

Particle Astrophysics at Fermilab/Computing Division

E881

Pierre Auger Observatory



E891
CDMS-II

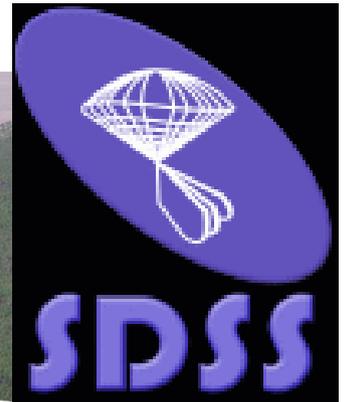
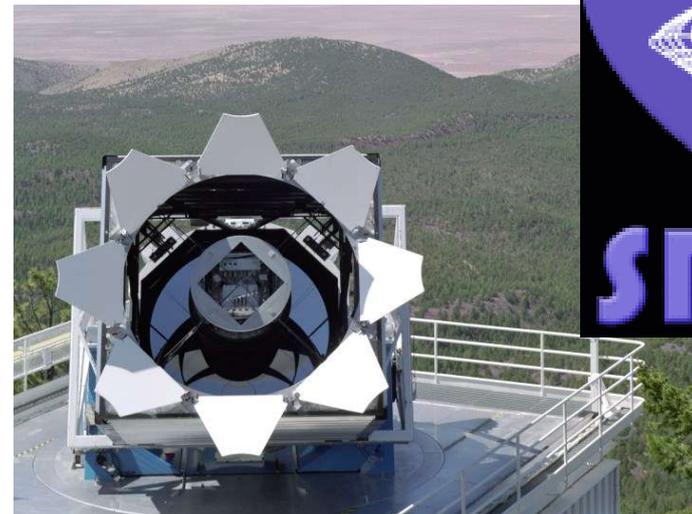
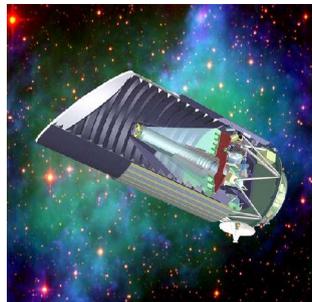


DARK ENERGY
Survey

E939
DES



R&D
SNAP/JDEM



E949
SDSS-II

Fermilab Center for Particle Astrophysics

Name Change! PAC -> CPA

**Unifies 5 astroparticle experiments,
scientists and theorists for exchange
of ideas, results, and people.**

CPA Updates

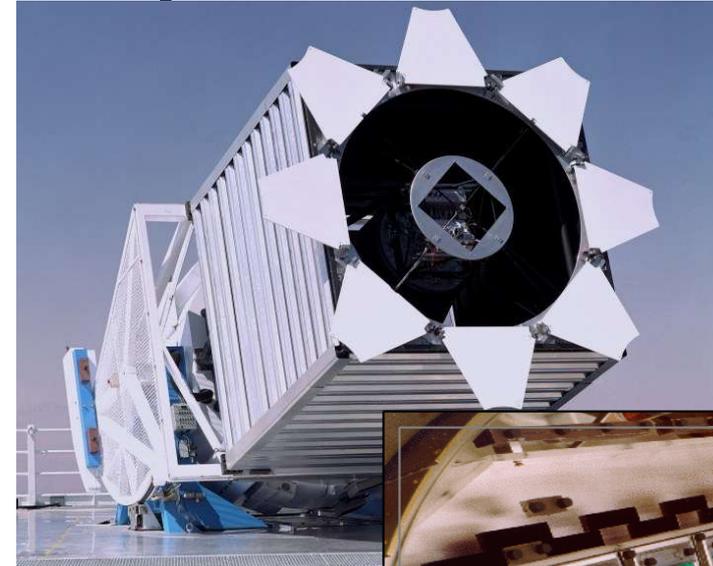
- **Scott Dodelson is “acting director”**
- **Search on for full-time director**
- **Working more as a “center”**
 - **Visitors**
 - **Seminar series, talks**
 - **Conferences, workshops**
 - **Postdocs**
 - **Space**



Sloan Digital Sky Survey-II (E949)

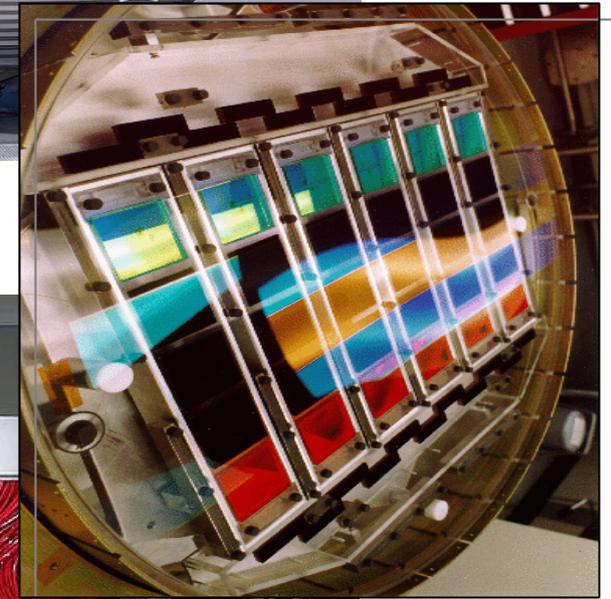
Collaboration: ~150 scientists from
Am. Museum Nat. History, Astrophysical Inst.
Potsdam, U. Basel, Cambridge U., Case Western
Reserve, U. Chicago, Drexel U., Fermilab,
Institute for Adv. Studies, Japanese Participation
Grp, Johns Hopkins U., JINA, Kavli Institute for
Part. Astro., Korean Scientist Group, LAMOST
(China), Los Alamos Nat. Lab, Max Planck Inst.
Astron., Max Planck Inst. Astrophy., New Mexico
State U., Ohio State U., U. Pittsburgh, U.
Portsmouth, Princeton U., US Naval Obs., U.
Washington

Update since July, 2006: None!

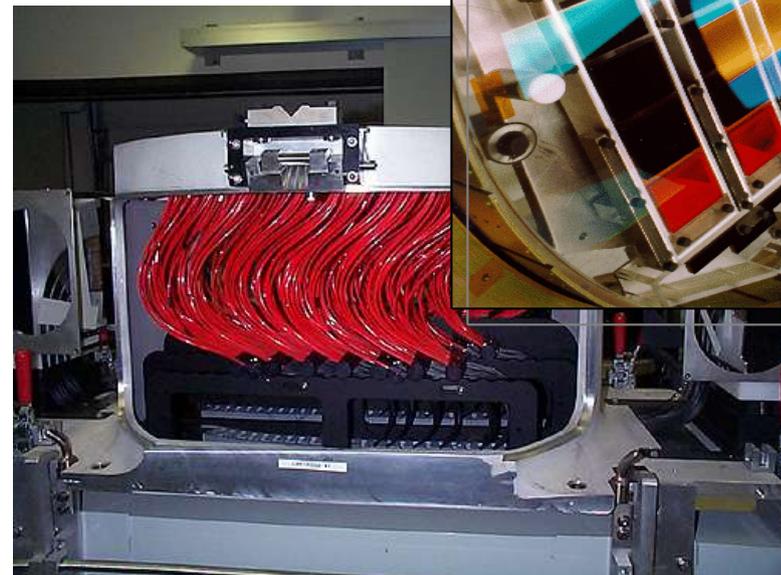


Beamline

Calorimeter



Massive
Spectrometer





SDSS II - the sequel

3 year mission (2005-2008)

Legacy:

- Complete SDSS program
- Imaging and Redshift survey - Large scale structure

SEGUE:

