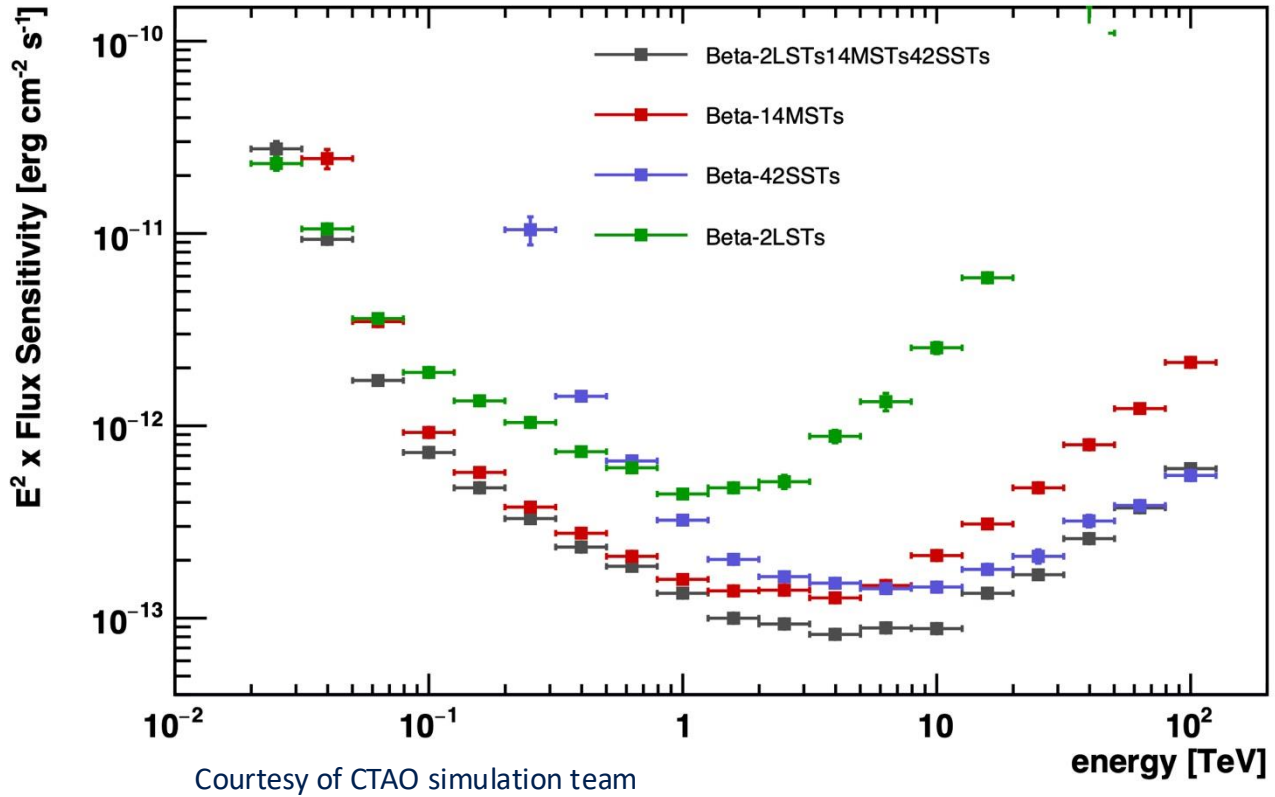
SST Programme

CTAO | SST COLLABORATION

The Small-Sized Telescopes of CTAO:
status and future development

Gianpiero Tagliaferri on behalf
of the CTAO *SST Consortium*

The CTAO in context (alpha configuration performance)



Courtesy of CTAO simulation team

3 types of telescopes:

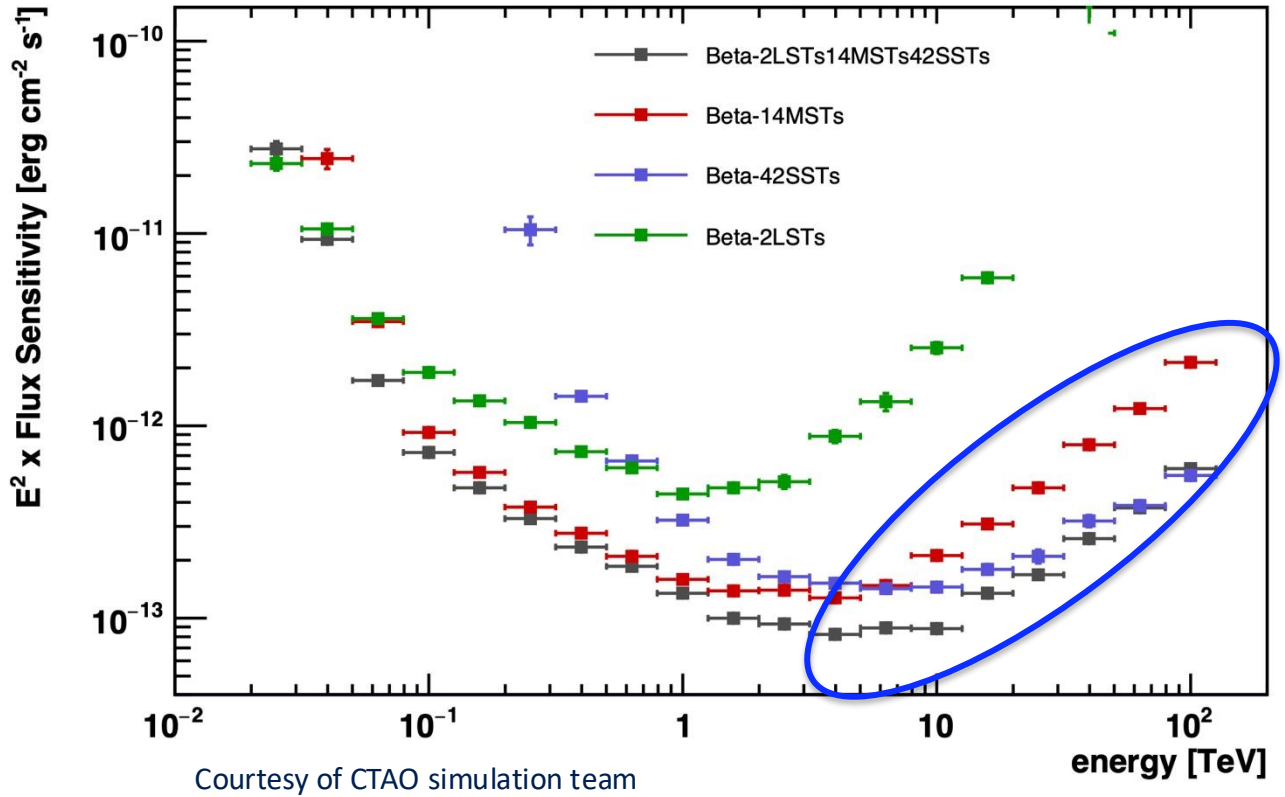
- LST (23m diameter)
- MST (12 m diameter)
- **SST (4m diameter)**

