SpinQuest Operations

Stephen Pate

New Mexico State University

SpinQuest Review, December 2, 2020

SpinQuest Operations

- The focus here is on starting regular physics running, which we anticipate to occur in late 2021 when the MI beam begins to be delivered to the NM4 hall.
- Assumptions:
  - Spectrometer was fully commissioned in beam during Spring 2021.
  - Target was brought into full remote operation during the 2021 shutdown.
- The first run would last from November 2021 to May 2022. (But can't run target fully cold in May due to LCW temperature.)

Achieving our Physics Goals

- The primary physics goal is to extract the Sivers asymmetry in Drell-Yan production for both proton and deuteron targets with roughly equal statistical significance.
- This will enable the determination of the $\bar{u}$ and $\bar{d}$ contributions to that asymmetry.
- The NH_3 target has a higher polarization than the ND_3 target (80% vs. 32%), but the latter has a better dilution factor (0.18 vs 0.30). This would suggest we should take more data on the ND_3 target (FOM .02 vs .01). However, as this DNP target has not been used in a high-intensity proton beam before, there are a number of operational details that remain to be studied before the relative running times can be optimized.
- To fully understand the operation of the DNP target in the MI beam, we will run for several months with the NH_3 target after beginning physics operations. At an appropriate time we will switch to operation of the ND_3 target, so that we can have approximately equal numbers of POT for both targets in one year.

Achieving our Physics Goals

- After the first year of running, we will perform maintenance of the spectrometer components (hodoscopes, chambers, tubes) and endeavor to improve the target operation -- we will no doubt learn a lot during that first year!
- For systematic purposes, we may decide to change some aspect of the spectrometer configuration during the shutdown; for example, we might decide to reverse the direction of the FMag and KMag fields, or that of the target magnet.
- Then in the second year of running, we would collect appropriate amounts of data on both the NH_3 and ND_3 targets, based on analysis of the year-1 data during the shutdown.
- In both running years, some data with “empty” or “nuclear” targets will be taken for systematic purposes (probably during May when LCW temperature is too high for cryo operation).

Day 1 Physics

- We will study the transverse single-spin asymmetry in J/ψ production during a special run with the polarized NH_3 target, as our first physics measurement.
- Using a different trigger to emphasize the invariant mass range of the J/ψ, we expect this run to take 1-2 weeks.
- A recent PHENIX publication (**Phys. Rev. D 98, 012006**) on this same asymmetry has made this a topic of considerable interest. (The NMSU group were lead authors on that paper.)

Production Onsite Subsystem Experts (24)

- **Polarized Target:** Dustin Keller, Anchit Arora, Ernesto Diaz Fernandez, Zulkaida Akbar, Ishara Fernando, Mikhail Yurov, David Ruth, Vibodha Bandara
- **Scintillator Hodoscopes:** Forhad Hossain, Liliet Calero Diaz
- **Wire Chambers:** Kei Nagai, Nuwan Chaminda
- **Proportional Tubes:** Zhaohuizi Ji, Kun Liu, Anchit Arora
- **Fiber Hodoscopes:** Cristina Mantilla Suarez, Kun Liu
- **Beam Cherenkov:** Rick Tesarek
- **FMag and KMag:** Rick Tesarek
- **NIM Trigger:** Forhad Hossain, Liliet Calero Diaz
- **FPGA Trigger:** Minjung Kim, Noah Wuerfel
- **DAQ:** Zong-Wei Zhang, Ching-Him Leung, Paul Reimer
- **Online Monitoring:** Kenichi Nakano, Catherine Ayuso
- **Onsite Computing:** Ching-Him Leung, Paul Reimer
- **Online Reconstruction:** Catherine Ayuso, Noah Wuerfel (URA supported)
- **Offline Reconstruction:** Abinash Pun, Zulkaida Akbar
- **Slow Controls:** Mikhail Yurov

Shift-taking

- 2-person shifts: Shift Leader and Target Monitor
- 8-hour shifts: 3 per day
- 7 months (November through May) = 210 days

  → 1260 shift-persons
- 51 people currently in the collaboration

  → Average shift load is 24.7 8-hour shifts

Target Activities

Activity	Period	Duration
Anneal and Spin Flip	16 hours	2.5 hours
Target Material Replacement	7 days	8 hours
Target Cell Replacement and Insert Maintenance	14 days	8 hours
Thermal Equilibrium (TE) Measurement	3 per material load; once after insertion, again midway through use, lastly right before removal	4 hours

Fitting these into a weekly schedule, we have 123 hours/week for data-taking (73%).

