The introduction to learning Poisson/Superfish & Astra codes

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Winter 96

Electromagnetic field simulation code

- ▷ POISSON/SUPERFISH
- ▷ MAGIC
- ▷ MAFIA
- ▷ COMSOL
- ▷ CST
- ▷ HFSS
- ▷ FEMLAB, ect.

Beam Dynamic code

- ▷ ASTRA
- ▷ PARMILA
- ▷ PARMELA
- ▷ TRACK
- ▷ MAGIC
- ▷ COMSOL
- ▷ CST, ect.

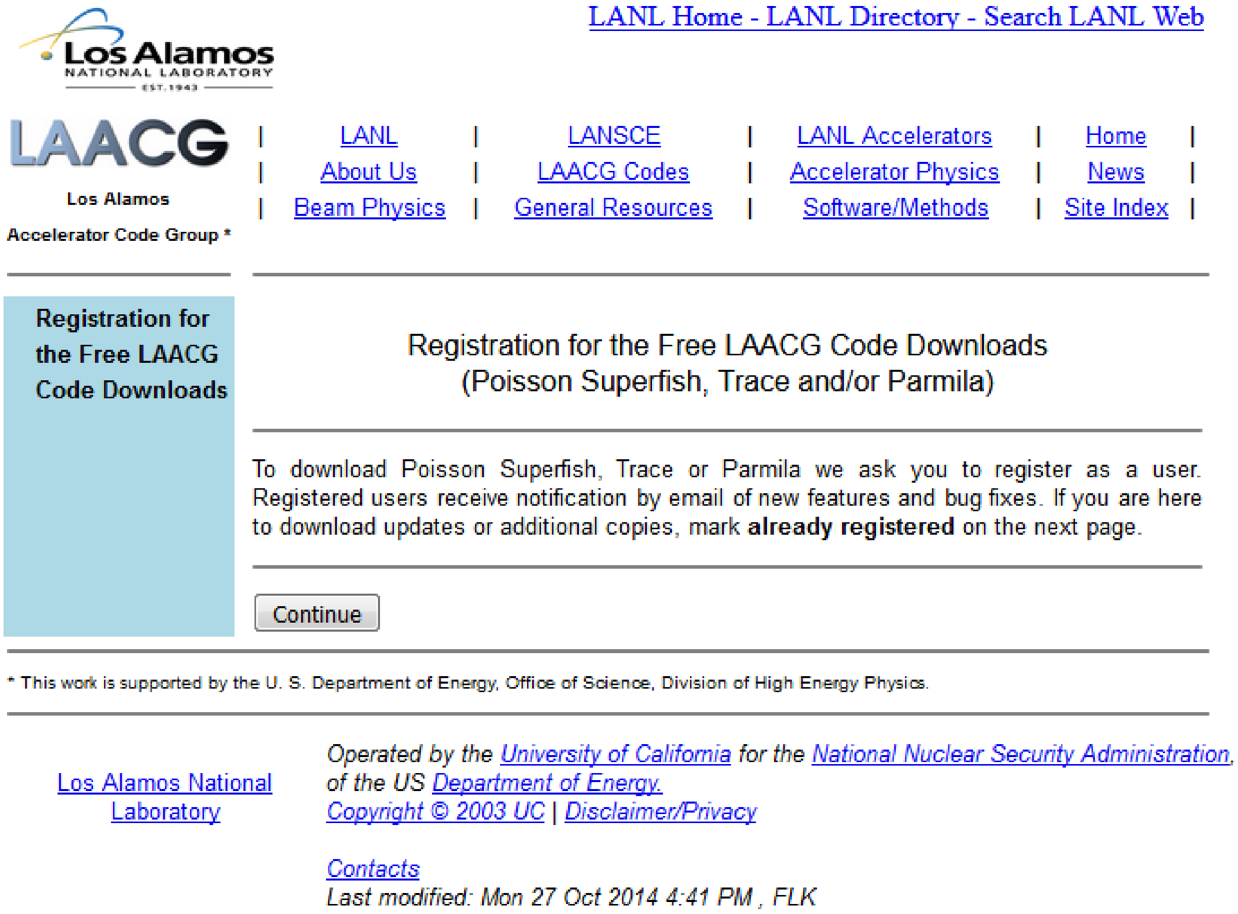
Poisson Superfish

Los Alamos National Laboratory
1976

Introduction I

- a collection of programs for calculating static magnetic and electric fields and radio-frequency electromagnetic fields in either 2-D Cartesian coordinates or axially symmetric cylindrical coordinates.

- **Getting Started with Poisson Superfish:** The best way to learn about Poisson Superfish is to run the sample problems described in the documentation.