CTAO-N => 4 LST + 9 MST

CTAO-S => 14 MST + **37 SST**

(from Italian PNRR: +2 LST + **5 SST**)

The CTAO in context (alpha configuration performance)



Courtesy of CTAO simulation team

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SST: a dual-mirror Cherenkov telescope

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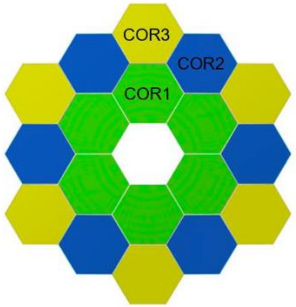
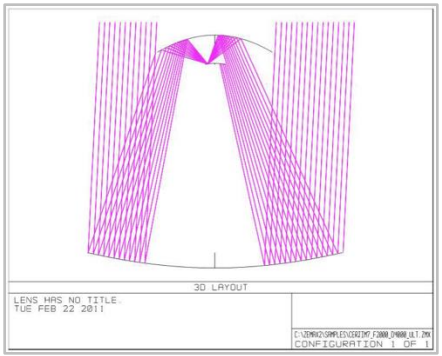
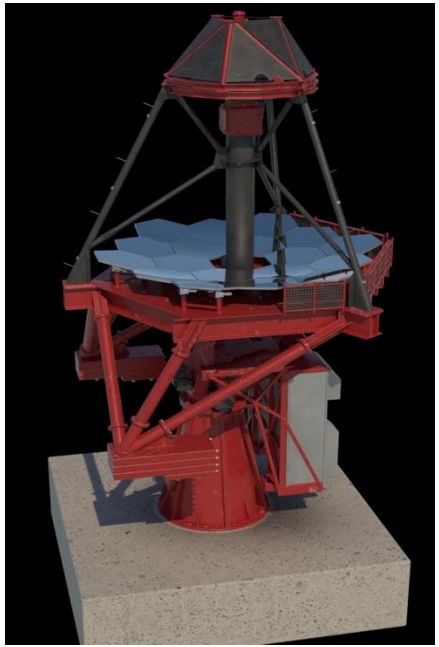
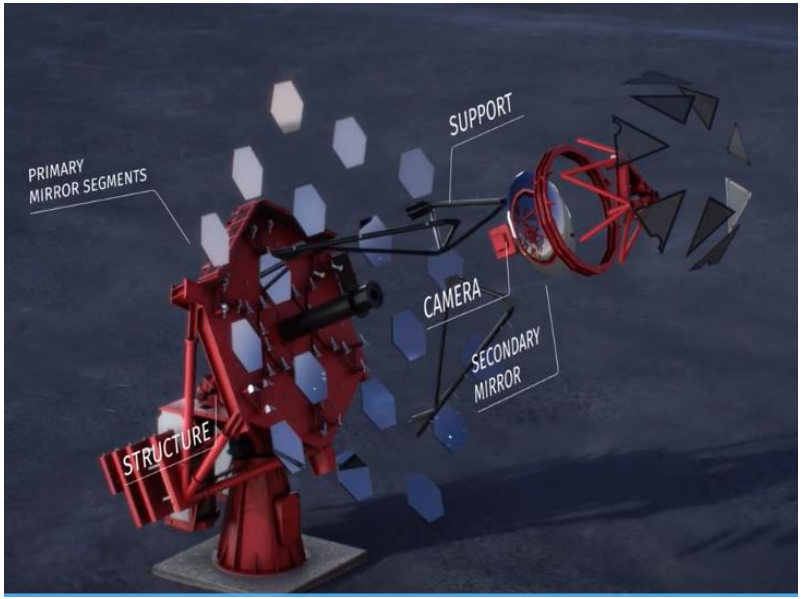
Segmented primary mirror design



The SST optical system is based on a slightly modified dual-mirror Schwarzschild-Couder design







Top level SST Telescope Requirements

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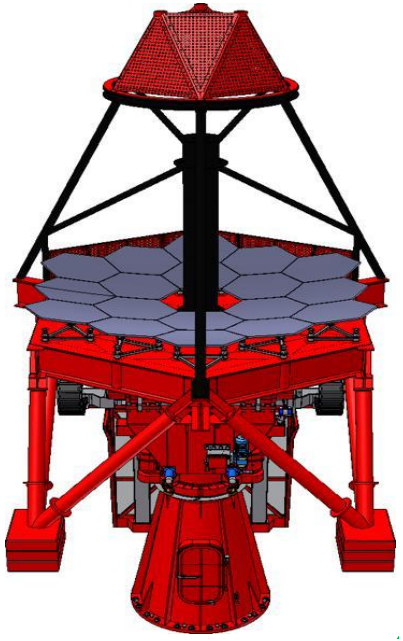

	Smal-Sized Telescope (SST)
Required energy range	1 Tev - 300 TeV
Energy range (in which subsystem provides fully system sensitivity)	5 TeV - 300 TeV
Number of telescopes	37 (South) alpha configuration (+ 5 from Italian PNRR funds) 0 (North)
Optical Design	Schwarzschild-Couder
Primary reflector diameter	4.3 m
Secondary reflector diameter	1.8 m
Effective mirror area (including shadowing)	>5 m2
Focal lenght	2.15 m
Total weight	17.5 t
Field of view	8.8 deg
Number of pixel in SST-CAM	2048
Pixel size (imaging)	0.16 deg
Photodetector type	SiPM
Telescope data rates (before array trigger)	>600 Hz
Telescope data rates (readout of all pixels; before array trigger)	2.6 Gb/s
Positioning time to any point in the sky (>30° elevation)	90 s
Pointing Precision	< 7 arcsecs
Obsevable sky	Any astrophysical object with elevation > 24 degrees