Weekly Target Run Plan

<table>
<tr><th></th><th>Sunday</th><th>Monday</th><th>Tuesday</th><th>Wednesday</th><th>Thursday</th><th>Friday</th><th>Saturday</th></tr>
<tr><td>0:00</td><td rowspan="4">TE Measurement</td><td rowspan="3">Anneal & Flip</td><td></td><td></td><td rowspan="3">Anneal & Flip</td><td></td><td rowspan="3">Anneal & Flip</td></tr>
<tr><td>1:00</td><td></td><td></td><td></td></tr>
<tr><td>2:00</td><td></td><td></td><td></td></tr>
<tr><td>3:00</td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>4:00</td><td></td><td></td><td></td><td rowspan="4">TE Measurement</td><td></td><td></td><td></td></tr>
<tr><td>5:00</td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>6:00</td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>7:00</td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>8:00</td><td rowspan="3">Anneal & Flip</td><td></td><td rowspan="3">Anneal & Flip</td><td rowspan="8">Target Material and/or Cell Replacement (hall access)</td><td></td><td rowspan="3">Anneal & Flip</td><td></td></tr>
<tr><td>9:00</td><td></td><td></td><td></td></tr>
<tr><td>10:00</td><td></td><td></td><td></td></tr>
<tr><td>11:00</td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>12:00</td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>13:00</td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>14:00</td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>15:00</td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>16:00</td><td></td><td rowspan="3">Anneal & Flip</td><td></td><td rowspan="4">TE Measurement</td><td rowspan="3">Anneal & Flip</td><td></td><td rowspan="3">Anneal & Flip</td></tr>
<tr><td>17:00</td><td></td><td></td><td></td></tr>
<tr><td>18:00</td><td></td><td></td><td></td></tr>
<tr><td>19:00</td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>20:00</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>21:00</td><td></td><td></td><td rowspan="3">Anneal & Flip</td><td></td><td></td><td></td><td></td></tr>
<tr><td>22:00</td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>23:00</td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
</table>

Protons on Target: Constraints

- "Quench commissioning" will determine how much proton intensity we can tolerate. We expect this to be ~3-10x10^{12} protons/spill, based on beam heating simulations and expected cooling power.
  - The lower limit assumes the **nominal** cooling power of the helium recirculator.
  - The upper limit assumes we pump helium to **enhance** the cooling of the target magnet.
  - This range is based on simulations and needs to be verified during commissioning.
- The shielding assessment for the NM4 hall limits us to 1x10^{13} protons/spill.

MI Beam Quality

Each RF bucket delivered to the NM4 hall should have about 10^5 protons in it, but this number has a very broad distribution.

1) Buckets with too few protons are less useful for the obvious statistical reasons.
2) Buckets with too many protons (sometimes more than one order of magnitude too many) overwhelm the spectrometer detectors and create large DAQ deadtimes; these are rejected from the data-stream by a Cherenkov detector veto.