	SFTOC.DOC	This file, containing the table of contents and suggestions for viewing and printing.
	SFINTRO.DOC	General information about the software installation, features in the codes, references, history, SF.INI configuration, and technical support.
Codes description	SFFILES.DOC	Brief descriptions of all the input and output files used in the Poisson Superfish codes.
	SFCODES.DOC	Information about the main programs Autofish, Automesh, Fish, CFish, Poisson, and Pandira.
	SFPOSTP.DOC	Information about the postprocessor programs WSFplot, SFO, SF7, and Force.
	SFCODES2.DOC	The automated tuning programs CCLfish, CDTfish, DTLfish, MDTfish, ELLfish, and RFQfish.
	SFCODES3.DOC	General purpose plotting programs Quikplot and Tablplot, and utility programs Beta, Kilpat, List35, ConvertF, SF8, FScale, SegField, and SFOtable.
Example	SFEXMPL1.DOC	Discussion of rf-field example files for Fish, CFish, and Autofish contained in the Examples\RadioFrequency subdirectories.
	SFEXMPL2.DOC	Discussion of the static-field example files for Poisson and Pandira contained in the Examples\Magnetostatic and Examples\Electrostatic subdirectories.
	SFEXMPL3.DOC	Discussion of the tuning-program example files contained in the Examples\CavityTuning subdirectories.
Theory	SFPHYS1.DOC	Theory of electrostatics and magnetostatics from John Warren’s treatment in the 1987 Reference Manual
	SFPHYS2.DOC	Properties of static magnetic and electric fields from John Warren’s treatment in the 1987 Reference Manual
	SFPHYS3.DOC	Boundary conditions and symmetries from John Warren’s treatment in the 1987 Reference Manual
	SFPHYS4.DOC	Numerical methods in Poisson and Pandira from John Warren’s treatment in the 1987 Reference Manual
	SFPHYS5.DOC	RF cavity theory from John Warren’s treatment in the 1987 Reference Manual

Summary of the Poisson Superfish codes

Poisson Superfish codes
- Autofish
- Automesh
- Fish
- CFish
- Poisson
- Pandira

Postprocessors
- WSFplot
- SFO
- SF7
- Force

Automated tuning programs
- CCLfish
- CDTfish
- DTLfish
- ELLfish
- MDTfish
- RFQfish
- SCCfish

Utility programs
- List35
- Beta
- Kilpat
- ConvertF
- FScale
- SF8
- SegField
- SFOtable

Plotting programs
- Quikplot
- Tablplot

Input File

- Problem descriptions of up to ten 80-character title lines are supported in all the codes.
- has extension: AF, AM
- contains: REG, PO, and MT namelist variables that define the problem parameters and the geometry.
- can use either a dollar sign ($) or an ampersand (&) as the namelist delimiter.
- Comments can appear on any line in the input file after a semicolon (;) or exclamation mark (!).
- Variable KPROB must appear in the first REG namelist.

Variable	Superfish	Poisson
NBSUP	1	0
NBSLO	0	1
NBSRT	1	0
NBSLF	1	0

Field	Dirichlet	Neumann
Magnetic	parallel to boundary.	perpendicular to boundary.
Electric	perpendicular to boundary.	parallel to boundary.

0 indicates a Dirichlet boundary and 1 indicates a Neumann boundary

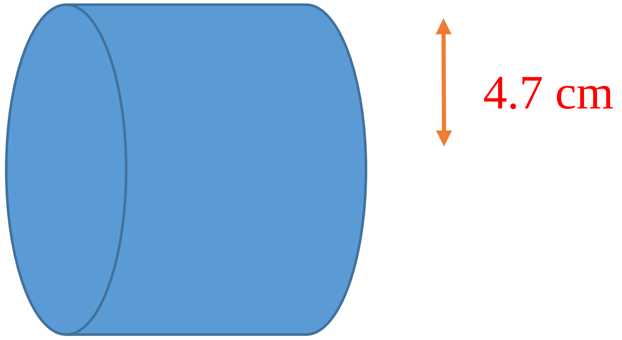
Poisson Superfish Example 1
A Pillbox cavity

For the accelerating mode (TM_{010}), the resonant wavelength is:

