# *Accurate Spin Tracking on Modern Computer Architectures for Electron-Ion Colliders*

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*Izaak Beekman — Paratools, Inc, Eugene, OR*

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*JLEIC Collaboration Meeting, Newport News, VA*

*2 April 2019*

# *Future Plans for Zgoubi Include Enhancements to both Performance and Usability*

Implement a Zgoubi graphical interface in Sirepo. *(40%)*

Implement single-click execution of Zgoubi on available linux clusters. *(25%)*

**GUI**

Update the Zgoubi code base to the Fortran 2018. *(60%)*

Re-implement Zgoubi's particle update algorithm. *(50%)*

Parallelize Zgoubi using Fortran 2018. *(35%)*

**performance**

Implement symplectic tracking for field maps. *(10%)*

Add closed-orbit correction to Zgoubi. *(75%) F. Méot*

**capabilities**

Assess and improve the spin dynamics in electron and ion rings for the eRHIC design. *(starting soon)*

Benchmark Zgoubi with BMad and other codes used for simulating JLEIC ring designs. *(starting soon)*

**science**

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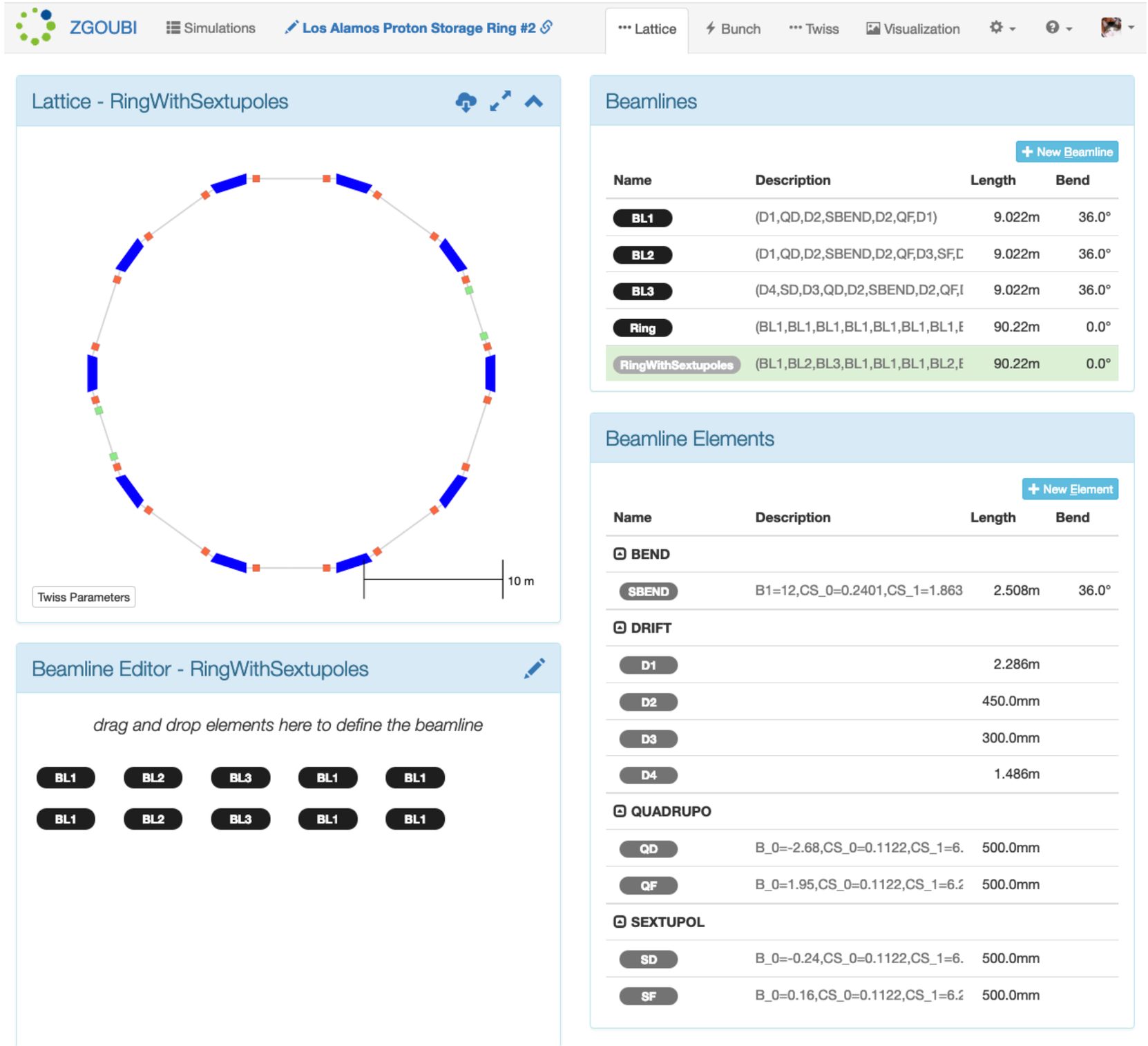
**science**