SST: the actors

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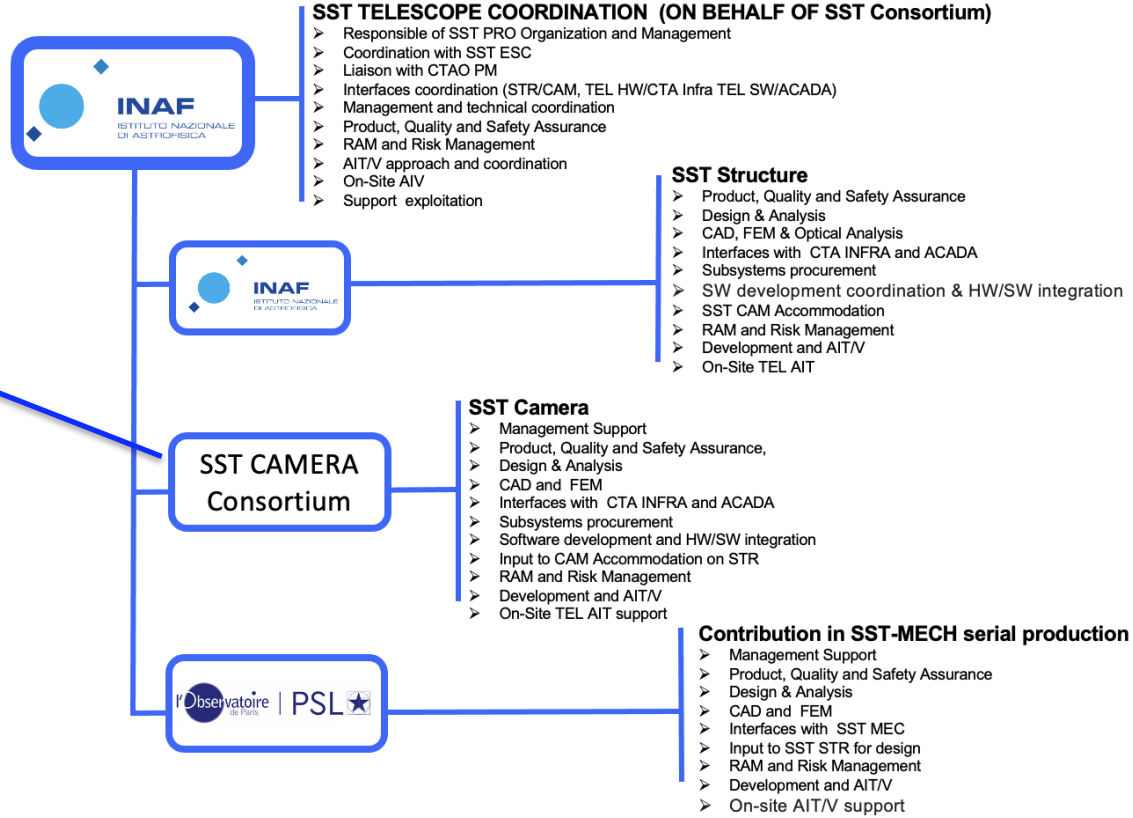
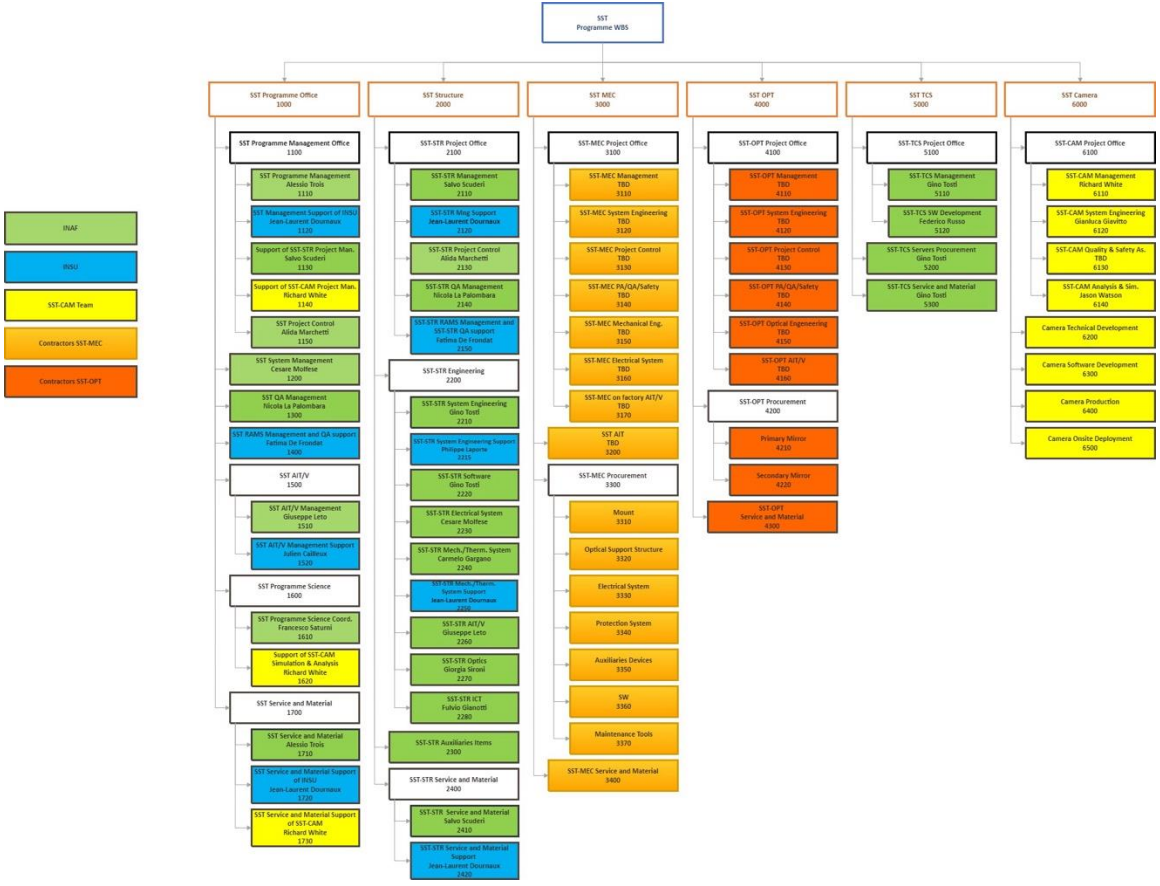
SST Camera Consortium

- **DE:** MPIK, DESY, ECAP
- **UK:** Universities of: Durham, Leicester, Liverpool, Oxford
- **NL:** UvA, Groningen
- **JP**: Nagoya
- **AU**: Universities of: Adelaide, Western Sydney, Sydney, Australian National, New South Wales, Monash, Curtin

The **IAG-USP** Institute from Brazil will contribute to the AIT/AIV activities in Chile



