```
//Exception handler
#include "Utilities/TkrException.h"

#include <queue>
#include <iterator>
#include <vector>

// This defines how the priority_queue for leaf nodes will be ordered
struct TkrVecNodeLeafOrder
{
public:
    bool operator()(const Event::TkrVecNode* left, const Event::TkrVecNode* right) const
    {
        bool order = false;

        // Recover distances to main branch (remembering that if 0 it IS the main branch)
        int leftDistToMain  = left->getBiLyrs2MainBrch()  > 0 ? left->getBiLyrs2MainBrch()  : 100000;
        int rightDistToMain = right->getBiLyrs2MainBrch() > 0 ? right->getBiLyrs2MainBrch() : 100000;

        // Most number of bilayers wins (longest)
        if      (leftDistToMain > rightDistToMain) order = false;
        else if (leftDistToMain < rightDistToMain) order = true;
        else
        {
            // Nothing else left but straightest
            // Use the scaled rms angle to determine straightest...
            double leftRmsAngle  = left->getBestRmsAngle() * double(left->getNumBiLayers()) / double(left->getDepth());
            double rightRmsAngle = right->getBestRmsAngle() * double(right->getNumBiLayers()) / double(right->getDepth());

            //if (left->getBestRmsAngle() < right->getBestRmsAngle()) return true;
            if (leftRmsAngle > rightRmsAngle) order = true;
        }

        return order;
    }
};

class TkrTreeTrackFinderTool : public AlgTool, virtual public ITkrTreeTrackFinder
{
public:
    // Constructor
    TkrTreeTrackFinderTool( const std::string& type,
                            const std::string& name,
                            const IInterface*  parent);

    /// @brief Intialization of the tool
    StatusCode initialize();
```

1
00:00:12,160 --> 00:00:04,030
[Music]

2
00:00:12,180 --> 00:00:16,260
Julie McEnery: Fermi is an observatory designed to see the

3
00:00:16,280 --> 00:00:20,360
most extreme places in the universe. We see gamma rays, which are are the highest-energy

4
00:00:20,380 --> 00:00:24,400
form of light, and with each object that we see these gamma rays from, what we're doing is

5
00:00:24,420 --> 00:00:28,450
exploring some of the places in the universe with most extreme environments.

6
00:00:28,470 --> 00:00:32,550
Matthew Wood: The kinds of objects that it can study are pulsars and neutron

7
00:00:32,570 --> 00:00:36,610
stars, black holes, as well as dark matter.

8
00:00:36,630 --> 00:00:40,660
The main challenge in detecting gamma rays is that

9
00:00:40,680 --> 00:00:44,710
the Earth's atmosphere is opaque to them, so to get around that we

10
00:00:44,730 --> 00:00:48,760
use satellites in space to measure gamma rays. Julie: We don't have

11
00:00:48,780 --> 00:00:52,820
lenses and mirrors because gamma rays would just go straight

12
00:00:52,840 --> 00:00:56,880
through them. The main instrument on Fermi is the Large Area Telescope.

13
00:00:56,900 --> 00:01:00,920

It's a telescope that detects gamma rays by converting them into

14
00:01:00,940 --> 00:01:04,990
electron-positron pairs. Those are charged particles, so fundamentally

15
00:01:05,010 --> 00:01:09,120
our detector is designed to measure the tracks of those

16
00:01:09,140 --> 00:01:13,210
charged particles moving through and from that figure out where the gamma ray came from.

17
00:01:13,230 --> 00:01:17,270
The problem is that in the environment of

18
00:01:17,290 --> 00:01:21,350
low Earth orbit there's a very large number of charged particles. So for every

19
00:01:21,370 --> 00:01:25,410
gamma ray that we detect, ten thousand charged particles are coming

20
00:01:25,430 --> 00:01:29,530
through our detector. So we have to be able to tell the difference between

21
00:01:29,550 --> 00:01:33,630
that one gamma ray from those ten thousand charged particles,

22
00:01:33,650 --> 00:01:37,740
and that's the challenge. Often, they deposit a

23
00:01:37,760 --> 00:01:41,820
large amount of energy and stuff splashes up in all directions and you end up with

24
00:01:41,840 --> 00:01:45,830
extra hits in the tracking part of the detector that are not actually

25
00:01:45,850 --> 00:01:49,910
from the original electron and positron, but rather from

26
00:01:49,930 --> 00:01:54,020
energy that's kicked up when they interact further in the calorimeter.

27
00:01:54,040 --> 00:01:58,080
Philippe Bruel: So, to analyze these events we have written

28
00:01:58,100 --> 00:02:02,200
a very long and complex program that basically

29
00:02:02,220 --> 00:02:06,210
uses all the information that was recorded by the instrument

30
00:02:06,230 --> 00:02:10,310
and figures out what is the direction of the gamma ray,

31
00:02:10,330 --> 00:02:14,410
its energy, and whether or not it's

32
00:02:14,430 --> 00:02:18,560
a real gamma ray and not a charged cosmic ray.

