U.S. Particle Accelerator School

Education in Beam Physics and Accelerator Technology

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Introduction to Elegant and SDDSToolkit

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What It Is

elegant: *Ele*ctron *G*eneration *an*d *T*racking

- Has its roots as a matrix code, but has been extended considerably over the years

- Define a beam (by one of several means)
- Define the accelerator

We will learn where and how

- Track beam particles through the accelerator; (x,x',y,y',t,p_z)
- Calculate the accelerator's R-matrix;
- Vary parameters to obtain desired beam parameters at the end of the accelerator;
- etc.

Command File (*.ele): Beam Definition, etc.

- Built up of "modules", each addressing specific actions.
  - The order of the modules is important (otherwise error messages are sent).
  - Many options per module (default switches are usually ok)
  - Few modules are really needed at the beginning.

```
&run_setup
  lattice    ="Ele_Tu_06.lte"
  use_beamline= L0
  output     = %s.out,
  centroid   = %s.cen,
  sigma      = %s.sig,
  final      = %s.fin,
  parameters  = %s.par,
  magnets    ="%s.mag"
  p_central_mev = 100.
&end

&run_control  &end
```

```
&bunched_beam
      bunch                = %s.bun,
      n_particles_per_bunch    = 20000,
      emit_nx              = 1.0e-6,
      emit_ny              = 1.0e-6,
      use_twiss_command_values = 1,
      momentum_chirp           = 0.      !   at the entrance
      sigma_dp              = 0.1E-5,
      sigma_s              = 0.5E-3,
!      sigma_s              = 0.002E-3,
      distribution_type[0]
="gaussian","gaussian","gaussian",
&end

&track    &end
```

Lattice File (*.lte)

- Build up "elements", each with specific parameters.
  - The order of definition of elements is not important, but beamlines must follow all elements they inclde.
  - Many parameters per element (default values are usually ok for single particle dynamcs)
  - Few elements to sketch a linac

```
%  50  sto V_L0_1
%  3.0 sto F_L0_1
%  90  sto P_L0_6

!- Accelerating structure. Max. gain (on-crest phase) is 90deg --

CAV_1: RFCA,  L=1.326,  volt="V_L0_1 1.e6 *", freq="F_L0_1 1.e9 *",
phase="P_L0_1", &
change_p0=1,  end1_focus=1,   end2_focus=1,   n_kicks=1

 L0: LINE = ( Q, CAV_1 )
```

Our First Building Blocks

Beam Charge:

```
Q: CHARGE, TOTAL=0.3E-09
```

Drift:

```
D_S1_1    : DRIFT, L= D_S1
```

Quadrupole Magnet (Defocusing):

```
Q_S1_1    : QUAD, L= LQ_S1,  K1=-1.1820
```

Dipole Magnet (Rectangular):

```
B_C1_1: CSBEN, L=0.3, ANGLE="B_C1_ANGLE -1 *", &
       E2="B_C1_ANGLE -1 *"
```

Accelerating Structure (with Wakefield):