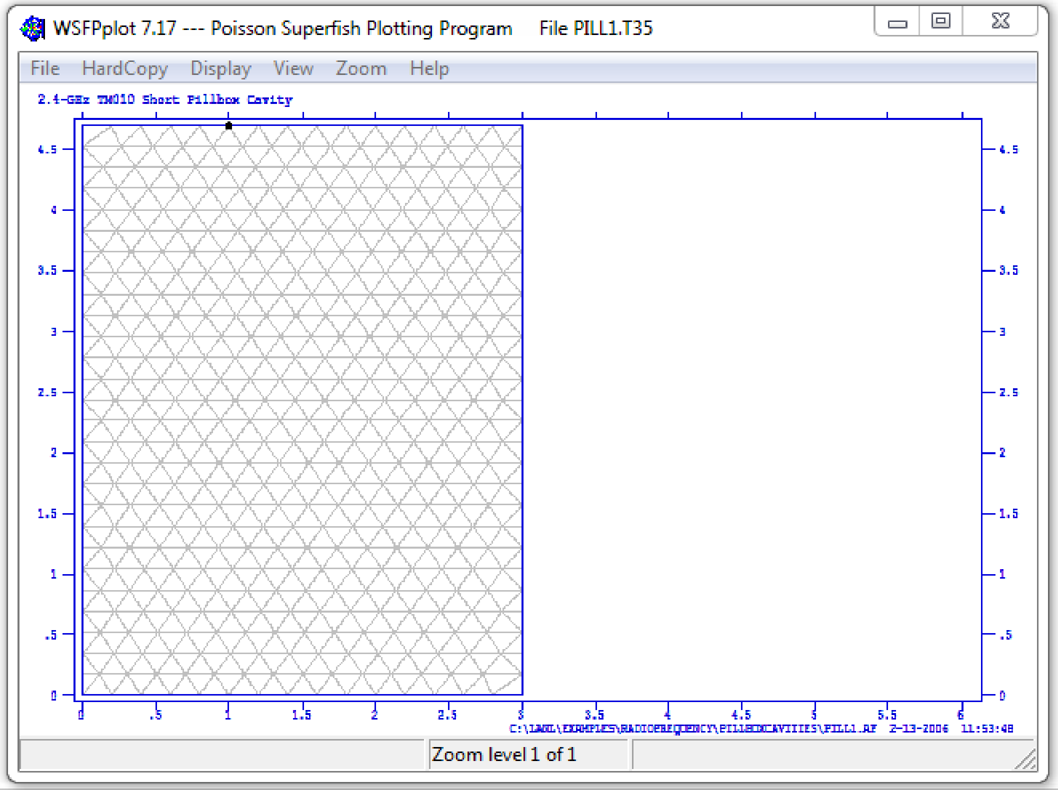
$$\lambda = \frac{\pi D}{x_1}$$

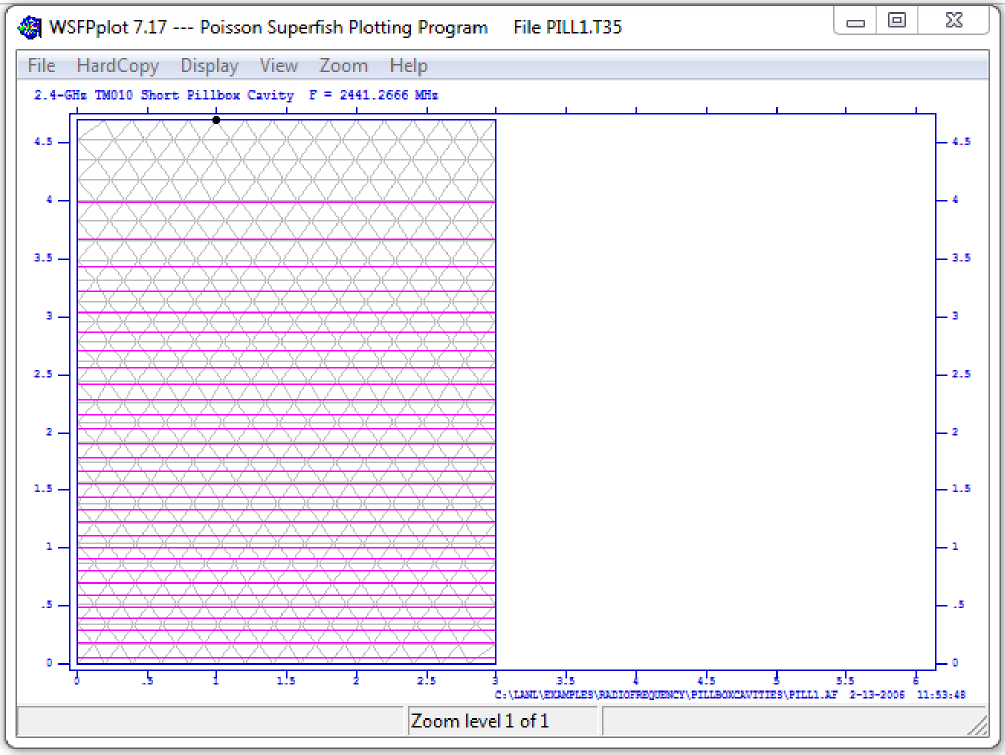
$$x_1 = 2.40483$$

x_1 - first root of the zero-th order Bessel function J_0 (x)



```
2.4-GHz TM010 Short Pillbox Cavity

; example 1

$reg kprob=1,              ; Superfish problem
dx=.2,                     ; X mesh spacing
freq=2400.,                ; Starting frequency in MHz
xdri=1.,ydri=4.7 $         ; Drive point location

$po x=0.0,y=0.0 $          ; Start of the boundary points
$po x=0.0,y=4.7 $
$po x=3.0,y=4.7 $
$po x=3.0,y=0.0 $
$po x=0.0,y=0.0 $
```

