MIT Lab Facilities and R&D Plans

PAC meeting 12 June 97
David Shoemaker

Recent history of R&D at MIT

- finishing contributions to initial LIGO
  - PNI: high sensitivity phase measurement, suspended interferometer
  - FMI: first complete ifo configuration test, length/alignment tested
  - photodiode, optical lever, Physics Environment Monitor prototypes
  - modeling covering both design and R&D
- some forward-looking work
  - dual-recycled interferometer studies
  - organization of suspension/isolation work in community

MIT lab moving

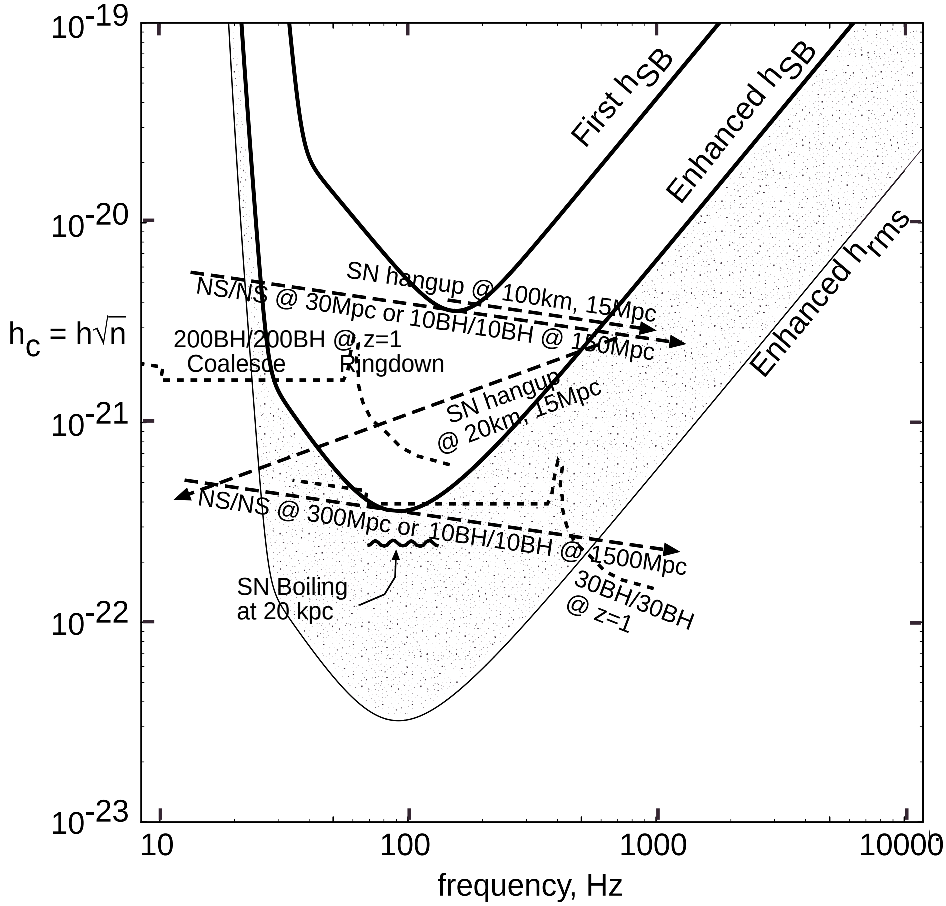
- building 20 to be torn down
  - 'the procreative eyesore'
- use opportunity to plan new facility for detector support, Adv R&D
  - allows present activities and some growth in staff (faculty)
  - enables LIGO to plan for future

Roles of Campus laboratories

Both MIT and CIT campus labs have similar roles

- campus support of commissioning and operation (Mike Zucker's talk)
  - › modeling
  - › service: contamination, scattering measurements
  - › quick experiments to pursue ifo troubleshooting, e.g.,
  - › tabletop optical measurements
  - › mechanical transfer functions
- advanced R&D
  - › advanced subsystems: near term
  - › advanced LIGO: long term
  - › participation/direction of the Ligo Science Collaboration
  - › a focus for outside collaborators
- training of students
  - › engagement in all of above