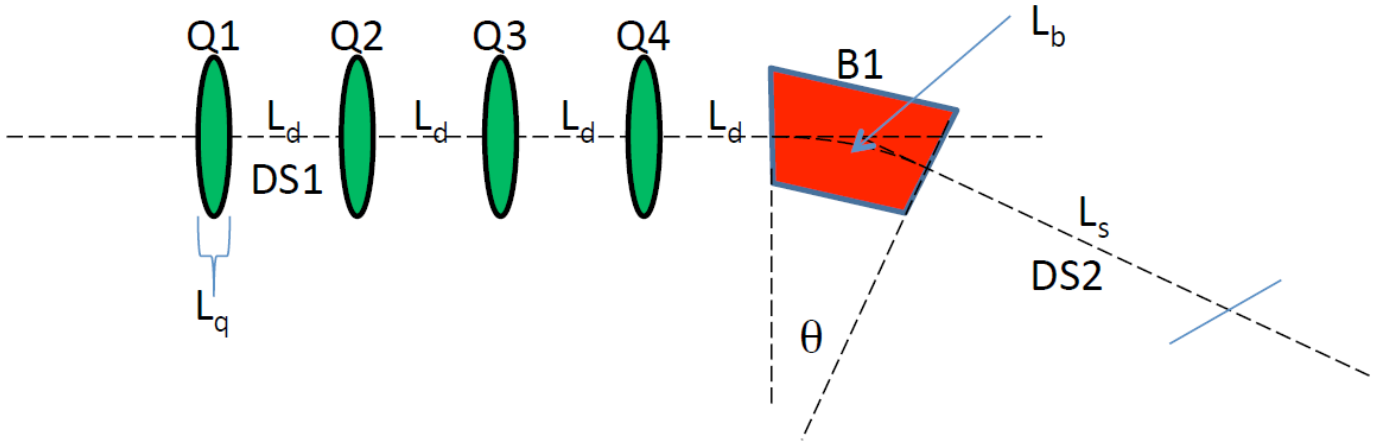
```
CAV_1 :  RFCW, L=1.326,  &
volt="V_L0_1 1.e6 *", freq="F_L0_1 1.e9 *", phase="P_L0_1", &
change_p0=1,  end1_focus=1,   end2_focus=1, &
cell_length=33.15e-3, &
zwakefile="Zwake_S1S7_Trieste_5mm.sdds",tcolumn="t",wzcolumn="W"
```

RF Deflecting Cavity (Vertical):

```
VRFD: rfdf, frequency=3e9, phase=90, voltage="V_VRFD", &
tilt=1.5707963
```

Example

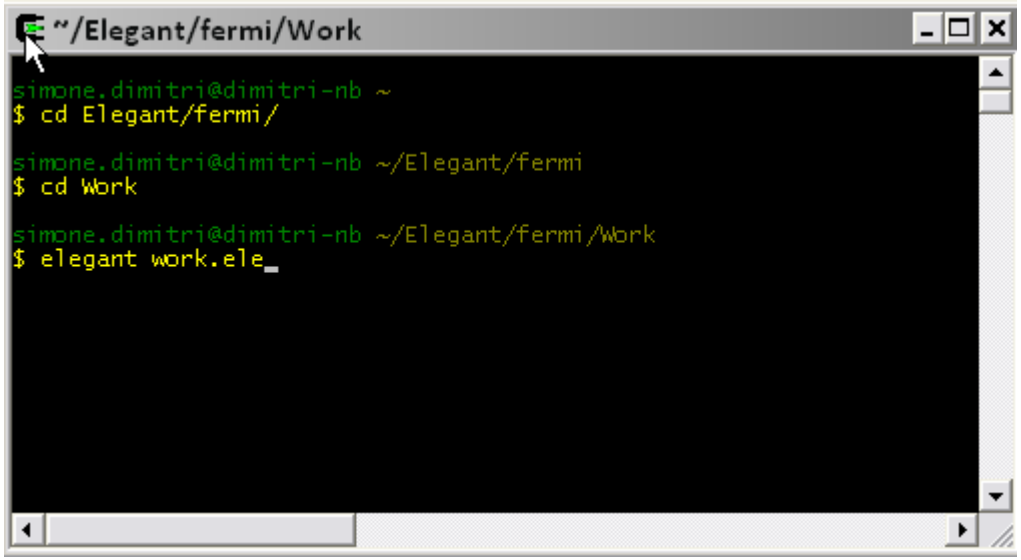
Courtesy D. Nguyen,
USPAS 2014




```
Q1:  quad, L=0.1, K1=2
Q2:  quad, L=0.1, K1=-4
Q3:  quad, L=0.1, K1=2
Q4:  quad, L=0.1, K1=0

DS1: drift, L=0.4
DS2: drift, L=1.0

B1: sbend, L=0.6, angle="pi 6 /"

test: line=(DS1, Q1, DS1, Q2, DS1, Q3, DS1, Q4, DS1, B1, DS2)
```