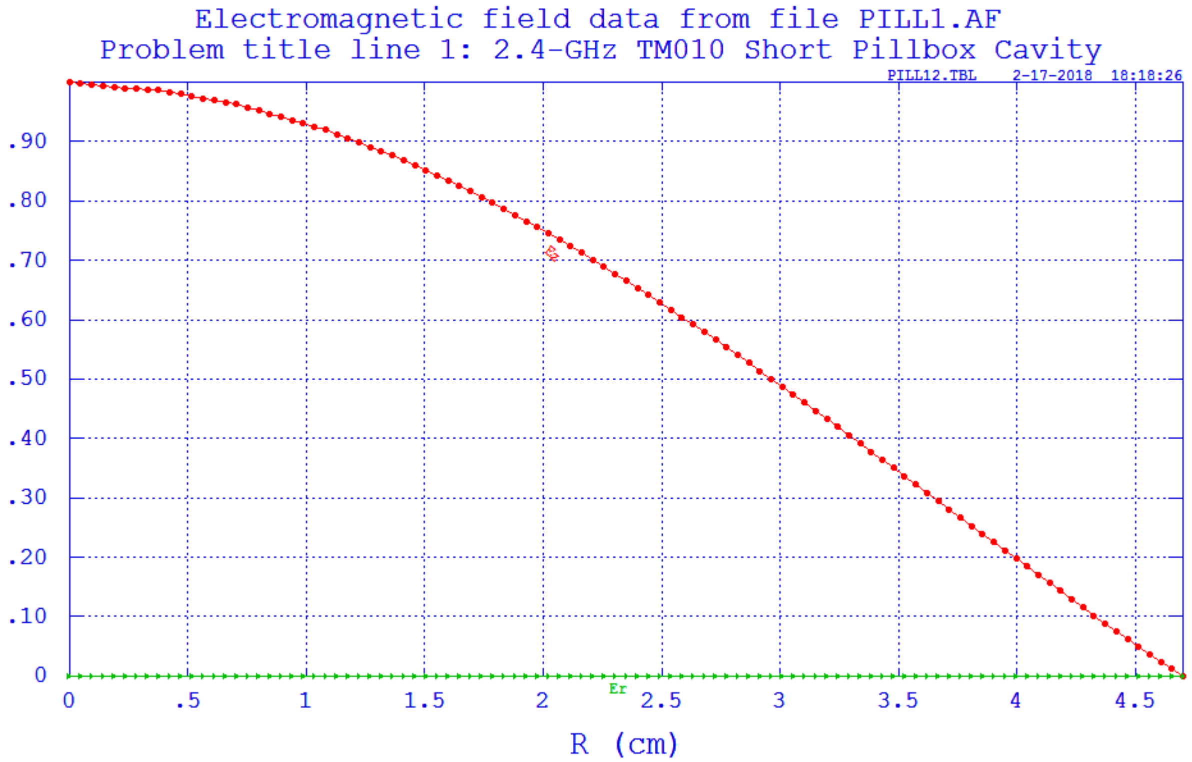




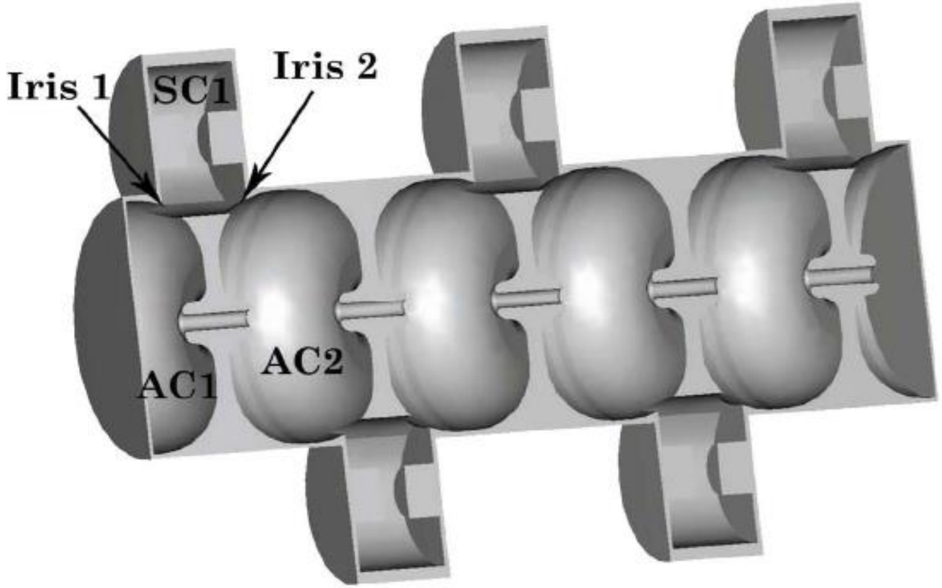
```
All calculated values below refer to the mesh geometry only.
Field normalization (NORM = 0):      EZERO =      1.00000 MV/m
Frequency                                  =   2441.26656 MHz
Particle rest mass energy                  =   938.272029 MeV
Beta =  0.4885913           Kinetic energy =      137.096 MeV
Normalization factor for E0 =  1.000 MV/m  =     5165.416
Transit-time factor                        =    0.0001896
Stored energy                              =  2.45655E-04 Joules
Using standard room-temperature copper.
Surface resistance                         =     12.89047 milliOhm
Normal-conductor resistivity               =      1.72410 microOhm-cm
Operating temperature                      =      20.0000 C
Power dissipation                          =     107.3166 W
Q     =   35111.9          Shunt impedance =      279.547 MOhm/m
Rs*Q  =   452.608 Ohm                Z*T*T =        0.000 MOhm/m
r/Q   =     0.000 Ohm  Wake loss parameter =      0.00000 V/pC
Average magnetic field on the outer wall   =      1371.08 A/m, 1.21161 W/cm^2
Maximum H (at Z,R = 0.8,4.7)               =      1370.97 A/m, 1.21143 W/cm^2
Maximum E (at Z,R = 0.4,4.7)               =   4.3707E-04 MV/m, 1.02619E-05 Kilp.
Ratio of peak fields Bmax/Emax             =    3941.7412 mT/(MV/m)
Peak-to-average ratio Emax/E0              =       0.0004

Wall segments:
Segment   Zend        Rend          Emax        Power       P/A         dF/dZ      dF/dR
          (cm)        (cm)         (MV/m)        (W)     (W/cm^2)    (MHz/mm)   (MHz/mm)
-----------------------------------------------------------------------------------------
         0.0000      4.7000
   2     3.0000      4.7000      4.3707E-04     107.3       1.211       0.000     -52.00
-----------------------------------------------------------------------------------------
                                   Total        107.3
```

