FFA School - OPAL Introduction

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FFA School - OPAL Introduction

Outline

All Information

https://gitlab.psi.ch/OPAL/src/wikis/home

Outline

Running on your Laptop & and on HPC Cluster I

OPAL without argument i.e. interactive session

```
# opal
Ippl> CommMPI: Parent process waiting for children ...
Ippl> CommMPI: Initialization complete.
>                 ____  _____        ___
>                / __ \|  __ \ /\    | |
>               | |  | | |__) /  \   | |
>               | |  | |  ___/ /\ \  | |
>               | |__| | |  / ____ \| |____
>                \____/|_| /_/    \_\______|
OPAL>
OPAL> This is OPAL (Object Oriented Parallel Accelerator Library) Version 2.1.0
OPAL>              git rev. 33a9bd1999808243eb17be7093b3b9065e531c6f
OPAL>
OPAL>
OPAL>                        (c) PSI, http://amas.web.psi.ch
OPAL>
OPAL>
OPAL> The optimiser (former opt-Pilot) is integrated
OPAL>
OPAL> Please send cookies, goodies or other motivations (wine and beer ... )
OPAL> to the OPAL developers opal@lists.psi.ch
OPAL>
OPAL> Time: 07:18:17 date: 18/11/2019
OPAL>
OPAL> Reading startup file "/Users/adelmann/init.opal".
OPAL> Finished reading startup file.
==>
```

Running on your Laptop & and on HPC Cluster II

Interactive help

```
==>help,fieldsolver;
    8 help,fieldsolver;
OPAL>
OPAL> The "FIELDSOLVER" statement defines data for a the field solver
OPAL> Attributes:
OPAL>          string          BCFFTT          Boundary conditions in z(t): open, periodic
OPAL>          string          FSTYPE          Name of the attached field solver: FFT, FFTPERIODIC, SAAMG, AMR,
OPAL>          real            MX              Meshsize in x
OPAL>          real            MY              Meshsize in y
OPAL>          real            MT              Meshsize in z(t)
OPAL>          logical         PARFFTX         True, dimension 0 i.e x is parallelized
OPAL>          logical         PARFFTY         True, dimension 1 i.e y is parallelized
OPAL>          logical         PARFFTT         True, dimension 2 i.e z(t) is parallelized
OPAL>          string          BCFFTX          Boundary conditions in x: open, dirichlet (box), periodic
OPAL>          string          BCFFTY          Boundary conditions in y: open, dirichlet (box), periodic
OPAL>          string          BCFFTZ          Boundary conditions in z(t): open, periodic
OPAL>          string          GREENSF         Which Greensfunction to be used [STANDARD | INTEGRATED]
OPAL>          real            BBOXINCR        Increase of bounding box in %
OPAL>          string          GEOMETRY        GEOMETRY to be used as domain boundary
OPAL>          string          ITSOLVER        Type of iterative solver [CG | BiCGSTAB | GMRES]
OPAL>          string          INTERPL         interpolation used for boundary points [CONSTANT | LINEAR | QUADR
OPAL>          real            TOL             Tolerance for iterative solver
OPAL>          real            MAXITERS        Maximum number of iterations of iterative solver
OPAL>          string          PRECMODE        Preconditioner Mode [STD | HIERARCHY | REUSE]
OPAL>          real            RC              cutoff radius for PP interactions
OPAL>          real            ALPHA           GreenÕs function splitting parameter
OPAL>          real            EPSILON         regularization for PP interaction
```

Running on your Laptop & and on HPC Cluster III

OPAL with input file on 4 cores

```
# mpirun -np 4 $OPAL_EXE_PATH/opal  filename.opal --info 0
Ippl> CommMPI: Parent process waiting for children ...
Ippl> CommMPI: Child 1 ready.
Ippl> CommMPI: Child 3 ready.
Ippl> CommMPI: Child 2 ready.
Ippl> CommMPI: Initialization complete.
Ippl> CommMPI: Started job 1 on host 'fast-dude.local'.
Ippl> CommMPI: Started job 2 on host 'fast-dude.local'.
Ippl> CommMPI: Started job 3 on host 'fast-dude.local'.
...
==>
```