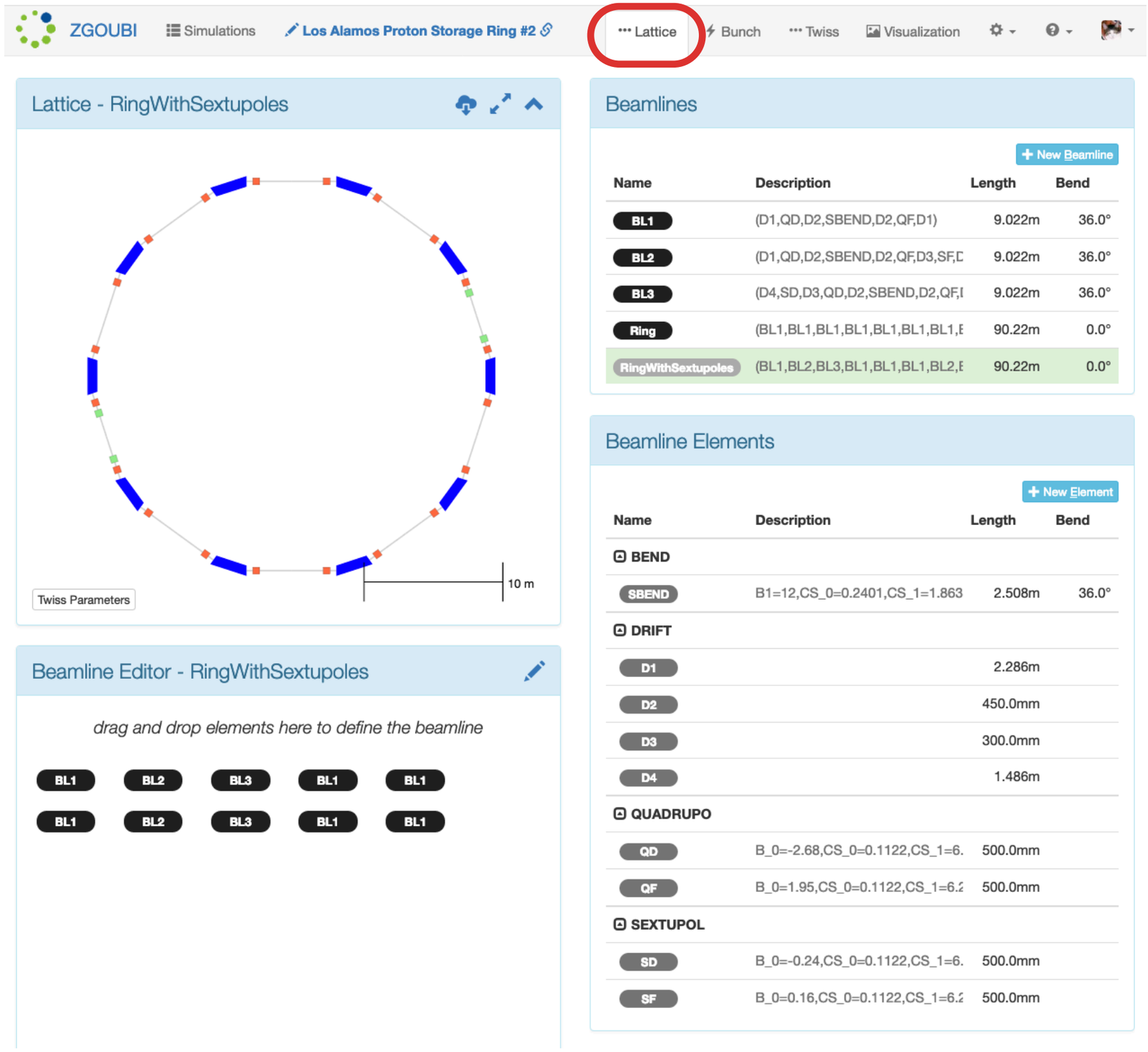
# *Streamline Zgoubi Simulations: Implement a Sirepo Interface for Zgoubi*

Sirepo



# *The Sirepo Interface for Zgoubi: Build (or Import) a Lattice*

Sirepo

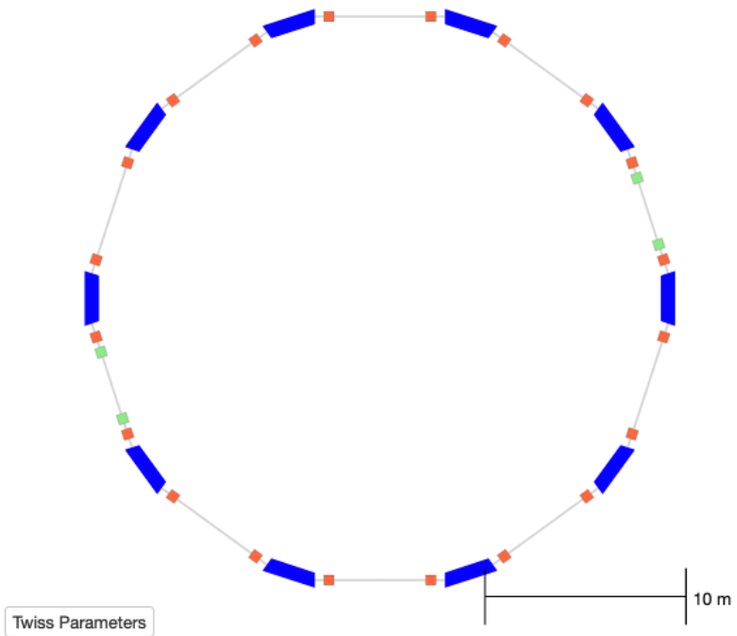


# The Sirepo Interface for Zgoubi: Build (or Import) a Lattice—cont.

Sirepo

ZGOUBI | Simulations | Los Alamos Proton Storage Ring #2 | Lattice | Bunch | Twiss | Visualization

**Lattice - RingWithSextupoles**




Twiss Parameters

**Beamline Editor - RingWithSextupoles**

*drag and drop elements here to define the beamline*

BL1 BL2 BL3 BL1 BL1

BL1 BL2 BL3 BL1 BL1

**Beamlines**

+ New Beamline

| Name | Description | Length | Bend |
|---|---|---|---|
| BL1 | (D1,QD,D2,SBEND,D2,QF,D1) | 9.022m | 36.0° |
| BL2 | (D1,QD,D2,SBEND,D2,QF,D3,SF,D | 9.022m | 36.0° |
| BL3 | (D4,SD,D3,QD,D2,SBEND,D2,QF,D | 9.022m | 36.0° |
| Ring | (BL1,BL1,BL1,BL1,BL1,BL1,BL1,BL1,E | 90.22m | 0.0° |
| RingWithSextupoles | (BL1,BL2,BL3,BL1,BL1,BL1,BL2,BL2,E | 90.22m | 0.0° |

**Beamline Elements**

+ New Element

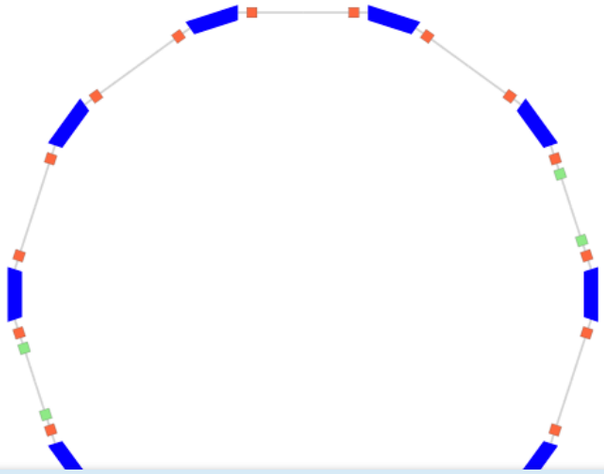
| Name | Description | Length | Bend |
|---|---|---|---|
| BEND | | | |
| SBEND | B1=12,CS_0=0.2401,CS_1=1.863 | 2.508m | 36.0° |
| DRIFT | | | |
| D1 | | 2.286m | |
| D2 | | 450.0mm | |
| D3 | | 300.0mm | |
| D4 | | 1.486m | |
| QUADRUPO | | | |
| QD | B_0=-2.68,CS_0=0.1122,CS_1=6. | 500.0mm | |
| QF | B_0=1.95,CS_0=0.1122,CS_1=6.2 | 500.0mm | |
| SEXTUPOL | | | |
| SD | B_0=-0.24,CS_0=0.1122,CS_1=6. | 500.0mm | |
| SF | B_0=0.16,CS_0=0.1122,CS_1=6.2 | 500.0mm | |