SFO

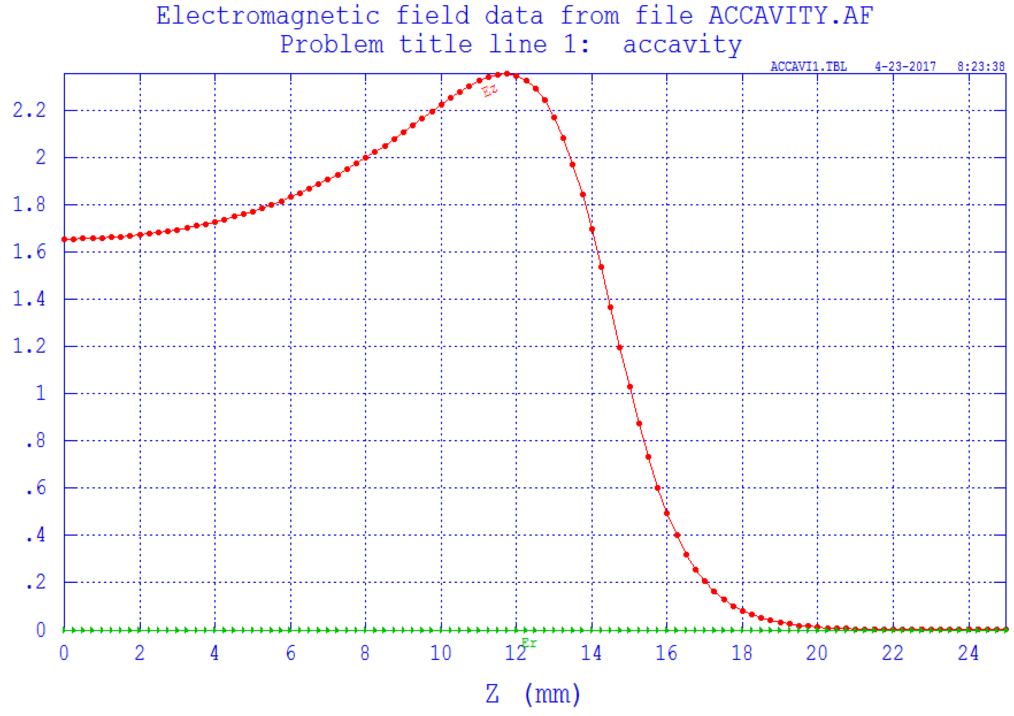
SF 7

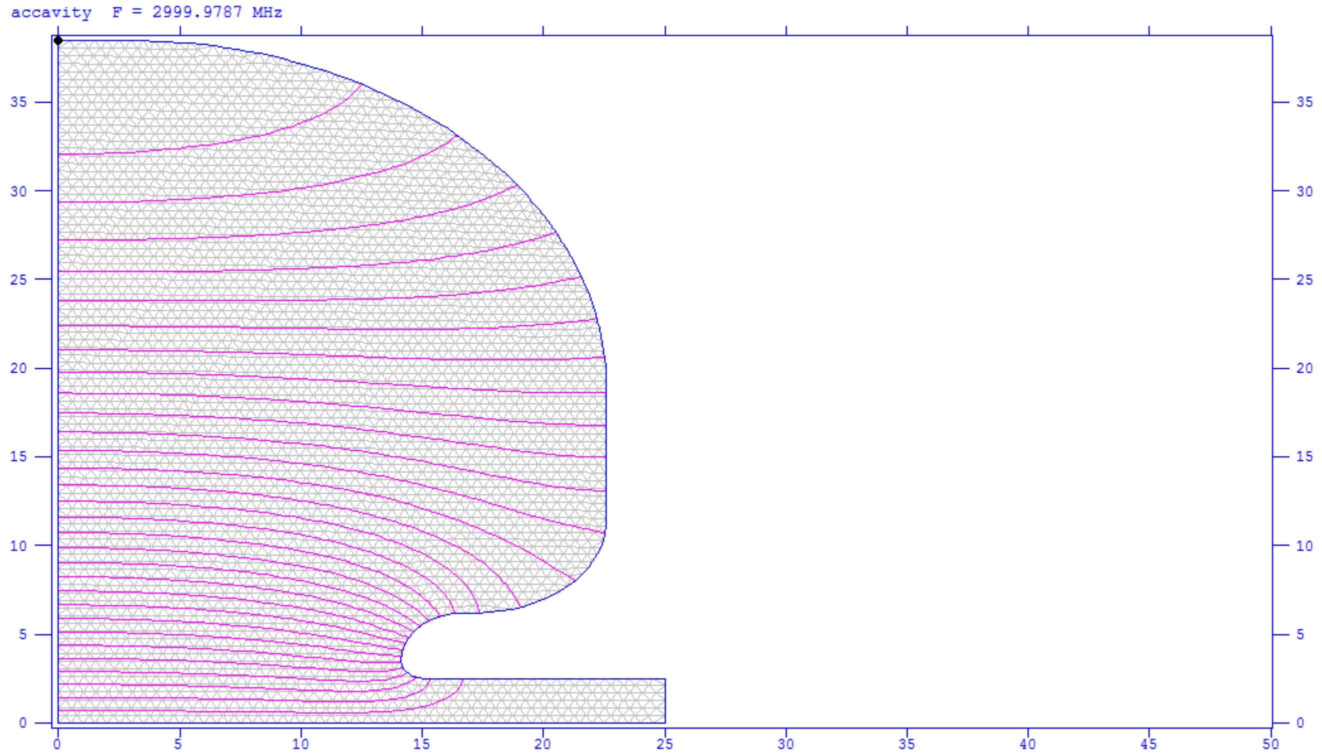


Poisson Superfish Example 2
Accelerating Cavity



```
accavity
$reg freq=2998.5,KPROB=1,kmethod=1,norm=1,icylin=1,CONV=.1,rmass=-1,
xdri=0.000000,ydri=38.460000,dx=.1,NBSUP=1 ,NBSRT=1,NBSLO=0,NBSLF=1,beta=1,TEMPC=20$
$po,x=0.0000,y=0.0000$
$po,x=0.0000,y=38.4600$
$po,x=3.0000,y=38.4600$
$po,nt=2,x0=3.0000,y0=18.8600,x=19.6000,y=0.0000$
$po,x=22.6000,y=11.5000$
$po,nt=2,r=5.3000,x0=17.3000,y0=11.5000,theta=-90.0000$
$po,x=16.8000,y=6.2000$
$po,nt=2,r=2.7000,x0=16.8000,y0=3.5000,theta=180.0000$
$po,nt=2,x0=15.1000,y0=3.5000,x=0.0000,y=-1.0000$
$po,x=25.0000,y=2.5000$$po,x=25.0000,y=0.0000$
$po,x=0.0000,y=0.0000$
```





Astra
A Space Charge Tracking Algorithm

DESY
1997

The ASTRA program package can be downloaded free of charge for non-commercial and non-military use.

ASTRA MANUAL	Astra documentation March 2017
Examples	
Utility programs	
	Astra for 64 Bit LINUX
	Astra for Windows
	Astra for Macintosh OSX

A collection of examples input decks for ASTRA:

Manual Example	To get started: Input decks from the Astra Manual
Aperture	Using the namelist 'Aperture'

A collection of utility programs provided by various users:

Converts Astra output particle distribution to Elegant SDDS compliant input

Index of /~mpyflo/Astra_for_WindowsPC

Name	Last modified	Size	Description
Parent Directory	28-Aug-2017 11:26	-	
Astra.exe	12-Oct-2017 16:56	2.2M	
fieldplot.exe	02-Jun-2017 09:46	2.7M	
generator.exe	23-Mar-2017 15:34	981k	
lineplot.exe	15-Apr-2016 14:36	1.6M	