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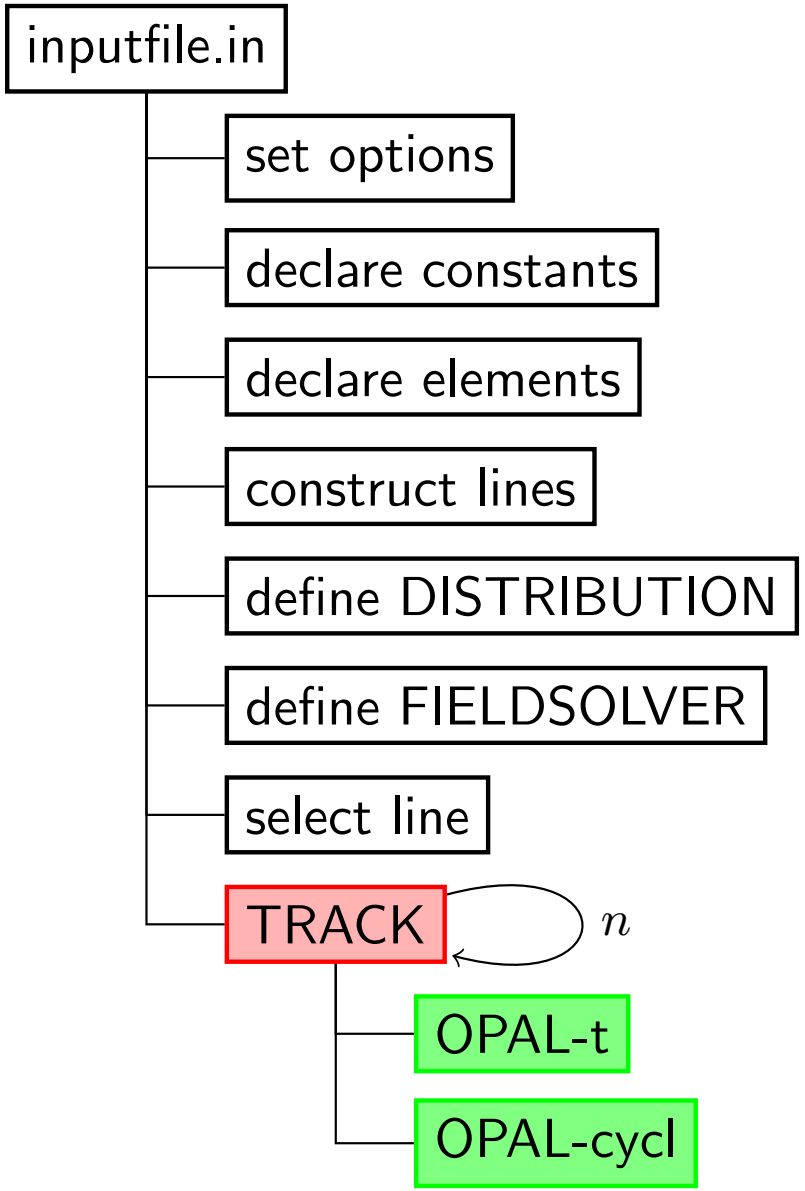