# The Sirepo Interface for Zgoubi: Build (or Import) a Lattice—cont.

Sirepo

ZGOUBI | Simulations | Los Alamos Proton Storage Ring #2 | Lattice | Bunch | Twiss | Visualization

## Lattice - RingWithSextupoles



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| Ring | (BL1,BL1,BL1,BL1,BL1,BL1,BL1,I | 90.22m | 0.0° |
| RingWithSextupoles | (BL1,BL2,BL3,BL1,BL1,BL1,BL2,I | 90.22m | 0.0° |

## Beamline Elements

+ New Element

| | | Length | Bend |
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| | | 2.286m | |
| | | 450.0mm | |
| | | 300.0mm | |
| | | 1.486m | |
| QD | B_0=-2.68,CS_0=0.1122,CS_1=6. | 500.0mm | |
| QF | B_0=1.95,CS_0=0.1122,CS_1=6.2 | 500.0mm | |
| SEXTUPOL | | | |
| SD | B_0=-0.24,CS_0=0.1122,CS_1=6. | 500.0mm | |
| SF | B_0=0.16,CS_0=0.1122,CS_1=6.2 | 500.0mm | |

### New Beamline Element

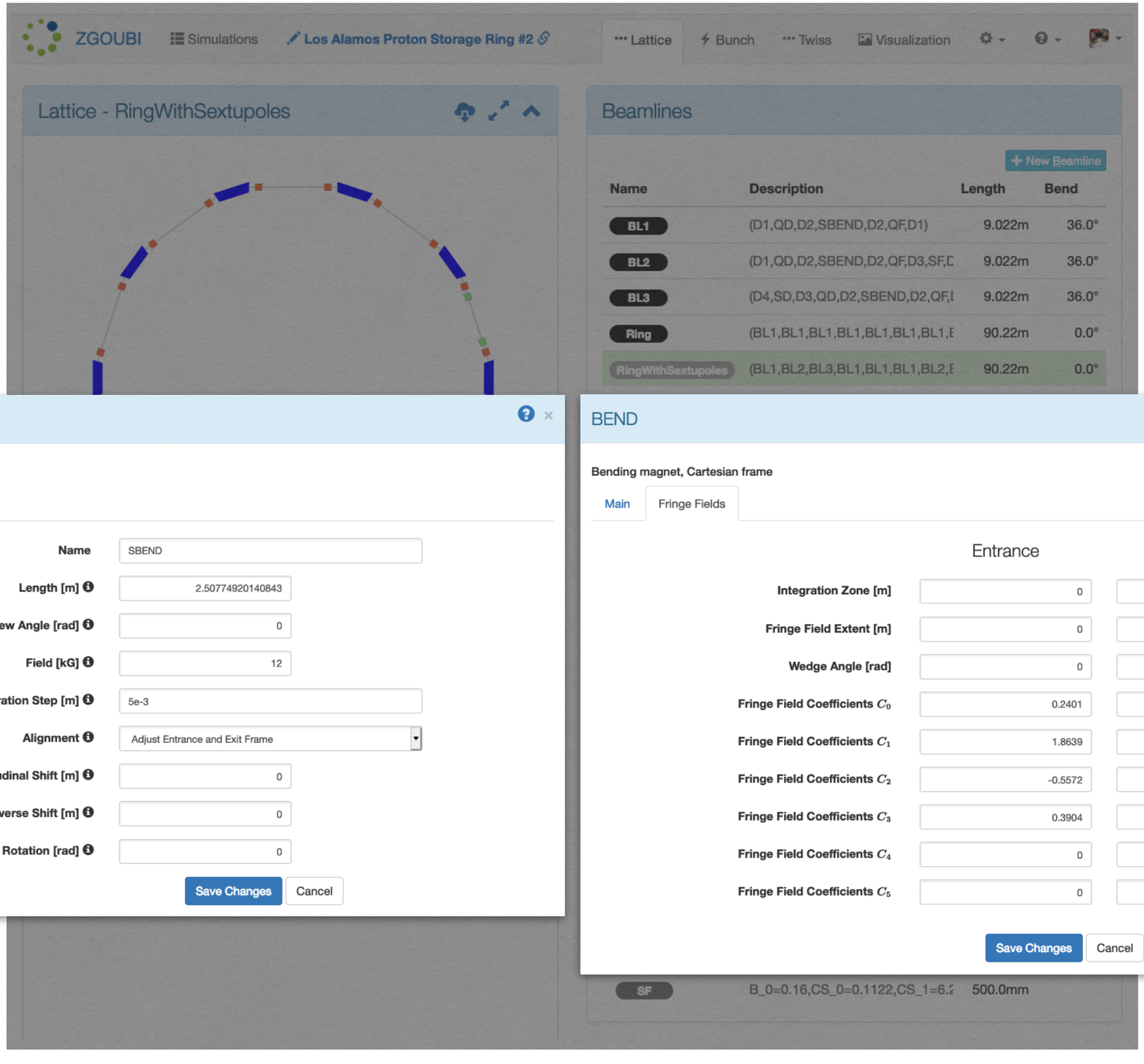
Basic | Advanced | All Elements

| | | |
|---|---|---|
| AUTOREF | BEND | CHANGREF |
| DRIFT | MARKER | MULTIPOL |
| QUADRUPO | SEXTUPOL | YMY |

Close

# *The Sirepo Interface for Zgoubi: Build (or Import) a Lattice—cont.*

Sirepo

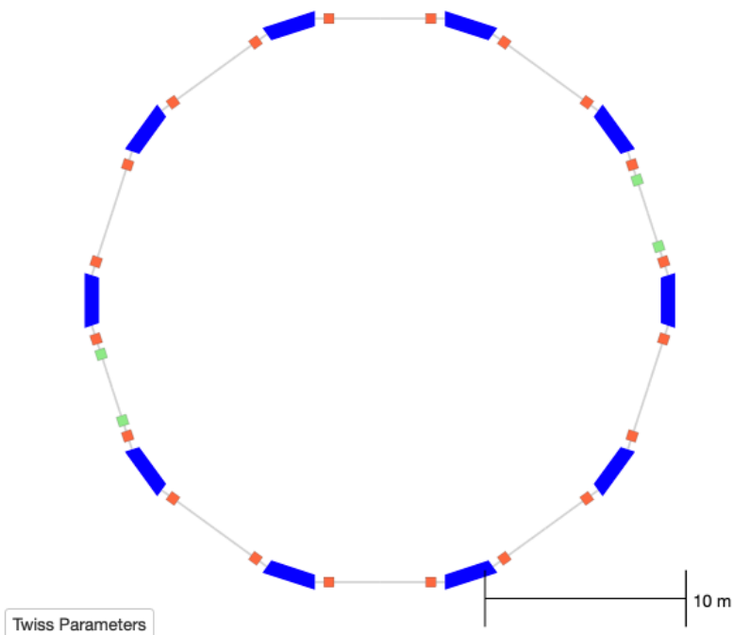


# *The Sirepo Interface for Zgoubi: Build (or Import) a Lattice—cont.*

Sirepo

ZGOUBI | Simulations | Los Alamos Proton Storage Ring #2 | Lattice | Bunch | Twiss | Visualization

