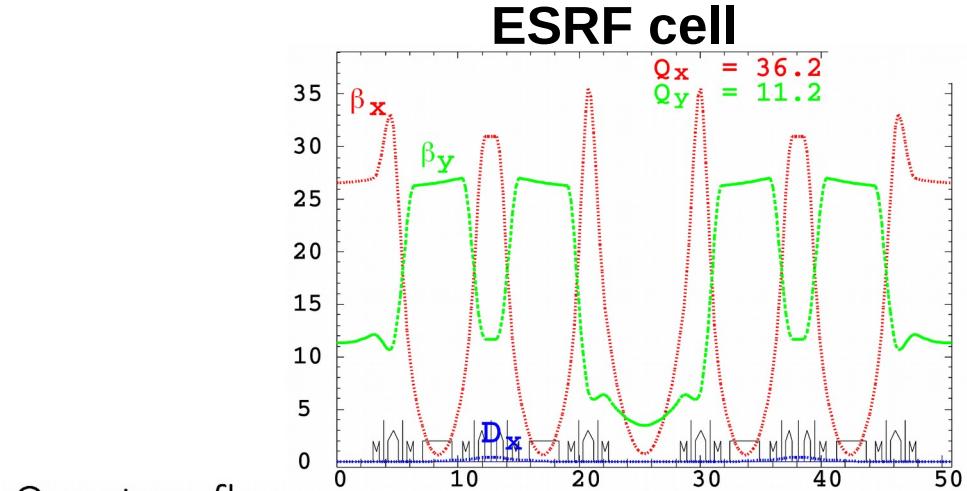
Tutorial 1 - ESRF — Fanglei Lin & Boaz Nash

<https://www.sirepo.com/zgoubi#/lattice/tDy5NG6Z>

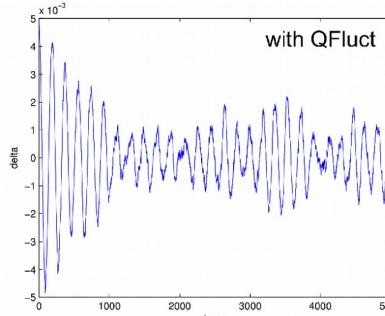
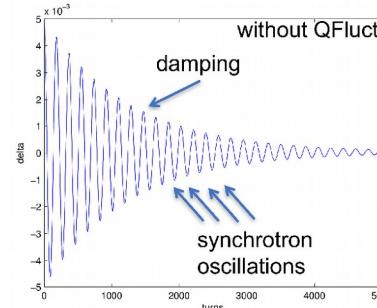
This tutorial includes two exercises to study the simulation of synchrotron radiation (SR) and electron spin dynamics in Zgoubi.

The first focusses on a single dipole magnet to explore the details of the Monte Carlo method.

The second introduces the ESRF lattice and simulates the process of beam equilibration in the presence of SR.