Choice of a research focus



- longer observation of inspiraling binaries; larger bandwidth for impulsive events; better signal to noise for extraction of physics from waveform
- astrophysically most likely place to find sources (scaling arguments)
- changes in specific interests possible (probable!) after first discovery

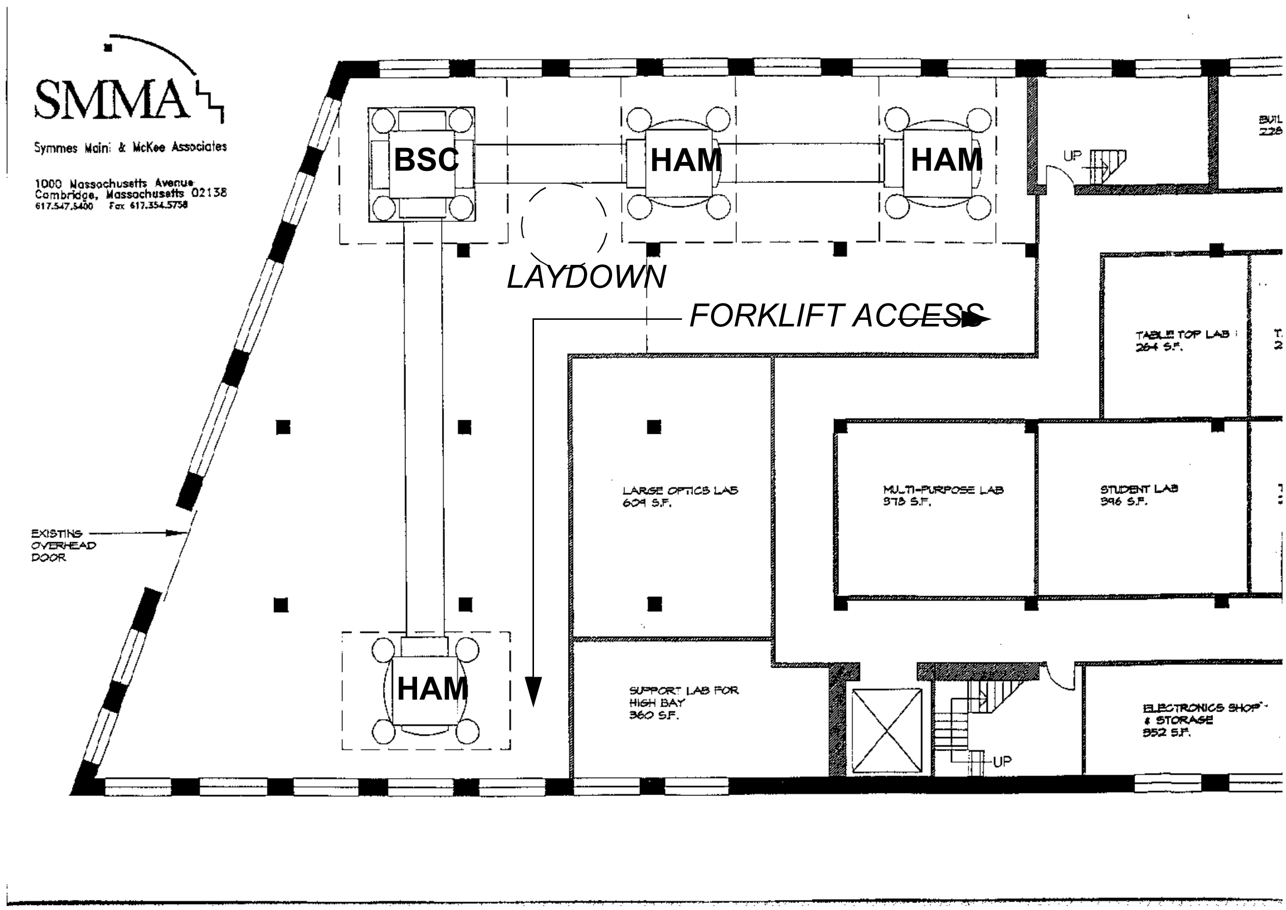
Advanced R&D plan for LIGO targets this area