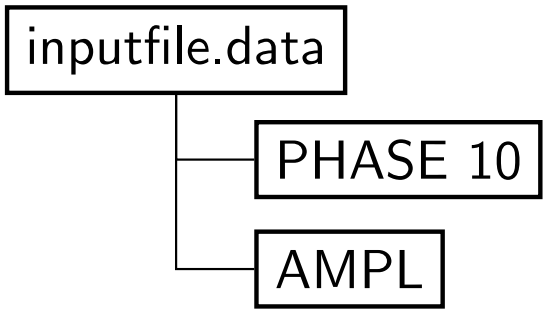
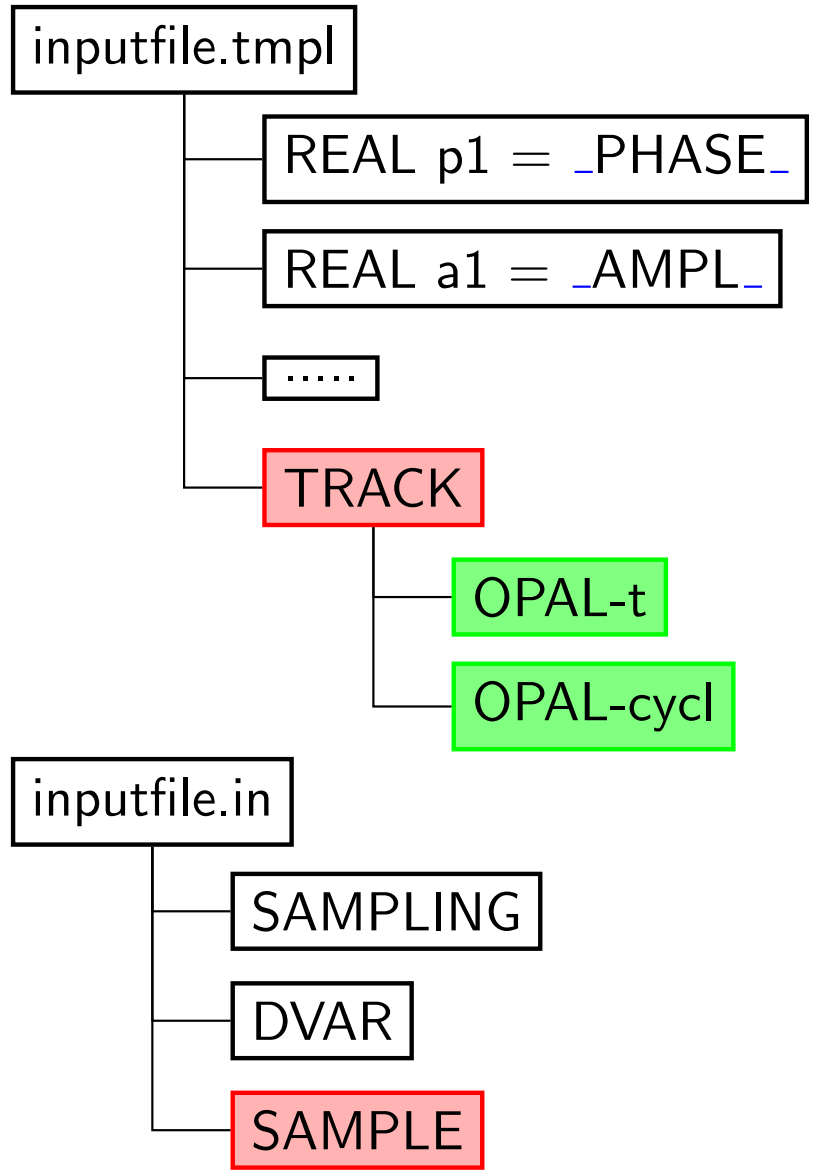
General Tracking Structure