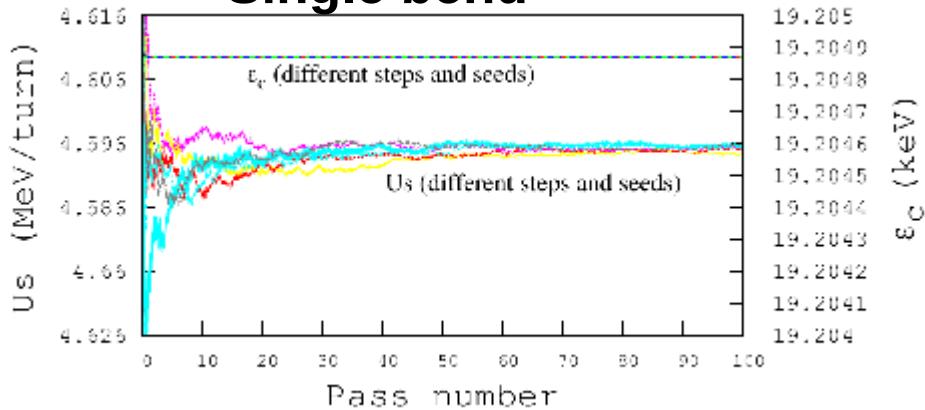


Quantum fluctuation
longitudinal dynamics

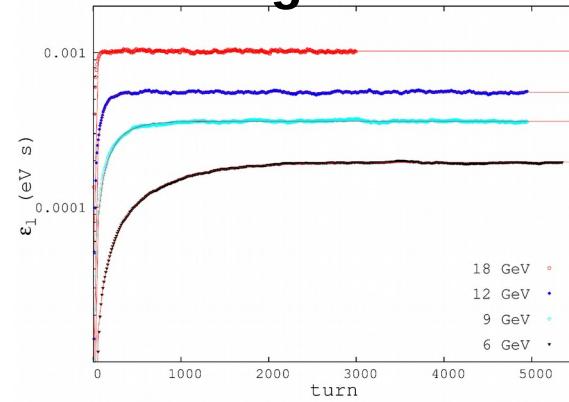


Tracking with and without quantum fluctuations

Single bend



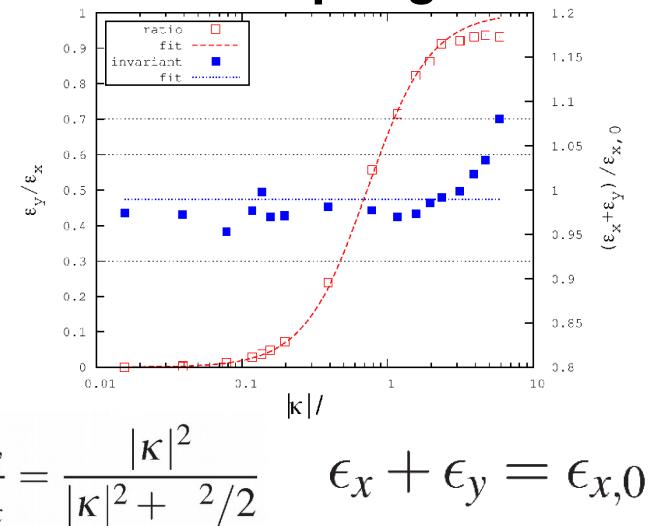
Equilibrium longitudinal emittance



Energy scaling of ESRF SR dynamics quantities

	Energy loss U_s (MeV/turn)	$\epsilon_{l,eq}$ (μ eV.s)	σ_l (mm)	τ_l (ms)	$\epsilon_{x,eq}$ (nm)	τ_x (ms)	τ_y (ms)
Scaling:	γ^4	$\gamma^{3/2}$	$1/\gamma^{1/2}$	$1/\gamma^3$	γ^2	$1/\gamma^3$	$1/\gamma^3$
6 GeV	4.5956 [4.5956]	196 [192]	9.37 [9.309]	1.769 [1.769]	6.90 [6.83]	3.547 [3.546]	3.501 [3.540]
9 GeV	23.263 [23.263]	358 [352]	7.67 [7.601]	0.548 [0.524]	15.87 [15.37]	1.020 [1.051]	1.040 [1.049]
12 GeV	73.518 [73.518]	554 [542]	6.67 [6.582]	0.225 [0.221]	28.18 [27.32]	0.447 [0.443]	0.439 [0.443]
18 GeV	372.16 [372.16]	1022 [996]	5.42 [5.375]	0.068 [0.066]	65.77 [61.46]	0.132 [0.131]	0.130 [0.131]
Theory	$\frac{c_\gamma}{2\pi} E_s^4 I_2 = \frac{\alpha E_s}{2\Omega_s} \sigma_s^2 = \frac{\alpha c}{\Omega_s} \sigma_{\frac{\Delta E}{E}} = \frac{3T_{rev}}{2r_0\gamma^3(2I_2 + I_4)} = \frac{c_\gamma \gamma^2 I_5}{J_x I_2} = \frac{3T_{rev}}{2r_0\gamma^3(I_2 - I_4)} = \frac{3T_{rev}}{2r_0\gamma^3 I_2}$	$\frac{\alpha E_s}{2\Omega_s} \sigma_s^2 = \frac{T_{rev} E_s}{U_s J_l} = \frac{c_\gamma \gamma^2}{J_x \rho} \mathcal{K}$	$\frac{\alpha c}{\Omega_s} \sigma_{\frac{\Delta E}{E}} = \frac{T_{rev} E_s}{U_s J_x} = \frac{T_{rev} E_s}{U_s J_y}$				
	$\frac{c_\gamma E_s^4}{\rho}$	$\frac{\alpha E_s}{\Omega_s} \frac{c_\gamma \gamma^2}{J_l \rho}$					