**Lattice - RingWithSextupoles**




Twiss Parameters

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BL1 BL2 BL3 BL1 BL1

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**Beamline Elements**

+ New Element

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|---|---|---|---|
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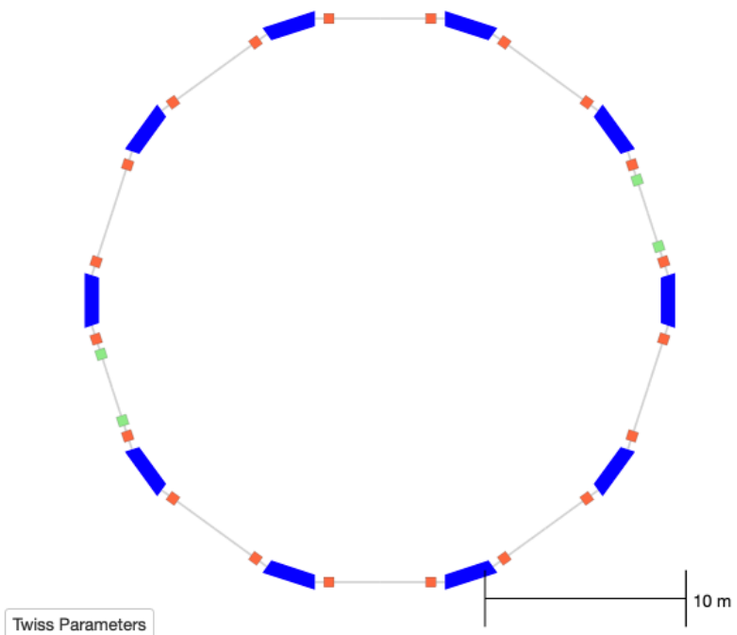
Sirepo

ZGOUBI | Simulations | Los Alamos Proton Storage Ring #2 | Lattice | Bunch | Twiss | Visualization

## Lattice - RingWithSextupoles




Twiss Parameters

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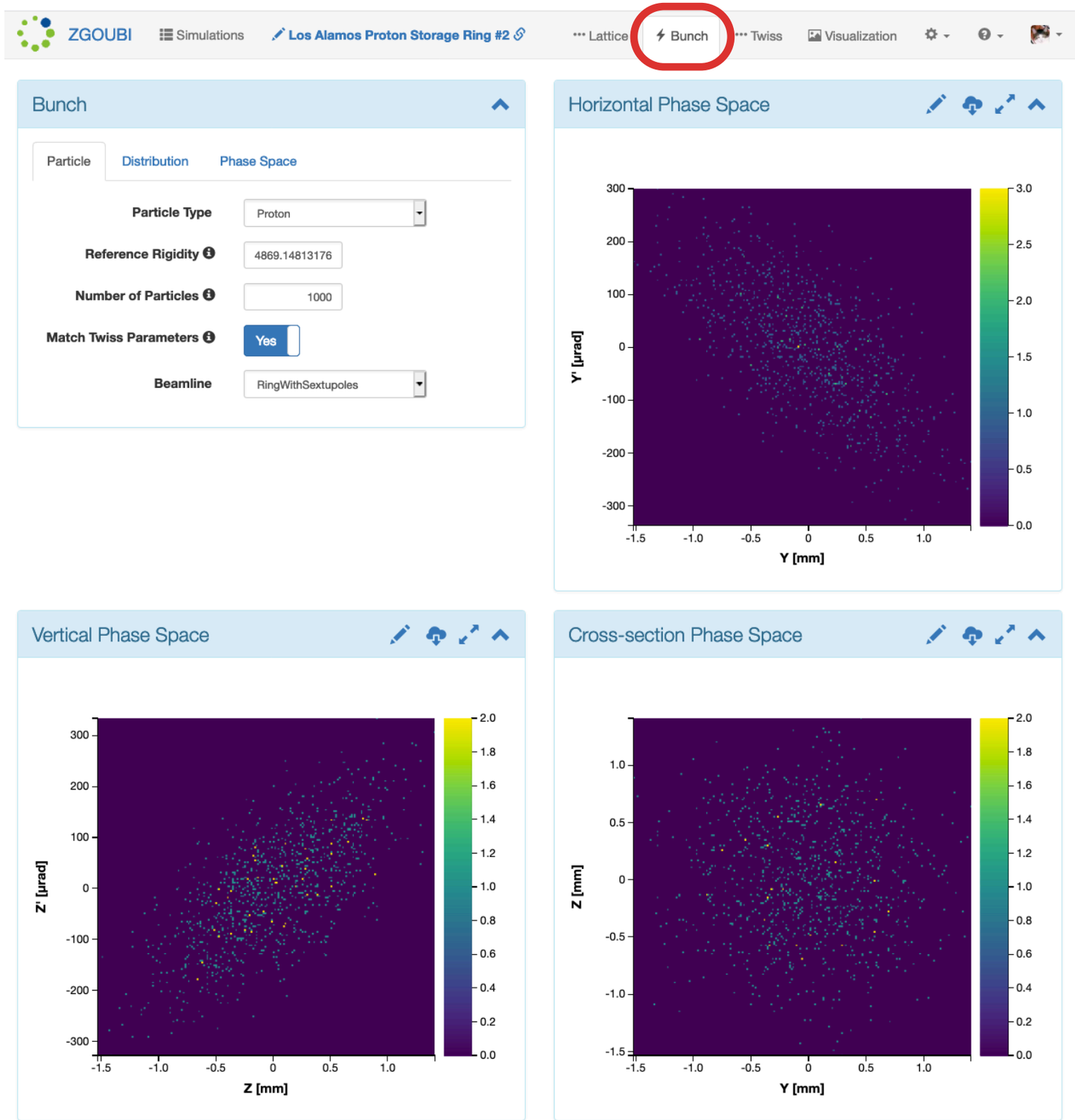
# *The Sirepo Interface for Zgoubi: Generate a (matched) bunch*