SST - WBS


SST Programme WBS
SST Programme Office 1000
SST Structure 2000
SST MEC 3000
SST OPT 4000
SST TCS 5000
SST Camera 6000
SST Programme Management Office 1100
SST Programme Management Alessio Trois 1110
SST Management Support of INSU Jean-Laurent Dournaux 1120
Support of SST-STR Project Man. Salvo Scuderi 1130
Support of SST-CAM Project Man. Richard White 1140
SST Project Control Alida Marchetti 1150
SST System Management Cesare Molfese 1200
SST QA Management Nicola La Palombara 1300
SST RAMS Management and QA support Fatima De Fronsat 1400
SST AIT/V 1500
SST AIT/V Management Giuseppe Leto 1510
SST AIT/V Management Support Julien Cailleux 1520
SST Programme Science 1600
SST Programme Science Coord. Francesco Saturni 1610
Support of SST-CAM Simulation & Analysis Richard White 1620
SST Service and Material 1700
SST Service and Material Alessio Trois 1710
SST Service and Material Support of INSU Jean-Laurent Dournaux 1720
SST Service and Material Support of SST-CAM Richard White 1730
SST-STR Project Office 2100
SST-STR Management Salvo Scuderi 2110
SST-STR Mng Support Jean-Laurent Dournaux 2120
SST-STR Project Control Alida Marchetti 2130
SST-STR QA Management Nicola La Palombara 2140
SST-STR RAMS Management and SST-STR QA support Fatima De Fronsat 2150
SST-STR Engineering 2200
SST-STR System Engineering Gino Tosti 2210
SST-STR System Engineering Support Philippe Laporte 2215
SST-STR Software Gino Tosti 2220
SST-STR Electrical System Cesare Molfese 2230
SST-STR Mech./Therm. System Carmelo Gargano 2240
SST-STR Mech./Therm. System Support Jean-Laurent Dournaux 2245
SST-STR AIT/V Giuseppe Leto 2260
SST-STR Optics Giorgia Sironi 2270
SST-STR ICT Fulvio Gianotti 2280
SST-STR Auxiliaries Items 2300
SST-STR Service and Material 2400
SST-STR Service and Material Salvo Scuderi 2410
SST-STR Service and Material Support Jean-Laurent Dournaux 2420
SST-MEC Project Office 3100
SST-MEC Management TBD 3110
SST-MEC System Engineering TBD 3120
SST-MEC Project Control TBD 3130
SST-MEC PA/QA/Safety TBD 3140
SST-MEC Mechanical Eng. TBD 3150
SST-MEC Electrical System TBD 3160
SST-MEC on factory AIT/V TBD 3170
SST AIT TBD 3200
SST-MEC Procurement 3300
Mount 3310
Optical Support Structure 3320
Electrical System 3330
Protection System 3340
Auxiliaries Devices 3350
SW 3360
Maintenance Tools 3370
SST-MEC Service and Material 3400
SST-OPT Project Office 4100
SST-OPT Management TBD 4110
SST-OPT System Engineering TBD 4120
SST-OPT Project Control TBD 4130
SST-OPT PA/QA/Safety TBD 4140
SST-OPT Optical Engeneering TBD 4150
SST-OPT AIT/V TBD 4160
SST-OPT Procurement 4200
Primary Mirror 4210
Secondary Mirror 4220
SST-OPT Service and Material 4300
SST-TCS Project Office 5100
SST-TCS Management Gino Tosti 5110
SST-TCS SW Development Federico Russo 5120
SST-TCS Servers Procurement Gino Tosti 5200
SST-TCS Service and Material Gino Tosti 5300
SST-CAM Project Office 6100
SST-CAM Management Richard White 6110
SST-CAM System Engineering Gianluca Gievitto 6120
SST-CAM Quality & Safety As. TBD 6130
SST-CAM Analysis & Sim. Jason Watson 6140
Camera Techeical Development 6200
Camera Software Development 6300
Camera Production 6400
Camera Onsite Deployment 6500
INAF
INSU
SST-CAM Team
Contractors SST-MEC
Contractors SST-OPT

Industrial Contracts Status

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SST-MEC Tender #1: INAF 25 SST-MEC + Telescopes Integration

- selected the Dal Ben company
- *The contract has been signed with Kick-Off on June 3rd, 2024, activities ongoing*
- *Next important milestone is the CDR (December 2024/January 2025)*

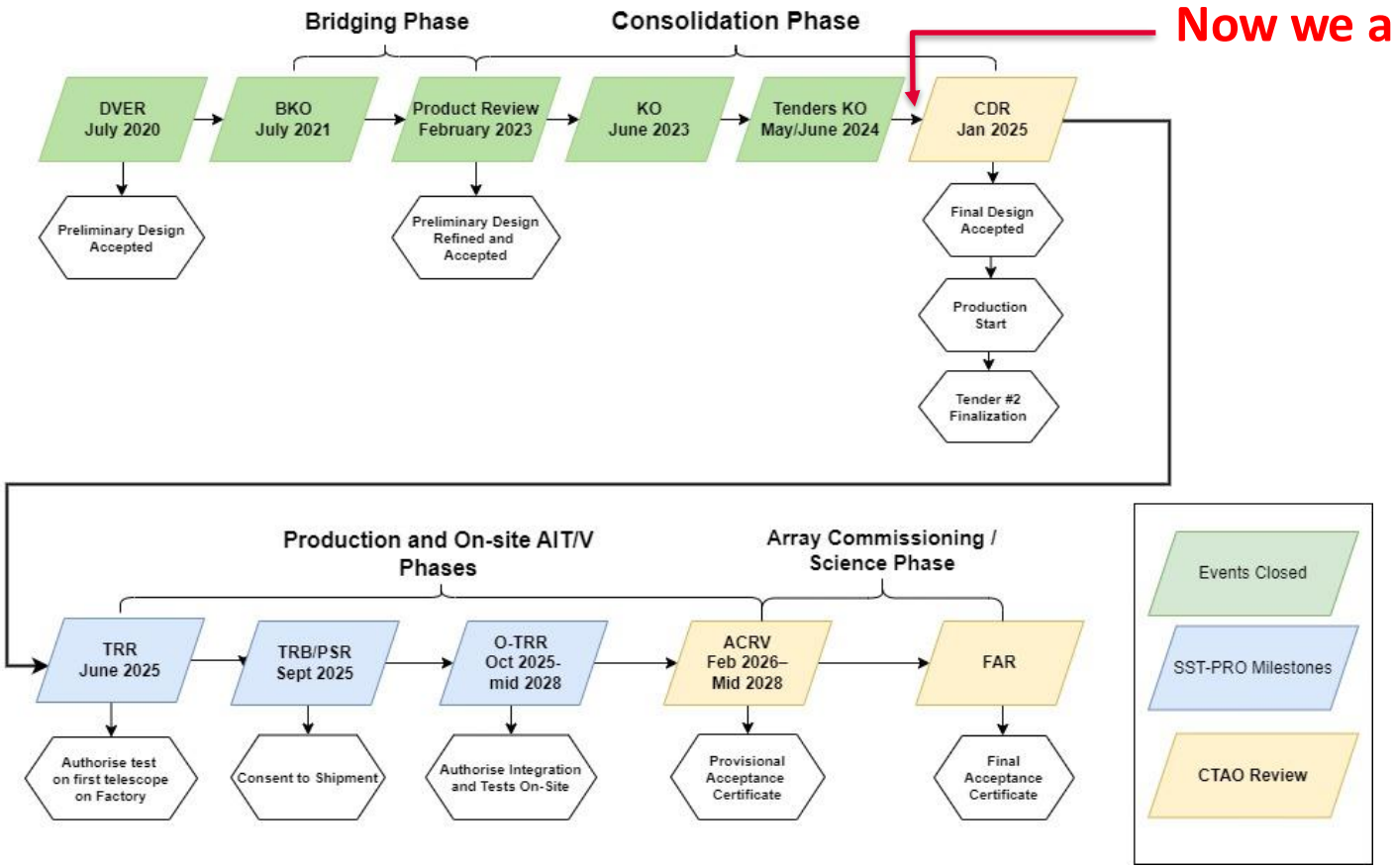
SST-MEC Tender #2: CNRS 12 SST-MEC + Telescopes Integration