Coupling

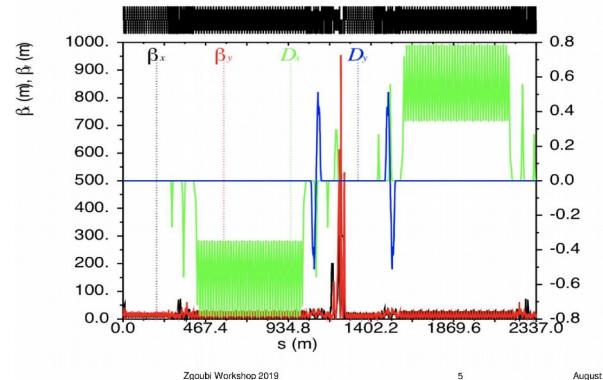


$$\frac{\epsilon_y}{\epsilon_x} = \frac{|k|^2}{|k|^2 + 2/2} \quad \epsilon_x + \epsilon_y = \epsilon_{x,0}$$

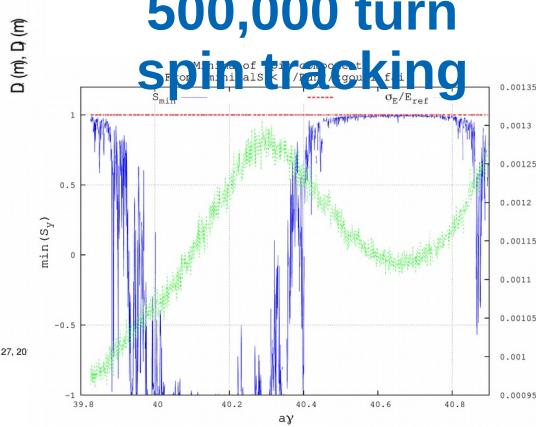
Tutorial 2 - JLEIC Electron Ring Simulations — Fanglei Lin & Boaz Nash

This exercise simulates spin dynamics and polarization lifetime in the 12 GeV, figure-8, zero-spin-tune JLEIC:

- examine the JLEIC electron ring lattice.
- turn on spin tracking and track for one turn, watching spin evolution around ring.
- consider spin transfer matrices and spin tune.
- compute invariant spin direction around ring and plot.
- turn on synchrotron radiation and examine spin diffusion for a distribution of electrons.

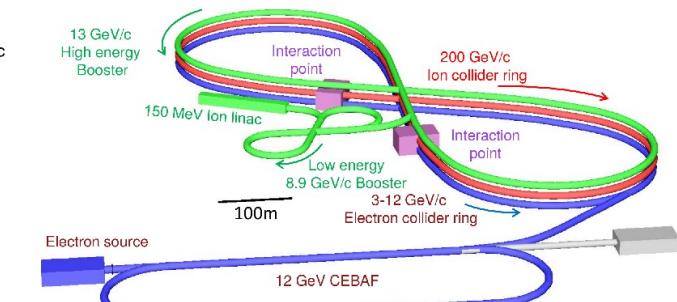


500,000 turn spin tracking



JLEIC Layout

- Electron complex
 - CEBAF
 - Electron collider ring: 3-12 GeV/c
- Ion complex
 - Ion source
 - SRF linac: 150 MeV for protons
 - Low Energy Booster: 8.9 GeV/c
 - High Energy Booster: 13 GeV/c
 - Ion collider ring: 200 GeV/c
- Up to two detectors at minimum background locations
- Upgradable to 140 GeV CM by doubling ion energy



Zgoubi Workshop 2019

Wednesday, 28 Aug. - CBETA FFAG ERL

Talks: N. Tsoupas

Tutorial leaders: F. Méot, N. Tsoupas

Machines: CBETA ERL

09:00 – 09:20 Talks

Field Map Simulations for CBETA ERL — Nick Tsoupas [20 min]
(See *this* workshop)

09:45 – 12:00 Tutorial

12:30 – Excursion to Rocky Mountain National Park

Tutorial: CBETA ERL — François Méot & Nicholaos Tsoupas

CBETA recirculates electron bunches to 150 MeV using a

- superconducting RF linac, FFA return arcs,**
- four-line spreader and combiner sections,**
- and energy recovery.**

A series of three exercises introduces to the simulation of a four-pass ERL. These exercises showcase several of Zgoubi's strengths (e.g., 'GOTO' for recirculation).

It is also an opportunity to introduce accurate tracking in magnet field maps.