- formal description see Appendix B of the manual https://gitlab.psi.ch/OPAL/Manual-2.1/wikis/home
- interpreter (MAD-Language with extensions)
- input files can be structured `CALL, "elementDefs.in";`
- control structures `if, while`
- access to the operating system `SYSTEM,"ls -l";`
- Subroutine-like commands can be defined by a `MACRO` statement.



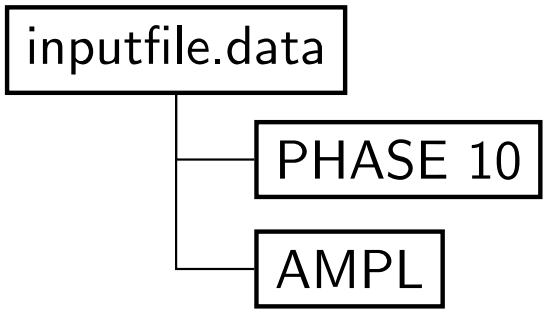
Sampler Structure

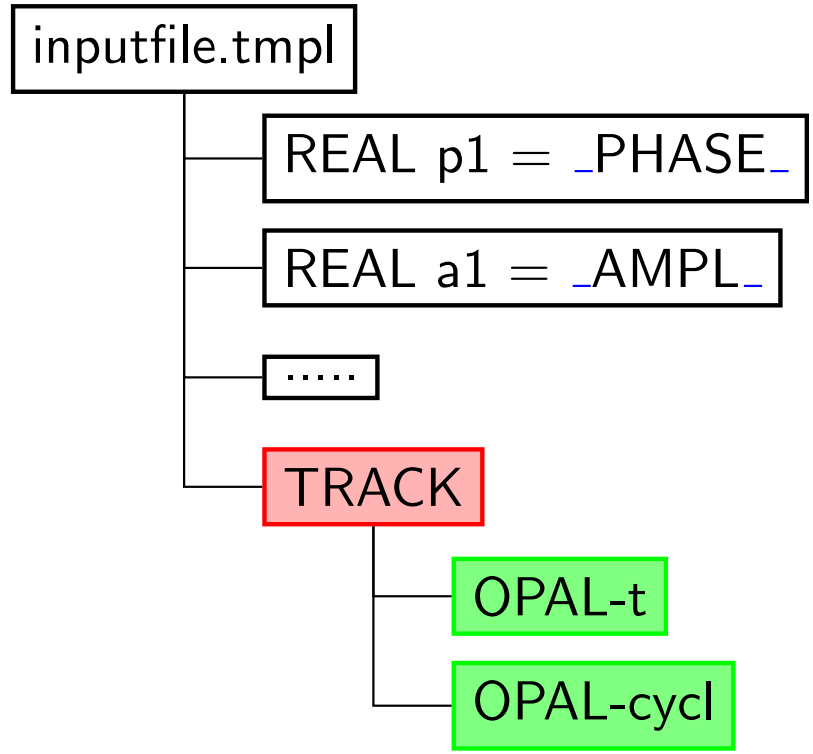




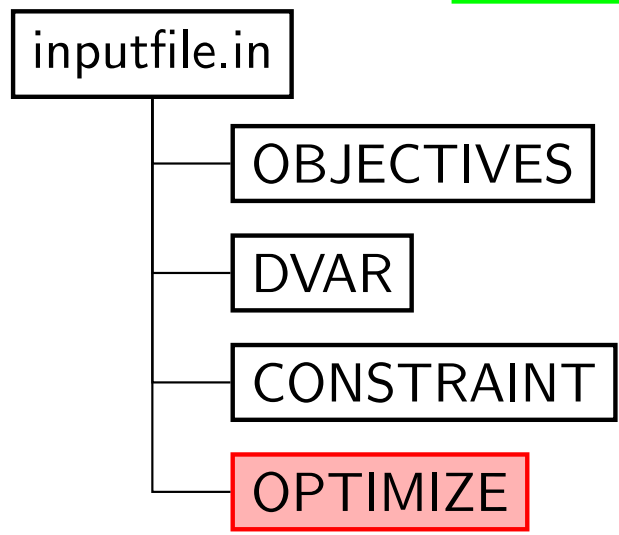
- replace values in marked variables
- formal description see https://gitlab.psi.ch/OPAL/Manual-2.1/wikis/sampler

MOO Structure





- replace values in marked variables
- formal description see
  https://gitlab.psi.ch/OPAL/Manual-2.1/wikis/optimiser



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Units

a consistent set of units is still work in progress

Quantity	**Dimension**
Length	m (metres)
Angle	rad (radians) & deg
Quadrupole coefficient	m^{-2}
Multipole coefficient, 2n poles	m^{-n}
Electric voltage	MV (Megavolts)
Electric field strength	$\mathrm{MV/m}$
Frequency	MHz (Megahertz)
Particle energy	GeV or eV
Particle mass	$\mathrm{GeV/c}^2$
Particle momentum	$\beta\gamma$ or eV
Beam current	A (Amperes)
Particle charge	e (elementary charges)
Impedances	MΩ (Megohms)
Emittances	m rad [1]
RF power	MW (Megawatts)

[1] (normalized and un-normalized)

Constants & Functions

- general constants: PI, TWOPI, DEGRAD, RADDEG, E, CLIGHT
- masses: EMASS, PMASS, HMMASS, UMASS, CMASS, MMASS, DMASS, XEMASS

Functions

- RANF, GAUSS, ABS, TRUNC , ROUND , FLOOR , CEIL, SIGN , SQRT, LOG, EXP, SIN, COS, ABS, TAN, ASIN, ACOS, ATAN, ATAN2 , MAX, MIN, MOD POW

Display constants and variables:

```
1 ==>value,PMASS;
2 OPAL > value: PMASS={0.938272}
3
4 ==>value,{PMASS,XEMASS};
5 OPAL > value: {PMASS,XEMASS}={0.938272,115.505}
```

OPAL is type save (since 2.x.x)

- REAL rfFreq = 1300.0;

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Output Files I

	OPAL-T	OPAL-CYCL
x.stat [2]	◉	◉
x.h5 [3]	◉	◉
x-Angle0...3.dat		◉
x-afterEachTurn.dat		◉
x-trackOrbit.dat		◉

In the directory `data` output regarding survey data are stored. This is all experimental.