- call for tender to be issued by the end of 2024

SST-OPT Tenders (INAF):

- Primary mirrors (M1): selected the Media Lario Company, the activities have just started
- Secondary mirrors (M2): contract is on going (for the first five mirrors)

SST Programme Status



SST baseline configuration

- The SST baseline configuration selected by CTAO in 2020 is based on:
  - The ASTRI-Horn prototype + the modifications introduced for the development of the ASTRI-Mini Array
  - The SST-CAM, that is an evolution of the CHEC-S camera
  - and implementing:
    - The condition/requirement for operating within CTAO
    - Possible further optimization of the mechanical design of the M1 dish

CHEC-S

SST: input from ASTRI-Horn and ASTRI-MA, lessons learnt and solutions directly tested

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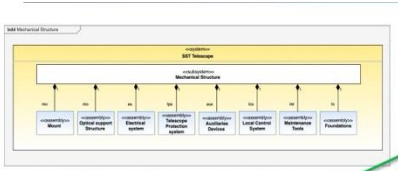
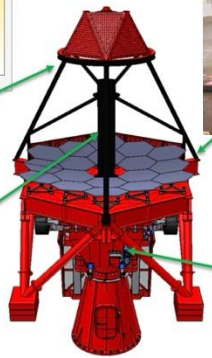
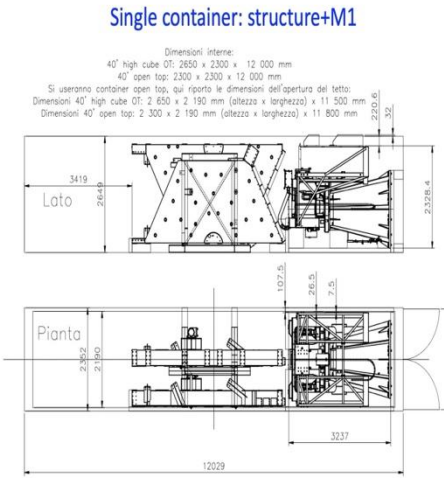


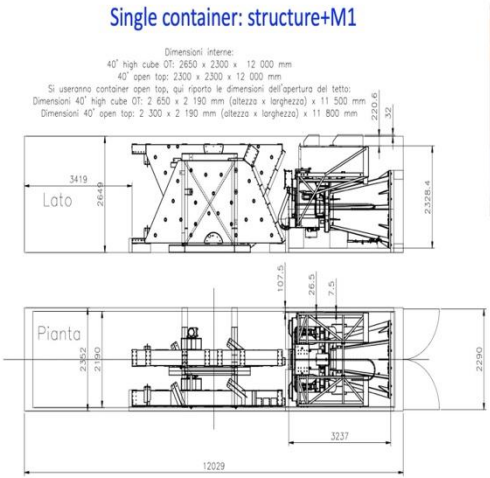
SST –STR decomposition



Single container: structure+M1



TRI-Horn and ASTRI-MA, solutions directly tested



TRI-Horn and ASTRI-MA, solutions directly tested

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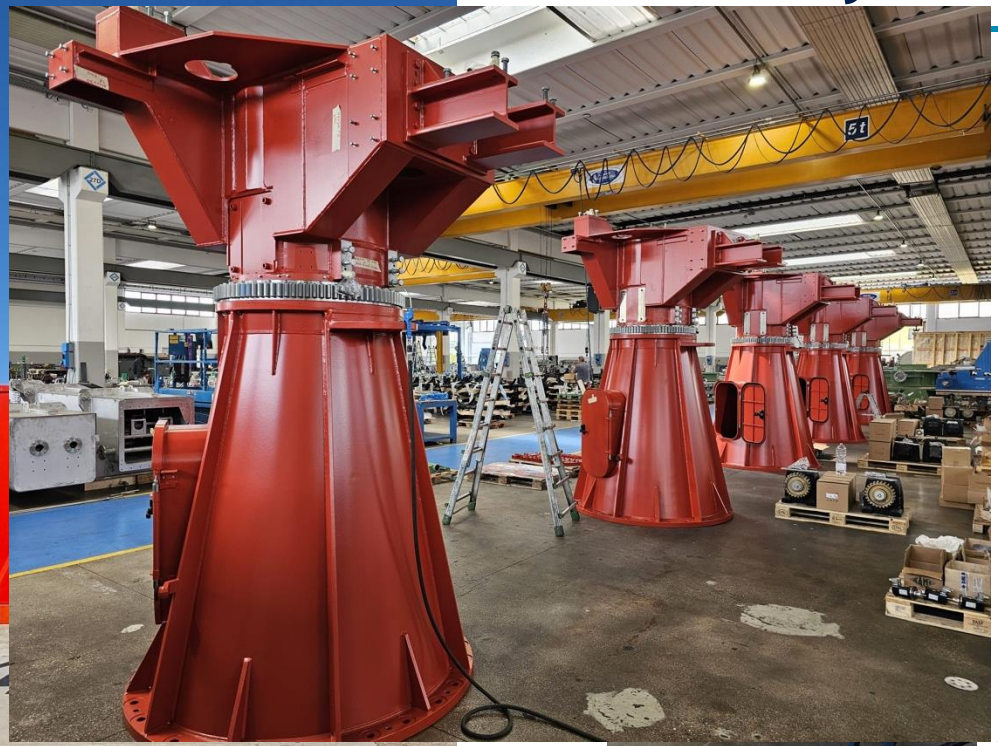