Sirepo



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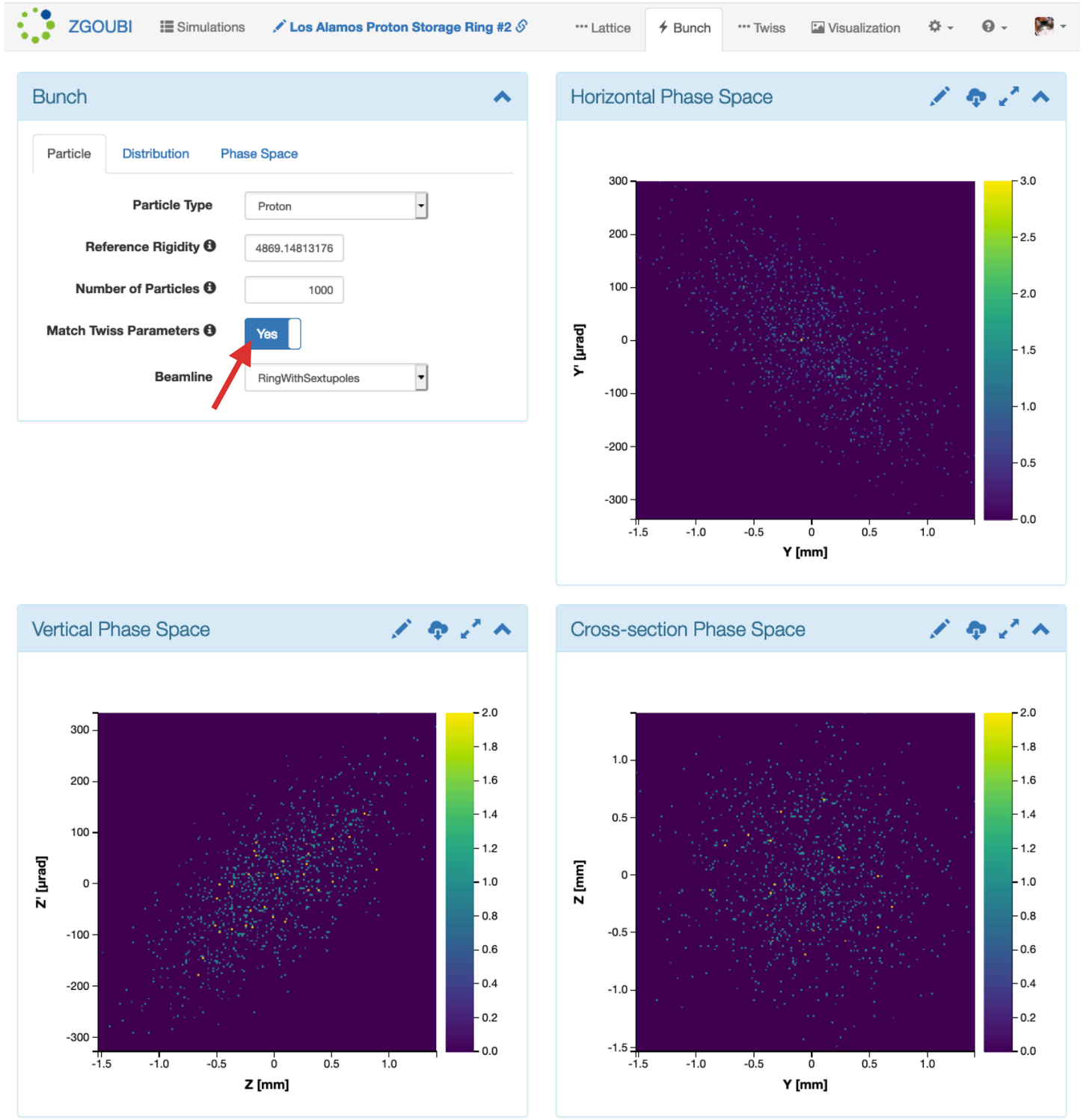
Sirepo