Content of the `data` directory

```
1 q1_3D.opal                          - flat input file
2 q1_DesignPath.dat                   - in floor coordinates + E & B fields
3 q1_ElementPositions.sdds
4 q1_ElementPositions.txt
5 q1_ElementPositions.py
```

[2] SDDS compatible

[3] 100% HDF5 compatible

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Quadrupole Triplet I

Quad-Simple-Test-1.in

```
1  OPTION, ECHO=FALSE;
2  OPTION, PSDUMPFREQ=1000;
3  OPTION, STATDUMPFREQ=1;
4  OPTION, VERSION=20000;
5
6  TITLE, STRING="Quad Test";
7
8  REAL Edes   = 0.590;
9  REAL gamma  = (Edes+PMASS)/PMASS;
10 REAL beta   = sqrt(1-(1/gamma^2));
11 REAL P0     = gamma*beta*PMASS;
12
13 QP1: QUADRUPOLE, L=0.644, ELEMEDGE=2.000, K1= 4.744;
14 QP2: QUADRUPOLE, L=0.644, ELEMEDGE=3.644, K1=-5.616;
15 QP3: QUADRUPOLE, L=0.644, ELEMEDGE=5.288, K1= 4.744;
16
17 D:   DRIFT,      L=2.000, ELEMEDGE=5.288+0.644;
18
19 QUADTEST: LINE=(QP1,QP2,QP3,D);
20
21 D1: DISTRIBUTION, TYPE=GAUSS,
22 SIGMAX=  5*1.0e-03,   SIGMAPX= 0.696*1.0e06,  CORRX= 0.0,
23 SIGMAY=  5*1.0e-03,   SIGMAPY= 0.310*1.0e06,  CORRY= 0.0,
24 SIGMAZ=  0.005,       SIGMAPZ= 0.0,           CORRZ= 0.0, R61= 0.0, INPUTMOUNITS=EV;
25
26 FS1:FIELDSOLVER, FSTYPE=NONE, MX=64, MY=64, MT=64,
27                  PARFFTX=true, PARFFTY=true, PARFFTT=true,
28                  BCFFTX=open, BCFFTY=open, BCFFTT=open;
29
30 BEAM1: BEAM, PARTICLE=PROTON, PC=P0, NPART=1000, BCURRENT=2.0e-03, BFREQ=50.6328e6, CHARGE=1;
31
32 SELECT, LINE=QUADTEST;
33
34 TRACK, LINE=QUADTEST, BEAM=BEAM1, MAXSTEPS=6000, DT=1.0e-11, ZSTOP=8.0;
35  RUN, METHOD = "PARALLEL-T", BEAM=BEAM1, FIELDSOLVER=FS1, DISTRIBUTION=D1;
36 ENDTRACK;
37 STOP;
```

Quadrupole Triplet II

std out of OPAL

```
>                 _____  _____        ___
>                / __ \|  __ \ /\    | |
>               | |  | | |__) /  \   | |
>               | |  | |  ___/ /\ \  | |
>               | |__| | |  / ____ \| |____
>                \____/|_| /_/    \_\______|
OPAL>
OPAL> This is OPAL (Object Oriented Parallel Accelerator Library) Version 2.1.0
OPAL>             git rev. 33a9bd1999808243eb17be7093b3b9065e531c6f
OPAL>
OPAL>
OPAL>                       (c) PSI, http://amas.web.psi.ch
OPAL>
OPAL>
OPAL> The optimiser (former opt-Pilot) is integrated
OPAL>
OPAL> Please send cookies, goodies or other motivations (wine and beer ... )
OPAL> to the OPAL developers opal@lists.psi.ch
OPAL>
OPAL> Time: 08:08:44 date: 18/11/2019
OPAL>
OPAL> Reading startup file "/Users/adelmann/init.opal".
OPAL> Finished reading startup file.
OPAL> * Reading input stream "q1.in".

....

OPAL> * ************* D I S T R I B U T I O N ****************************************
OPAL> *
OPAL> * Number of particles: 1000
OPAL> *
OPAL> * Distribution type: GAUSS
OPAL> *
OPAL> * SIGMAX     = 5.0000e-03 [m]
OPAL> * SIGMAY     = 5.0000e-03 [m]
OPAL> * SIGMAZ     = 5.0000e-03 [m]
OPAL> * SIGMAPX    = 3.8524e-02 [Beta Gamma]
```