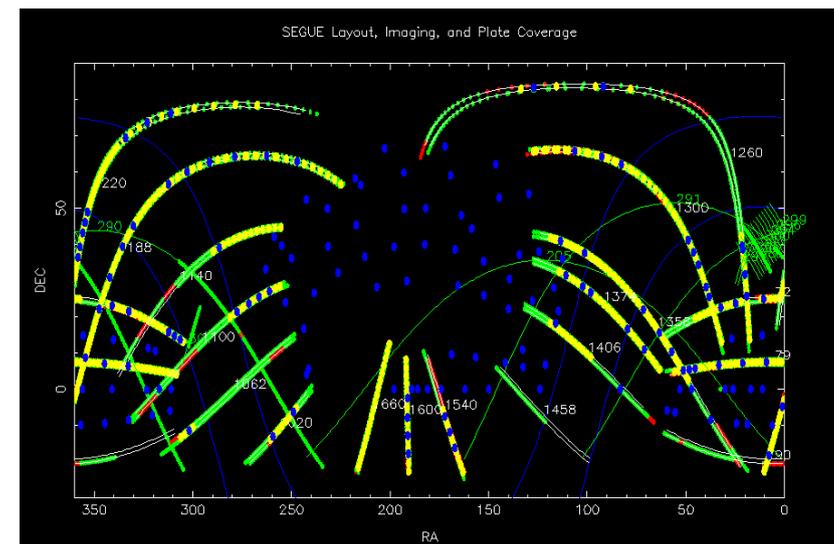
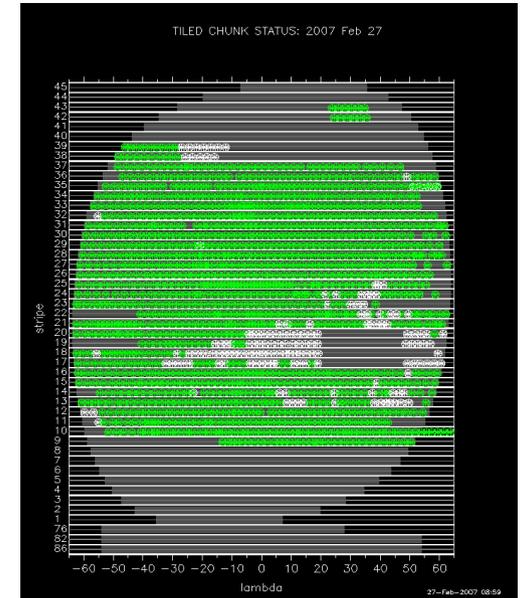
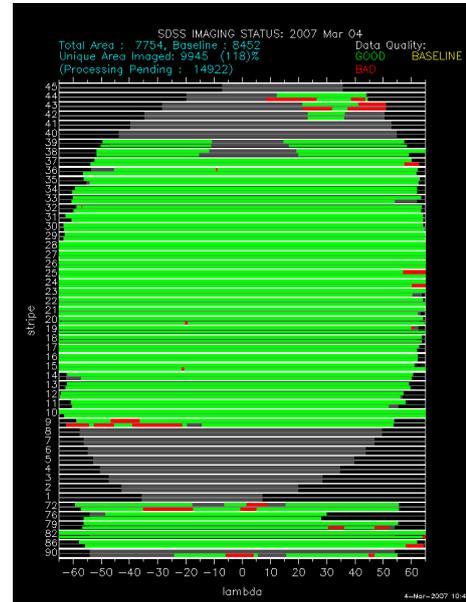
- Milky Way halo – Dark Matter probes

Supernovae

- Low and intermediate redshift, Dark Energy probe

Funding:

- Sloan, DOE, NSF, NASA, Japanese Mongbukagakusho, Max Planck Society, HEFCE





FNAL tasks and resources ***in SDSS-II***

- **Fermilab Interests**
- **13 scientists (3 divisions)**
 - **3 current postdocs (including 1 Brinson)**
 - **Update: Last postdoc started Sept. 2006**

Tasks

**Plugplate design
Legacy, SEGUE, SNe
Survey planning
Data processing
Data distribution
Project mgmt.
Project director support
APO Engineering/
Technical support**

- **Required resources**
 - **4 FTE scientist (mainly from CD)**
 - **10 FTE CP, admin, tech.**
 - **Update: 4 personnel previously in PPD are now in CD/EAG**
 - **\$300K M&S/yr**
- **Funding**
 - **Significant cost sharing with SDSS project (\$1.2 million)**

CD Tasks - Data Processing

- Defining document - SSP 240
- Responsible Organization - FL/CD/EAG
- Stakeholders - E949 collaboration
- Leader - S. Kent
- Update: Full reprocessing of spectro data upcoming
- Next round of file server replacement/expansion coming
- Responsibilities
 - Survey planning
 - Observing software maintenance
 - SDSS website
 - Data Processing Operations (including SNe)
 - Pipeline maintenance
 - Data Distribution
 - **DAS**
 - **Data to CAS**
 - **Web pages**

Deliverables -->>

- **DAS**
- **Data to CAS**
- **Web pages**

CD Tasks - DAQ

- **Defining document - SSP261**
- **Responsible organization - FL/CD/CEPA**
- **Stakeholders - E949 collaboration**
- **Leader - G. Guglielmo**
- **Responsibilities**
 - **DAQ hardware maintenance**
 - **DAQ software underpinnings maintenance**
 - **Update - ~0.25 FTE per month ongoing**

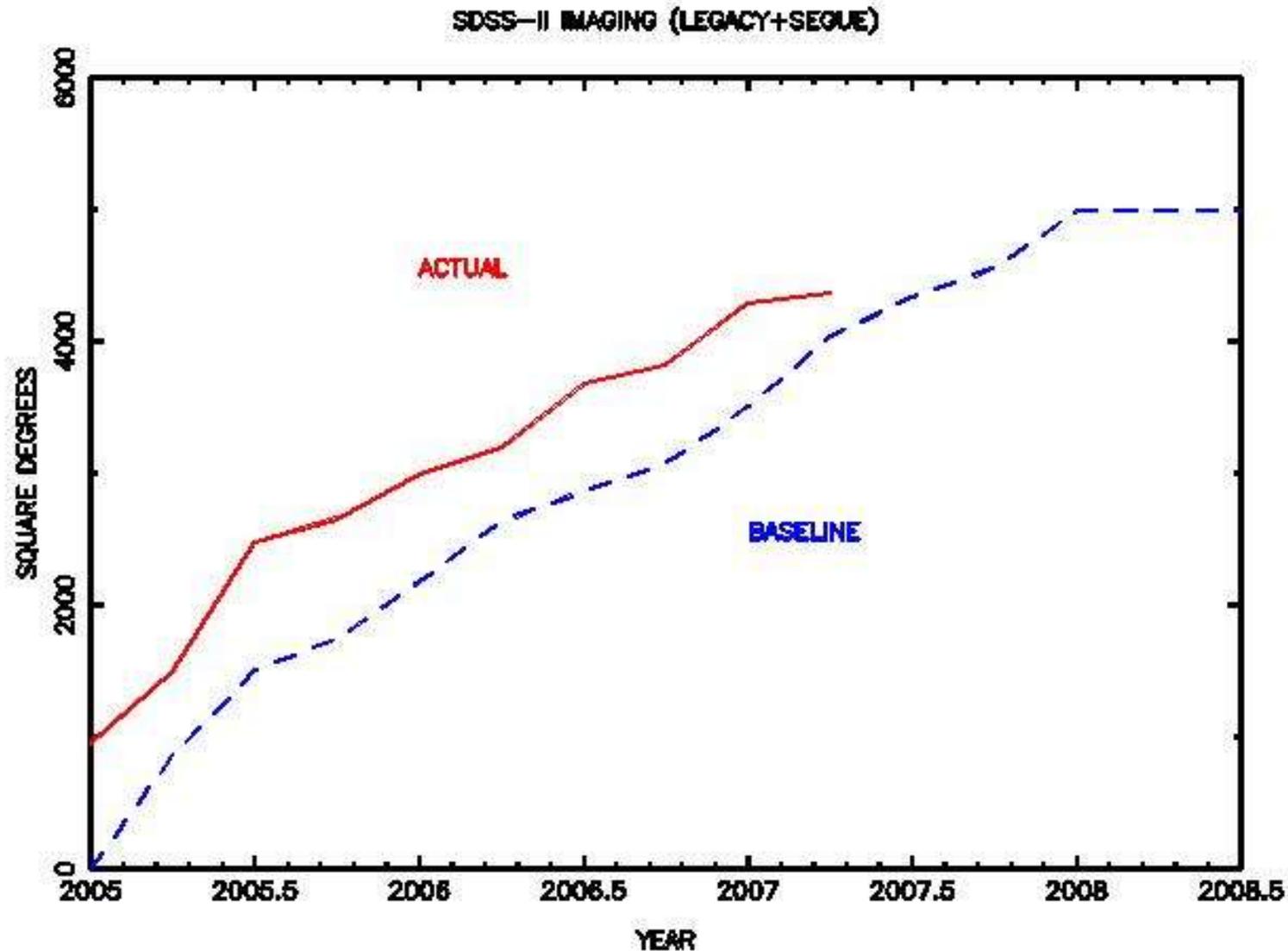
CD Tasks - Catalog Archive Server

- Defining document - SSD 268
- Responsible organization - FL/CD/CSS
- Stakeholders - E949 Collaboration
- Leader - J. Trumbo/J. Schmidt
- Responsibilities
 - Deploy, install, and operate Catalog Archiver Server (hardware and software)
- Updates
 - Continuous evolution of “data model”
 - Jim Gray MIA