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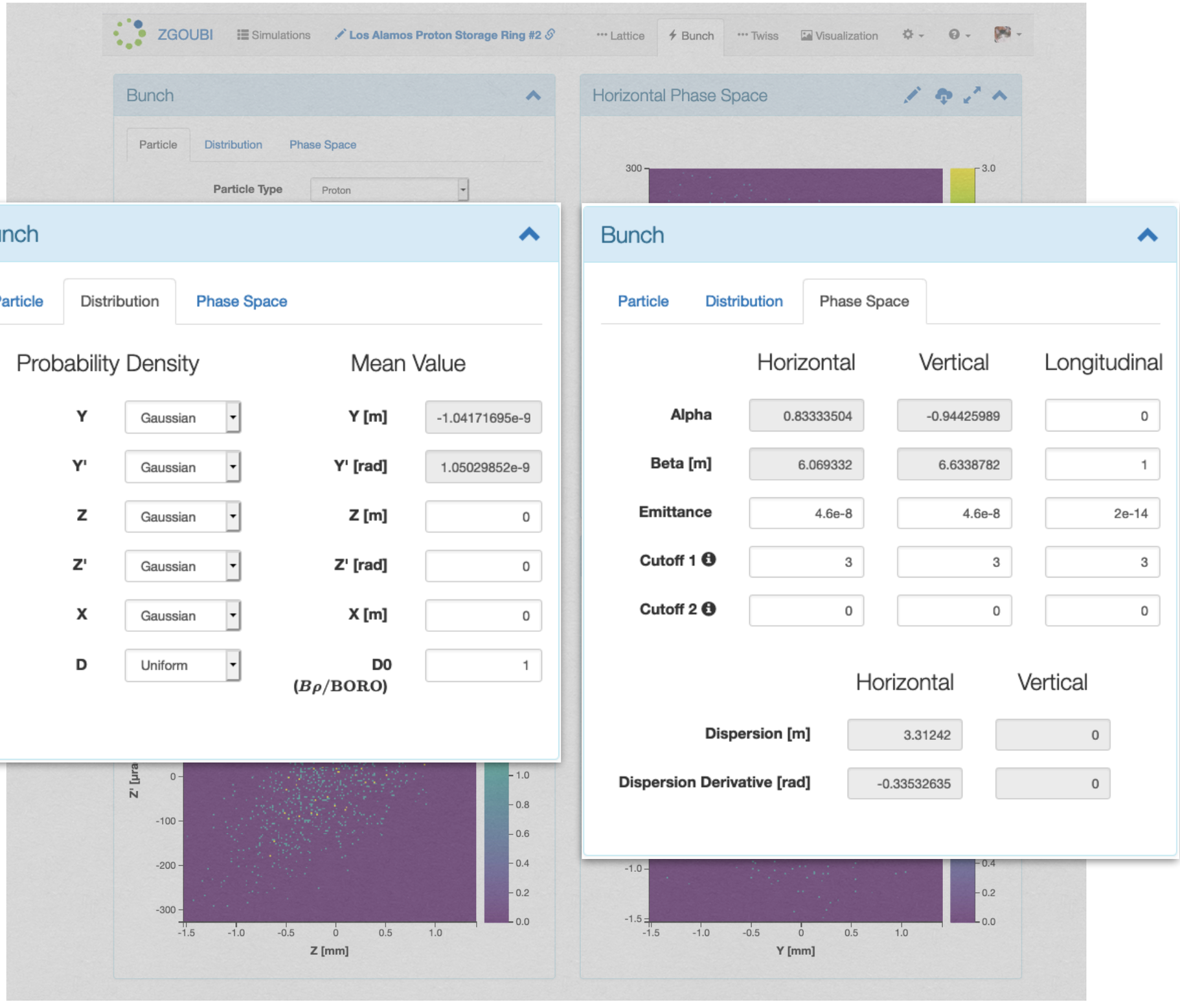
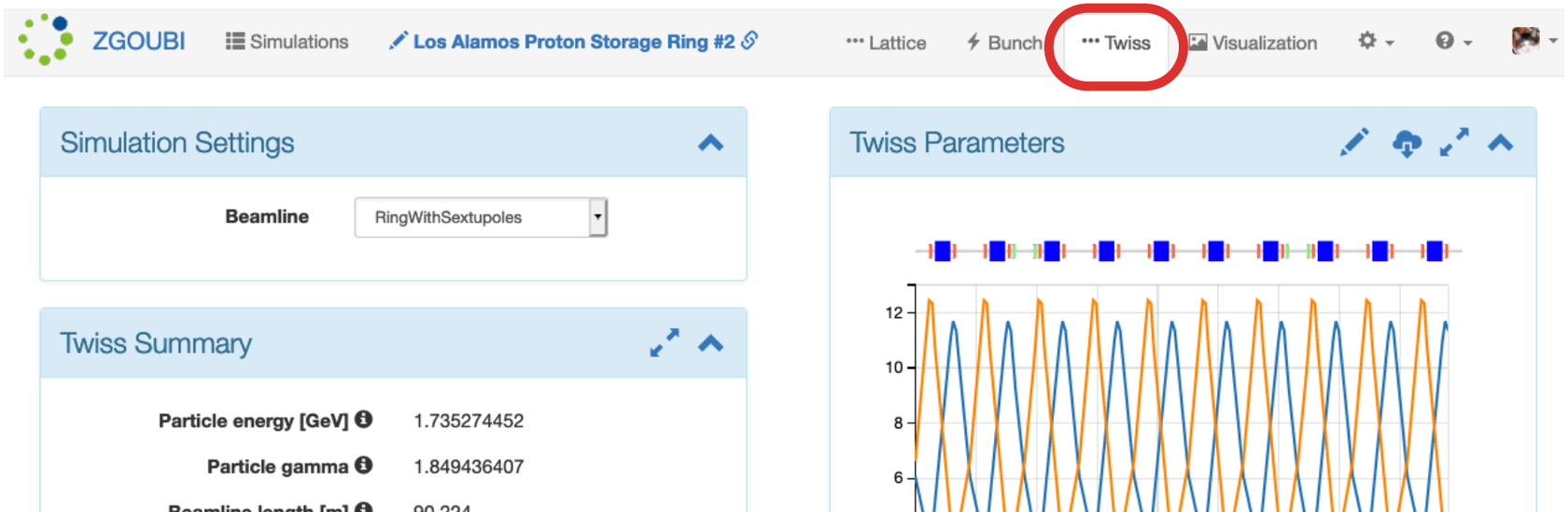
Sirepo



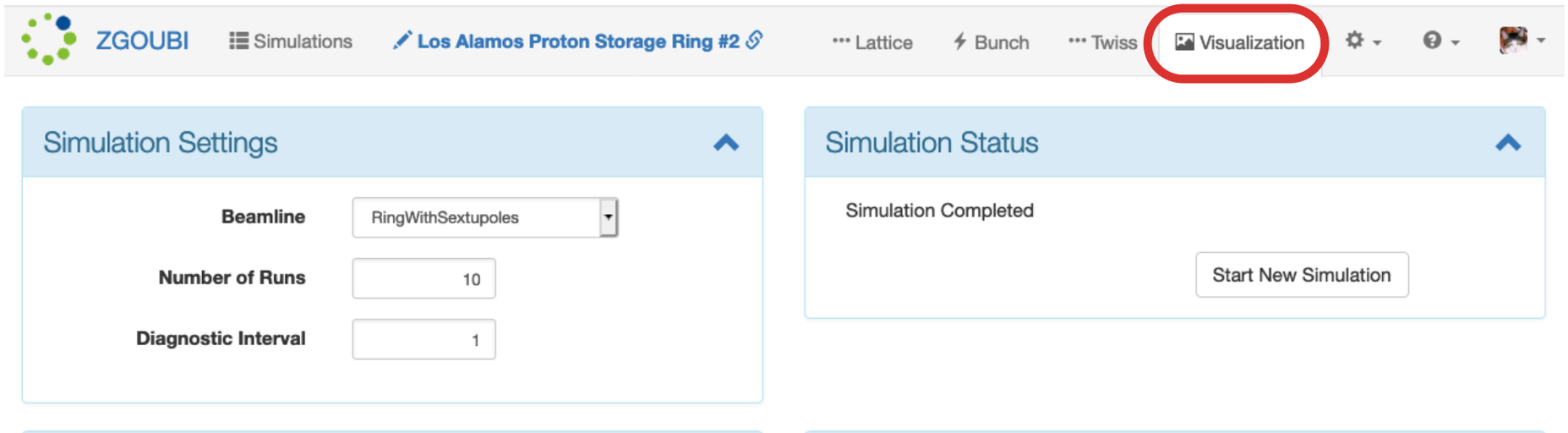
# *The Sirepo Interface for Zgoubi: View Lattice Parameters*