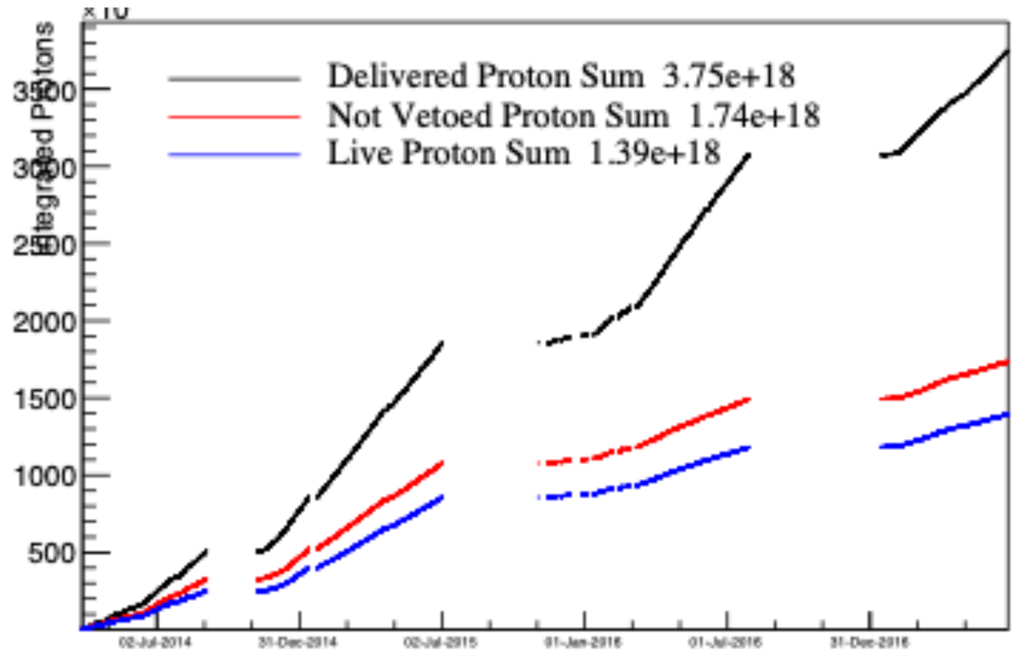
Items (1) and (2) resulted in a "quality factor" of ~50%, during the SeaQuest experiment.

This factor was taken into account in the SpinQuest proposal.

Three kinds of Protons

SeaQuest developed three different ways of talking about protons in the beam.

- Delivered Protons (“POT”) – number of protons delivered to the beam dump irrespective of any other consideration
- Nonvetoed Protons – protons in buckets that did not trigger the Cherenkov veto
- Live Protons – protons that arrived on the target when the DAQ was live