SDSS Status

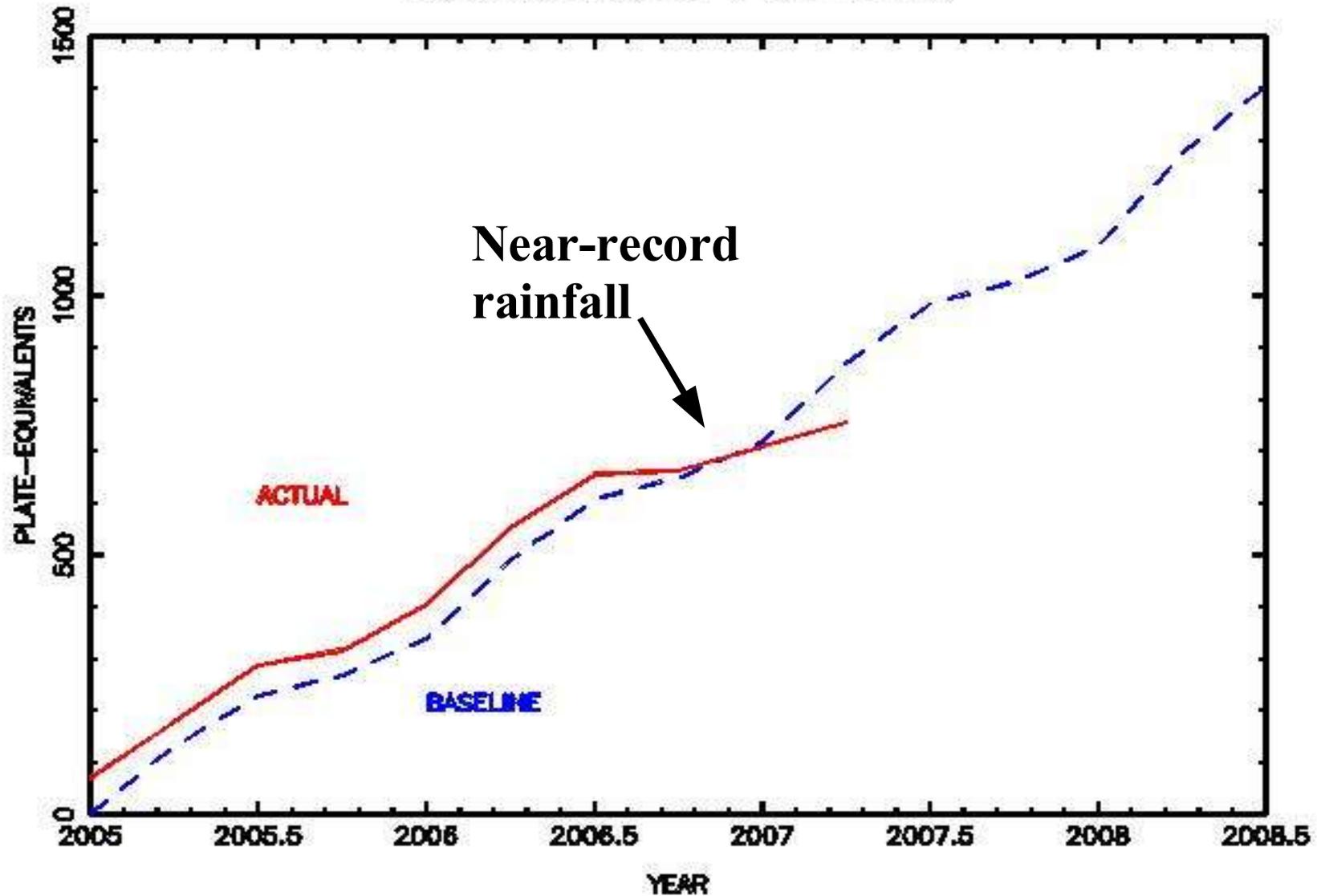
- **We are just finishing year 7 of "steady state operations"**
- **Data Releases occur in quantized intervals - DR6, to be released to public, includes all data from years 1-6.**
- **Issues**
 - **DLT -> network copy overall working OK. (J. Hendry makes sure all data are copied to enstore)**
 - **End of offsite tape storage**
 - **All tapes seem to have been retrieved OK, now in tape vault in FCC**
 - **Tape migration project – projected finish early July**

Integrated Luminosity - Imaging



Integrated Luminosity - Spectroscopy

SDSS-II SPECTROSCOPY (LEGACY+SEGUE)



Supernova Results

Year	Predicted	Observed
2005	60-70	74*
2006	60-70	Analysis in progress

***SDSS “clean sample”**

SDSS Impact

HIGH-IMPACT ASTRONOMICAL OBSERVATORIES

1287

TABLE 1. HIGH-IMPACT OBSERVATORIES

Rank	Facility	Citations	Participation
1	SDSS	1843	17.4%
2	ESO	1365	12.9%
3	HST	1124	10.6%
4	WMAP	1121	10.6%
5	Keck	642	6.0%
6	Kamiokande	372	3.5%
7	Chandra	365	3.4%
8	ACBAR	207	2.0%
9	NOAO	202	1.9%
10	Las Campanas	176	1.7%

we did not include them in this study. For those papers that included observational data we determined the facility or facilities used by the authors examining the observation sec-

published in 2002 and 2003 (Madrid et al. 2006). This allows us to see the evolution with time of the different high-impact facilities.

The SDSS ranks as the facility with the highest impact in astronomy for the second year in a row. This astronomical survey is made with a dedicated 2.5-meter telescope on Apache Point Observatory in New Mexico. ESO, that ranks second this year, was ranked 10th in 1998 and has climbed its way to be among the five observatories of highest impact every year since 2001.

HST and the Wilkinson Microwave Anisotropy Probe rank closely third and fourth respectively. HST is a permanent member of this list of high-impact observatories ranking year after year among the top five. WMAP ranked first on a previous ranking based on the analysis of papers published in 2003 (Madrid et al. 2006).

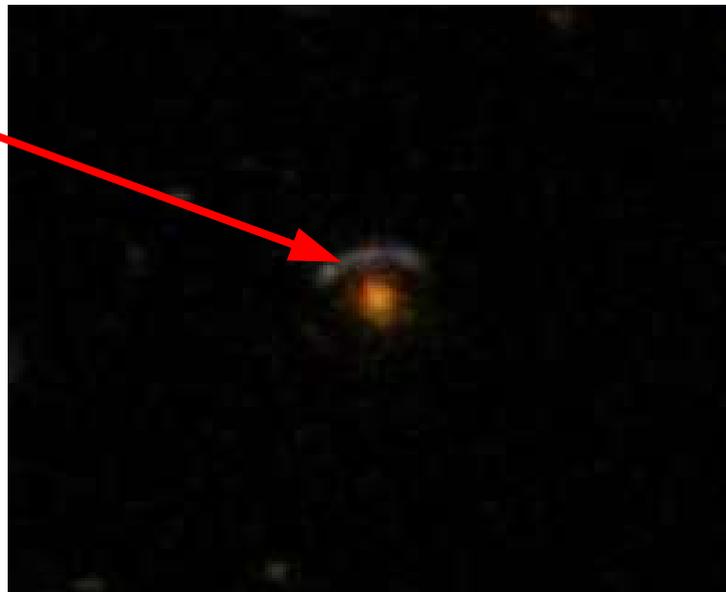
based on number of citations to published papers

Research

- **Gravitationally lensed Arcs**

- Identify objects in SDSS data - follow up with other telescopes (ARC 3.5 m, HST, Spitzer, etc.)
- Attracting particle physicists, who contribute real work.
- Some proposals for followup involve requests for funding (HST, Spitzer).

**Galaxy
at redshift
 $z=2.7$**



**8 o'clock Arc:
Using Dark Matter as
a “zoom” lens**

**Benefit to DOE of Dark
Matter: \$85 million**

**Several more being
investigated**

More Research

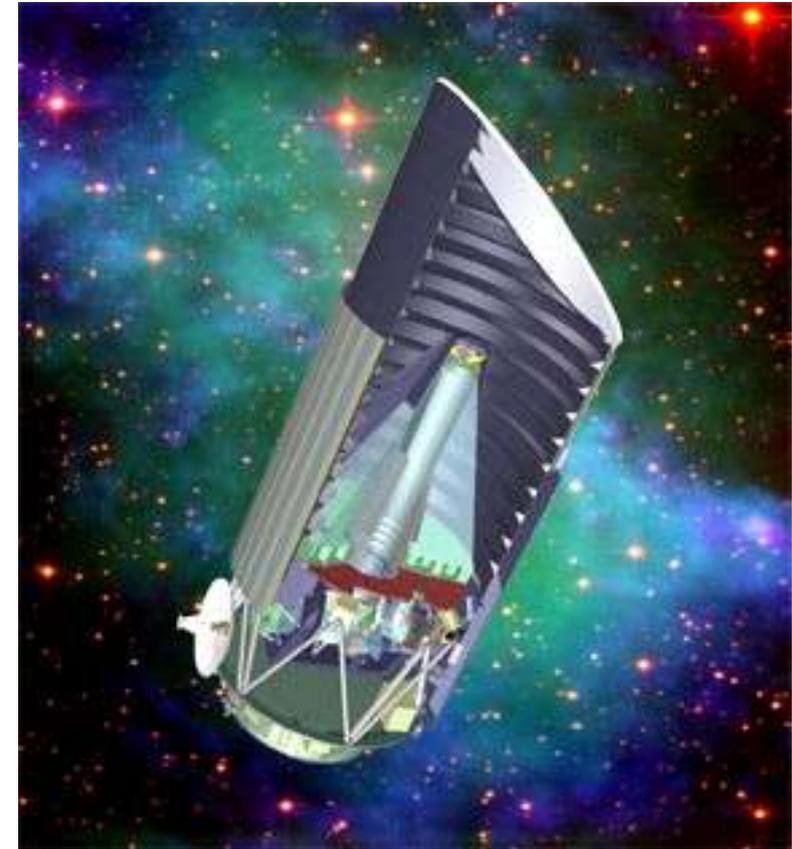
- **SDSS SEGUE**
 - Yanny
- **Non-SDSS gravitational lenses**
 - Kubo
- **Planet search**
 - Steffen
- **Chalk talks**
 - 20 minutes max, no visual aids