- collaboration an important aspect
  - › GEO, Stanford, JILA, Syracuse, PSU, LSU, Moscow
- our plan designed to be complementary but with leading role

Requirements for a test interferometer

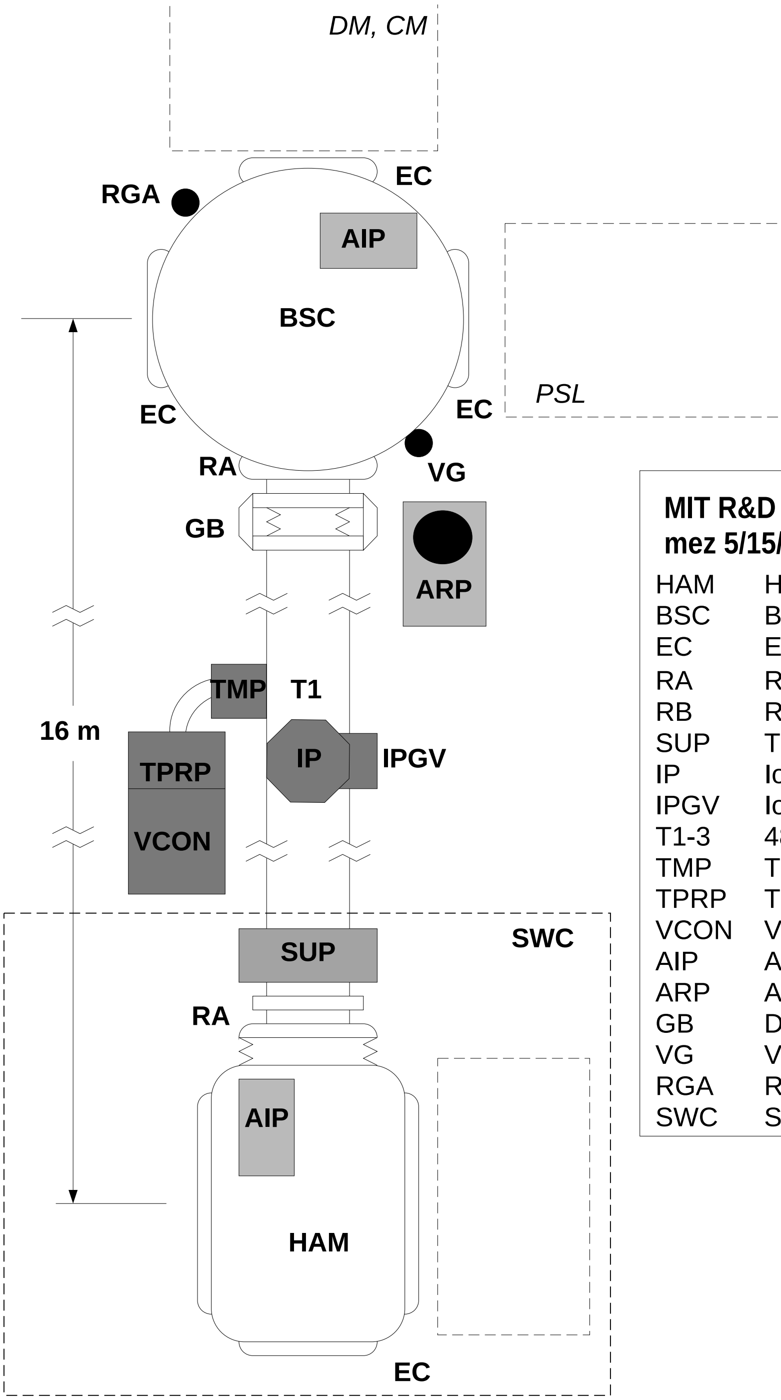
- ability to test optical interferometer as well as mechanical designs
  - 40m over-subscribed; PNI example of work-in-parallel
  - can specialize to low-frequency studies in a non-exclusive way
  - sets length scale (~15 m), geometry (‘L’ configuration of vac sys)
- full-scale testing of mechanical components
  - development: eliminates scaling of resonances, interference
  - interaction of existing and added design elements
  - qualification: final testing of hardware to be installed
  - reduces down-time for LIGO ifo
  - sets size scale to that of LIGO vacuum equipment
- LIGO vacuum hardware
  - assures right problems to be solved in design
  - installation practice off-line from LIGO
- supporting lab infrastructure
  - physical: mech/elec shops, cleaning/prep, control, lightsource, storage
  - visitors offices/labspaces
  - human: manager, technicians, engineers