Sirepo



# *The Sirepo Interface for Zgoubi: Visualize the Beam*

Sirepo

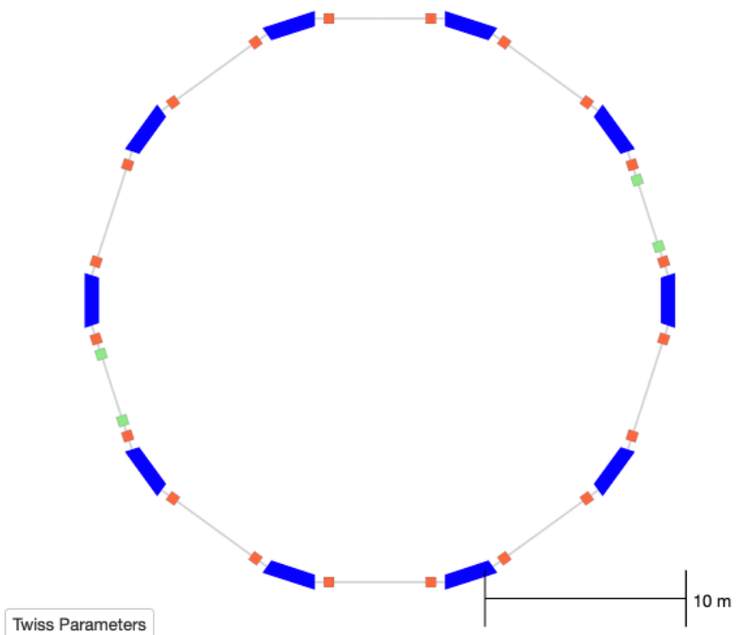


# *The Sirepo Interface for Zgoubi: Share your Work—Effortlessly!*

Sirepo

ZGOUBI | Simulations | Los Alamos Proton Storage Ring #2 | Lattice | Bunch | Twiss | Visualization

## Lattice - RingWithSextupoles




Twiss Parameters

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## Beamline Elements

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| D1 | | 2.286m | |
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| D4 | | 1.486m | |
| QUADRUPO | | | |
| QD | B_0=-2.68,CS_0=0.1122,CS_1=6. | 500.0mm | |
| QF | B_0=1.95,CS_0=0.1122,CS_1=6.2 | 500.0mm | |
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| SD | B_0=-0.24,CS_0=0.1122,CS_1=6. | 500.0mm | |
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# *Improve Performance: Parallelize Zgoubi using Fortran 2018*

Modern Fortran provides facilities for two levels of parallelism:

Fine-grain, at the loop level—requires *pure* functions (no side effects allowed!)

```
do concurrent(iord = 0:nord)
   B(iord+1) = derivB(iord)
end do
```

Coarse-grain, at the processor level—*collective operations*

```
co_min(a)
co_max(a)
co_sum(a)
co_reduce(a, op)
```

and *coarrays*, which "answer the question, 'What is the smallest change required to convert Fortran into a robust and efficient parallel language?'"—John Reid, *ISO/IEC JTC1/SC22/WG5, N1824 (2010)*

Coarray syntax implements a Single Program Multiple Data (SPMD) model. A single program is replicated in units called *images*, and the number of images may be chosen at run time. You must still devise appropriate parallel algorithms, but the case of non-interacting particles is essentially trivial.

```
real :: a[*]   ! scalar coarray
real, dimension(10) :: x[*], y[*]   ! array coarray
real :: m(0:21,6)[*]   ! matrix coarray
type(particle) :: ptcl(128)[*]   ! derived type coarray

x(:) = y(:)[q]   ! access remote data on image q
```