On the horizon

- **Long-term archiving plans**
 - **Maintain 2 copies of complete archive in tapes robots at separate locations (FCC, GCC)**
 - *Disaster mitigation - Story of Macho project and Mt. Stromlo fire.*
 - **Keep public version (a subset of complete archive) "spinning"**
- **AS2 (After Sloan-II)**
 - **4 projects have been selected. 6 years operations.**
 - **FNAL participation TBD - we provide an enormous amount of support currently.**
 - **Disposition of FNAL equipment**

SNAP/JDEM

- **JDEM: Joint DOE/NASA Dark Energy Mission**
- **SNAP: DOE project proposed as the JDEM experiment.**
- **Science: Precision Dark Energy**
- **Techniques:**
 - **Supernovae redshifts out to $z=2$**
 - **Wide area hi-res Weak lensing**
- **Strengths:**
 - **High statistical precision (2000 objects)**
 - **High systematic precision**
- **Timescale: launch beyond 5 year horizon**



SNAP - FNAL Tasks and Resources

Tasks

- **Software & Simulations**
- **Calibrations**
- **Electronics**
 - Mass Memory
 - FPGA controllers
 - ASICs
- **CCD testing**
- **CCD packaging (new)**
- **(radiation shield)**
- **(wide area science)**

Resources

- **FTEs - relatively constant**
 - 2.25 Scientist (1.1 from CD)
 - 3.75 Eng/CP/Tech (2 from CD)
- **M&S**
 - \$68K per yr
- **Defining document**
 - letter to Mike Witherell (augmented by MOU's with LBNL)

SNAP Risk List

SNAP Risk List

Rev E

Risk Nr.	Initiator	Initiation Date	Owner	Condition	Possible Consequence(s)	Context	Prob. occur	Impact	Rank	NASA Color	Current mitigation activities
20	Heetderks	2004-01-20	Heetderks	It is proposed to separate the instrument optics from the rest of the instrument and procure each on a separate AO	Would split the well-integrated SNAP instrument into 2 parts >> Greatly complicates the design of the resulting fragments >> Very large impact on both cost and schedule		3	5	22	Red	
3	Kujawski	2002-00-00	Bebek	SNAP mission depends on the development of a modified NIR detector	If new detector development is not successful, Science requirements may not be met		3	5	22	Red	Development contracts in place with two vendors.
16	Kujawski	2002-00-00	Pankow	Instrument requires a shutter mechanism For operation of visible CCD's	Mechanism may fail on orbit >> Drastic reduction of science yield		1	5	15	Yellow	Need activity here?
4	Kujawski	2002-00-00	Ealet	Spectrograph optics include an image slicer design which has not been flown in space	Specs not met >> Fail to fulfill science		1	5	15	Yellow	Space qualification of slicer and rest of optics is on going
14	Kujawski	2002-00-00	Lampton	Instrument I&T requires complex and difficult testing	1) Cost and schedule may exceed estimates 2) Testing may be compromised >> Hubble like failure		2 1	3 5	8 15	Green Yellow	Development of I&T flow is an on going activity
1	Kujawski	2002-00-00	Bebek	Science requires a CCD with better specs than current state of art (under dev't at LBNL)	1) Specs not met >> Fail to fulfill science 2) Yield or mfg. problems >> Cost, schedule impact		2 1	4 2	14 3	Yellow Green	Major effort on LBNL CCD dev't: Substantial progress made.
11	Kujawski	2002-00-00	Pankow	Science system design requires ACS specs near high end of state of art	Specs not met >> Science yield is reduced		2	4	14	Yellow	1) Industry studies performed 2) UCB group developing complete SNAP ACS model
21	Heetderks	2004-01-20	Pankow	Dither requirements on SNAP ACS are not well understood or clearly defined	Spacecraft vendor may have difficulty in understanding and hence in meeting the requirements >> Fail to fulfill science		3	2	11	Yellow	Science team working on spec
2	Kujawski	2002-00-00	Lampton	Science puts stringent requirements on instrument optic design	Specs not met >> Fail to fulfill science		1	4	9	Green	Major effort on optics dev't. Visible conceptual design done.
10	Kujawski	2002-00-00	Deustua	Need absolute photometric calibration of ~1% to achieve full science requirements	Specs not met >> Science yield is reduced		2	3	8	Green	Study in process
17	Kujawski	2002-00-00	Jelinsky	Careful thermal design is required to insure that instrument operates correctly	Specs not met >> Science yield is reduced		1	3	6	Green	Substantial effort underway on thermal eng'ring of instrument
18	Kujawski	2002-00-00	Jelinsky	Spacecraft must be placed in correct orbit to meet science requirements	Correct orbit not attained >> Science yield is reduced		1	3	6	Green	1) LBNL developing orbit capability 2) GSFC orbit study planned
19	Heetderks	2004-01-20	Levi	Requirements on filters not defined	Development more difficult than anticipated >> Cost and schedule impact		2	2	5	Green	Requirements definition is now well under way
6	Kujawski	2002-00-00	Lippe	CRIC ASIC is new design with stringent power, noise, & rad specs	Specs not met >> need re-design		1	2	3	Green	Major effort on CRIC ASIC design. Needed results in hand.
7	Kujawski	2002-00-00	Lippe	CCD clock circuit is new design	Specs not met >> need re-design		1	2	3	Green	Design and B/B of clock circuit is in process
9	Kujawski	2002-00-00	Heetderks	Data storage between downlinks drives need for a large space rated memory	Memory of sufficient size not available >> science data is reduced		1	2	3	Green	Study of issues underway by FNAL group

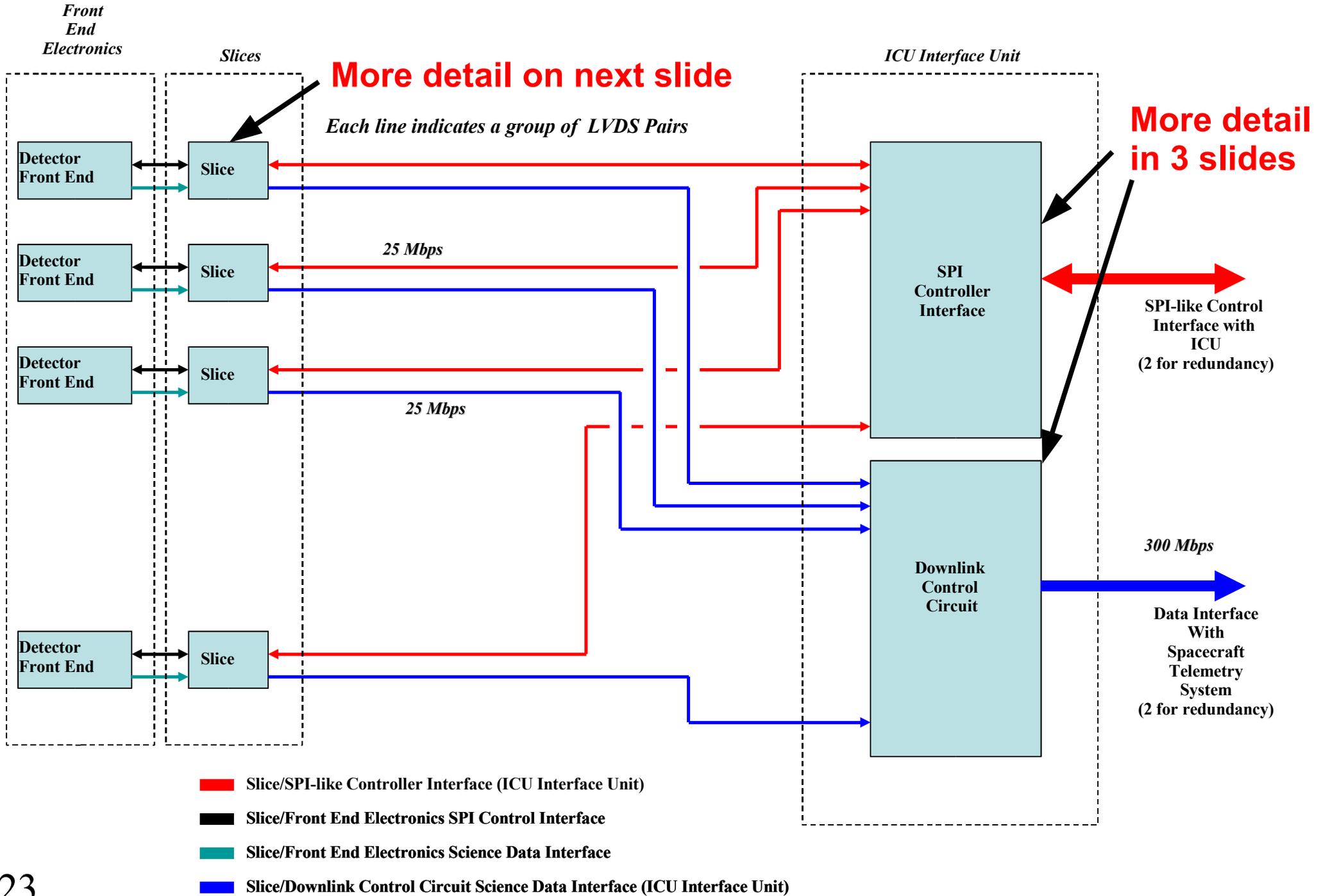
SNAP Status

- **Calibrations - July 2006 review**
 - **Proposal to CPA for Guest Scientist**
- **Simulations framework**
 - **Continuing active development**
 - **Proposal for C. Stoughton to spend ~1 yr at LBNL**
- **DOE solicitation for R&D on Dark Energy experiments -**
 - **Only FNAL component that survived is work on CCD packaging.**
 - **Funding cut from \$5 million to \$3 million(?)**
 - **Heavily oversubscribed.**