postpro.exe	04-Aug-2017 15:25	2.3M	

Apache/1.3.41 Server at www.desy.de Port 80

Introduction I

- The Astra (**A** **S**pace Charge **Tr**acking **A**lgorithm) program package consists of the five parts:
- 1. The program *generator* which may be used to generate an initial particle distribution.
- 2. The program *Astra* which tracks the particles under the influence of external and internal fields.
- 3. The graphic program *fieldplot* which is used to display electromagnetic fields of beam line elements and space charge fields of particle distributions.
- 4. The graphic program *postpro* which is used to display phase space plots of particle distributions and allows a detailed analysis of the phase space distribution.
- 5. The graphic program *lineplot*, which is used to display the beam size, emittance, bunch length etc. versus the longitudinal beam line position or versus a scanned parameter, respectively.

Introduction II

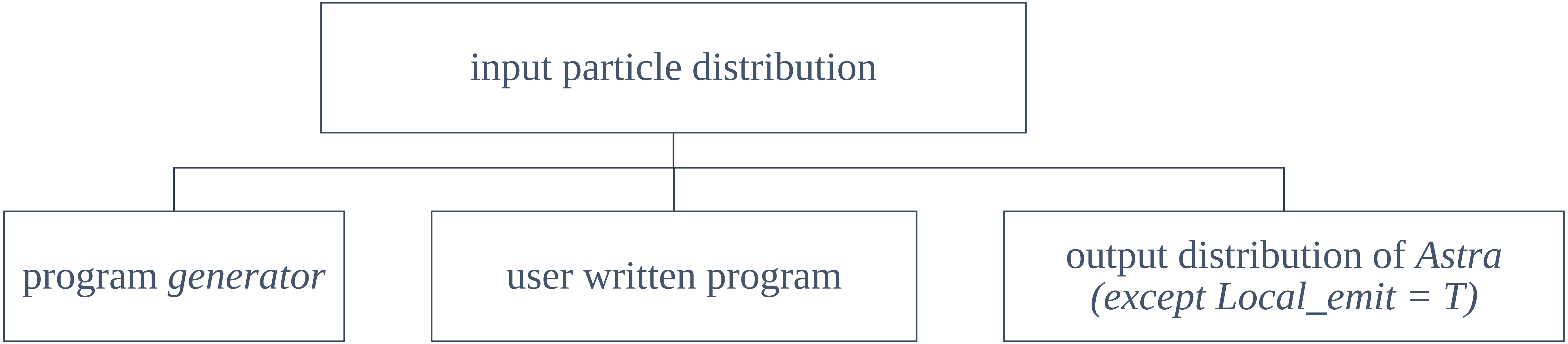
- *Astra* is written in Fortran 90 and runs on different platforms.
- The minimal form of a namelist is:

```
& Name
/
```

- only those namelist which are required need to be specified and they can appear in arbitrary order.
- a namelist parameters are specified in the form: ‘name = Value
- Specifications are separated by a comma or a line feed.
- Character input (keywords and file names) has in general to be enclosed by quotation marks (‘ ‘).
- The input of keywords is not case sensitive. general only the first character(s) are significant → (**bold letters** in this manual)