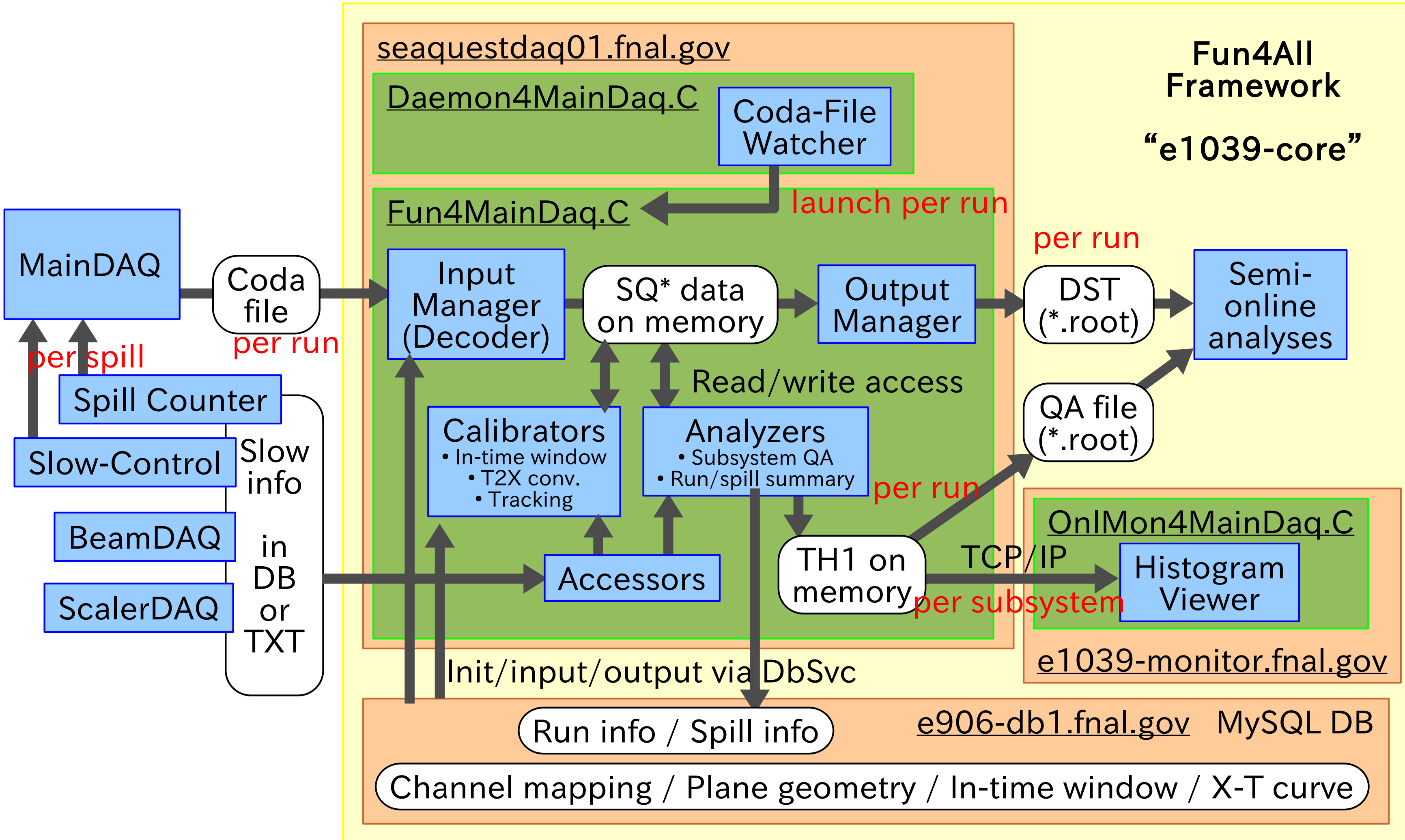


Protons on Target

	Nominal Cooling	Enhanced Cooling
Spill Intensity	3×10^{12} protons/spill	10×10^{12} protons/spill
Spills per day	1440	1440
Number of days	400	400
→ Delivered Protons (POT)	1.7×10^{18}	5.8×10^{18}
Target uptime	0.73	0.73
Beam Quality Factor	0.5	0.5
DAQ Live Time	0.95	0.95
→ Live Protons	0.60×10^{18}	2.0×10^{18}

SpinQuest proposal and sensitivity plots assumed 1.5×10^{18} live protons over the two-year running period.
→ Some enhanced cooling (involving pumping of helium) will be necessary to achieve our physics goals.