Quadrupole Triplet III

```
OPAL> * SIGMAPY    = 2.5708e-02 [Beta Gamma]
OPAL> * SIGMAPZ    = 0.0000e+00 [Beta Gamma]
OPAL> * AVRGPZ     = 1.2857e+00 [Beta Gamma]
OPAL> * CORRX      = 0.0000e+00
OPAL> * CORRY      = 0.0000e+00
OPAL> * CORRZ      = 0.0000e+00
OPAL> * R61        = 0.0000e+00
OPAL> * R62        = 0.0000e+00
OPAL> * R51        = 0.0000e+00
OPAL> * R52        = 0.0000e+00
OPAL> * CUTOFFX    = 3.0000e+00 [units of SIGMAX]
OPAL> * CUTOFFY    = 3.0000e+00 [units of SIGMAY]
OPAL> * CUTOFFLONG = 3.0000e+00 [units of SIGMAZ]
OPAL> * CUTOFFPX   = 3.0000e+00 [units of SIGMAPX]
OPAL> * CUTOFFPY   = 3.0000e+00 [units of SIGMAPY]
OPAL> * CUTOFFPZ   = 3.0000e+00 [units of SIGMAPY]
OPAL> *
OPAL> * Distribution is injected.
OPAL> *
OPAL> * ******************************************************************************
OPAL>
OPAL> * ************* B E A M ******************************************************
OPAL> * BEAM        BEAM1
OPAL> * PARTICLE    PROTON
OPAL> * CURRENT     2.0000e-03 A
OPAL> * FREQUENCY   5.0633e+07 MHz
OPAL> * CHARGE      +e * 1.0000e+00
OPAL> * REST MASS   9.3827e-01 GeV
OPAL> * MOMENTUM    1.2063e+00
OPAL> * NPART       1.0000e+03
OPAL> * ******************************************************************************
OPAL>
OPAL> * ************* F I E L D S O L V E R ****************************************
OPAL> * FIELDSOLVER  FS1
OPAL> * TYPE         NONE
OPAL> * N-PROCESSORS 1
OPAL> * MX           6.4000e+01
OPAL> * MY           6.4000e+01
```

Quadrupole Triplet IV

```
76  OPAL> * MT            6.4000e+01
77  OPAL> * BBOXINCR      2.0000e+00
78  OPAL> * XDIM          parallel
79  OPAL> * YDIM          parallel
80  OPAL> * Z(T)DIM       parallel
81  OPAL> * ******************************************************************************
82  OPAL>
83  OPAL> Size of map 8 sections
84  OPAL> Key: (0.000000 - 1.999619) number of overlapping elements 0
85  OPAL> Key: (1.999619 - 2.643283) number of overlapping elements 1
86  OPAL>                            QP1
87  OPAL> Key: (2.643283 - 3.644275) number of overlapping elements 0
88  OPAL> Key: (3.644275 - 4.287940) number of overlapping elements 1
89  OPAL>                            QP2
90  OPAL> Key: (4.287940 - 5.288932) number of overlapping elements 0
91  OPAL> Key: (5.288932 - 5.932596) number of overlapping elements 1
92  OPAL>                            QP3
93  OPAL> Key: (5.932596 - 7.932215) number of overlapping elements 1
94  OPAL>                            D
95  OPAL> Key: (7.932215 - 8.028806) number of overlapping elements 0
96  OPAL>
97  OPAL> * ************** B U N C H ************************************************
98  OPAL> * NP                = 1000
99  OPAL> * Qtot              =        0.040 [fC]         Qi    =        0.000 [fC]
100 OPAL> * Ekin              =      590.000 [MeV]        dEkin =        0.000 [eV]
101 OPAL> * rmax              = (     13.42136 ,     14.77381 ,     14.40314 ) [mm]
102 OPAL> * rmin              = (    -13.06193 ,    -14.25516 ,    -14.63385 ) [mm]
103 OPAL> * rms beam size     = (      4.71067 ,      4.79158 ,      4.99116 ) [mm]
104 OPAL> * rms momenta       = (  3.67373e-02 ,  2.47364e-02 ,  0.00000e+00 ) [beta gamma]
105 OPAL> * mean position     = (      0.00000 ,      0.00000 ,     -0.00000 ) [um]
106 OPAL> * mean momenta      = (  6.93889e-20 ,  1.06165e-18 ,  1.28494e+00 ) [beta gamma]
107 OPAL> * rms emittance     = (  1.34588e-04 ,  9.21877e-05 ,  0.00000e+00 ) (not normalized)
108 OPAL> * rms correlation   = ( -1.39797e-02 ,  1.50006e-03 , -0.00000e+00 )
109 OPAL> * hr                = (    420.36967 ,    460.77735 ,    460.90460 ) [um]
110 OPAL> * dh                =   1.00000e-10 [%]
111 OPAL> * t                 =        0.000 [fs]         dT    =       10.000 [ps]
112 OPAL> * spos              =        0.000 [um]
113 OPAL> * ******************************************************************************
```