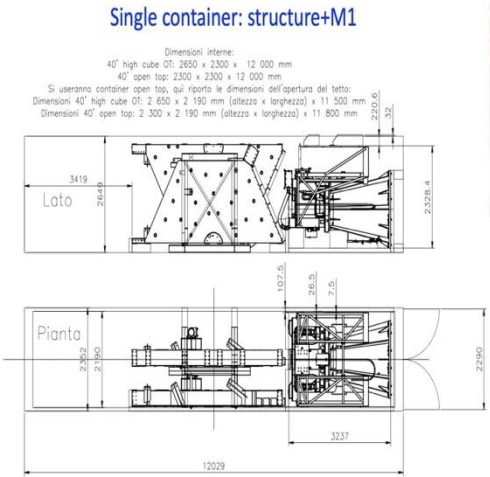

SST on-site integration plan

Feedback to SST from ASTRI-MA on-site integration

1. Install the telescope base, that includes the AZ fork & AZ motors, the electric cabinets and the EL actuator
2. Perform the base levelling and grouting
3. Assemble M1 dish
4. Install M1 dish
5. Assemble & install the OSS structure
6. Install the M2 support structure & Pointing Monitoring Camera
7. Install the counterweights
8. Install the M1 segments and actuators

SST-CAM
Overview

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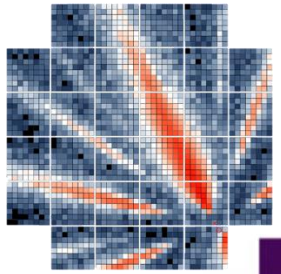
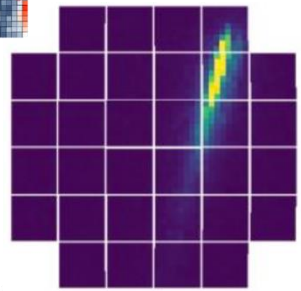
- Development based on 2 prototypes
  - CHEC-M (MAPMs)
  - CHEC-S (SiPMs)
- Low Cost, High Performance
  - Fine pixelation, large FoV
    - 32 modules of 64 pixels each
    - Tile on a radius of curvature of 1 m
    - 6 mm x 6 mm (~0.15º) pixels
    - 2048 SiPM pixels
    - 9º FoV
  - Efficient trigger & full waveform readout
    - @1GSa/s for all pixels in every event
    - Max readout rate: 1200 Hz
  - Continuous measurement of DC light
    - NSB estimation & astrometry

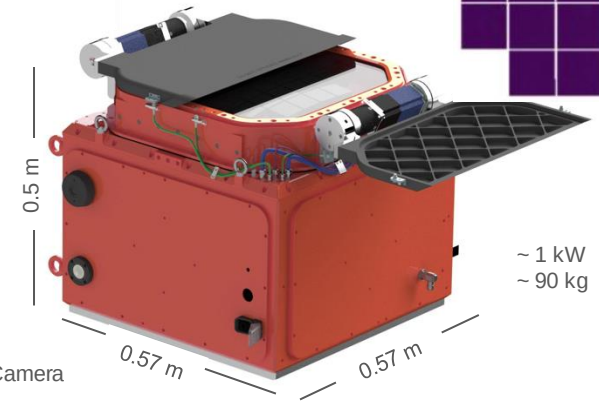
CHEC-S Prototype



Simulation:
300 TeV γ
16 SSTs

CHEC-S on
ASTRI Data





SST-Camera

~ 1 kW
~ 90 kg

SST-CAM
Camera Design

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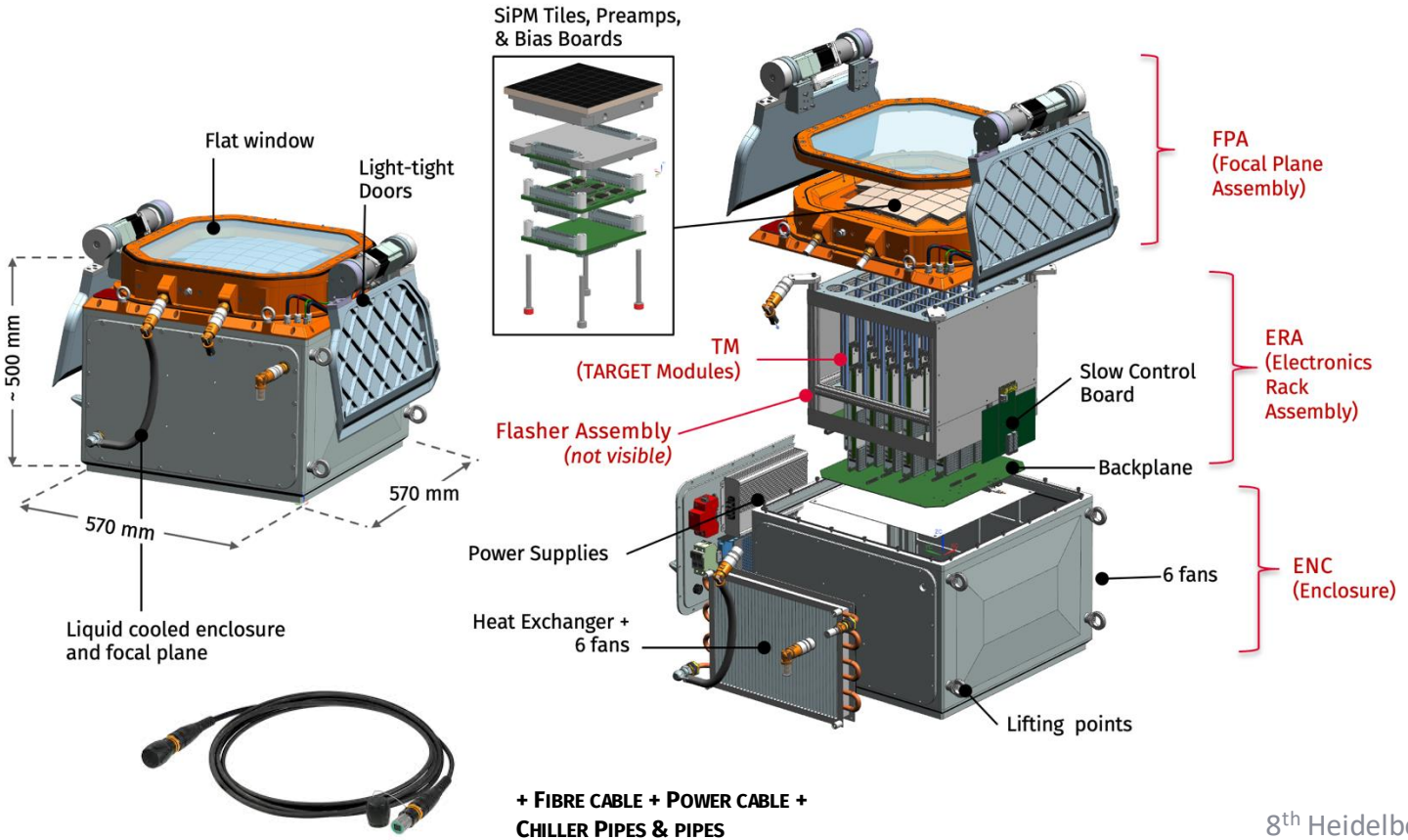