# *Improve Performance: Parallelize Zgoubi using Fortran 2018*

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x(:) = y(:)[q]   ! access remote data on image q
```

A coindex indicates communication.
The programmer must ensure that

* coarray indices are properly resolved
* synchronization occurs as appropriate.

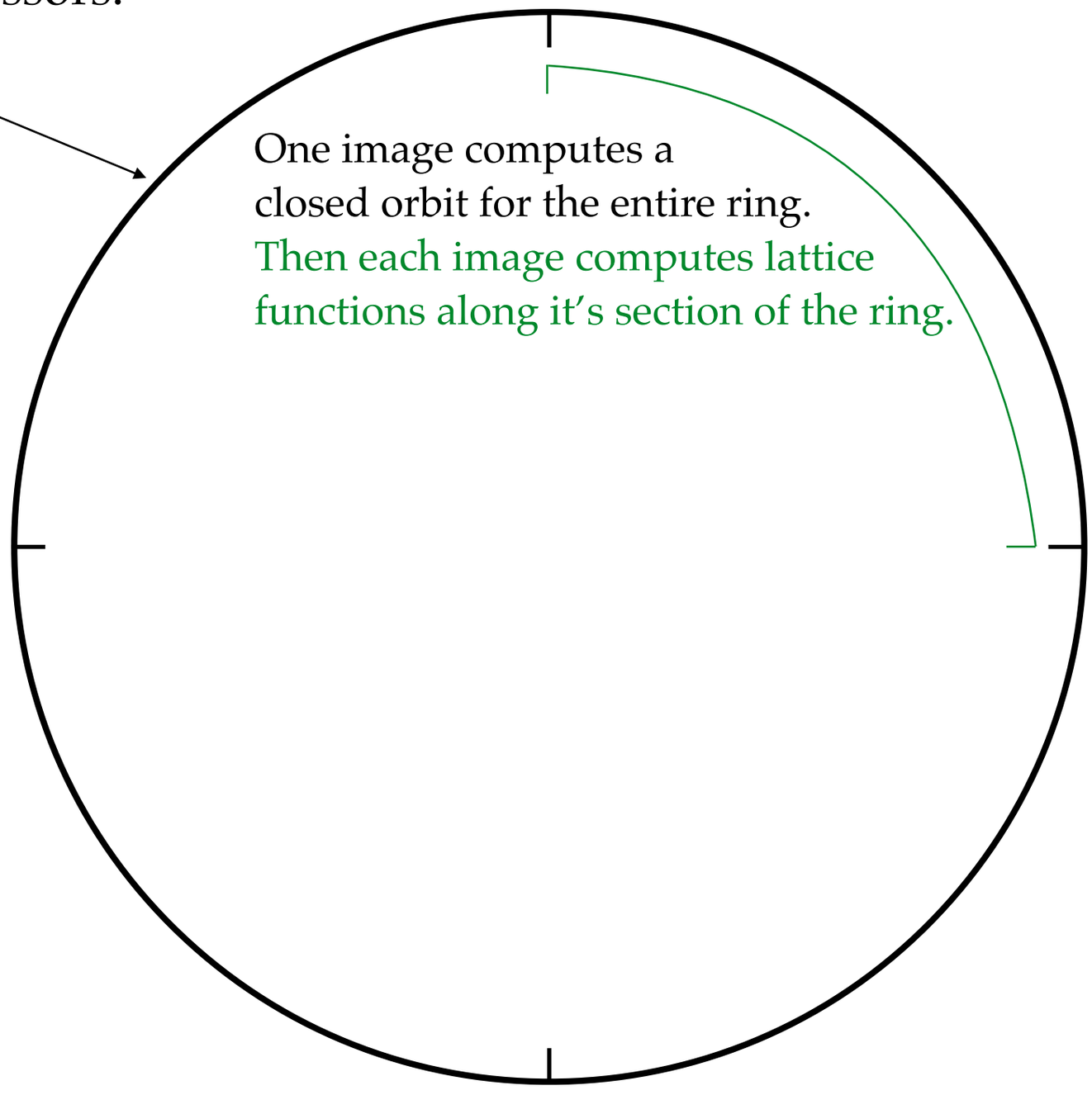
The new Fortran standard includes new intrinsics that simplify the process, *e.g.* random_init.

# *Improve Performance: Parallelize Zgoubi using Fortran 2018*—cont.

Opportunities for paralellizing Zgoubi:

- Distribute particles on multiple processors.
- Distribute lattice computations.
- Distribute machine energies.
- Distribute misalignments.
- Various scans:
  - dynamic aperture;
  - polarization studies

*etc.*



# *Thank you!*

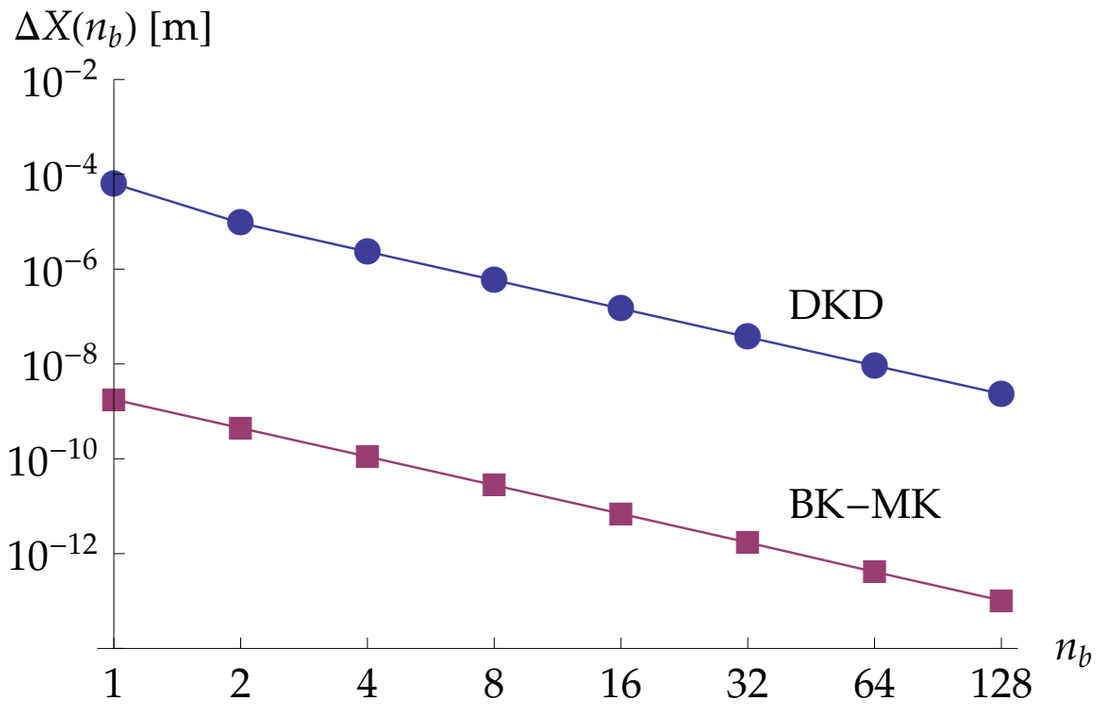
Supported in part by the US Department of Energy, Office of Science,
Office of Nuclear Physics, including Award No. DE-SC0017181.

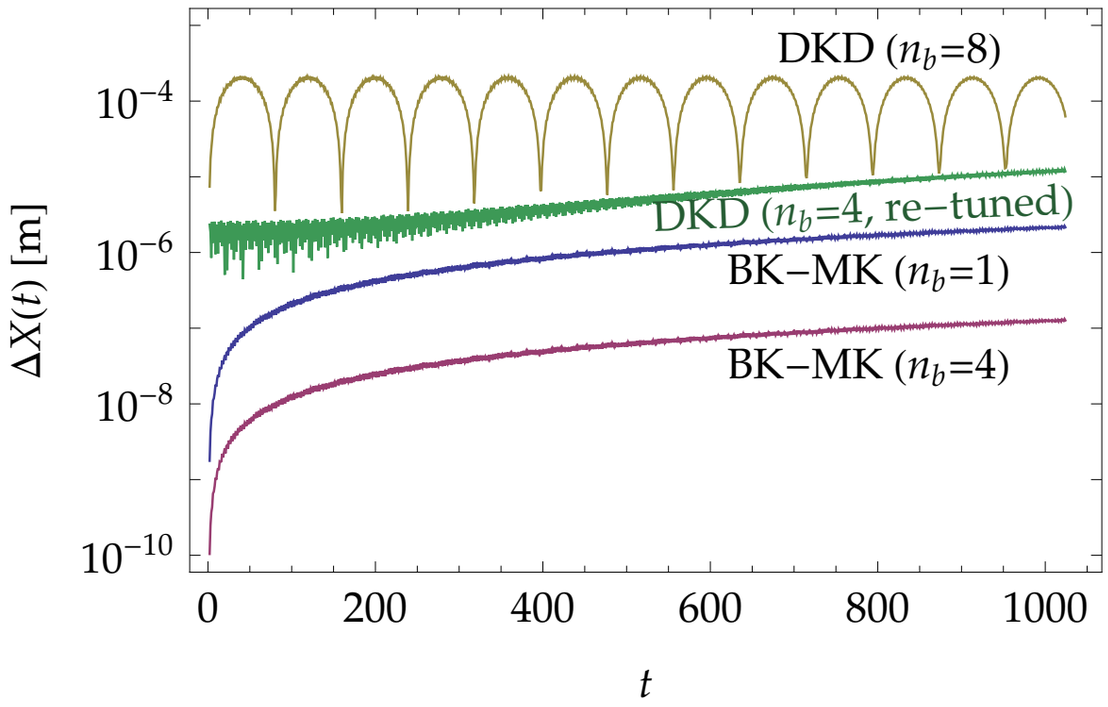
Sirepo https://sirepo.com/

radiasoft *Boulder, Colorado USA — www.radiasoft.net*

# The Accuracy of Orbital Tracking Affects Spin Tracking

Orbit




Spin