Electronics Update - Summary

- **Continuing Activities (since last project status review)**
 - **Slice Hardware/Firmware**
J. Chramowicz, J. Marriner, A. Prosser, R. Rivera (CD)
X. Chen, M. Larwill (PPD)
 - **DAQ System Engineering**
B. Haynes, J. Marriner, M. Turqueti (CD)
 - **Memory Testing Hardware/Firmware/Support**
G. Deuerling (CD)
W. Wester (PPD)
 - **ASIC Test Engineering**
S. Bledsoe, J. Chramowicz, J. Marriner, R. Rivera, A. Prosser, M. Turqueti (CD)
H. Cease (PPD), D. McGinnis (AD)

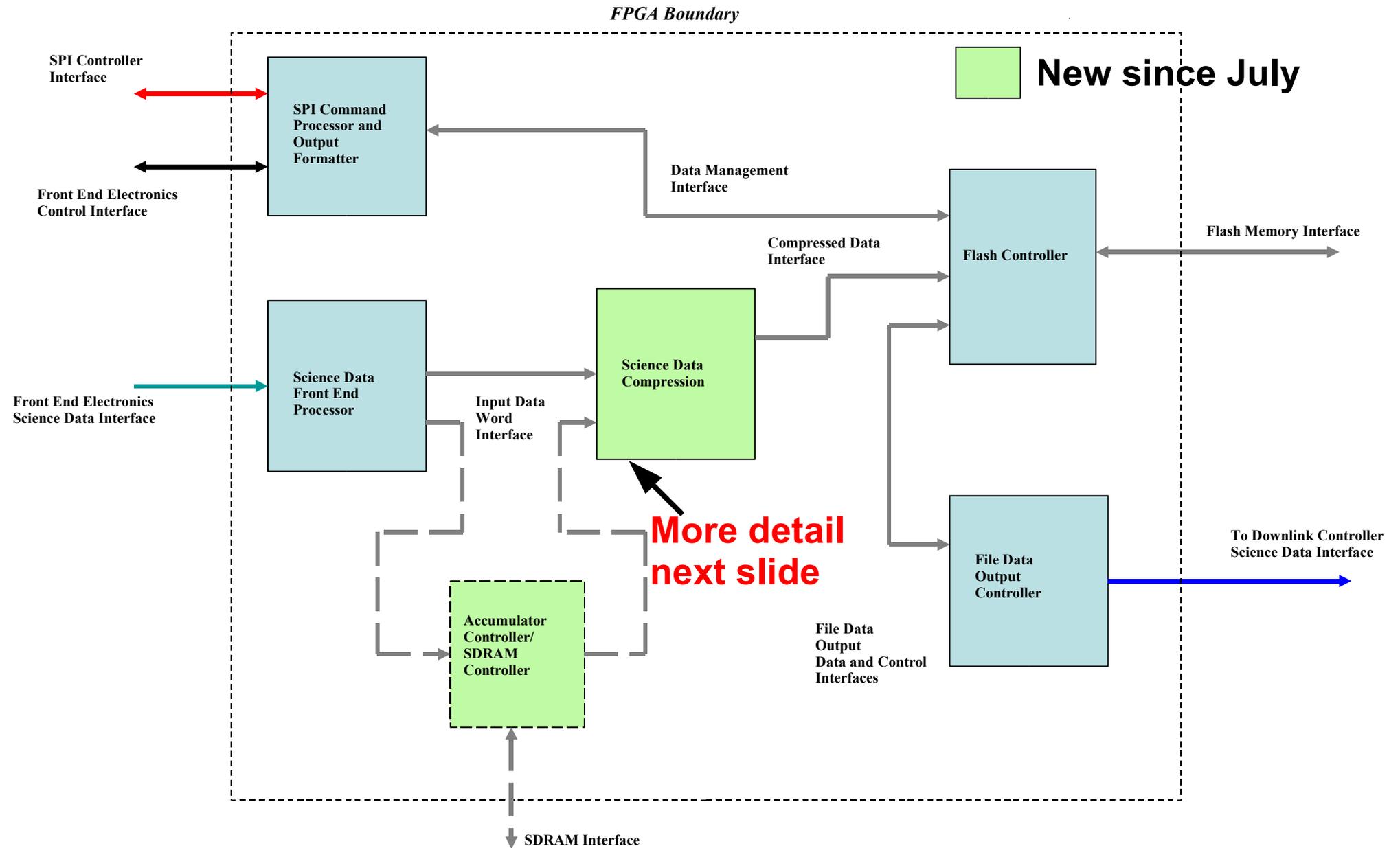
Slice Concept – DAQ and Control



Slice FPGA Functional Blocks

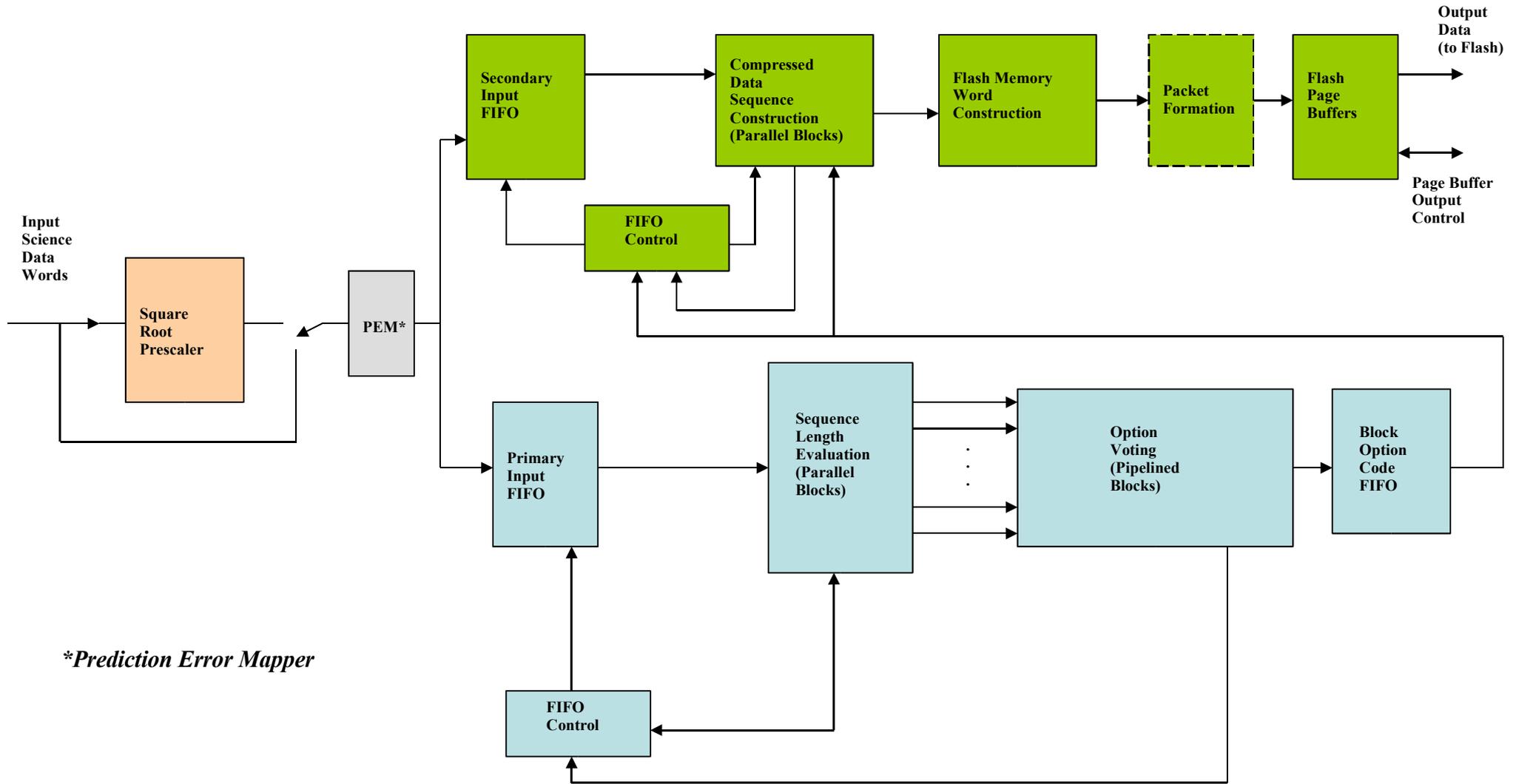
Completed Last July

New since July



Slice FPGA Functional Blocks

Science Data Compression Block



**Prediction Error Mapper*



CCSDS Compression Option Evaluation Blocks

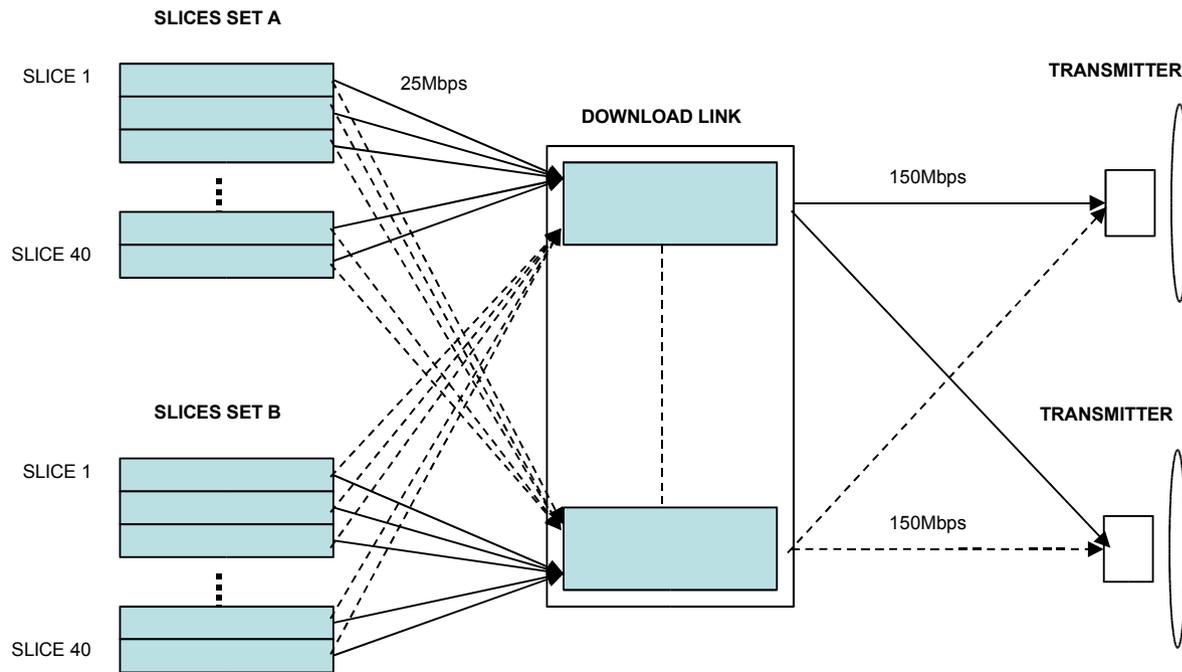


CCSDS Sequence and Memory Word Construction Blocks

DAQ System Engineering

- **Downlink Controller**
 - Provides interface between slice memories and telemetry
