THE DYNAMIC APERTURE OF LEP AT HIGH ENERGY

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ABSTRACT: At the highest operating energies of LEP, the beam occupies a large phase space volume (emittances) because of the strong synchrotron radiation effects. The stable phase space volume required is comparable to the dynamic aperture, itself in large part determined by radiative effects such as beta-synchrotron coupling. Tune-dependences on the three oscillation amplitudes are also important. We review the present understanding of the physics determining the dynamic aperture, the computational techniques used to determine it and their relation to the most recent measurements. Improvements in dynamic aperture can be achieved by a variety of means including changes of optics, tunes, multipole correctors and the RF voltage distribution.

Variables $\left(10^3\sqrt{A_x / \mathrm{m}}, 10^3\sqrt{A_y / \mathrm{m}}, \sqrt{A_t} / \%\right)$ where

$$x = \sqrt{\beta_{1x} A_x} \cos\left(2\pi Q_x s / C + \mu_x(s) + \varphi_x\right) + \sqrt{\beta_{2x} A_y} \cos\left(2\pi Q_y s / C + \mu_y(s) + \varphi_y\right)$$
$$+ D_x \sqrt{A_t} \cos\left(2\pi Q_s s / C + \mu_t(s) + \varphi_t\right) \qquad \text{etc.}$$

Efficient Object-oriented Tracking Technology

Mathematica packages for tracking and viewing/analysis.
Automatic 4-D scan (runs MAD, assimilates its output).
Scan includes synchrotron phase: $\left(10^3\sqrt{A_x / \mathrm{m}}, 10^3\sqrt{A_y / \mathrm{m}}, \sqrt{A_t} / \%, \varphi_t\right)$
because of strong radiation and high $Q_s \approx 0.1$

`findDynap[...]`

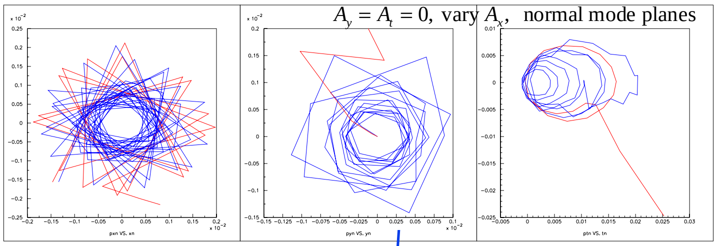
creates **`survivalData`** and **`dynapData`** objects.

Dynamic aperture limits for LEP2

- RF voltage limit (max A_t)
- Detuning with amplitude, especially $\dfrac{\partial Q_y}{\partial A_x}$
- Radiative beta-synchrotron coupling instability
  radiation loss at large betatron amplitudes in quadrupoles $\Rightarrow$ synchrotron motion
- Chromatic effects

Tracking with element-by-element mean synchrotron radiation (damping) for dynamic aperture (needed to get RBSC). Tracking with quantum fluctuations gives beam distribution (Barbarin, Jowett, Iselin, EPAC '94).

Radiative beta-synchrotron coupling instability



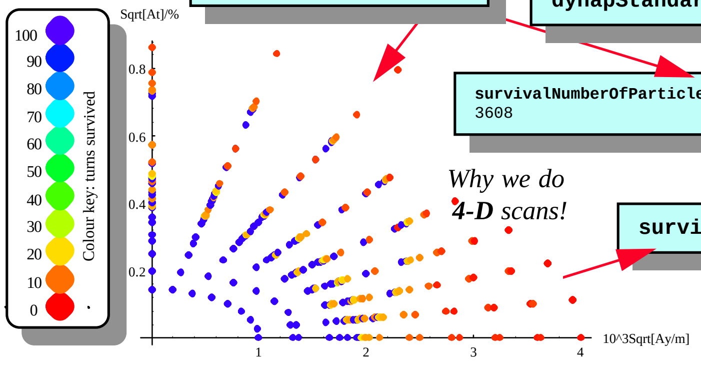
`dynapEmittances[DA87]`
{0.0287, 0.00057, 0.00136}

`survivalPlotYT[SD87]`

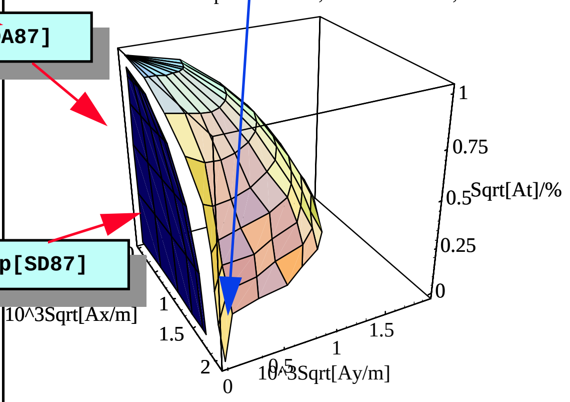
`dynapStandardPlot3D[DA87]`

`survivalNumberOfParticles[SD87]`
3608

`survivalToDynap[SD87]`



H05R46v2 bx*=2.5m Sept96 87 GeV,VRFSC=38MV,VRFC=2.2 M



Second surface is {10, 10, 7}sigma ellipsoid

Finding your way around the viewing package

```
?dynap*
dynapBoundary
dynapBoundaryFullyCou
dynapBoundaryTX
dynapBoundaryXY
dynapBoundaryYT
dynapData
dynapEditEmittance
dynapEditTitle
dynapEmittanceEllipsoid           dynapStandardXYPlot
dynapEmittances                   dynapStandardYTPlot
dynapFullyCoupl
dynapInputResca
dynapLegend
dynapLineStyles
dynapOptions3D
dynapProjectTX
dynapProjectXY                    dynapXYPlot
dynapProjectYT                    dynapYTPlot
```

```
?dynapEditEmittance
dynapEditEmittance[dynap,m,emittvalue]
returns a dynapData object identical to
dynap except that it resets the value
of the emittance of mode m (=1,2,3) to
emittvalue.
```

```
?survivalNumberOfParticles
survivalNumberOfParticles[data_survivalData]
returns the number of particles in a
survivalData object.
```

Phase advance in arc cells $\Rightarrow$ *detuning* (radiation in quadrupoles, mainly from low-β)

lattice	$\partial Q_x/\partial A_x$	$\partial Q_y/\partial A_x$	$\partial Q_y/\partial A_y$	I_{6x}	I_{6y}
● 90°/60°	1,750	-27,500	18,210	62.8	207.9
● 90°/90°	950	-13,930	960	84.5	226.1
● 108°/60°	23,560	-81,180	75,430	75.4	218.2
● 108°/90°	23,650	-17,060	11,340	79.2	216.3

Some success with multipole correctors etc.; see Y. Alexahin, CERN-SL-95-110 (AP).

Change to 108 °/90 ° optics appears to be best way to increase dynamic aperture for energies beyond about 90 GeV.