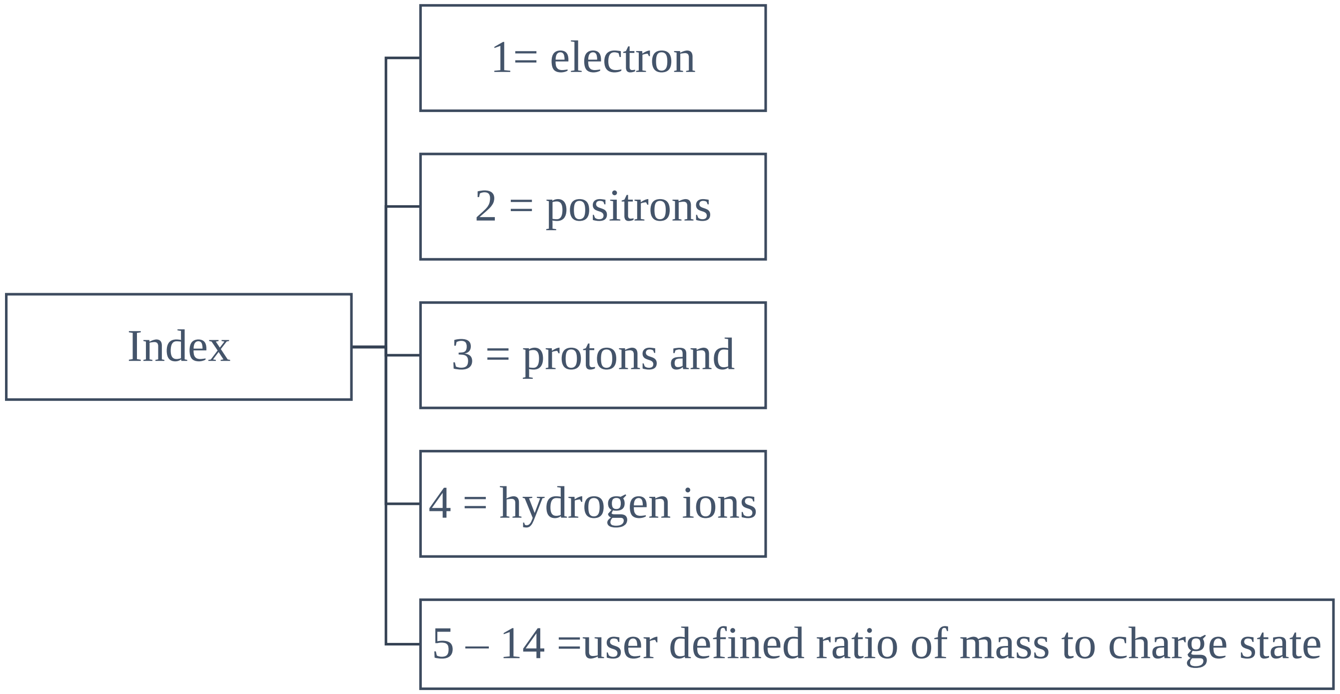
Definition of the initial particle distribution

- distribution file name should end with the extension '.ini' or with '.zpos.run'. zpos = four digit number & run = three digit number specifying the run number
- Mix different kinds of particles as an initial particle distribution



	1	2	3	4	5	6	7	8	9	10
Parameter	x	y	z	px	py	pz	clock	macro charge	particle index	status flag
Unit	m	m	m	eV/c	eV/c	eV/c	ns	nC		

- ▷ The first line = the reference particle
- ▷ **Longitudinal particle coordinates, i.e. z, pz and t are given relative to the reference particle.**



status flags

Status flag	Comment	Status
-99[1]	average position of distribution	will not be tracked
-95	ref. particle only; $Z_0 > ZStop$	lost
-94	ref. particle only; more than Max_Step steps	lost
-92[2]	probe rejected by space charge at the cathode	lost
-91[2]	rejected by space charge at the cathode	lost
-90	probe particle before Z_{min}	lost
-89	particle before Z_{min}	lost
-86[3]	probe particle traveling backwards	lost
-85[3]	particle traveling backwards	lost
-31	particle discarded by user	lost
-30	particle preliminary discarded by user	lost
-22	probe secondary electron, lost on aperture	lost
-21	secondary electron, lost on aperture	lost
-20	passive probe particle, lost on aperture	lost
-19	passive particle, lost on aperture	lost
-17	trajectory probe particle, lost on aperture	lost
-15	standard particle, lost on aperture	lost
-6	passive probe particle, at the cathode	not yet started
-5	passive particle, at the cathode	not yet started
-4	secondary particle	not yet started
-3	trajectory probe particle at the cathode	not yet started
-1	standard particle, at the cathode	not yet started
0	passive probe particle	tracking[4]
1	passive particle	tracking[4]
3	trajectory probe particle	tracking
4	cross over particle[5]	tracking
5	standard particle	tracking
6, 9…33	probe secondary electrons of generation 1, 2…10 or higher	tracking
8, 11…35	secondary electrons of generation 1, 2…10 or higher	tracking

Passive particles

- Particles with a negative status flag are either lost by some mechanism or not yet started.

- Passive particles are tracked as normal particles;
- But not taken into account for
  - The calculation of internal beam parameters; emittance, size, etc.
  - The set-up of the space charge grid
  - The calculation of space charge fields

generator

- *generator* generates an initial particle distribution file.
- The input file for *generator* has to have the extension ‘.in’.
- The default file name is ‘generator.in’.
- The input file consists of a single namelist named INPUT.

```
&INPUT
 FNAME = 'Example.ini'
 Add=FALSE,       N_add=0,
 IPart=10200, Species='electrons'
 Probe=True,  Noise_reduc=f,              Cathode=F
 Q_total=1.0E0

 Ref_zpos=0.0E0,   Ref_Ekin=2.0E0

 Dist_z='u',     sig_z=1.0E0,
 Dist_pz='u',          sig_Ekin=1.5,

 Dist_x='g',     sig_x=0.75E0,
 Dist_px='g',          Nemit_x=1.0E0,
 Dist_y='g',           sig_y=0.75E0,
 Dist_py='g',          Nemit_y=1.0E0,
/
```