Test Interferometer



- First stage: HAM+BSC, 1.2 m x ~15m connecting tube; isolation stacks
  - › operational in fall 98
- Second stage: complete 'L' vacuum system
  - › operational in early 2001
- high-bay accommodating LIGO Vac Eq, supporting labs - details tomorrow

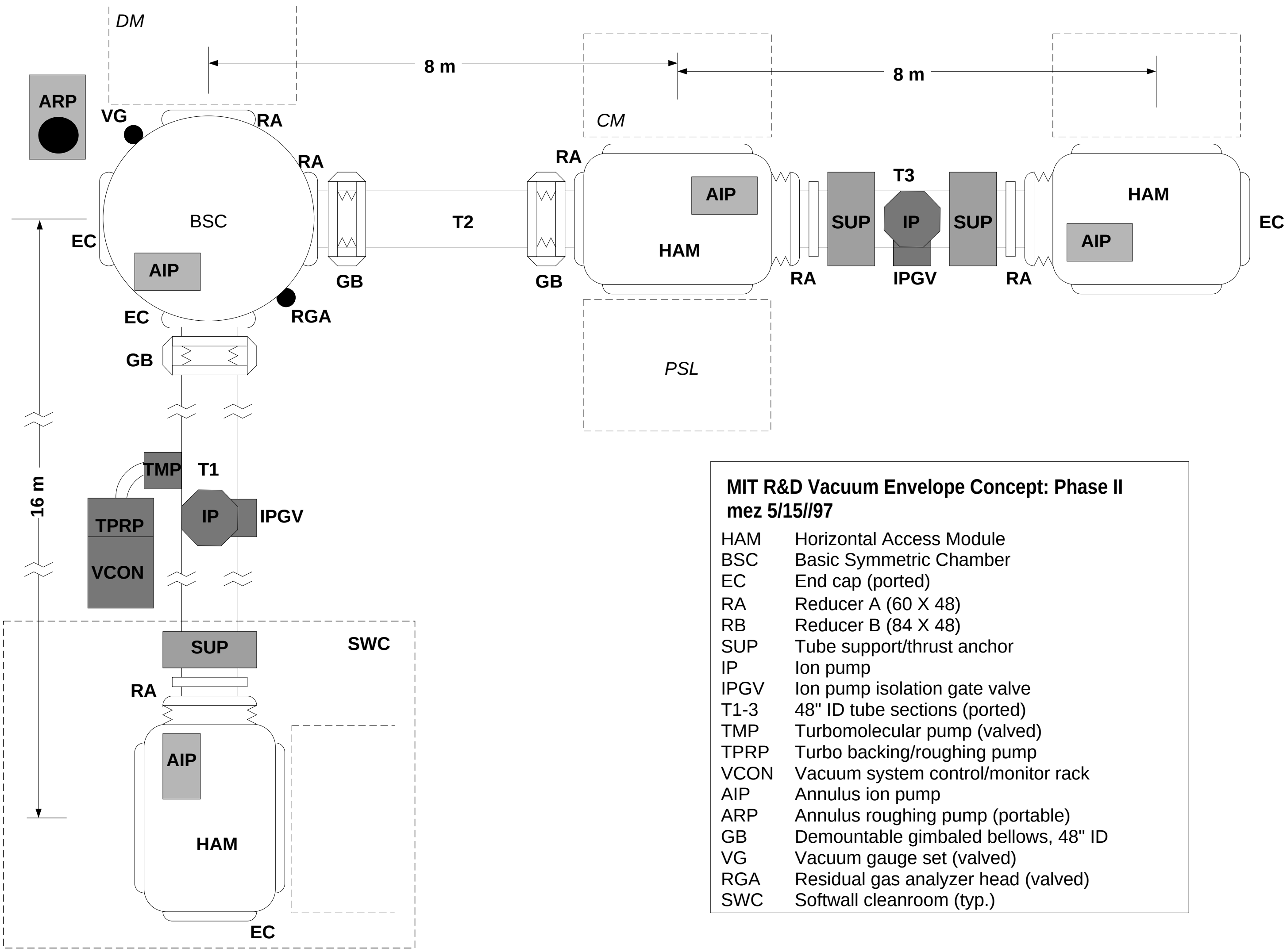
Phase 1



MIT R&D Vacuum Envelope Concept: Phase I
mez 5/15/97

HAM	Horizontal Access Module
BSC	Basic Symmetric Chamber
EC	End cap (ported)
RA	Reducer A (60 X 48)
RB	Reducer B (84 X 48)
SUP	Tube support/thrust anchor
IP	Ion pump
IPGV	Ion pump isolation gate valve
T1-3	48" ID tube sections (ported)
TMP	Turbomolecular pump (valved)
TPRP	Turbo backing/roughing pump
VCON	Vacuum system control/monitor rack
AIP	Annulus ion pump
ARP	Annulus roughing pump (portable)
GB	Demountable gimbaled bellows, 48" ID
VG	Vacuum gauge set (valved)
RGA	Residual gas analyzer head (valved)
SWC	Softwall cleanroom (typ.)

Phase 2


DM
8 m
8 m
ARP
VG
RA
RA
BSC
EC
AIP
RGA
EC
GB
T2
GB
RA
CM
AIP
HAM
RA
T3
SUP
IP
SUP
IPGV
RA
HAM
AIP
EC
PSL
16 m
TMP
T1
TPRP
IP
IPGV
VCON
SUP
SWC
RA
AIP
HAM
EC
MIT R&D Vacuum Envelope Concept: Phase II
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HAM Horizontal Access Module