See *this* Workshop

Thursday, 29 August — Electrostatic Devices in Zgoubi

Introduciton talks: L. Serani, F. Méot

Tutorial Leaders: L. Serani, F. Méot

Machines: GANIL HRS-DESIR mass separator; Wien filter spin rotator;
ExB Nanoprobe

09:00 – 09:55 Talks

Th1: Electrostatic Spectrometers — Laurent Serani [20 min]

Th2&3: ExB fields: 1/ Nanoprobe. 2/ Spin Rotator — François Méot
[20 min]

10:10 – 12:30 Tutorial TutTh1

13:30 – 15:00 Tutorial TutTh2

15:00 – 15:30 Coffee Break

15:30 – 17:30 Tutorial TutTh3

TutTh1: Magneto- and Electrostatic Mass Separator —

Laurent Serani

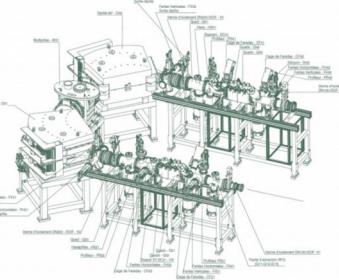


High Resolution Separator for Spiral2 Design and performances

Laurent Serani
On behalf of the HRS Working Group



Central multipole and
quadrupole: all electrostatic.
Bends are magnetic.



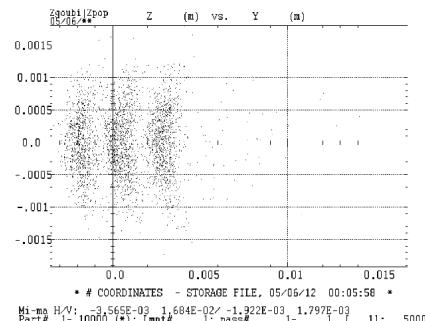
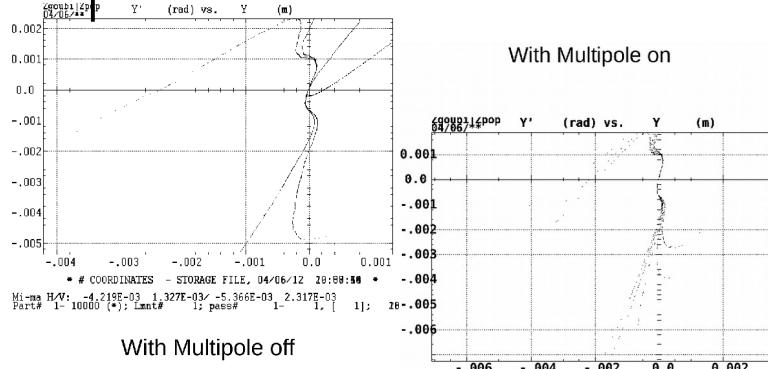
Two sites of Production with fento to pico Amps beams intensity
Broad Species
Transportation energy at 60keV



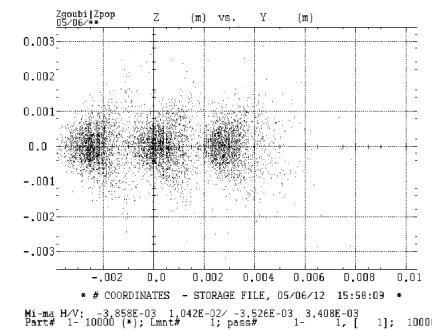
Need to have a setup with good resolution and hight efficiency



Resolution after roughly aberrations correction
at the focal plane



R=4m on one side of each Dipole
+ correction with the Multipole



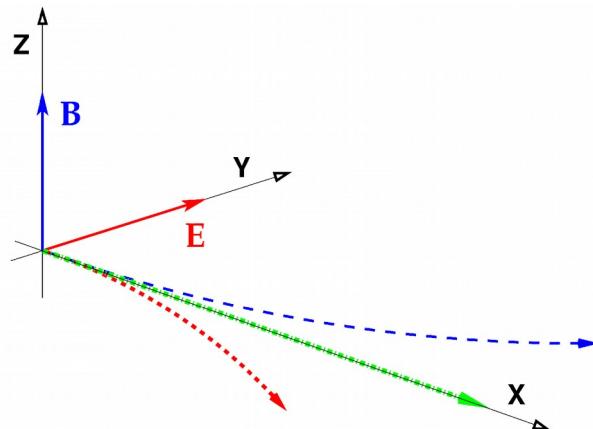
R=4m on both side of each Dipole
Without correction with the Multipole