SST-CAM
Key Components

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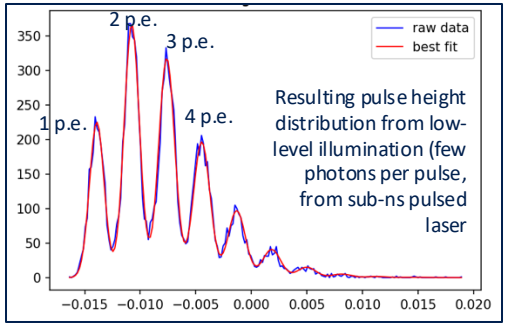
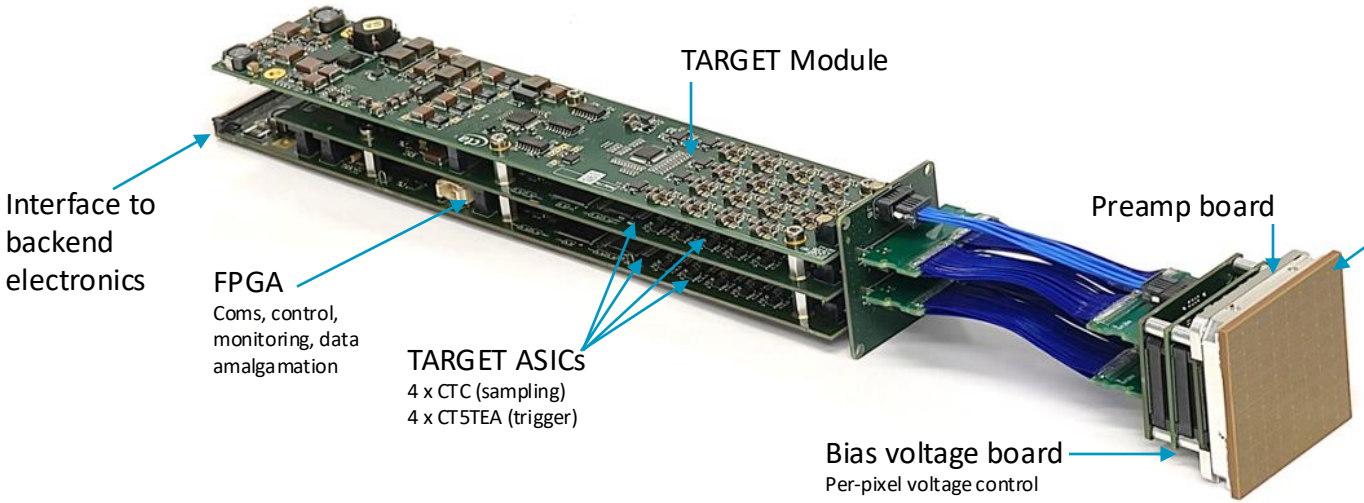
- SiPM attached to preamp boards and bias-voltage supply board
- Heatsinks coupled to liquid cooled focal plane
- Cables remove radius of curvature
- 64-channel TARGET Modules
  - Leicester & ECAP (based on TARGET ASICs)
  - Triggering, digitisation (1 Gsa/s traces), DC signal readout

TARGET
- Developed by Gary Varner (U. Hawaii)
- Details:
  - https://arxiv.org/abs/1607.02443
  - https://arxiv.org/abs/1610.015





Hamamatsu S14521–1720	
Pixel area	6.0 x 6.0 mm^2
Microcell size	50 µm
Spectral response range	220 to 900 nm
Peak PDE	58 %
Breakdown voltage V_{bd}	38±3 V
Operating Overvoltage	5.9 V
Prompt OCT probability	~ 3 %
Pixel Fill factor	74 %
V_{bd} Temperature dependence	34 mV/(°C)

Camera Design & Development

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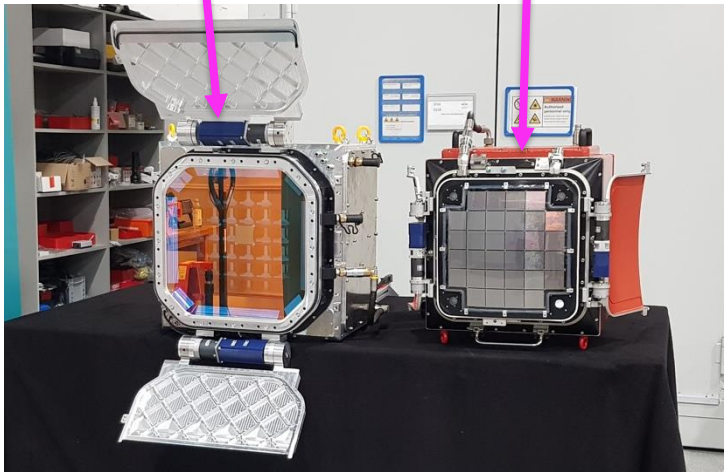
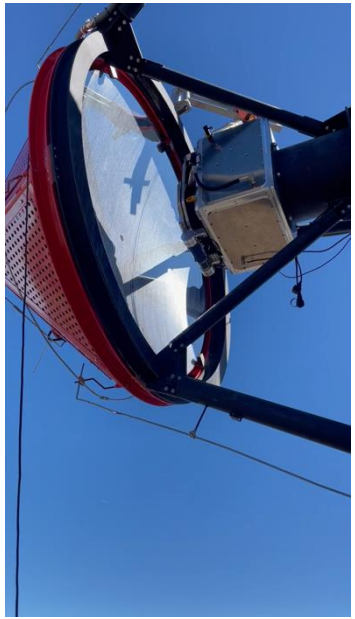
Mechanical CAM built next to the CHEC-S prototype

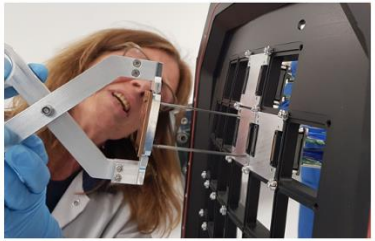


Mechanical CAM mounted on ASTRI-1 in Tenerife (November 2023)