1D distribution: **uniform distribution**

$$f(x) = \frac{1}{FWHM} \quad \text{for } |x| \le \frac{FWHM}{2}$$

$$0 \quad \text{elsewhere}$$

▷

rms value $\sigma = \frac{FWHM}{2\sqrt{3}}$

Dimension	**Key word**	**Parameter** *FWHM* or σ	**unit**
temporal[1]	Dist_z = '**uniform**'	Lt or sig_clock	ns
longitudinal[2] z	Dist_z = '**uniform**'	Lz or sig_z	mm
longitudinal E_{kin}	Dist_pz = '**uniform**'	LE or sig_Ekin or emit_z	keV or keVmm
transverse x	Dist_x = '**uniform**'	Lx or sig_x	mm
transverse y	Dist_y = '**uniform**'	Ly or sig_y	mm
transverse p_x	Dist_px = '**uniform**'	Lpx or sig_px or Nemit_x	eV/c or mrad mm
transverse p_y	Dist_py = '**uniform**'	Lpy or sig_py or Nemit_y	eV/c or mrad mm

[1] active if Cathode = TRUE, [2] active if Cathode = FALSE

1D distributions

- **inverted parabola (longitudinal)**
  - The inverted parabola distribution produces linear longitudinal space charge fields.

$$f(z) = \frac{3}{4z_{\max}}\left(1 - \frac{z^2}{z_{\max}^2}\right) \qquad |z| \le z_{\max}$$

- **Gaussian distribution**

$$f(x) = \frac{1}{\sqrt{2\pi}\sigma}\exp\left(-\frac{1}{2}\frac{x^2}{\sigma^2}\right)$$

FWHM value $\qquad FWHM = 2\sqrt{-2\ln(0.5)} = 2.35\sigma$

- **truncated Gaussian distribution**

$$f(x) = \frac{1}{\sqrt{2\pi}\sigma_{inp}}\exp\left(-\frac{1}{2}\frac{x^2}{\sigma_{inp}^2}\right) \qquad \text{for } |x| \le C_{Cut}\sigma_{inp} \qquad \frac{C_{Cut}\sigma_{inp}}{\sqrt{3}} \le \sigma_{out} \le \sigma_{inp}$$

2D distributions

- **radial uniform distribution**

$$f(x,y) = \frac{1}{\pi r^2} \qquad \text{for} \quad x^2 + y^2 \le r^2$$

$$0 \qquad \text{elsewhere}$$

Dimension	**Key word**	**Parameter** r or σ	**unit**
transverse x, y	Dist_x = 'radial uniform'	Lx or sig_x	mm
transverse p_x, p_y	Dist_px = 'radial uniform'	Lpx or sig_px or Nemit_x	eV/c or mrad mm

- **(truncated) 2D-Gaussian distribution**

Dimension	**Key word**	**Parameter** σ_{imp}, C_{Cut}	**unit**
transverse x, y	Dist_x = '2D-Gaussian'	sig_x, C_sig_x	mm, dim. less
transverse p_x, p_y	Dist_px = '2D-Gaussian'	sig_px or Nemit_x, C_sig_px	eV/c or mrad mm, dim. less

3D distributions

▷ **isotropic momentum distribution**

$$p_x^2 + p_y^2 + p_z^2 = P^2 = E_{kin}^2 + 2$$

Dimension	**Key word**	**Parameter E_{kin}**	**unit**
p_x, p_y, p_z	Dist_pz = 'isotropic'	LE	keV

▷ **photo emission from a Fermi-Dirac distribution**

$$\sigma p_x = \sigma p_y = \sqrt{\frac{E_{phot} - \phi_{eff}}{3 m_0 c^2}}$$

Dimension	**Key word**	**Parameter** Φ_{eff} , E_{phot}	**units**
p_x, p_y, p_z	Dist_pz = '**FD_300**'	phi_eff, E_photon	eV

▷ **uniformly filled ellipsoid**

$$f(x,y,z) = \frac{3}{4\pi Lx\, Ly\, Lz} \qquad \text{for} \quad \frac{x^2}{Lx^2} + \frac{y^2}{Ly^2} + \frac{z^2}{Lz^2} \leq 1$$

$$0 \qquad \text{elsewhere}$$

CAVITY I

- RF, static electric and magnetic fields and fields generated by linear plasmas.
- cavity fields may be generated by analytical calculations, measurements or numerical codes.
- field table $\longrightarrow$ z-position (column 1 in m) & longitudinal on-axis electric field amplitude (column 2 in arbitrary units)
- The transverse field components are calculated from the derivatives of the on-axis field.
- The polynomial expansion extends to 1st order or 3st order .
- The polynomial expansion is perfect already in first order for a pure sine-like spatial wave.

CAVITY II

- **Static electric fields:** The name should start with ‘DC’ or the frequency, Nue( ), should be set to zero.
- **Static magnetic fields:** 3D field map
- **TE modes:** the file name has to start with ‘TE_’.
- **Dipole modes:** 3D field map
- **Traveling wave structures:** The file name has to start with ‘TWS’.
  - superposition of real and imaginary parts
  - The transverse field are derived according to a 1st order polynomial expansion
  - least one RF period plus the input and output coupler cells
  - file a first line is added
  - For a beta matched structure a wave number has to be specified