33
00:02:18,580 --> 00:02:22,640
So, obviously, software is really important for the LAT.

34
00:02:22,660 --> 00:02:26,810
Matthew: The software that we use to analyze the LAT data

35
00:02:26,830 --> 00:02:30,850
has gone through many revisions over the course of the mission, but Pass 8 is

36
00:02:30,870 --> 00:02:34,940
really the first revision of the software where we took into account

37
00:02:34,960 --> 00:02:39,010
all the experience that we gained from operating

38
00:02:39,030 --> 00:02:43,090

the LAT in its orbital environment. Julie: Pass 8

39
00:02:43,110 --> 00:02:47,160
has given us the equivalent of an in-space hardware upgrade,

40
00:02:47,180 --> 00:02:51,300
but on the ground. Matthew: We've increased the sensitivity of the LAT instrument

41
00:02:51,320 --> 00:02:55,360
by 40 percent and this is roughly equivalent to

42
00:02:55,380 --> 00:02:59,510
launching another LAT instrument and operating it as well for seven years.

43
00:02:59,530 --> 00:03:03,600
So it's a fairly substantial improvement in the LAT performance.

44
00:03:03,620 --> 00:03:07,660
Julie: The most immediate, kind of shocking, benefit of

45
00:03:07,680 --> 00:03:11,750
Pass 8 is our ability to view the sky

46
00:03:11,770 --> 00:03:15,870
at high energies where we have particularly improved our

47
00:03:15,890 --> 00:03:19,930
angular resolution, so the sharpness is very evident, and we've added

48
00:03:19,950 --> 00:03:23,990
lots more gamma rays, so we filled in what was kind of

49
00:03:24,010 --> 00:03:28,100
a spotty sky. Pass 8 has

50
00:03:28,120 --> 00:03:32,220
made everything better, but one of the things that it's made better is that it's

51
00:03:32,240 --> 00:03:36,420
allowed us to open our gamma-ray eyes to higher energies than before, so that's a completely

52
00:03:36,440 --> 00:03:40,500
new view, and it's allowed us to open our gamma-ray energy eyes to, at energies

53
00:03:40,520 --> 00:03:44,600
lower than before, so that's another completely new view. In addition to

54
00:03:44,620 --> 00:03:48,680
improving everything across the entire energy range.

55
00:03:48,700 --> 00:03:52,790
We have a wider field of view. We see more photons from

56
00:03:52,810 --> 00:03:56,860
any given point in our detector than we did before. Matthew: The improvement

57
00:03:56,880 --> 00:04:00,910
that we've made to the software retroactively apply to all the data that we've

58
00:04:00,930 --> 00:04:05,010
collected, and so these improvements significantly enhance

59
00:04:05,030 --> 00:04:09,140
what we can do with the data we already have, as well as the data

60
00:04:09,160 --> 00:04:13,210
that we'll collect in the future. Julie: With Pass 8, we're able to go back to the

61
00:04:13,230 --> 00:04:17,350
sensor-by-sensor information and we can reprocess that data

62
00:04:17,370 --> 00:04:21,440
into the improved performance that we get with Pass 8,

63
00:04:21,460 --> 00:04:25,460

from the first day of the mission, from August 2008,

64
00:04:25,480 --> 00:04:29,480
right the way up to the present day. Philippe: So with Pass 8, we

65
00:04:29,500 --> 00:04:33,540
use more completely and more efficiently all the information

66
00:04:33,560 --> 00:04:37,640
that is recorded by the instrument. One thing that I like is

67
00:04:37,660 --> 00:04:41,720
that these photons took a lot of time

68
00:04:41,740 --> 00:04:45,800
to come to Earth, so that it's a pity to

69
00:04:45,820 --> 00:04:49,870
just miss one of them. So I'm glad that with Pass 8 we're

70
00:04:49,890 --> 00:04:53,980
more efficient and we record every gamma ray that passes

71
00:04:54,000 --> 00:04:58,070
through us. Julie: Look, obviously I'm biased. You know, I do think it's really cool.

72
00:04:58,090 --> 00:05:02,110
And, you know, when I first started working on Fermi, and

73
00:05:02,130 --> 00:05:06,200
you know, you start, you think "Oh how does this detector work?" and then you think more and think more

74
00:05:06,220 --> 00:05:10,250
about it. This is really cool! This is really cool even if you weren't doing any

75
00:05:10,270 --> 00:05:14,410
astrophysics with it. And then you add the astrophysics and it's awesome.

76
00:05:14,430 --> 00:05:18,560
[Music]