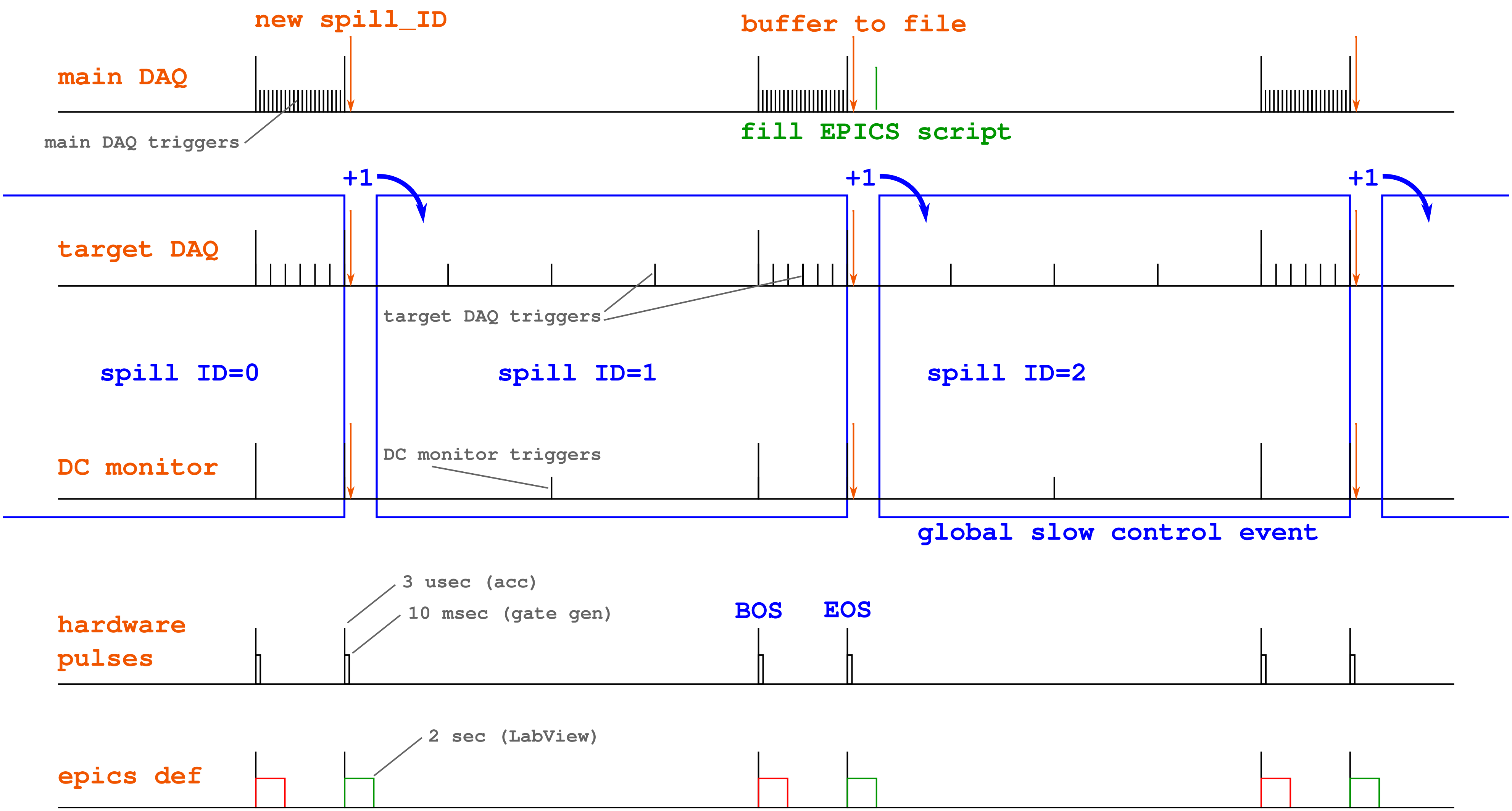
Beam and Scaler Event Data Stream



There have been many changes since SeaQuest, especially the import of the "Fun4All" data analysis framework from the PHENIX experiment.

Slow Control Events

Some slow control data (especially target and drift chamber) are collected on a spill-by-spill basis, both before and during the spill.



Slow Control Data Stream

standalone daqs → tsv output

subsystem calls → std output → read_slowcontrol → tsv output

tsv output → fill_epics → epics → epics tools

epics → epics archiver → history plots / correlation plots

Summary:

DAQ systems and the various detector subsystems provide slow control data in a unified “tab separated values” (tsv) file format. These tsv files are archived.

The tsv files are used to populate EPICS variables, which then are displayed, manipulated, and archived in the EPICS format.

Operations Summary

- A collection of experts are already in residence at Fermilab. (including 12 grad students and 10 postdocs)
- The SeaQuest spectrometer has been restored to operation, is being exercised with cosmic rays, and will be commissioned in beam in Spring 2021.
- The DAQ and Slow Control systems have been tested with cosmic ray data and will be commissioned in beam as well.
- The target should be fully operational by the end of Summer 2021 and we have a plan for operation during physics running.
- **We will be ready to begin to explore the light quark sea contribution to the Sivers asymmetry.**