Quadrupole Triplet V

```
OPAL> Track start at: 08:08:44, t= 0.000 [fs]; zstart at: 0.000 [um]
OPAL> Executing ParallelTTracker, initial dt= 10.000 [ps];
OPAL> max integration steps 6000, next step= 0
ParallelTTracker > 08:08:44 Step    999 at 2.366 [m], t= 10.000 [ns], E=590.000 [MeV]
OPAL > * ************** B U N C H ************************************************
OPAL > * NP                = 1000
OPAL > * Qtot              =        0.040 [fC]         Qi    =        0.000 [fC]
OPAL > * Ekin              =      590.000 [MeV]        dEkin =      895.611 [keV]
OPAL > * rmax              = (     185.37701 ,     146.86937 ,      12.33195 ) [mm]
OPAL > * rmin              = (    -197.42235 ,    -138.35192 ,     -17.62990 ) [mm]
OPAL > * rms beam size     = (      62.99021 ,      49.04130 ,       5.06084 ) [mm]
OPAL > * rms momenta       = (  4.10423e-03 ,  4.85975e-02 ,  1.20926e-03 ) [beta gamma]
OPAL > * mean position     = (       0.00366 ,      -0.00120 ,      -1.39327 ) [mm]
OPAL > * mean momenta      = (  1.27189e-05 , -5.28997e-06 ,  1.28478e+00 ) [beta gamma]
OPAL > * rms emittance     = (  1.37204e-04 ,  9.26413e-05 ,  4.75964e-06 ) (not normalized)
OPAL > * rms correlation   = (  7.31029e-01 ,  9.98750e-01 ,  1.14396e-02 )
OPAL > * hr                = (    420.36967 ,    460.77735 ,    460.90460 ) [um]
OPAL > * dh                =   1.00000e-10 [%]
OPAL > * t                 =       10.000 [ns]         dT    =       10.000 [ps]
OPAL > * spos              =         2.366 [m]
OPAL > * ******************************************************************************
....
OPAL > * ************** B U N C H ************************************************
OPAL > * NP                = 1000
OPAL > * Qtot              =        0.040 [fC]         Qi    =        0.000 [fC]
OPAL > * Ekin              =      590.000 [MeV]        dEkin =       68.607 [keV]
OPAL > * rmax              = (     14.85380 ,     16.45715 ,      9.54633 ) [mm]
OPAL > * rmin              = (    -13.16767 ,    -22.29317 ,    -51.69839 ) [mm]
OPAL > * rms beam size     = (      4.79412 ,      5.20133 ,      8.23718 ) [mm]
OPAL > * rms momenta       = (  3.68500e-02 ,  2.43947e-02 ,  9.26340e-05 ) [beta gamma]
OPAL > * mean position     = (       0.01017 ,      -0.08442 ,      -7.33525 ) [mm]
OPAL > * mean momenta      = ( -8.07248e-06 , -3.92537e-05 ,  1.28495e+00 ) [beta gamma]
OPAL > * rms emittance     = (  1.34711e-04 ,  9.86154e-05 ,  5.88012e-07 ) (not normalized)
OPAL > * rms correlation   = (  1.97079e-01 ,  3.85801e-02 ,  1.35451e-01 )
OPAL > * hr                = (    420.36967 ,    460.77735 ,    460.90460 ) [um]
OPAL > * dh                =   1.00000e-10 [%]
OPAL > * t                 =       33.810 [ns]         dT    =       10.000 [ps]
OPAL > * spos              =         8.000 [m]
```