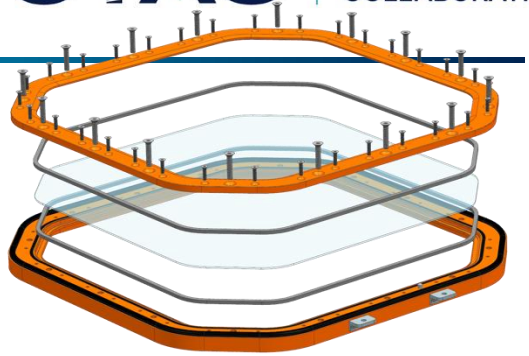


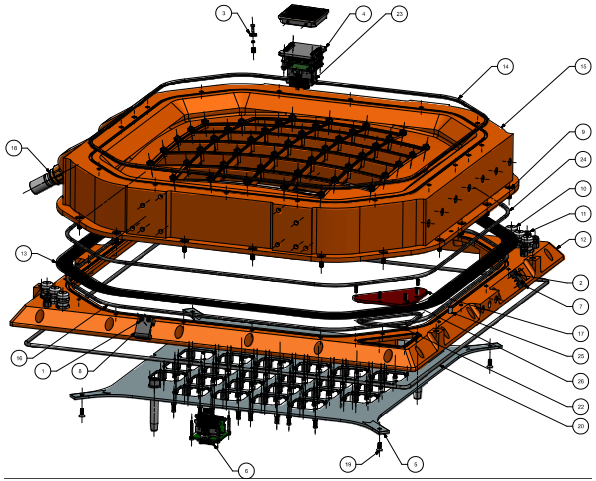
SST-CAM
Next Steps

- Autumn
  - Delivery of Quarter Backplane (supports 8 TARGET modules) with first FW release
  - Quarter Camera (QCAM) assembly setup complete
  - Production of first full (Engineering) Camera ECAM TMs in Germany
  - Send chiller & other support items to Tenerife
- By end of 2024
  - Quarter Camera (QCAM) build and test
  - Design for ECAM complete
  - Many parts for ECAM (and even batch 1) ordered or in hand
- 2025
  - On-sky tests with QCAM
  - ECAM build and test



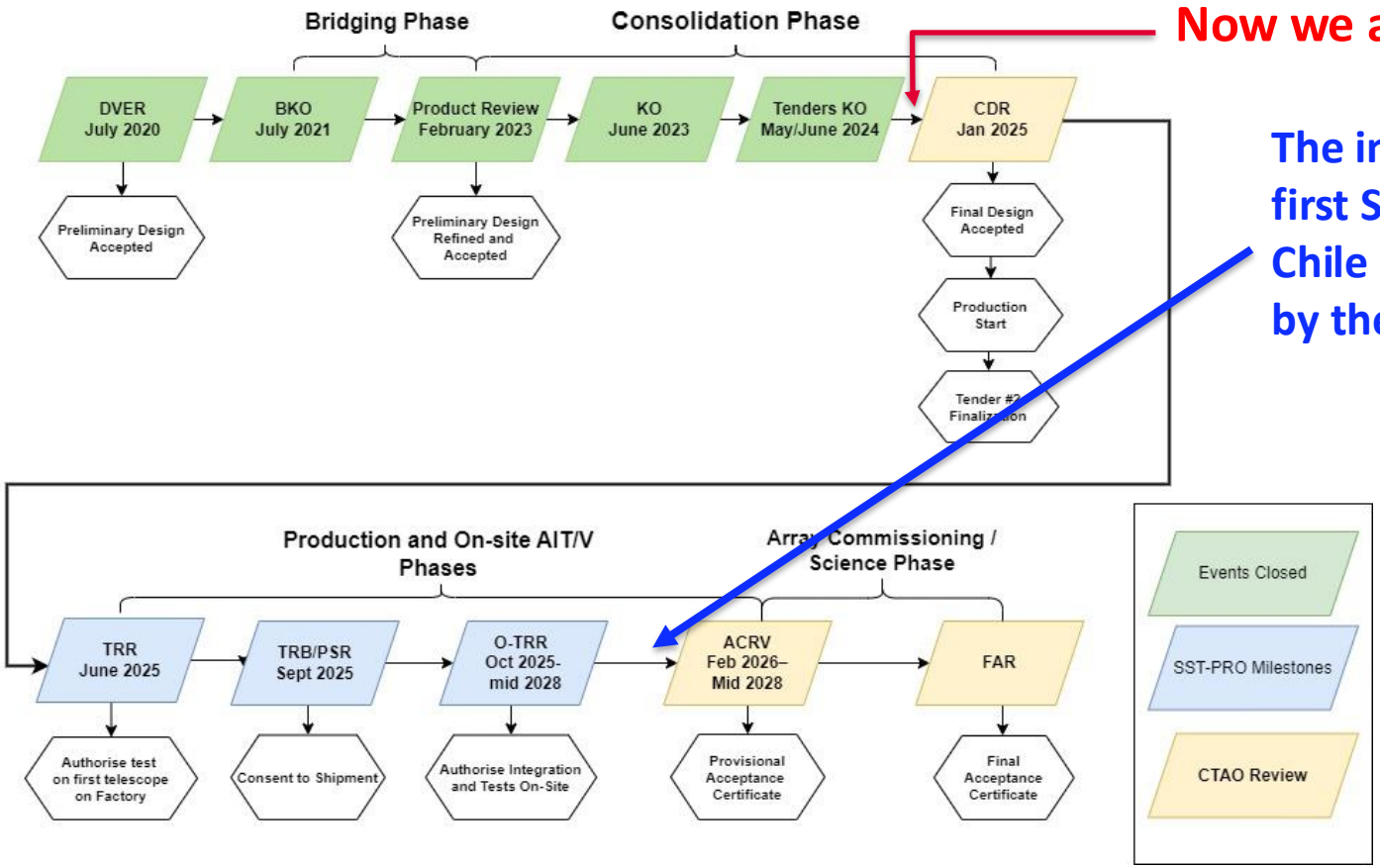
Practice of QCAM focal plane assembly.





Final design of liquid cooled camera focal plane, with window assembly

SST Programme Status



The integration of the first SST Telescope in Chile is expected to start by the end of next year

Assuming a successful CDR and that the construction of the southern site in Chile starts early next year

Conclusions

- SST baseline based on ASTRI-HORN+CHEC-S camera
- Upgrades on the electromechanical structure already introduced in the ASTRI-MA project
- Significant upgrades introduced in the SST-CAM after the CHEC-S prototype
- Further modifications introduced during the Bridging Phase, in particular on the M1 dish, and approved at the PDR (Preliminary Design Review) by CTAO
- Industrial contract assigned and ongoing to derive the final SST electromechanical structure design to be approved at the CDR (Jan 2025) by CTAO
- Good feed-back from ASTRI-MA development (on the structure, integration, transportation, etc)
- SST-CAM development is well under way, including the production of a QCAM by the end of 2024 and an engineering camera by mid-2025
- Finalisation of I/F definition, maintenance, on-site integration, logistic options are ongoing with CTAO