 - Aggregates file data from all slices for transmission to ground
- **SPI Interface Controller**
 - Interface between Instrument Control Unit and Slices, Downlink Controller
 - Protocol being developed with collaboration (G. Haller, SLAC)

THE DOWNLOAD LINK PURPOSE



- Serialize data coming from the 80 slices.
- Provide a steady traffic of data to the transmitter.
- Format the output data in transfer frames.
- If the transmitter block itself doesn't implement any of these then implement it: Convolutional encoder, Reed-Solomon, Non-return to zero encoding and Periodic convolution interleaver.

POSSIBLE SOLUTIONS

▷ ONE BY ONE WITH VARIABLE CLOCK RATE

Pros:

Simpler solution.

Cons:

Skew compromises the maximum speed.

Larger number of lines between slices and download link.

▷ MULTIPLE SLICES AT 25MHZ

Pros:

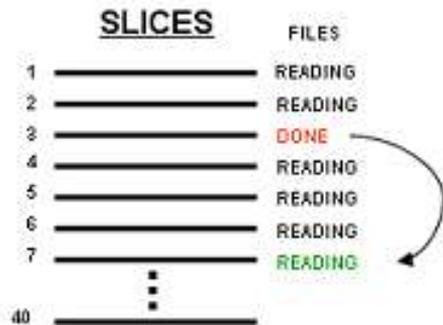
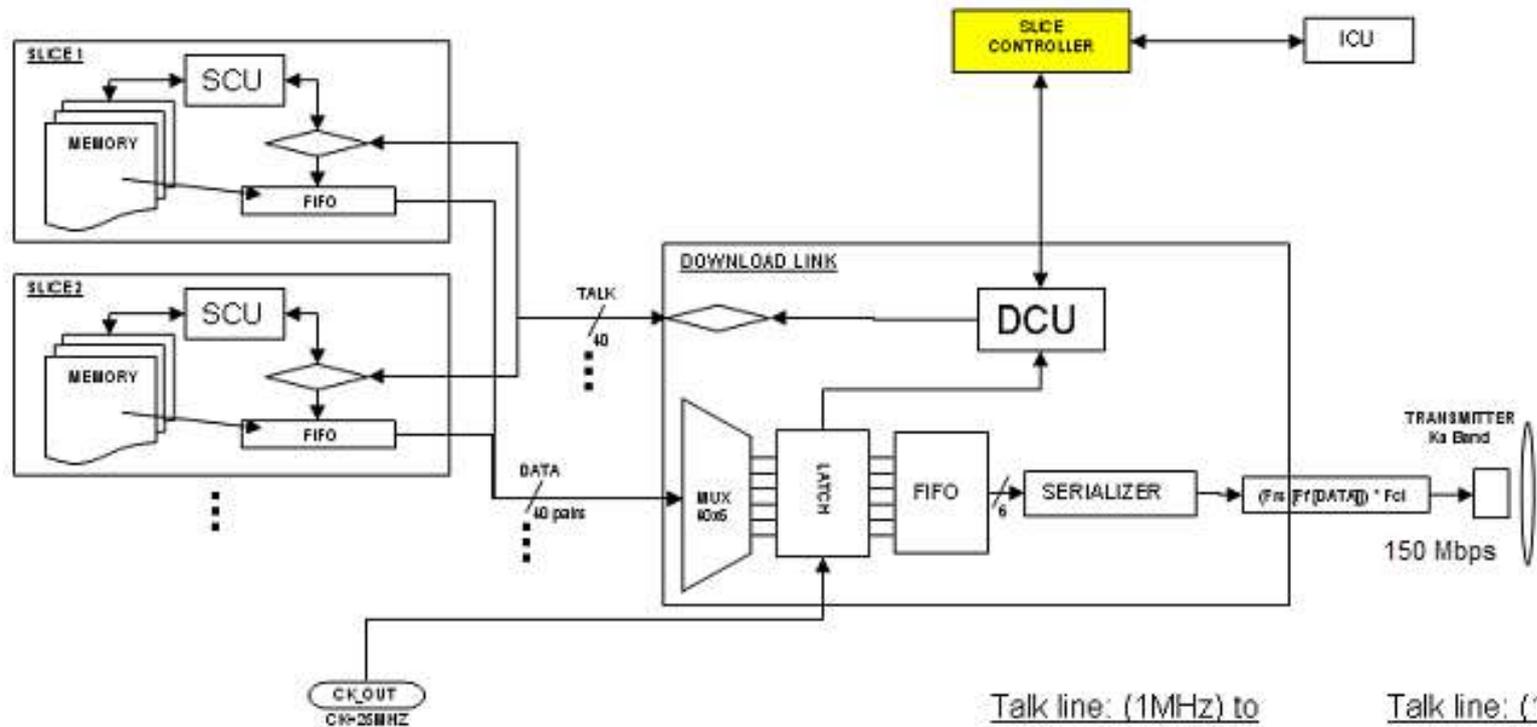
Don't use fast clocks running outside the download link block.

Smaller number of lines between slices and download link.

Cons:

More complex circuit.