BSC Basic Symmetric Chamber
EC End cap (ported)
RA Reducer A (60 X 48)
RB Reducer B (84 X 48)
SUP Tube support/thrust anchor
IP Ion pump
IPGV Ion pump isolation gate valve
T1-3 48" ID tube sections (ported)
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Research plan for the new installation

Target: 'Advanced Subsystem' suspension to be ready in 2003

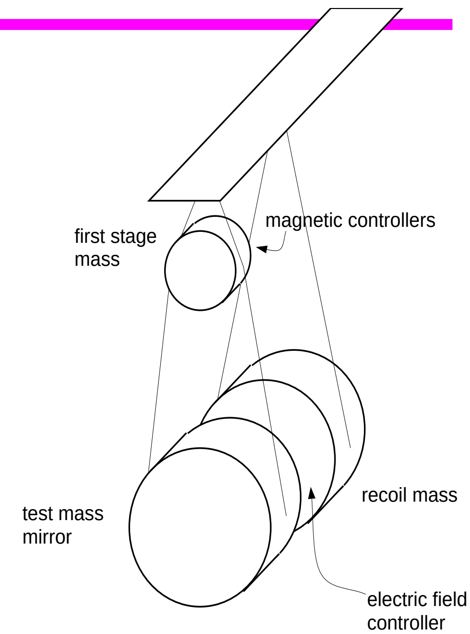
(end of first data run)

- explicitly a double pendulum suspension
  - › incremental changes in other mechanical subsystems
- R&D schedule calculated back from that date
  - › '2007' advanced LIGO suspension in background until ~2003)

Significant steps in design process

- establishing requirements, interfaces, design constraints (~now)
- determining the state of the art, lessons from initial LIGO
- conceptual design (1998)
- construction and test of lab prototypes of aspects of design (1999)
- initial complete prototype testing (2000)
- test of final design (2001)
- qualification of suspensions to be installed (2002)

Guesses and Preferences



Once requirements are set,

- conceptual design subject to pet notions...