If the Life is as Zgoubi, the Life will be great

TutTh2: Wien Filter as spin rotator — François Méot

Exercises in due form, and solutions, are available on sourceforge repository:

<https://sourceforge.net/p/zgoubi/code/HEAD/tree/trunk/exemples/KEYWORDS/WIENFILTER/>



$$\theta_s = \underbrace{(1 + a\gamma) \frac{BL}{B\rho}}_{\approx 50^\circ \text{ from } \vec{B}} - \underbrace{(a\gamma + \frac{\gamma}{1 + \gamma}) \beta^2 \frac{BL}{B\rho}}_{\approx 20^\circ \text{ from } \vec{E}} = 30^\circ$$

TutTh3: ExB Nanoprobe — François Méot

The exercise, including instructions, solutions zgoubi files, etc. is available on sourceforge:

<https://sourceforge.net/p/zgoubi/code/HEAD/tree/trunk/exemples/achromatDoublet/>

Nuclear Instruments and Methods in Physics Research A 340 (1994) 594–604
North-Holland

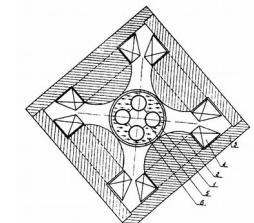
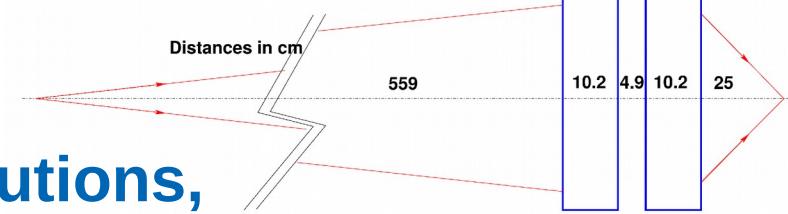
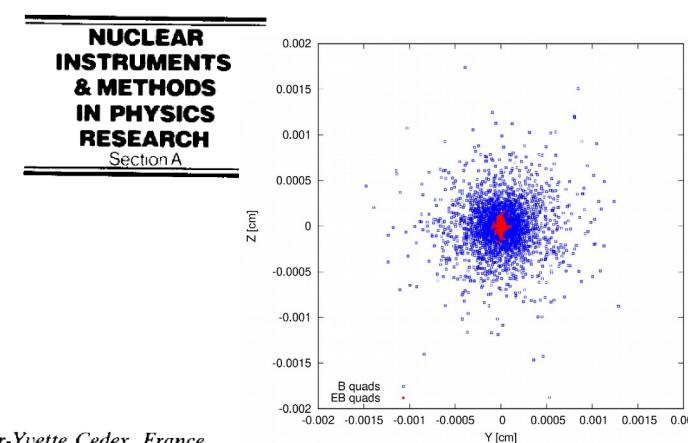


Fig. 13. A scheme of the achromatic electromagnetic quadrupole (after ref. [9]): 1) vacuum pipe, 2) magnetic pole pieces, 3) return yoke, 4) coils, 5) electrodes, 6) plexiglas. In the text, the electrodes and the magnetic poles are assumed to present the same pole tip radius, $a = 4 \times 10^{-2}$ m, instead of what is schemed here. At the electrodes, $\phi = 714.2$ V, while at the magnetic poles $B = 0.3649$ T.



Generalization of the Zgoubi method for ray-tracing to include electric fields

E. Méot¹

Groupe Théorie, Laboratoire National SATURNE, DSM-CEA & IN2P3-CNRS, CE Saclay, 91191 Gif-sur-Yvette Cedex, France

(Received 1 June 1993; revised form received 1 October 1993)

Friday, 30 August — Future Developments for Zgoubi, Interfaces, User Feedback

Talks: D. Abell, Z. Wu, P. Moeller, S. Sheehy

09:00 – 10:00 Future Developments for Zgoubi (D. Abell)
10:00 – 10:30 Symplectic Tracking in Zgoubi (Zhigang Wu)
10:30 – 10:45 Coffee Break
10:45 – 11:45 Sirepo (P. Moeller)
11:45 – 12:15 Workshop Summary (S. Sheehy)
12:15 Adjourn Workshop