MULTIPLE SLICES AT 25MHZ (Current solution being pursued)



Talk line: (1MHz) to SLICE

- Start talk - 1000
- Full speed - 1100
- Half speed - 1110
- Stop - 1111

Talk line: (1MHz) to DOWNLOAD LINK

- NO DATA - Line High

Total number of wires: 80(LVDS differential)

40(CMOS bidirectional)

ASIC Test Engineering

- **Room Temperature Tests**
 - **FRIC0 Test Hardware Built and Tested**
 - **All Functions of the ASIC are verified**
- **Cryogenic Testing**
 - **BTEV Dewar Installed in FCC3. Operating as planned**
 - **ASIC Testing Underway (full functionality, power spectra at ~140 deg K)**
 - **Special attention paid to safety – J. Chramowicz**

Flash Memory Radiation Testing

- **Testing in IUCF Cyclotron Completed in Summer, 2006**
 - **Test Hardware/Software Performed Well**
- **Further Testing Scheduled for April, 2007 at Berkeley**

SNAP - Future

- **National Academies Space Studies Board is conducting “Town Hall Meetings” to determine priority ordering of NASA's “Beyond Einstein” missions**
 - **JDEM**
 - **ConX**
 - **LISA**
 - **Inflation Probe**
 - **Black Hole Finder**
- **Next Meeting is April 4 in Chicago**
 - **Registration Deadline is March 26**



The Dark Energy Survey (DES)

DARK ENERGY
SURVEY

E939

Program:

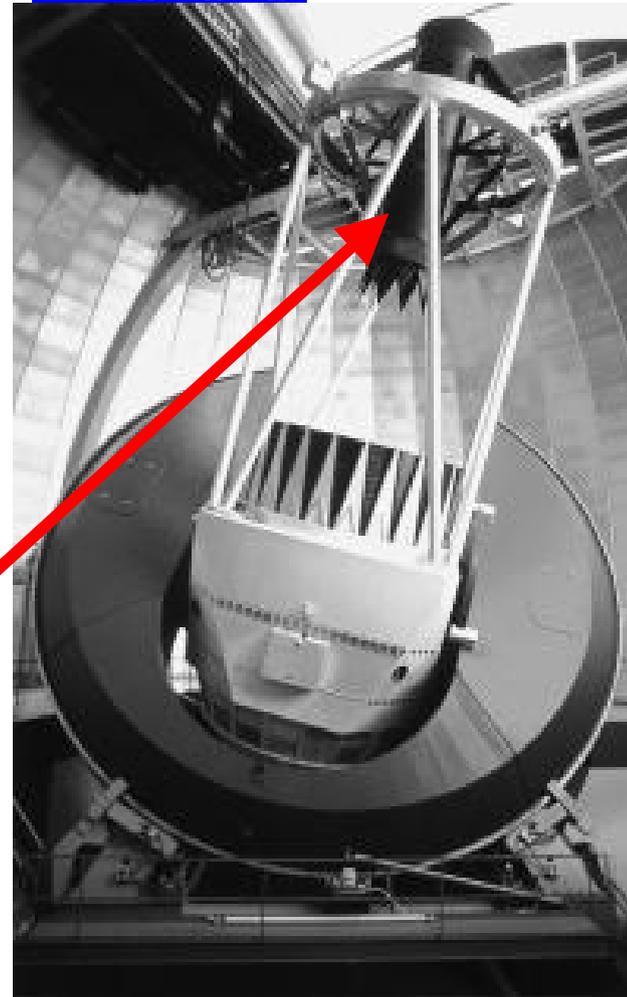
- 5000 sq. deg. survey of the Southern Galactic Cap
- Measure dark energy with 4 complementary techniques:
 - › Clusters
 - › Weak Lensing
 - › Baryon Oscillations
 - › Supernovae
- *Overlap with South Pole Telescope S-Z cluster survey*

New Equipment:

- Fermilab lead: 2.2 Degree field 512 MPixel camera
- UIUC lead: Data Management, public archive

Survey

- 5 year survey: 2010-2015
- Stage III D.E. experiment



Use the Blanco 4M Telescope at the Cerro-Tololo Inter-american Observatory (CTIO)

Update: P939 => E939

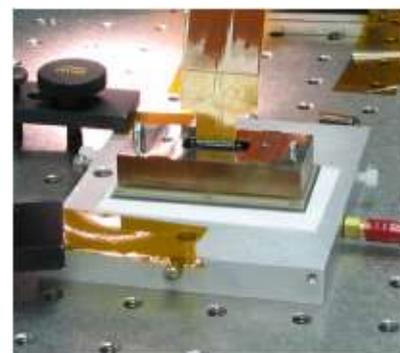
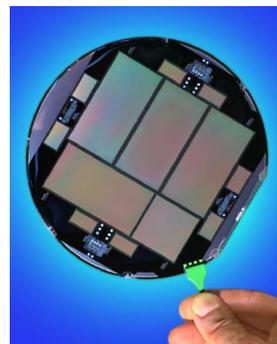
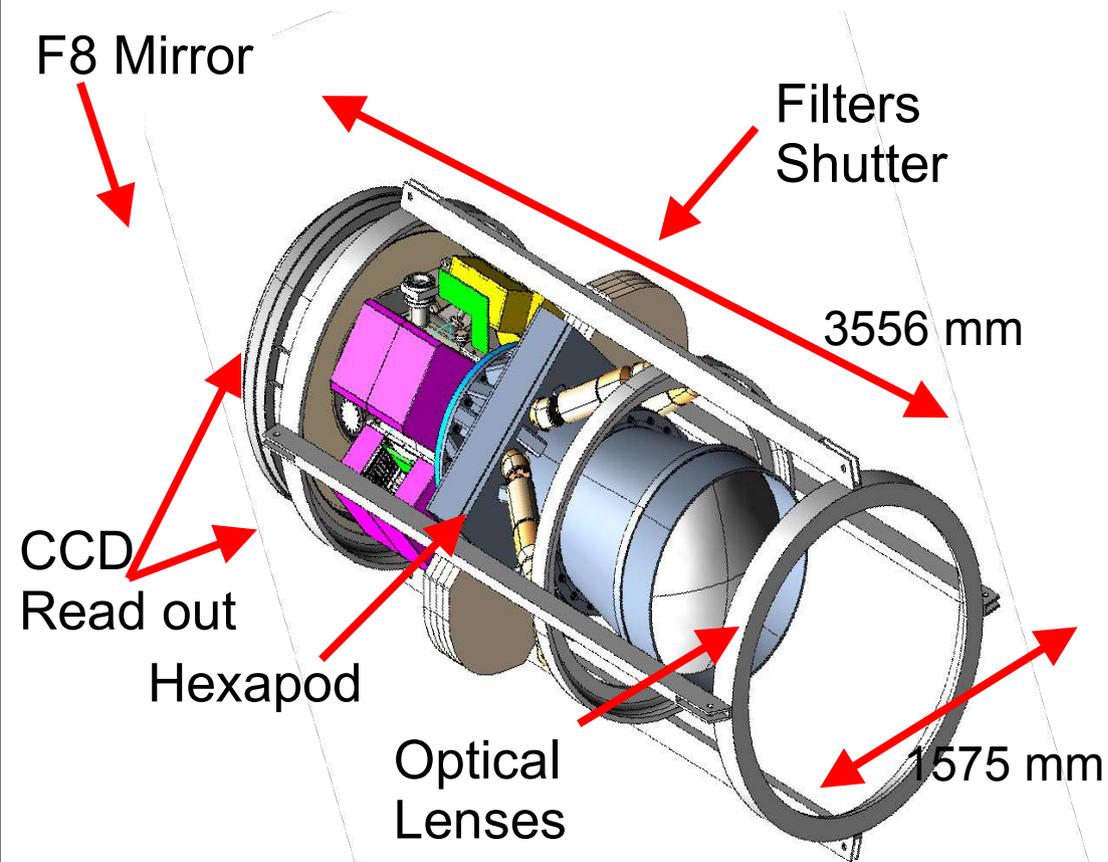


DARK ENERGY SURVEY

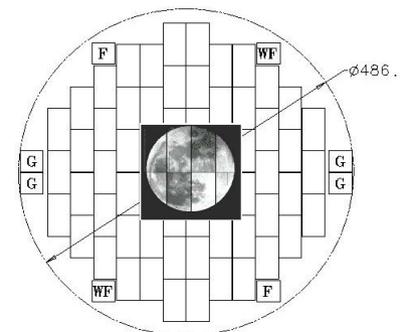
The DES Instrument: DECam

DECam will be larger than any existing CCD camera

Fermilab Role:
DECam project management
CCD packaging
CCD readout (lead)
CCD Focal plane and vessel
Optical Corrector barrel
Cage and hexapod/alignment
Simulations, Calibrations



62 2kx4k Image
CCDs: **520 MPix**
8 2kx2k Guide,
focus, alignment



UK will provide optical elements
Spain will provide production electronics

DES - CD Tasks and Resources

- **Tasks**

- **Simulations**
- **Science planning**
- **Pipeline software (calibrations)**
- **Optical design (requirements)**
- **Support CCD testing**
- **Web site, document management**
- **DAQ (Monsoon) evaluation**

- **Resources**

- **1.7 FTE - scientist**
- **.75 FTE - CP**
- **\$57K M&S**
 - **File servers**
 - **Travel**

DES – Status update

- **Tasks & Updates**

- **Simulations & pipeline software - delivered for data challenge 2 (ImSim2)**
- **Labview being integrated with SISPI system**
- **Monsoon – PPD, Barcelona making good progress fixing & upgrading HW.**
- **NSF proposal submitted Jan 2007**
- **CCD testing - moving along (mostly a PPD effort) - making good progress with HW. MySQL database now used to store test data.**
- **Optics - CDR in Mar 2006**
- **SISPI Workshop in March 2007**
- **Director's Review Data Management in March 2007 (NCSA and Fermilab)**