Ideas of a target design to pursue

- try to eliminate ALL actuation of the test mass
  - › concerns about damping of internal modes
  - › also, damping of pendulum
  - › requires two-loop suspension
  - › hard control problem
- aggressive active 'outside layers' required for above
  - › need to reduce seismic input such that BW < wire-resonance suffices
  - › external actuators with external sensing probably needed (STACIS-like)
  - › may also need damping of specific stack resonances (internal actuators?)
- 'monolithic' fused silica construction
  - › test mass: allows transmission through substrate
  - › sapphire end test masses, if polishing, coating, attachment resolved
  - › suspension fibers: improved Q, simplifies interface at test mass
  - › requires bonding techniques, under development
- upper mass with vertical leaf spring suspension
  - › required if seismic isolation of two stages to be realized
- avoid reaction mass
  - › adds complication in control dynamics; should not be needed for actuators

Specific activities at MIT

Requirements: mid-97 --> end 97

- requirements/interfaces/constraints based on initial LIGO
- visits to/from Glasgow (ongoing design of double pendulum)
- modeling of noise performance and control aspects
- staff: dhs, gg to spend a little time
- start search for experienced scientist to join effort

Design of configuration prototype: mid 98

- right number of masses, actuation points
- full scale, but Al masses, wire suspensions

Fabrication: end 98

Tabletop tests in air: early 99

- target: characterize LF XF, resonances, actuator
- michelson with one suspended element
- also iterations on design if needed

-- Phase 1 Test Interferometer in lab, shakedown completed Jan 99 --

Vacuum tests of a single suspension, one suspended element: June 99

- target: GW-band transfer function, pointing stability

Specific activities at MIT continued

Fabrication of two suspensions: Sept 99

- test of suspended cavity, 15m baseline: Sept 2000
  - in parallel with PNI suspended cavity
  - locking tests
  - noise tests to limit of laser stabilization using PNI suspended cavity
- refine design with results from research

Fabrication of 4 (6?) suspensions (modifs of prototypes?) March 01

-- Complete Test Interferometer in lab, shakedown completed March 01--

- installation of complete ifo
  - all double suspensions (at least on TMs)
  - either initial LIGO optical/readout configuration OR
  - incremental change, having been modeled/tested in advance

Test, noise and control characterization march 02

- also diagnostic readouts (wire/vertical)
- any data from optical configuration changes

fabrication of production suspensions Jan 03

installation/qualification of final suspensions Sept 03

Other R&D

Optics

- configuration modeling in conjunction with tabletop experiments at CIT, UFla
- small-scale advanced subsystems work
  - e.g., output mode cleaner
  - post-modulation readout techniques
  - modulation/detection/control tests on simplified configurations

Mechanical design

- active seismic reduction
  - in conjunction with new lab/MIT initiative
  - as part of suspension research
- possible alternative passive isolation studies: springs, resonance control

Some advanced topics

- too far away for specifics, but...
  - very aggressive seismic isolation (to gravity gradient limit at ~10 Hz)
  - optical configurations tolerant of high power/thermal focussing
  - means of producing very large test masses (Q, optics)
- ...all as coordinated within the Lab and with lots of collaboration

Facilities and Plans for R&D

Phase transition in LIGO

- from Project to Laboratory

Phase transition at MIT LIGO

- change in lab space
- opportunity to target activities and plan facilities to support them

First priority: Support initial LIGO installation and commissioning

- some of this is in fact R&D to respond to mysteries at the sites
- lots of it is people not in the lab in 98-99
- slows down labwork
- but: some continuity of labwork vital

Advanced R&D

- necessary for LIGO in the long term, important to scientific vitality of LIGO Lab
- MIT Test Interferometer and facility to play an important role
- significant investment for LIGO and MIT
- requires commitment of manpower and imagination from MIT Lab
    - › responsibility to support activities from LIGO Lab, collaborators
- provides vital resource for advancing interferometer design
- provides focus for MIT Lab efforts, LIGO Science Collaboration as well

Data analysis

- The third piece of LIGO Lab activity: following talk by Peter Fritschel