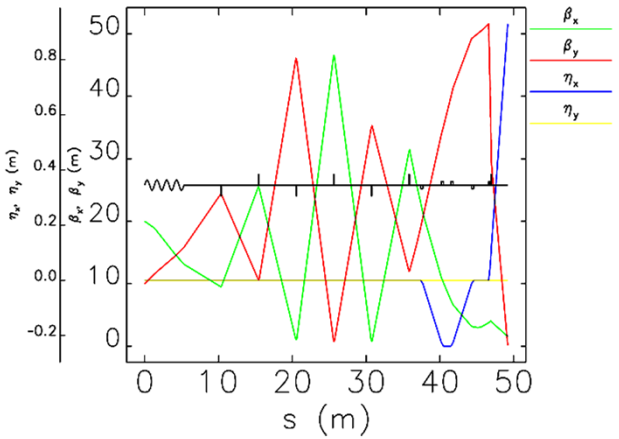
How to Run Elegant

- ELEGANT and SDDS-Toolkit available both for Linux and Windows.
  - This Course, **Cygwin** Linux-emulator running on Windows.
- ELEGANT provides info on the files used for run directly onto the shell and in a *.log file.
  - Look to **Warning messages** in the Shell (suggestions on element definitions, settings, and so on). They do not stop the run.
  - **Error messages** in the Shell stop the run. You must fix errors before running again.



Output Files

- Most of them specified in the ***.ele** file, **&run_setup** module.
  - You can choose the *rootname.**
- All are binaries by default, including self-describing head-lines.
  - Self-Describing Data Set (SDDS) format, needs **SDDS-Toolkit** for post-processing.
  - SDDS also for converting output files to *ascii* format.
- Output data can be manipulated or **plotted** with SDDS command lines or, better, coded in scripts.
  - Many scripts already available in your folder. Build yours own by yourself!



SDDSToolkit Commands

- **sddsquery** ***rootname.cen***

```
12 columns of data:
NAME            UNITS           SYMBOL          FORMAT          TYPE    FIELD  DESCRIPTION
                                                                        LENGTH
s               m               NULL            NULL            double  0       Distance
ElementName     NULL            NULL            %10s            string  0       Element name
ElementOccurence NULL            NULL            %6ld             long    0       Occurence of element
ElementType     NULL            NULL            %10s            string  0       Element-type name
Cx              m               <x>             NULL            double  0       x centroid
Cxp             NULL            <x'>            NULL            double  0       x' centroid
Cy              m               <y>             NULL            double  0       y centroid
Cyp             NULL            <y'>            NULL            double  0       y' centroid
Cs              m               <s>             NULL            double  0       mean distance traveled
Cdelta          NULL            <$gd$r>         NULL            double  0       delta centroid
Particles       NULL            NULL            NULL            long    0       Number of particles
pCentral        m$be$nc         p$bcen$n        NULL            double  0       Reference beta*gamma

1 parameters:
NAME                UNITS               SYMBOL              TYPE                DESCRIPTION
Step                NULL                NULL                long                Simulation step
```

$$pCentral = \beta\gamma = \sqrt{\frac{2T}{m_e c^2}}$$

- **sddsprocess** **-define=col,T"pCentral 2 pow 0.511 * 2 /"** ***rootname.cen***
- **sddsplot** **-col=s,T** ***rootname.cen*** **-col=s,Profile** ***rootname.mag***
- **sddsprintout** **-col=ElementName -col=s -col=T**

Website information

Go to website for download and manual:

http://www.aps.anl.gov/Accelerator_Systems_Division/Accelerator_Operations_Physics/manuals/elegant_latest/elegant.html

Manual includes:

Capabilities of elegant

Highlights of What's New in Version 25.2.1 ← *updates*

Namelist Command Dictionary ← ***command file (*.ele)***

Element Dictionary ← ***lattice file (*.lte)***

Specialized Tools for Use with elegant ← *other codes interface, post-processing, scripts…*

The rpn Calculator («1 1 +»)

Examples ← *very instructive!*

Bibliography

Forum

Go to website and register:

https://www.aps.anl.gov/Accelerator_Systems_Division/Accelerator_Operations_Physics/phpBB3/

- Q&A grouped by topic
- Prompt answer by authors (and users forum)
- Many tricks and details are not in the Manual