DES – Upcoming Events

- **CD1 Review May 1-3**
- **ImSim3**
 - **Priority M&S:**
 - **1 File Server (24 TB)**
 - **Enstore Tapes (140 TB)**
- **Collaboration Meeting (London, Sept 2007)**

NVO - National Virtual Observatory

- **Leader - Kent/Annis**
- **Status - No-cost extension to Sept. 2007**
- **Resources - summer students**
- **Accomplishments**
 - **Testing of numerous NVO software packages and web interfaces**

iVDGL Status

- **iVDGL has "morphed" into OSG**
- **Stakeholders: EAG (SDSS), DES**
- **TAM cluster continues to serve as the "tier 1" center; TAM is part of FermiGrid but is no longer available as a general compute node.**
- **Several SDSS (and now DES) analysis applications deployed**
 - **Cluster finder - DONE**
 - **Southern Coadd - Continuing**
 - **Quasar spectrum template fitting - DONE**
 - **DES simulations for ImSim - Continuing**
 - **NEO search - Continuing**
 - **All SDSS data processing runs on FermiGrid - Continuing**

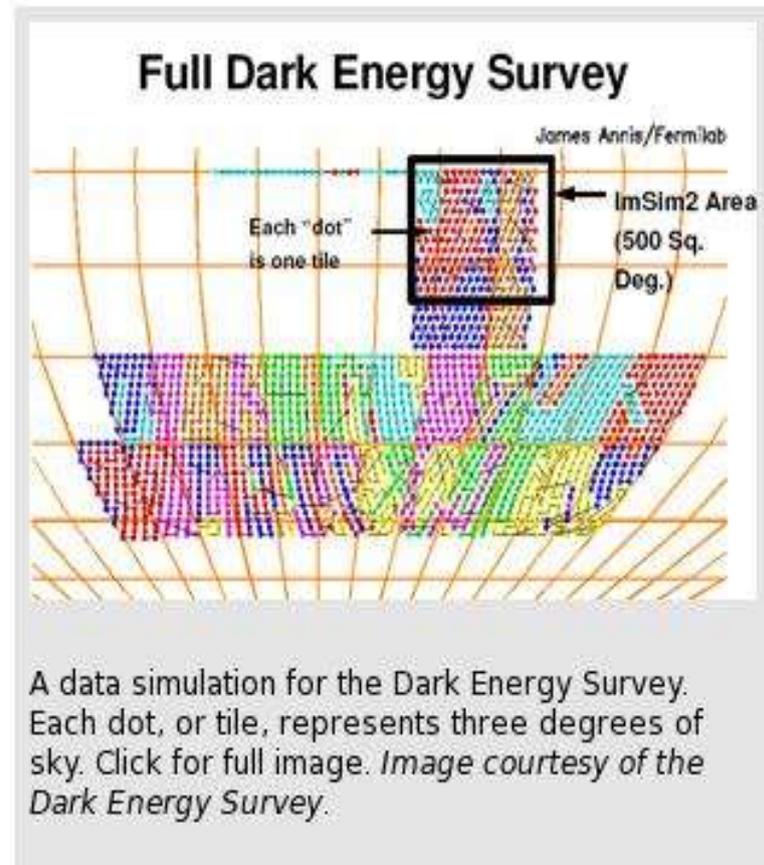
Recent ISGTW Publicity

Image of the Week - Dark Energy Survey on OSG

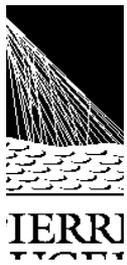
The Dark Energy Survey will image 5,000 square degrees of sky in the Southern Hemisphere as part of its investigation into dark energy. Surprisingly, the expansion of the universe is accelerating. Dark energy is thought to be responsible for this phenomenon.

The DES experiment, proposed to start operations in 2010, is already using grid computing. Currently DES is computing astrophysical data simulations on the Open Science Grid to prepare the data management systems to receive and analyze data in a series of "data challenges."

To learn more visit the DES [Web site](#)



A data simulation for the Dark Energy Survey. Each dot, or tile, represents three degrees of sky. Click for full image. *Image courtesy of the Dark Energy Survey.*



The Pierre Auger Project (E881)

A new cosmic ray observatory to study

The Highest Energy Cosmic Rays

$>10^{19}$ eV

Energy Spectrum - Direction - Composition

Two Large Air Shower Detectors

Mendoza, Argentina (construction underway)

Colorado, USA (in planning)



Surface detector station

1600 total

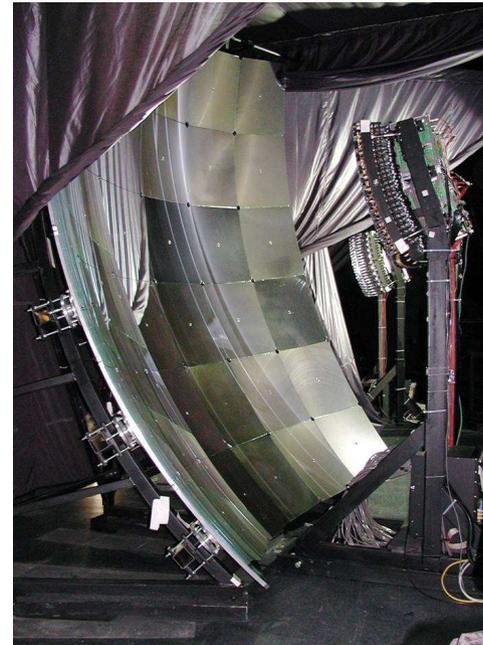
Status

Construction

Commissioning

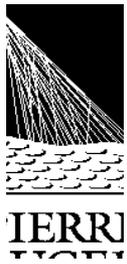
Data taking

First Results in 2005



Fluorescence telescope

24 total



The Auger Collaboration

Participating Countries - 63 Institutions, ~269 Scientists

Argentina

Australia

Bolivia*

Brazil

Czech Republic

France

Germany

Italy

Mexico

Netherlands**

Poland

Portugal**

Slovenia

Spain

United Kingdom

USA

Vietnam*

****Associate countries***

*****New countries***

Support

DOE, NSF – Funding agencies in 15 other countries. US support about 25%.



Fermilab Participation

- **Fermilab Participation**
 - **Scientists – 5 full time + 2 Part time+1 postdoc**
 - **Opening for 1 new postdoc**
 - **Staff – 2 full time**
 - **Activities**
 - **Project Management**
 - **Construction**
 - **Commissioning**
 - **Data analysis**
 - **Group size – approximately constant; may grow slightly as Auger North evolves.**
- **Funding**
 - **~\$250K M&S/yr – mostly travel and project office support**

Current Status

- **1296 of 1600 tanks deployed**
- **Last of fluorescence detectors saw first light in Feb 2007**
- **Auger North in planning/design phase.**

Software infrastructure

- **Support of augerd1**
 - Filling nicely, good for a year or two (62 % full).
- **MySQL server on augerd1**
 - Used for calibration data
 - Auger collaborators are invited to connect and get data from it
- Access to the FermiGrid for access to Offline reconstruction of our sample, with 16 nodes max allocated
- Paul L. is doing analysis of the Surface Detector (SD) calibration rates, looking for an explanation of the diurnal variation.

CDMS - Direct Detection of Dark Matter (E891)

CDMS Collaboration at Soudan



CDMS Institutions

DOE Laboratory

Fermilab

LBNL

DOE University

Brown

Minnesota

Stanford

UC Santa Barbara

NSF

Case Western Reserve

Colorado (Denver)

Santa Clara

UC Berkeley

Other

Caltech

Florida

Fermilab role in CDMS

- **Scientific (3 FTE → 4 FTE)**
 - 3 Scientist + 1 postdoc
 - Project Manager, Soudan operations and infrastructure, cryogenics, electronics, analysis, electronics, analysis
 - Need another scientist/postdoc
 - Cryogenics/detector/electronics interface + analysis
- **Technical and Administrative (4 FTE → 7 FTE)**
 - Engineering/Technicians -> New cryogenics, electronics
 - 0.25 FTE administrative (need more project management help)
- **Budget (2006)**
 - \$0.5M M&S
 - \$1.3M Labor

CD Participation and Status

- **Updates**
 - DAQ support
 - Some support for compute clusters at Soudan, FNAL
 - **40 retired nodes from CDF now set up as a cluster for near-realtime analysis**
 - **Plans to ship data over network**
- **Status**
 - **Currently taking data (20 GB per day) – continue for another ~ 1 yr**

CDMS - Future

- **P5, FY 2008 roadmap: "We recommend the start of construction on ...**
 - **The next phase of the Cryogenic Dark Matter Search experiment, using a 25 kg detector deep underground to significantly extend our sensitivity for direct detection of dark matter.**

Summary

Fermilab Experimental Particle Astrophysics Program is vibrant, with multiple operating and planned experiments

Each operating experiment is a world-leader in its particular field

Vision for the future: precision experiments to investigate what the universe can tell us about dark matter, dark energy, and the most energetic particles