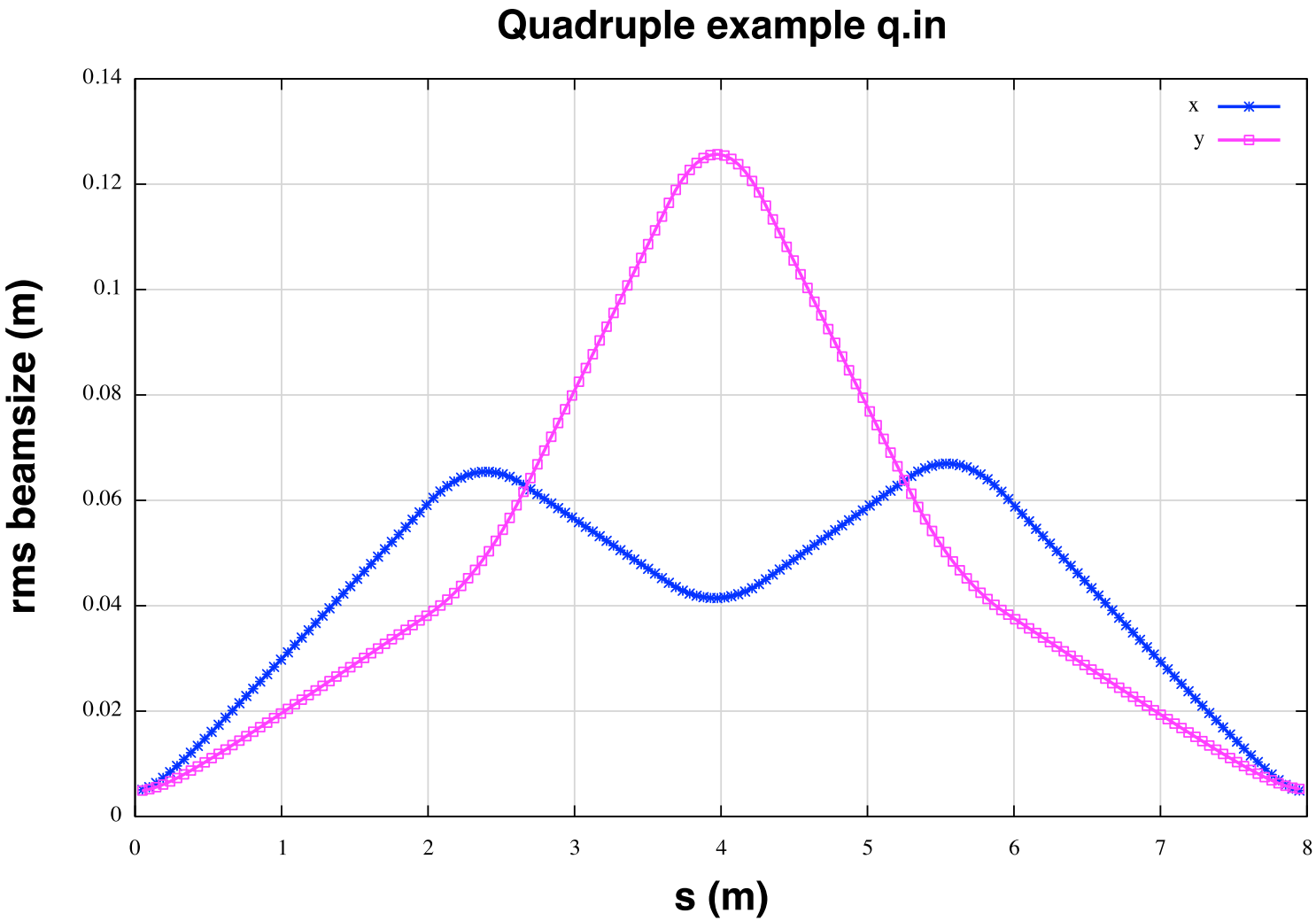
Quadrupole Triplet VI

```
152 OPAL > * ******************************************************************************
153 OPAL >
154 OPAL> done executing ParallelTTracker at 08:08:45
155 OPAL> * End of input stream "q1.in".
156 Timings> ------------------------------------------------------------
157 Timings>      Timing results for 1 nodes:
158 Timings> ------------------------------------------------------------
159 Timings> mainTimer.......... Wall tot =    1.67545, CPU tot =       1.62
160 Timings>
161 Timings> Binaryrepart........ Wall max =          0, CPU max =          0
162 Timings>                     Wall avg =          0, CPU avg =          0
163 Timings>                     Wall min =          0, CPU min =          0
164 ...
```

Simple Data Analysis - gnuplot

Gnuplot (q.gpl)

```
1 plot  "q1.stat" using 2:6 every 20 with linespoint  ti "x " ls 3, \
2       "q1.stat" using 2:7 every 20 with linespoint  ti "y" ls 4;
3
```



pyOPALTools

https://gitlab.psi.ch/OPAL/pyOPALTools/wikis/home

Demo